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Winter School on

GIS Based Watershed Planning in Agriculture

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Foreword

The Winter School on Geographical Information System (GIS) based Watershed Planning in Agriculture is one of the several outcomes of a series of endeavors by the Centre for Land Resources Research and Management and the Department of Soil Science and Agricultural Chemistry to enhance the knowledge domain and capability of the Kerala Agricultural University in employing state-of-the-art technologies for planning agricultural development. The attempts of the Kerala Agricultural University to develop and employ innovative methodologies for GIS based watershed development commenced almost over a decade ago along with the emergence of advances in this direction at the global level. The Centre for Land Resources Research and Management, which was established in 2000, has been immensely instrumental in spearheading research and development on GIS based interventions in agriculture. Recent developments in the domain of spatial technology have further sharpened our capability to visualize the complex patterns and relationships that characterize real-world planning and policy problems. Exploring the potential of GIS in planning, implementing and monitoring developmental interventions has assumed greater significance of late, with the increased emphasis on watershed based planning as a strategy of rural and agricultural development as declared by the central as well as state governments. As regards agriculture, the spatial and temporal characteristics of the inputs for planning and implementation of development programme warrants intense use of GIS based technologies. Many development agencies are exploring the possibilities of GIS enabled operations in their respective area of concern.

It was in this backdrop the Centre for Land Resources Research and Management and the Department of Soil Science and Agricultural Chemistry of the College of Horticulture jointly thought of consolidating their experiences in order to offer a Winter School on GIS based Watershed Planning. The team of scientists who have designed the content and methodology of the winter school has put in earnest efforts to provide the delegates with the latest information on the application of GIS in watershed based development approaches. With the watershed based development planning gathering wider national attention, this effort has turned out to be a timely academic exercise that would be of immense use to resource persons from different parts of India. Moreover, as far as I know, the deliberations in the winter school has been able to provide directions to harness the efforts of various agencies that have ventured into the field of watershed planning based on GIS. Many resource persons with wide variety of experiences in watershed based development planning and GIS technology have been brought to a common platform to evolve a methodology for ICT enabled development planning in agriculture.

I profusely appreciate the efforts of Dr. N. Saifudeen, Dr. P R Suresh and Dr. K C Marykutty for bringing out this compilation, which I hope would be a landmark in the literature on GIS based watershed development and a harbinger to further exercises. I proudly present the compilation for professionals and academicians who are earnestly involved in using GIS for agricultural development.

Vellanikkara
21. 12.2006

Associate Dean
College of Horticulture

Prologue

Presumably, agricultural planning in India is undergoing a major paradigm shift from centralized and prescriptive methodology to decentralized and participatory approach. It is true that different connotations of people's participation and micro level planning had been in vogue though partially in the approaches of the last two five-year plans. However, this had not materialized due to lack of bold and proactive steps towards democratic decentralization and the provisions thereof that enable decentralized and grass roots level development planning. This has been seriously addressed in the eleventh five-year plan with the Government of India insisting all the agricultural and rural development programmes to be formulated and implemented on the basis of watersheds; the most manageable and scientific unit as far as human development is concerned. Following this, several states have ventured into democratic decentralization and grass roots level planning in the wake of the 73rd and 74th constitutional amendments.

The Winter School on GIS Based Watershed Planning in Agriculture has been conceived in view of the growing importance of the concept of watershed planning and the ever increasing possibility of employing Information Communication Technologies to facilitate grassroots level developmental interventions. GIS applications are being employed the world over in a wide variety of activities ranging from agriculture to warfare. However, using the potential of GIS for micro level planning is only being gradually made use of, as it requires the involvement of the efforts of a multi disciplinary team that can look into different aspects of grass roots level development. This winter school has squarely addressed that issue by providing the participants with sufficient exposure to GIS technologies as well as the myriad non-technical issues involved in any watershed based development programme. The course included theoretical as well as practical sessions on delineation and characterization of watersheds, inventorising local resources, state of the art tools liked GPS, collection of relevant information through participatory learning and final integration of data from divergent sources. The learning experiences were enriched by field trips to model watersheds that helped the trainees acquire first hand information on both technology as well as field level problems related to water shed delineation and development intervention.

With the announcement of Haryali, the national watershed development programme and the stipulation of the state government to concentrate on watershed based local level planning through local bodies in the eleventh plan, administrators, extension functionaries, people's representatives and the farming community at large are looking upon the intellectual resources available with the Kerala Agricultural University in this domain of knowledge. We strongly believe that this programme has been able to create a resource group with adequate orientation to this emerging field of knowledge and they could be of immense utility to similar efforts in the state each one hail from. As far as we are concerned, this programme has been quite gratifying, as it has helped us consolidate all the expertise, acumen and experiences of the Kerala Agricultural University in GIS based watershed planning that have been acquired out of the series of concerted efforts that began almost over two decades ago. The pioneering efforts of the Centre for Land Resources Research and Management established in 2000 to undertake research on the issues of ICT based grass roots level planning has also been sufficiently vindicated with the immense response from across the country to participate in this winter school.

Moreover, several resource persons and institutions that have been working in near isolation in spite of distinct stakes in watershed development planning in the state could be brought together to develop synergies.

We are thankful to the *Centre for Earth Science Studies, Department of Soil Conservation, Agricultural Finance Commission, Kerala Forest Research Institute, Kerala State Remote Sensing and Environment Centre, Kerala State Land Use Board, Integrated Rural Technology Centre, Rubber Research Institute of India, Attappadi Hill Area Development Society, Department of Forests, Model Agronomic Research Station, Chalakkudy, Communicaiton Centre, Mannuthy, Cropping System Research Centre, Karamana, District Rural Development Agency, College of Horticlture, Virtual University in KAU, Kelappaji College of Agricultural Engineering and Technology, Tavanur, College of Forestry, College of Veterinary and Animal Sciences,. Agricultural and Fodder Research Station, National Institute of Hydrology* for heartily sparing their valuable resources to make the school unique with diverse contents and experiences.

Profound gratitude is due to the Indian Council of Agricultural Research for providing us with the financial assistance that helped this programme materialize.

We acknowledge the encouragement meted out to us to conduct the progamme quite hassle free by the Associate Dean, College of Horticulture.

We also thank all who have earnestly involved in the organization and implementation of the winter school, particularly the staff of the Department of Soil Science and Agricultural Chemistry for the selfless dedication and commitment.

We look forward to establish and maintain such multidisciplinary spirit and synergy across the country in the area of watershed planning and development and firmly believe that the delegates of the workshop would profess this spirit in the true sense in their respective institution and state.

Dr. N Saifudeen
Dr. P R Suresh
Dr. KC Marykutty

GIS BASED WATERSHED PLANNING IN AGRICULTURE: AN OVERVIEW

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Introduction

Planning is a widely accepted way to handle complex problems of resource allocation and decision-making. It involves the use of collective intelligence and foresight to chart direction, order, harmony and progress in public activity relating to human, environment and general welfare. Panchayaths are the basic units for planning and administration because they are institutional entities. However, for agricultural interventions, a Micro-watershed is the ideal unit for planning, because it is the natural unit of biophysical resources in any area, from where primary production and allied activities can be organised in a sustainable fashion. Agriculture in Kerala (as elsewhere) is not just cropping but farming. Farming is a multi-product system evolved through generations on our heterogeneous resource base. The farmer' objective is not maximising income from specific crops, but from unit of land, and the resource system as a whole.

Planners and decision-makers have to depend upon spatial and non-spatial data for optimal interpretation. Therefore, large volume of data is gathered whenever preparation of physical plan is taken up and a good number of maps are also prepared as a part of the exercise on plan formulation. Government officials work at different levels and take location/area specific decision related to rural development. Spatial treatment of data (i.e. presentation of data on maps) are pre-requisites for taking these types of decisions. There is a vast scope for the use of geoinformatics in facilitating the decision making process at various levels of decentralised planning.

The enactment of the 73rd and the 74th Constitutional Amendments in 1996 made the district, the panchayat union and the village panchayat as three levels of planning for the implementation of rural development programmes. The amendment listed 29 subjects as sectors of planning under the New Panchayat Raj dispensation. That is, since 1996, the decision-making in the area of rural development has been decentralised. The elected representatives often take area/location specific decisions. They are in need of maps on a large scale, particularly at the panchayat union and village panchayat levels. Thus, there is a vast scope for the use of geoinformatics facilitating the decision making process at various levels of decentralised planning.

In the Indian sub-continent a number of agencies, both governmental and private, are involved in the preparation and provision of maps for official and commercial purposes. Due to changes in the methodology of planning, levels of planning and areas of planning, the requirement for maps and their use have increased in recent years.

The maps available with the Government departments at the district level at present bristle with inherent problems like non-availability and obsolescence and they are inaccessible to many of the potential users. The major disadvantage is that they fail to furnish the geographical information required by the officials or the elected representatives. Therefore, the departments, which take area/location specific decisions based on the information available in the maps, are forced to use these maps with several inadequacies and obsolescence.

Maps

From a Babylonian map on clay tablet dating back to 2300 B.C. to digital cartography of the present day, map making has made tremendous progress. In modern society, maps constitute the most important source of geographical, physical, economic, scientific and sociological information. Maps are used extensively in the fields of agriculture, animal sciences, forestry, fisheries, rural and urban development, ground water surveys, environmental studies and geotechnical investigations, among several other sectors.

Maps are invaluable repository of information on which decentralised rural planning and developmental decisions can be based. Maps are tools for Visual Representation of actual places, depicting the interrelationship between them; Better understanding of our surroundings; Involving communities for more interaction with their immediate natural and built environment; Facilitating communities to base their demand / need from government Agencies.

The planners need to have at their disposal sophisticated data management systems to handle spatially correlated data. However, today no system has been built to compile this geographically referenced data on a systematic manner and store them for retrieval at a subsequent point of time.

Geographic Information System (GIS)

Recent technological advances in domain of spatial technology are making considerable impact in planning related activities. This domain of planning is of prime importance for countries like india with varied geographic patterns, cultural activities etc. In the cartographic domain advances in computer hardware and mapping software have already encouraged many planning departments to move from traditional cartographic methods toward digital mapping and geographical information systems (GIS). The purpose of using a GIS is that, maps provide an added dimension to data analysis which brings us one step closer to visualizing the complex patterns and relationships that characterize real-world planning and policy problems. Relationships among neighboring regions in the country are explicit in maps, which allows for the visualization of spatial patterns that may be determined by some underlying process. For example, a clustering of high childhood mortality in a number of areas may point to some environmental condition that has caused this pattern. Higher fertility rates in another set of regions may point to a cultural preference for large families. This information could be used to adapt family planning outreach programs. Visualization of spatial patterns also supports change analysis which is important in monitoring of social indicators. This in turn should result in improved needs assessment. More advanced spatial analysis may include the combination of different data layers. Health authorities, for example, may be interested in estimates of the number of children in a certain age group that may be exposed to malaria. Climatic and topographic data can be used to determine the range of malaria mosquitoes. This range is unlikely to follow census boundaries, but in a GIS the two data layers can still be combined to derive the number of children living within the affected areas. In short, the availability of statistical and other information in spatially referenced form and the functions provided by a GIS can allow analyses that were previously too expensive or impossible to perform

Watersheds

Basically all the terms like watershed, catchment, river basin, drainage basin; region and river valley are synonymous. The size of a watershed can rage from a few hectares to thousands of hectares or square kilometers. The following system of classification, depending on the size of the entity, is adopted in general.

Category	Size	Scale of base map
	In lakh hectares	
Region	300 and above	1: 10 million
Basins	50 – 300	1: 4 to 6 million
Catchments	10 – 50	1:1 million
Sub-catchments	2 –10	1:1 million up to 250000
Watersheds	0.5 – 2	1: 250000 up to 50000
	In hectares	
Sub-watersheds	10000 – 50000	1: 50000
Macro-watersheds	1000 – 10000	1: 15000
Micro-watersheds	100 – 1000	1: 5000
Mini-watersheds	< 100	1: 4000

Categorisation of watersheds in Kerala

The undulating terrain of Kerala, except for the coastal areas (about 10 percent of total area), renders more than one micro-watershed within a Panchayath. The sizes of watersheds are highly variable and are delineated into different groups according to their size. The watersheds identified in Kerala are categorised as per the following table.

Sl. No.	Category	Area (ha)	Total number in Kerala
1	Macro watershed (River basin)	> 50,000	44
2	Sub – watershed	10,000-50,000	151
3	Milli watershed	1,000-10,000	960
4	Micro watershed	100-1,000	Not estimated
5	Mini watershed	1-100	Not estimated

Delineation of Watersheds

Delineation of watershed is the process of demarcating a hydrological and physiographical entity, encircled by a distinct ridgeline and surrounded by many such entities, which form a unit for the sake of administrative and technical feasibility, considering homogeneity of basic resources and problems.

Before delineating a watershed, the size of the proposed entity should be decided. The size of the watershed varies according to the size of the stream of river for which it forms a catchment. From the practical point of view for proper utilisation of land and water resources, a workable size of watershed should be decided in accordance with the aims and objectives of the development programme in a particular area.

Procedure: With the help of Topo Sheet

Topo sheet prepared by Survey of India should be made use of. Topo sheets contain the watercourses, contours at different intervals and other important natural and created physical features. The watercourses, ponds and lakes serve as a very good guideline for demarcating watershed unit. In the process of delineation of watershed boundary, the ridgeline is traced starting from a point, which is the outlet for run off from that particular area of land, keeping in view the water courses (streams) that contribute water to that selected point. A line is traced from this point along the ridgeline (dividing line) till it joins the same point. While tracing this line, the loops of contour should be considered for properly locating the boundary line. This line encircles the area of the watershed and delineates it from the adjacent watersheds.

Procedure: by Topographical Survey

The identified micro-watershed can also be delineated, by tracing out contours with smaller interval on the cadastral or revenue map of the area by conducting the topographical survey. The loops formed by the contours, watercourses and the physical features (natural and created) help in delineating the micro watersheds of required size with reference to the predetermined point on the drainage course.

The Micro-watersheds can also be delineated and demarcated on the cadastral or revenue map of the identified area directly by reconnaissance survey with reference to survey numbers and physical features, starting from the particular point on the drainage course and joining it back, walking along the dividing line (ridge line) of the micro watershed.

Codification of watershed

A national codification system is followed in India to avoid usage of the same symbol for different watersheds and to alleviate the ambiguity in indicating the same watershed by different agencies by different symbols. This will also help national level policy decisions on fixing priorities for development programmes. Codification is done following the hierarchy of bigger hydrologic units to smaller units. Alphanumeric codification using digits and alphabets is used. The following connotations are used for the watersheds of Kerala.

Watershed atlas

In Kerala, KSLUB has prepared watershed atlas for the entire 44 rivers, i.e., 44 watersheds. Sub watersheds and various microwatersheds are also depicted on the watershed atlas. The 44 watersheds of Kerala are serially numbered from the south along with the *first capital letter* of the name of the respective rivers. Each major watershed is divided into sub-watersheds in clockwise direction and is numbered with *Arabic numerals* serially. This is further divided into microwatersheds and is numbered in clockwise direction with *small alphabets.*

For instance, look at the code number of a microwatershed –20B 1a. 'B' stands for Bharathapuzha and '20' is its serial number from the south. '1' indicates subwatershed and 'a' is the name of the code of microwatershed. Bharathapuzha watershed (20B) and Periyar watershed (14 P) are two major watersheds of Kerala.

Bharathappuzha watershed 20B

Total area	3852.04 km²
No. of subwatersheds	50
No. of microwatersheds	290

Periyar watershed 14 P

Total area	5029.03 km²
No. of sub watersheds	183
No. of microwatersheds	448

Micro-watershed maps are prepared in the scale 1: 5000 or 1:4000. The maps should contain, ridge lines or boundary lines, main roads, administrative boundaries, water bodies and main places. It also should contain general information on soil and water resources. These maps may be used to prepare resource maps of scale 1:4000.

Characterisation of Watersheds

The approach of watershed Characterisation relates land to the flow of water from its origin, through the basin, to the plains and its effect on soil. For the scientific management of a watershed the basic data on climate, topography, hydrology, soil resources, natural vegetation, extend of soil degradation, farming systems and rural population have to be collected. Some of the features of a watershed, that are used for its characterisation are detailed below:

Location	Geographical location – Longitude – Latitude
Size	Total geographic area in ha or sq. Km
Shape	Geometric form, shape index, compactness coefficient
Slope	$S = (D \times L \times 100) \div A$ Where, S = average slope D = stream grade L = Average length of the contour A = Area of watershed
Geology	Type of rocks, stratigraphy
Soils	Types, capability, fertility status
Climate	Precipitation, temperature, humidity, wind velocity
Drainage	Drainage pattern, drainage density, Main stream length
Land use	Arable, Non- arable
Time of concentration	Time required for water (run-off) to reach the outlet
Ground water	Depth of ground water; quality of ground water
Demographic characteristics	Population, socio-economic status

Farmsteads/Homesteads

Consequent to the undulating topography of Kerala, different microenvironments (valleys, uplands, slopes and hill tops) are encountered even within small farmsteads, enabling cultivation of a variety of crops. It is common to find farmers in Kerala raising about 10 crops together (rice from the valleys; coconut, arecanut, banana etc. from the uplands of the lower slopes; and black pepper, rubber, cashewnut, etc. from the upper slopes) on their farms though small in size of 0.5-1.0 hectares. In addition, farmers rear different types of livestock and fish. They choose production activities that are mutually supportive, and foster synergy in resource use. Thus, a farm in Kerala means a heterogeneous resource base with multiple opportunities for development. So the idea of holistic view of the farm is inherent.

A group of farms constitute a micro-watershed in Kerala that is controlled by the biophysical resources that are manipulated at that level. A few micro-watersheds constitute a Panchayath where institutional, infrastructural and organisational support is provided.

Information needs for watershed development planning

The basic parameters necessary for planning for agriculture development in a watershed are listed below:

Agro-ecological information	
Type	Particulars
Location	Latitude, Longitude, Village, Taluk, District
Area	Geographical, Non-arable, Arable, Drainage lines
Land use	Crops, Vegetation, Agriculture practices, Inputs (Bio & Chem), Technology used, Irrigation facilities, Average production, etc
Soils	Texture, Structure, Depth, Organic matter, Fertility status, Infiltration rate, Irrigability classification
Meteorological	Rainfall, Daily Max. & Min. Temperature, Humidity, Wind velocity & direction, Daily sunshine hours.
Hydrologic	Size, Length & Width, Shape(Shape Index), Slope, Soil erosion status, Time of concentration, Run off intensity, Ground water status, Water resources (Ponds, Rivers, Streams), Stream grade, drainage density

Socio-economic Information	
Demographic	Human Population (Men, Women, Children), Religion & Caste wise strengths, Literacy level (Men and Women), Landless labour, Resource less poor, Skilled, semi-skilled, unskilled labour, Families headed by women, Average family size, Livestock population, Poultry, Fisheries, etc
Economic	Average size of land holding, Farm power, Number of employed members in a family, Availability of food, fodder, fuel, etc.
Infrastructure	Agro based industries, Market, Input supply agencies, Banks, Transport, Schools, Hospital, Communication facilities (Telephones, post offices etc.)

Resource analysis

Given the value of above parameters that are needed for multi-disciplinary exercises, what is needed for building a consistent and cohesive landuse plan for development is an analysis of the relationship between these parameters. The resource endowment of a watershed or an individual farm in its totality should be considered in designing the most suitable systems of agriculture. The essential role in this exercise is supposed to be played by agricultural and social scientists. Their guidance should be sought for developing alternate interventions in the resource units. This team must analyse the strength and weakness of the agro-climatic situations *vis-à-vis* the development needs of the region and should ensure viability of development plans specific to the given situation.

Further, the heterogeneity of resource base very often restricts the validity or applicability of the findings of single crop research! Added to that the long life span of perennial crops (which in fact dominates the cropping system comprising over 80% of the net cropped area) compounds the problem as research takes a much longer gestation period to produce outputs (coconut research is illustrative).

Therefore, unorthodox methodologies such as "reverse agronomy" are suggested. That is,

- Locate good performing farms and farmers, plants and land use systems
- Identify the biophysical and socio-economic factors that have contributed to the high performance
- Systematically analyse and find out the determinants of sustainability
- Recombine, test them for replicability in other locations and then suggest them

The plethora of agencies that are proliferating the agricultural and rural development sectors in Kerala seldom reach the level of individual farms. Therefore it will also be the duty of the resource analysis team to locate and facilitate necessary infrastructure for successful implementation of the proposed projects/ alternatives.

People's Participation

Watershed planning logically follows form and is corollary to the principle of decentralised planning and since the hallmark of watershed development is its orientation to local situations, there is much in common between these two approaches in terms of their objective and contents. Without involving people in the process of planning, no genuine democratic decentralisation can be brought about. People's participation in planning means that all decisions related to development planning would be taken by the people including defining the scope of development, choosing the development path, formulating plans, determining the priorities, deciding location, identifying beneficiaries, implementation, resource mobilisation, monitoring and supervision.

Conclusion

Watershed management is an attempt towards most natural and sustainable development at grass root level, duly considering the constraints of all the natural resources like land, water, vegetation, livestock and local population. Whenever and wherever the protection, development and sustained maintenance of natural resources are the priorities, watershed is taken as a unit for development programmes instead of revenue or administrative units. Moreover, flowing water forms the main nerve line of the economy of any region, and watershed management envisages a systematic and scientific approach towards conservation, harvesting, proper utilisation and safe disposal of flowing water from the moment it strikes the land surface in the form of a tiny rain drop till it joins the ocean.

Watershed planning, as an exercise, is issue based and situation specific. Its essence is sustainability of land and water based activities, and since sustainability demands consistency between agricultural activities and land qualities, a correlation between the two constitutes the core of watershed development planning. The recognition of the relationship between the natural phenomena (watersheds) and the imperatives of agricultural production constitutes the point of departure from traditional commodity based planning, and hence lends a new and highly essential dimension to agricultural development in the state. The main features of this paradigm shift in rural development from top down, commodity based approach to a bottom up resource based approach as described by Robert Chambers (you know him!!) are the following.

Item	Commodity - based, Top down approach	Resource - based, Bottom up approach
Point of departure	Things	People
Goals	Predetermined (closed), Short term	Adaptive (open), Long term
Key word	Planning	Participation
Focus of Decision making	Centralised	De-centralised
Methods / Rules	Standardised / Universal	Diverse / Local
Technology	Fixed "Package"	Varied "Basket"
Relationship with local people	Controlling, Inducing, 'Motivating'	Enabling, Supporting, "Empowering"
Local people seen as...	Clients, Beneficiaries, Recipients	Actors, Analysts, Partners
Outputs	Uniform, Infrastructure	Diverse, Capacity & Competence

Since farmers are the ultimate decision-makers only a fair combination of farmers experience and our expertise can serve the purpose and goal. Farmers do know the language of sustainable agriculture. What they do not know is the grammar and are therefore liable to err. In the same vein it can be said that the technique of planning used at present is usually not with tune and grammar. The Watershed planning team's role is to recast the planning strategies within the framework of a chaste language.

WATERSHED DEVELOPMENT: CONCEPT AND APPROACHES

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. In human affairs, water plays a crucial role. If properly cared for, it is the harbinger of life. If neglected, it can be the cause of disaster. Frequent occurrence of drought and shortage of water for irrigation and drinking are universal problems. Timely water supply is an essential requirement for successful farming. Large irrigation projects, however, cannot satisfy this need in all the rainfed farming tracts. In fact, the world is in the danger of an impending water crisis. Many even talk about impending water wars! Nearly one-third of the world population is literally crying for drinking water. When the drought is over, it is the turn of floods. Repeated destructive floods destroy vast areas of land every year, and take a heavy toll of human life.

Another problem of great concern is accelerated soil erosion practically in all regions of the world due to increased human activities and lopsided "developmental" activities. Water-induced erosion ruins astonishing amounts of topsoil every year and reduces the productive capacity of vast stretches of land. Other contemporary problems due to accelerated soil erosion and runoff include water logging of fertile valley bottoms; excessive siltation of irrigation and hydro-electric dams; pollution of rivers with the effluent of human settlements, reduction of water quality; siltation of streams and impairment of navigation; and deterioration of fish habitat. Loss of storage space for water in surface water resources and ground water depletion are also significant issues.

Problems related to natural resources are more common in the densely populated countries, especially the so-called 'developing' and 'under developed' countries. In such countries, there is tremendous pressure for water, food, feed, fibre, fuel, and living space. The land is exploited to the maximum in an effort to supply every possible need of the burgeoning population. For example, India with only a share of 2.4 percent of world geographical area has to support nearly 17 percent of world human population and about 15 percent of world cattle. Compounding the situation, India has only 1.0 percent of the world's forest area and only 0.5 percent of the world's grasslands. About 72 percent of rural households in India still depend upon firewood and 20 percent use cowdung as fuel. The age old practice of burning cowdung and crop residues for cooking purposes is depriving the crop lands of much needed organic matter through recycling. Increased rural energy needs will further hasten the degradation of already depleted biomass resources.

The worldwide importance 'watershed management' or 'catchment management' acquired in recent times must be seen in the background of concerns about the sustainability of life supporting natural resources such as land, water and vegetation.

The concept of watershed

The term '***watershed***' has been coined from ***water*** and ***shed*** to mean a ridge line of high land where rainwater on one side flow into one stream, and rainwater on the other side flow into a different stream. In the word 'watershed', the original meaning of 'shed' is *'to separate'* or *'to divide'* (Other meanings of 'shed' are '*to get rid of*' as in "shed clothes"; '*drop*' as in "shed tears"; and a '*small simple building*' as in "a waiting shed").

In the United Kingdom, the term '***catchment***' is used for the area that catches the runoff and flows into a particular river or lake, and 'watershed' is the word for the boundary of the catchment, i.e., the *ridge line* or *divide line* that sheds or separates water on either side. On the contrary, in USA, the term 'watershed' means the catchment (as used by the British), and they simply call the British watershed, a 'ridgeline' (Hudson, 1993).

In India and in many other countries too, watershed is the popular term to denote the catchment area mentioned already. It leads to some confusion in the international literature. Although the terms—*watershed, catchment,* and *drainage basin*— are synonymously used to denote ***the area that catches the runoff for a particular stream or river,*** many attribute some differences between them. 'Watershed' is a common term to refer to any sort of area that catches the runoff. A 'basin' is usually a big watershed, but the outlet must be sea or ocean, for example, the Indus basin and the Kavery basin. 'Catchment' is the term usually given to watersheds of tributaries or that of a big dam. A related word is 'river valley'. However, in perception, its meaning is slightly different, and it connotes the valley portions of the river catchments, and therefore, may be avoided to mean the entire catchment.

A rather precise definition for watershed is: "Watershed is a piece of land area bounded by a natural ridge line from which all the surface runoff drains to a common drainage point such as a streamlet, stream, rivulet, tributary, river, pond, lake, or estuary".

The size and shape of a watershed are determined by surface topography, and it is bound on all sides by a divide or ridgeline. ***Surface watersheds*** are defined by a simple process of identifying the highest elevations in land that drains to the surface water body—lake, pond, river, estuary, etc. The size of watersheds differs widely depending on the reference drainage point; ranging from just a few hectares to several million hectares. A watershed can be very small for a streamlet, sometimes covering less than one hectare; but can be very large for a big river, covering millions of hectares. Water from only a small area drains into a small stream. A river basin is comprised of several unit watersheds draining into its course through streamlets, streams, rivulets, and tributaries. Many smaller watersheds of streams are "nested" inside a larger watershed of a river.

Watershed area and command area

An irrigation project such as a dam has a watershed area or more specifically a catchment area and a command area. The land area, which can be irrigated by an irrigation project such as a dam, is called its ***command area*** as opposed to ***catchement area*** or ***watershed area*** from which the dam collects water drained through surface runoff (***Ayacut*** is the Indian name for command area of a river and ***Anicut*** the dam and the storage area). Command area can also be envisaged for a pond or a stream, the area irrigated through these sources.

Command area development approach is pursued in irrigated areas for its comprehensive development. Availability of water, the most critical factor in crop production, is assured and intensive farming of a specialised nature can be practised in command areas. The emphasis is to maximise production from unit area. Watershed area development approach, on the other hand, is adopted for rainfed areas where availability of water is dependent on rainfall. An element of uncertainty and risk is prevalent in the production systems as the rainfall may be erratic in amount, intensity and distribution. Therefore, diversified and mixed farming systems are commonly practised. Command area development ignoring watershed areas will not be successful in the end. Command areas may face problems, if the catchment areas of the dams are degraded resulting in silting and low storage.

The divisions of a watershed

All of us are living in a watershed, but in different parts of it. If we take the physiographic features into consideration, a watershed will have three distinct parts:

- the upper reaches,
- the intermediate reaches, and
- the lower reaches.

Erosion concerns differ widely between the people living in the upper reaches and those who live in the lower reaches. Land husbandry and conservation measures taken in the upper reaches have direct effects in the upper reaches and indirect effects in the lower reaches.

On an agricultural standpoint, a watershed is composed of five different sectors.

- The arable lands
- The grazing lands, which include village pastures and grazing grounds.
- The non-arable lands, which includes forests, barren, and agriculturally unproductive lands.
- The buildings and their premises, roads and rails, play grounds, etc.
- The network of natural drainage lines and points (rivers, streams, ponds, etc.)

All these sectors must be viewed together as these are hydrologically interspersed in a watershed. The ecological conditions prevailing in these sectors, the socio-economic conditions and the available expertise and genetic resources largely determine the geographical extent of these areas in a region. Their management by farmers and foresters has an important impact on the availability of plant nutrients and water for the cropping systems implemented in the arable areas.

Watershed characteristics

Watersheds have several distinct characteristics, which affect their functioning—that is, the manner in which the precipitation is disposed off. Rainwater moves from the upper reaches to the lower levels of a watershed. Retention of rainwater along the upper reaches improves the moisture status and general health of the watershed. The characteristics, which affect its functioning, are: size, shape, topography, geology, soil, climate, vegetation, land use, drainage, and ground water.

Size: The size of a watershed is an important feature, which determines the quantity of rainfall received in the whole watershed, retained, and disposed off. Larger the watershed, the larger will be the drainage channel and basin storage. Some are very large and include many smaller river basins. Smaller watersheds can be subdivided further into still smaller units. The ideal size for a small watershed to work with on voluntary partnership basis is about 500ha.

Shape: Watershed may have several shapes. Common shapes are square, rectangular, triangular, palm, oval etc. Shape determines the length: width ratio of the watershed, which in turn, affects the manner in which water is disposed off. Large watershed has high time of concentration and opportunity time for water to infiltrate, retain, evaporate, or be utilized by the vegetation. When watershed is shorter in length the reverse will be the situation.

Boundary: Another notable feature is the geographic boundary of the watershed. The boundary is formed by a ridgeline or high area from which water drains either towards or away from the watershed.

Topography: Topography is defined as the relief or physical landscape of the area. Flat, undulating and mountainous are some forms of topography. Mean elevation and slope are important features affecting topography. Length, degree, and uniformity of slopes affect both disposal of water and soil loss. Degree and length of slope affect the time of concentration and infiltration opportunity time of water. The nature of steepness of land has impacts on drainage of water. The faster the drainage, the more will be the potential for flooding and increased soil erosion.

Geology: Geological formation and rock types affect the disposition of water erosion, erodibility of channel and hill faces, occurrence of landslides, ground water potential and recharge, etc. This also determines sediment production. Igneous rocks such as quartzes and feldspars are hard, and do not erode easily; whereas, shales erode easily and quickly.

Soil: Soil properties vastly affect the characteristics of a watershed. For example, sandy soils allow the ground to soak up water faster. This reduces surface runoff, but can affect ground water. Clay soils, on the other hand, are tighter and do not allow as much water infiltration. This can lead to more runoff and soil erosion. Physical and chemical properties of soil influence to a great degree the disposition of water by way of infiltration, storage, and run-off. Erodibility, transportation, and deposition of soil are also a function of its properties.

Climate: Climatic parameters affect watershed functioning. Rainfall is a major factor, which affects the moisture regimes. Soil and vegetation in the watershed are affected by the temperature, humidity, and wind velocity and moisture availability.

Land use: Land use is essentially under the control of the land users and its judicious management is of vital importance to water shed management and functioning. Land use must be according to the capability of the lands.

Drainage: The ultimate function of a watershed is to receive precipitation and dispose it off. The fallen rains drain to an outlet. Drainage characteristics of a watershed is indicated by the drainage pattern, stream order, drainage density (length of drainage channels per unit area), and length of mainstream, which have their effect on the disposal of run off, sediment transport, and surface storage. Drainage pattern will affect the time of concentration of water. Topography regulates drainage.

Ground water: Ground water level is an important parameter with respect to watershed functioning. Water table contours or depths, water quality, etc. affects runoff and production potential in the watershed.

The rationale of taking watershed as a planning unit

In a watershed, the run off from any part of the area is ultimately concentrated to a point, where it can be controlled, reserved or recycled for the benefit of agriculture, power, or other uses. Everyone relies on water and other natural resources in the watershed for subsistence. Management of watershed envisages all-round development of the rainfed areas through integrated and efficient utilization of natural resources coming under the watershed area. Other developmental activities can also be done on watershed basis. Thus, a watershed—large or small— with its drainage patterns and different soil and land types, is perceived as a logical planning and management unit for agriculture or forestry. The following points illustrate the rationale in taking watershed as a planning unit.

1. *Watershed is an interdependent geo-hydrologic unit:* Watershed is a geo-hydrologic unit. Water availability in one watershed unit differs from another, although they may be present as surface water, soil moisture, and ground water and varies from season to season. The intake-outtake of water is peculiar to that particular watershed and all the hydrological processes taking place in a watershed are interrelated. Therefore, management of water is better achieved when it is evaluated and utilized on watershed basis, rather than any artificial unit.

2. *Land and water are linked:* Water is an integral part of land use. Land use is influenced by water, and it is needed for several functions such as crop production. At the same time, land use influences water characteristics by water partitioning at the soil surface and in the subsoil, and by the role of water as a carrier of solutes and sediment. Land and water are linked, and this land-water linkage may cause both land and water problems.

Water available to humans can be distinguished by a colour convention as green water and blue water (Falkenmark, 1993). Green water is precipitation and water on and in the soil, directly relevant to local vegetation or crops. A part of this "green water" is returned to the atmosphere through transpiration and a part through evaporation. Blue water is the fresh water in streams and lakes, in groundwater below the reach of roots and in aquifers. Blue water may be polluted by sediments from runoff, or by wastewater from urban or industrial use. "Land" includes the green water, that is, local precipitation and water in the soil and any local runoff and run-on. It, however, does not include blue water or irrigation supplies up to the field boundary. An integrated approach has to be taken to land, water, and their uses to avoid undesirable effects from human activities involving land-water linkages. The integrity of the water cycle makes the watershed the desirable spatial unit for conceptual integration.

3. *Water is the main agent causing erosion and watershed degradation:* Erosion due to water is a serious problem in the tropics. Loss of topsoil is the primary effect. In addition, it transports the eroded materials to far away places such as dams and reservoirs resulting in siltation and consequent loss of storage space. Paradoxically, water, which may be continuously in short supply for the most part of the year, may occur in torrential rains followed by flash floods in a brief period— the monsoon period. Management of rainfall and consequent runoff determines the productivity of various land management systems. By optimising the use of rainwater through land husbandry measures and reuse particularly during the dry season, the loss of protective cover and productivity of land surface can be minimised. The factors that influence runoff, soil erosion, sedimentation, and floods range from climate to physiography. The interaction of all these factors is best understood when examined based on the natural hydrologic unit, the watershed.

4. *Watershed has natural boundaries:* In India, rural developmental projects are conventionally done taking village as a base unit. This is mainly because of convenience, as village is an independent revenue unit and revenue records are maintained village wise. In many states, however, development works related to sectors such as agriculture and animal husbandry are done taking Panchayat as a unit. The village or Panchayat boundary is artificial, done mainly on considerations other than natural. A watershed, however, has natural boundaries with its drainage patterns and different soil and land types, and therefore, is a logical planning and management

unit related to agriculture and forestry.

5. *Economic development is always associated with an increase in water use*: As economic development is always associated with an increase in water use, proper management of water resources is an essential component of development. In other words, if a river basin is properly managed for water, then it is likely to be properly managed in other ways too. Water is an excellent monitoring mechanism and it is the best index of watershed management. A shortage of water is experienced in many sectors. In the country, agriculture is the largest consumer of water mainly for irrigation. However, demand for domestic and industrial sectors would also increase by 3-4 times and for power by 7-8 times. This increased demand can be met only through better water management practices involving conservation, harvesting and judicious use on watershed basis.

6. *Watershed*: an ideal unit for natural resource management: Natural resource management is a key area of watershed management. Soil, water, and vegetation are the three most important natural resources for the very existence of human beings and animals. These three are interdependent resources and management of one without a consideration of the other two is meaningless. In general, soil and vegetation are amenable to an easier manipulation. However, water is dependant on the climatic variable – rainfall, the management of which is possible only when it meets soil or vegetation. For managing these resources efficiently, collectively, and simultaneously, a suitable management unit has to be taken into consideration. If we take soil independently, then soil series, soil type or any other convenient unit of land will form a unit for soil management. Vegetation can be managed based on cropped area, cropping system, forest type, or some other unit. Such a conventional unit of management is not possible with water. As all the hydrological processes taking place in a watershed are interrelated, management of water is better achieved when it is evaluated and utilized on watershed basis. As soil, water, and vegetation are interdependent, effective management of soil and vegetation is also possible by taking watershed as a unit of management.

A stream, lake, or even a pond must be seen along with its entire watershed and all its physical, chemical and biological elements as part of a complex, integrated system. People living in most of these watersheds have altered the natural drainage lines around them. In a watershed, if the upland portion is being misused and degraded, it may disrupt the stability and productivity of the lowland portion of the watershed as well. Everything that is done in a watershed affects the watershed's system. Scientists and social leaders now recognize that the best way to protect the vital natural resources is to understand and manage them on a watershed basis.

Watershed management or development?

'***Watershed management***' may mean different things to different people. In brief, watershed management is the process of carrying out of some planned practices or strategies to attain certain desired objectives in terms of the functioning of the watershed without adversely affecting natural resources. It must positively influence activities and land characteristics within a watershed. You may also be confronted with the phrase 'watershed development'. Are there any differences? Well, apparently there are not many differences. Some like to say 'watershed management' for areas where soil erosion is high and people's involvement is less, and '***watershed development***' for areas where there are people and they are involved. '***Watershed based rural development***' is another terminology used in connection with rural development. It aims to promote socio-economic development through optimum utilization of natural resources such as land, water, and vegetation that mitigate the adverse effects of natural disasters such as drought and flood; provide employment; and restore ecological balance at micro level through easily and affordable low cost technologies. We also hear people talk about '***participatory watershed development***' and '***integrated watershed development***'. In common parlance, however, watershed management and watershed development are interchangeably used.

The main function of a watershed is *to receive the incoming rainfall, and then, dispose it off*. Therefore, the thrust of any watershed management programme is *optimum use of watershed precipitation* through improved water, soil, and biomass management.

The idea of "watershed development" has raised high expectations among various sections of the people, and they hope various interventions under the scheme will obviate most of their sustainability problems, and ultimately raise their living standards. However, attempts to mystify and romanticise watershed management will be counterproductive. It is not a panacea for all the problems related to natural resources management. Often, claims are made by interest groups that watershed management would restore ecological balance, ensure perpetual water supply and remove hunger and poverty. Even though watershed management is perceived as a multidisciplinary approach, all those involve in the planning and implementation may not be experts. It is essential that all interested should have a basic idea about the concept and functioning of watershed.

Objectives of watershed management

Watershed degradation is mainly due to the faulty and lopsided management of land, water, and vegetation through the activity of humans and animals. Watershed deterioration has several ill effects and affects people both economically and ecologically. The equilibrium between the three natural resources—land, water, and vegetation is broken. It accelerates denudation of forests. Crop production is affected, and a degraded watershed results in poor returns from farming. Erosion hazards are increased. It also increases quick siltation of reservoirs, lakes, and riverbeds. Water availability in the watershed is substantially reduced in terms of both quantity and quality. If the degradation is not arrested and measures to regain the original status are adopted, the livelihood of people is in jeopardy leading to poverty.

The main causes of watershed degradation can be listed as shown below:

- Wrong land use
- Unscientific management of crops, forests, and grasslands
- Farming without adopting soil and water conservation measures
- Non-adoption of better land husbandry practices
- Destruction of forests
- Illegal and unscientific sand mining and quarrying
- Conversion of wetlands
- Faulty road alignment and construction
- Over exploitation of ground water
- Industrialisation

The objectives of watershed management are generally determined based on the present and future economic and social requirements of the population of a large basin, of a region, or even of the nation as a whole. The causes of watershed degradation should also be taken into consideration. Watershed management may have one or more broad objectives as described below, or in some cases, combinations of modified forms of these objectives.

1. *Rehabilitation of natural resources*: The first objective is rehabilitation of already degraded natural resources. This consists of practices intended to repair watersheds that have deteriorated because of past misuse or unwise use, either accidental or intentional, for example: repeated fire, overgrazing, repeated over cutting of timber, improper tillage practices, and use of land for purposes to which it is not suited.

This objective of watershed management has received much earlier and more widespread consideration than the other objectives. Several years of neglect and destructive use have caused deterioration of vast areas of lands. A large proportion of this land is located in semiarid climates where conditions are such that rehabilitation is extremely difficult and costly. The need for more land to meet the needs of increasing populations requires the rehabilitation and rebuilding of these damaged areas.

One of the first steps in a rehabilitation programme is to remove or discontinue the cause of damage, if this has not already been done. If repeated fires are a major cause, an adequate programme of fire prevention and control is indicated. If overgrazing is the culprit, grazing should be materially reduced and carefully managed or discontinued until such time that the area is again able to provide this use. If unwise use has caused damage, a change in use should be made. For example, an area currently devoted to agricultural crop production might be converted to grass or forest trees yielding timber.

Having decided the cause of damage and remedial measures, the next step is to re-establish an adequate protective covering of vegetation by seeding of grasses or tree planting and through various biological and bioengineering measures. This must be supplemented in many cases by structural measures such as small dams, contour terraces and ridges, and similar devices.

2. *Conservation of natural resources*: The second objective of watershed management is conservation or protection. This consists of practices aimed at maintaining good watershed conditions that already exist while carrying on other uses of the land such as for timber growing and harvesting, grazing of livestock, recreation, or crop production. This objective is extremely important, although it has not had as long or widespread attention as rehabilitation.

Protection of watershed land that is already in good condition is vital because of at least three reasons. Firstly, it maintains productive capacity at a time when needs are growing at a rapidly increasing rate. Secondly, it prevents the development of destructive processes; and third, it is much less costly than rehabilitation of land following serious depletion. The productive capacity of our soils, forests, and watersheds must be conserved and maintained at any cost, if the needs of present and future generations are to be met.

Conservation measures for arable lands are usually based on a combination of the following concerns:

- Concerns on the declining productivity of land;
- Concerns on the decreasing water availability, especially annual water yield, peak flow and dry season base flow; and
- Concerns on water quality, as erosion leads to sedimentation on lowlands, siltation of lakes and reservoirs, and/or the eutrophication of water.

The inhabitants of a watershed perceive these three concerns differently. The second concern is shared by all the people inside and outside the watershed. The concerns on water quantity and quality are mainly valued by the people in the lower reaches, whereas the first aspect on declining productivity of land is mainly an upper reaches issue. The combination of these three concerns led to a near unanimous agreement of accepting erosion as the major contributor to loss of productivity of uplands as well as the cause of lowland problems with water quantity and quality. However, soil conservation measures will not address all these concerns to the same degree.

The need for this objective of watershed management can be illustrated by conditions in the Western Ghats. In this region, harvesting of virgin forest is rapidly pushing back into formerly inaccessible regions in the higher parts of the mountains. These areas constitute the headwaters of important rivers. It is essential that timber-harvesting operations be carried on in such a manner that growing sites are protected and soil and water are protected. In some cases, this may require the development of entirely new concepts and methods of timber harvesting and removal. In certain instances, timber harvesting will be deferred until such time that techniques are available that will insure full protection of the soil and water.

A better land use planning and land husbandry are essential for conservation of soil and water, which of course, maintain good watershed conditions with minimum of soil disturbance and alteration of existing hydrologic conditions. Construction of roads is an activity, which affect watershed functioning. Roads should be located and constructed in such a way to avoid unstable soils, prevent concentration of storm run-off and discharge of erodible material with grades maintained at a minimum, and no encroachment upon stream channels. Grazing system, timing, and intensity should be designed to avoid excessive soil compaction and to maintain a good protective covering of vegetation. In forest watersheds, adequate protection from wildfire needs no emphasis. Wherever required, fire belts, wind breaks, etc., must be provided.

3. *Improvement of water yields*: Availability of regular water supply for drinking, irrigation, and industry are major concerns. This is possible through improvement of water yields in the watersheds. Several water harvesting techniques aimed at either increasing total water yields or changing timing of yields better to suit human's needs can be adopted. However, this objective has received, in general, less attention through the years than either rehabilitation or conservation. This is recognizable because rehabilitation and protection represent the bare minimum necessity if we are just to survive even without materially improving worldwide standards of living. Probably, improvement of water yields is considered as the ultimate in

watershed management, because here we are improving on nature. Through the efforts, the functioning of a watershed is tailor made to meet best the needs of community.

The developing importance associated with this aspect of watershed management may be illustrated by situations in many developing countries. In India, a rapidly growing concern as to the adequacy of water supplies for increasing domestic, industrial, and agricultural needs is putting tremendous pressure for the management of watersheds in order to have increased water yields or extended water yield further into the dry summer months of the year. Intensive studies are under way to determine whether water yields may be materially influenced by changes of vegetation, the magnitude of such changes, and what are the conditions under which practices may be successful. The general subject of increasing water yields or materially changing the timing of water yield presents many unknown relations. This will require much intensive research to unravel the complex processes involved.

4. *Other objectives*: Apart from the above three major objectives, several secondary or minor objectives can be added. The three main objectives, which have just been described, cannot be reached without taking into consideration the needs and aspirations of the people concerned and without obtaining their actual co-operation. The programme must also envisage enhancing cash flow to the rainfed farmers through employment generation and development of the human and other economic resources especially through marketable surplus of agricultural and dairy products. These make the task all the more difficult as even watersheds in the highest elevations intended to be managed are frequently inhabited, and the welfare of their inhabitants must be fully recognized and provided for. Watershed management must find the necessary compromise between sometimes conflicting but legitimate interests.

The NWDPRA (National Watershed Development Project for Rainfed Areas) and the Hariyali project, two national programmes, have such additional objectives. The following are some of such additional objectives.

- Enhancement of agricultural productivity and production in a sustained manner.
- Restoration of ecological balance in the degraded and fragile rainfed ecosystems by greening these areas through appropriate mix of trees, shrubs and grasses.
- Reduction in regional disparity between irrigated and rainfed areas.
- Creation of sustained employment opportunities for the rural community including the landless labourers.
- Improvement of non-farm based livelihoods of small and marginal holders and landless people.
- Mitigating the adverse effects of extreme climatic conditions such as drought, flood, and desertification on crops, humans, and livestock population
- Promoting the use of simple, easy, and affordable technological solutions and institutional arrangements that make use of local technical knowledge and available materials.
- Improvement of the economic and social condition of the resource poor and the disadvantaged sections of the society including women.

In nutshell, a watershed development programme should deal with four major components.

- Conservation and development of natural resources
- Improvement of water yields
- Improved management of farm based production systems
- Improved management of non-farm based livelihoods of landless and marginal farmers residing in the watershed.

Possible level of intervention in major watershed units

When rainfall occurs, a portion of rain ***infiltrates*** into the ground, and some portion evaporates. The rest flows as a thin sheet of water over the land surface, which is the ***overland flow***. A natural soil is usually protected by litter and plant cover. When the vegetative cover is destroyed or removed from the soil, several problems crop up. The first effect is a reduction of infiltration capacity. When the possibility for quick infiltration is impaired, overland flow occurs excessively, and this causes rapid run-off, often accompanied by erosive action. If there is relatively an impermeable stratum in the subsoil, the infiltrating water moves laterally and joins the stream flow as ***subsurface flow***. If there is no impermeable layer in the sub soil, the infiltrating water ***percolates*** into the grounds and builds up the ***ground water***. The flow of water from ground water to a stream is called the ***base flow***. If the soil is low in permeability, it favours overland flow.

After water has entered the soil, some or all of it is held there by the molecular attraction of the soil particles. Any additional water moves under the force of gravity to some surface outlet or aquifer. Water retained in the capillary soil pores against the force of gravity is called ***capillary water*** and is said to be in ***retention storage***. The amount so held depends on the depth and other physical properties of the soil mantle. Water held in retention storage is not available for stream flow. However, it is available for plants; in fact, it is their principal source of water most of the time. Water in retention storage is also subject to depletion by evaporation.

When all the retention-storage space is fully occupied, the land is said to be at ***field capacity***. After this occurs, there is still some storage space for moving water. The water that moves as ***underground flow*** or ***base flow*** is, of course, the source of all the perpetual-flowing streams and recharging aquifers. In contrast to overland flow, which is intermittent with the recurring storms and is usually silt-laden, the underground flow is more constant and is clear and cool. It is the more valuable part of the water yield. The yield of a watershed in underground flow is partly dependent upon geological and other factors that cannot be modified by watershed management. Nevertheless, it also depends to a substantial extent upon infiltration and percolation, depth of soil mantle, humus content of the soil, and upon the extent to which retention storage has been depleted. All of these last-named factors can be influenced in a significant way by land-use practices.

Small watersheds- as responsive units of management at the village level

Small watersheds are the village level watersheds. A small watershed or micro watershed is one where the overland flow is the chief contributor to peak flows than base flows. A small watershed is very sensitive to high intensity rainfall of short durations and to land use mainly because the channel storage capacity is very limited. In size, it is usually less than 1000 hectares. The upper limit depends on the condition at which the above-mentioned sensitivities to high intensity rainfall and land use become practically lost due to channel storage. However, on large watersheds, the effect of channel flow or the basin storage effect becomes very pronounced so that such sensitivities are greatly suppressed.

A successful watershed development programme should work with a manageable size yet encompass all the different, but integrated areas. This enables faster measurable progress and stronger ties between stakeholders and the water body they affect. Usually, a micro-watershed of size 100 - 1000 ha is the optimum. The ideal size would be about 500 ha area. Microwatersheds are based on important streams or a group of streams in the villages and can be easily identified and delineated

Sub-catchments: These are drainage area of a medium or small tributary either above its confluence with a major river or above a dam reservoir. This unit is ideal for district-level multipurpose land use planning and conservation of dam catchment areas.

Catchments/ River basin areas: At the catchment level, possible interventions are catchment-level assessment of water resources and their potential use, especially downstream. This includes soil and water conservation or reforestation projects in upstream parts, irrigation and drainage projects in lower parts, and some fishery development. Identification and protection of spots with high biodiversity values; conservation of national parks, etc. should also get priority.

Lake catchments: The measures to be adopted are similar to that under river basin areas. However, it is with special attention to the influence of midstream water use on the sustainability of fisheries in the lake, aquifer management, and polluting influences.

Coastal zone watersheds: Estuaries and other watersheds in the coastal zone come under this group. This mainly involves integrated coastal zone management. As a part of this, measures such as upland forestation, selection of crops suiting the area, irrigation and drainage of the plains, protection of marshes and swamps, mangroves, fisheries and aquaculture, coastal defence works, water supply to towns, harbour development, and tourism can be included.

International river basins: International river basins traverse several distinct ecological and geological zones. For example, the Indus river basin and Brahmaputra river basin are international river basins. Possibilities of intervention include modelling of the conservation and development of upstream water resources for downstream water use based on existing international agreements on water sharing.

Better Land husbandry: A solution to soil problems in the watershed

Soil conservation programmes have been traditionally been propagated through various Governmental and non-Governmental agencies. In the past, most of the programmes for soil conservation concentrated on slowing down and trapping soil and runoff by the use of mechanical barriers. Techniques were selected based on the technical criteria rather than the financial costs and benefits associated with their adoption. Land uses were determined according to the biophysical capability of the land. The focus was on the physical limitations of the land, for example, slope, soil texture, soil depth, etc. and erosion risk than the needs and social cultural and economic circumstances of the land users. As Douglas (1996) stated there has been less awareness of the potential for improved agronomic and biologic measures to reduce soil loss and to maintain and enhance overall productivity.

Better land husbandry represents a shift in emphasis away from soil conservation for its sake to a more holistic approach. Just like crop husbandry or animal husbandry, the concept of husbandry is equally applicable to land as a concept of management and improvement of land resources. Land husbandry approaches management of soil, water, and vegetation in an integrated approach rather than trying to manage each natural resource separately (Hudson, 1992; Roose, 1996). For instance, frequent failures to several water management schemes are attributed to the non-consideration of the interrelationships between soil, water, and biomass. A new strategy, therefore, had to be developed taking better account of the needs of those in direct charge of the land- the farmers including livestock farmers and herders, by offering methods that would improve soil productivity such as soil structure, soil infiltration capacity, soil reaction, fertilization, etc., eventually resulting in better yields and farmers' profits. Roose (1987) named this method "**water, biomass and soil fertility management**" and later, "**Land husbandry**" by Shaxson *et al.* (1989).

Land husbandry may be defined as the care and management of the land for productive purposes. Better land husbandry as suggested by Douglas (1996) derives from the belief that farmers can manage and improve (husband) their land resources, thereby enabling the use of their land for productive purposes on a sustainable basis. According to this concept, control of soil erosion follows because of good land husbandry.

When the land is used for crop production, the most effective form of erosion management is to practice better land husbandry techniques. These involve land use, scientific management of crops, conservation tillage, addition of sufficient organic manures, integrated nutrient management, contour farming, and such other 'agronomic' measures. In addition, specific bio-engineering or engineering measures may be necessary to address particular problem areas. Such specific measures may include bunding, terracing, and construction of drainage structures.

Some concepts of better land husbandry

- Land degradation should be prevented before it arises, instead of attempting to cure it afterwards.
- Loss of soil productivity is equally important than the loss of soil itself.
- Erosion is a consequence of how the land is used and is itself not the cause of soil degradation.

- Crop yields are reduced more by a shortage of water than they are by a loss of soil and hence there should be more emphasis on rainwater management especially water conservation than soil conservation.
- Runoff should be reduced by encouraging infiltration before trying to control its overland flow. Therefore, agronomic measures are more significant than mechanical measures in preventing erosion and runoff.
- For maintaining soil productivity, addition and management of organic matter is a key factor.
- Soil and water conservation should be promoted as an integral part of a productive farming system rather than as a separate land management activity.
- Soil conservation activities must be 'bottom up' rather than 'top down' in orientation. These must be undertaken with the active co-operation and involvement of the farmers and local communities.
- Any proposed soil conservation activity must provide the farmers some short-term benefits, for higher yields, increased availability of forage, reduction in labour, and input costs.
- Indigenous land management practises and farmers knowledge are the starting points.

Erosion is a consequence of how land and its vegetation are managed, and is not itself the cause of soil degradation. Therefore, prevention of land degradation is more important than attempting to develop a cure afterwards.

Smallholder farmers adopt only those production strategies that will provide a reasonable return on the investment on labour and other resources. Conservation strategies or technologies that do not meet this criterion are likely to fail. Soil conservation programmes may lead to 'pseudo-adoption', if strong social pressure, subsidies or other government incentives are used to support adoption of practices that require substantial labour and other resource investment.

In upland systems, plant yields are reduced more by a shortage or excess of soil moisture or nutrients rather than by soil losses *per se*. Therefore, there should be more emphasis on rainwater management, particularly water conservation, and integrated nutrient management and less on soil conservation per se.

In the past, most soil conservation programmes used a top-down approach in 'dissemination' and 'extension' of 'best-bet' practices that were considered to be applicable for a wide range of farm situations. Top down programmes tend to focus primarily on the symptoms of erosion through subsidised terracing or other measures which have had mixed success when introduced by outside agencies. Soil conservation programmes that aim to reduce land degradation problems through treatment of causes require a long term, bottom-up approach supporting farmers who generally have detailed knowledge of their farm. They already know a wide range of potential interventions and choose between these interventions based on the resources and pressures on the farm household. Better land husbandry takes care of all these concerns.

Peoples participation in watershed planning

Participation of people is a prerequisite for the effective implementation of watershed management programmes. Without their active cooperation and involvement, the programmes may fail in the long run. Participation of people starts from the collection of basic data on resources, implementation and monitoring and follow-up of works already executed. Collection of accurate and reliable information on the resource base and socio-economic factors would help in getting a true reflection of existing realities in the watershed area. Data pertaining to all the characteristics of a watershed would be ultimately useful for proper planning of watershed development programmes.

In watershed planning, people are involved not only in collecting data but also its implementation. As it is a continuous research and action process by the local community, the technique is called Participatory Rural Appraisal (PRA). The techniques such as participatory mapping, transect walk, brain storming, focus group discussion, matrix ranking, timeline, and seasonality diagram are used to gather firsthand information about the watershed and the village community. The PRA exercises will be helpful to generate data on soil, hydrology, vegetation, exiting status of various production systems such as agriculture and livestock husbandry and the socio-economic realities such as demographic details and employment.

In addition to gathering information, participatory exercises help to interact with the village community in small groups to understand their perspectives, perceptions and priorities. This will lead to diagnosis of the important problems and a common understanding of people's priorities.

In practise, the information collected from the people through participatory exercises is verified with data about the village and the watershed available in the government departments, metrological data, revenue records, village survey reports, etc. This should be further supplemented, whenever considered necessary, with more detailed scientific surveys such as basic benchmark survey of land capability, satellite imagery of the watershed, contour survey, GIS, etc. To conduct these surveys, the watershed development team can seek the help of specialist agencies.

Capacity building

Community mobilization and training are pre-requisites for initiating development works in watershed projects. Prior sensitization and orientation training on watershed project management should be imparted to all concerned functionaries. Normally, for a typical watershed development programme, three main categories of persons are involved. They are administrators and managers, implementers, and trainers who are functioning at national, state, district or micro watershed levels.

The category of ***administrators and managers*** include officers from various related organizations, for example, the Ministry of Agriculture at national level, the Departments of Agriculture, and Soil and Water Conservation at the state and district levels, and the heads of Project Implementation Agency (PIA) and heads of the registered societies at micro-watershed level. ***Implementers*** include Watershed Development Team (WDT) members belonging to respective PIAs, office bearers of registered societies as well as para-professionals at the micro-watershed level, other participating members including land owners, and land-less families in the micro-watersheds. ***Trainers*** include full time existing faculty members of the identified training organizations, and part-time external resource persons.

Different categories of persons are required to perform separate tasks and responsibilities. For example, some functionaries may require skill in technological aspect while others in management and social aspects. As a part of capacity building, orientation and sensitization through short duration courses and enhancement of skills through medium to long duration courses are envisaged. A comprehensive time-bound action plan for capacity building of different categories of personnel shall be prepared keeping in view the sequence of activities and availability of training organizations. Specific guidelines are issued for the capacity building modules of various categories of personnel under Government sponsored schemes (GOI, 2005).

Watershed Development Programmes in India

After Independence, India made tremendous progresses in the field of agriculture. However, there was a mismatch between the progresses in rainfed areas and irrigated areas. In the earlier Five-Year plans, agricultural development schemes were mainly confined to irrigated areas. This was justified in view of the acute food shortage, and the urgent need to acquire self-sufficiency in food grains. The rest is history, and we know the success story of green revolution and consequent changes in the food front. Green revolution, however, almost bypassed the rainfed areas, remaining confined primarily to the irrigated tracts. Overemphasis of green revolution in irrigated areas created and aggravated several unintended agricultural, socio-economic, and ecological problems. Development of dry land farming was the major causality. Under the Plans, it got a raw deal and relegated to the back. In terms of productivity and sustainability, rainfed areas are still lagging behind due to many reasons.

Out of a total geographic area of 329 m ha, only 264 million ha is fit for vegetation. Of this land area, 67 million ha is under forests and almost 142 million ha is under cultivation (net area). It is estimated that 63 per cent (i.e., 89 million ha) of the cultivated area is rainfed, and contribute 45 per cent of the total food production. This means that about 55 per cent of the total production is from about 37 per cent of the cultivated area, which are irrigated. Although green revolution was a great success in irrigated areas, national food security is still in peril. It has often been observed that when rainfed crops suffer, because of drought or other natural calamities, there is sharp decline in the total production of food grains. Food security would be ensured, only if our rainfed croplands were productive. Shortage of pulses and oilseeds, which are mainly rainfed, is still a problem facing us. Occasionally, we have to rely on food import from foreign countries at exorbitant prizes. It is often said that "importing food is equivalent to importing employment."

Degradation and denudation of rainfed lands due to soil erosion and related hazards are causing great ecological imbalances. Protecting the rainfed catchments of irrigation projects is necessary for sustaining production and productivity in irrigated areas too. The deterioration of production environments in the catchments due to growing population, which accelerates erosion and siltation, was beyond the imagination of those who designed the structures. It was also realized that there existed a widespread disparity between the income of irrigated farmers and rainfed farmers. These concerns forced the Central and State governments to give more emphasis to rainfed areas through the adoption of sustainable practices.

One of the major initiatives undertaken by the Government of India through its Ministry of Agriculture was the implementation of a national level programme, ***NWDPRA*** (National Watershed Development Project for Rainfed Areas), for the development of rainfed areas through the watershed approach. A similar watershed approach has been adopted by the Ministry of Rural Development through its Department of Land Resources for developing the more resource poor areas such as drought prone, desert and wastelands and to provide sustainable means of livelihoods to the rural poor. The project called ***Hariyali*** is being implemented throughout India. The focus of these programmes is enhancement of the viability and quality of rural livelihood support systems. Hariyali is actually an amalgamation of Integrated Wastelands Development Programme (IWDP), Drought Prone Areas Programme (DPAP) and Desert Development Programme (DDP). New projects under the area development programmes would be implemented in accordance with the "Guidelines for Hariyali" with effect from 1.4.2003 (GOI,2003). The projects under Hariyali will be sanctioned by the Department of Land Resources in the Ministry of Rural Development.

NWDPRA scheme intended to generate successful models of development in all the community development blocks of the country where less than 30 percent of the arable area is under irrigation. The project endeavoured to achieve sustainable production of biomass and restoration of ecological balance in the rainfed tracts. It adopts a farming system approach on watershed management principles in order to conserve the precious rainwater and topsoil.

The mandate of the Ministry of Agriculture (i.e., NWDPRA) is to enhance production and productivity of rainfed areas through sustainable agricultural practices following watershed approach. The mandate of the Ministry of Rural Development (i.e., Hariyali) is development and maintenance of the natural resource base in rural areas for increased employment generation and improvement in the general socio-economic conditions of the rural poor through people's participation. While the Hariyali programmes are designed to address areas characterized by a relatively difficult terrain and preponderance of community resources, NWDPRA is expected to aim at increasing production and enhancing productivity in cultivated areas largely privately owned.

Criticisms and limitations of a watershed approach

Despite the thrust and importance given by many countries, watershed approach to natural resources management is not without criticisms or limitations. A major problem is with respect to adoption. Farmers in the upper reaches may not have much interest or concern for those at the lower reaches. It is a general impression that development activity is a job of the government and people have no say in it. People are not ready to spend money because of their limited resources. In the initial stages, there will be doubts about success and the people may be hesitant to participate. Every farmer moves at a different speed. The resources of the farmers in terms of labour and capital vary and they cannot all make progress in the same way at the same time. If all of the farmsteads in the watershed are not participating, the entire exercise may not have much impact.

Soil erosion, land slides, deforestation, sand mining, quarrying, waste disposal, poor quality water, wet land reclamation, filling up of water bodies such as ponds, levelling of small hills and hillocks for soil mining, and conversion of paddy fields are some of the environmental constraints for the development of watershed areas. Another major problem is the alignment of roads and construction of buildings, which cannot be altered. Each of this must be analysed and corrective measures taken.

Some practical problems should also be tackled. A watershed may extend to more than one village. Village level revenue data and watershed data may not match. This has to be reconciled. The peripheries of the village may be outside the watershed boundary and the villagers may feel isolated. Because of this reason, watershed development programmes are entrusted to Block Panchayats rather than Grama Panchayats or village. Furthermore, in watershed approach, more importance is given to group action and community projects. Individuals may not be interested in group activities.

Although there is a sound technical rationale for the watershed approach, it is very difficult to convince the local farmers of the existence of a watershed boundary. Local people rarely identify with a physical 'watershed' or 'catchment'. For the farmers and public, administrative, village, and farm boundaries are far more important than hydrological boundaries. In Kenya, they tackled this problem in a different way. Although watershed approach is followed, they have not adopted watershed in its true hydrologic sense. Instead, they choose a manageable area of about 100-200 ha for the work, where farmers have common problems (Kiara, *et al*, 1996). That is, 'watershed' has simply come to mean an 'area of focus'. If the whole district can be covered using this approach, then all the watersheds can be covered. Farmers organize themselves to plan and work with the support of the local extension agents. A multidisciplinary group of experts and extensionists assist in the identification of problems and opportunities and the development of a feasible and acceptable management plan. The planning process is carried out through Participatory Rural Appraisal and planning methodologies.

One of the primary steps needed to increase the rate of accomplishment in the field of watershed management is to educate the public as to watershed problems and actions needed to meet these problems. An urgent need is to identify real experts in the field and training of technical personnel in watershed management, as this is basic to success in this field. Result oriented research programmes on various aspects of watershed management should be materially increased. Watershed management plans should be developed for programmes that are sound technically, economically, and socially. Necessary financing for carrying out the needed programmes, and monitoring during the implementation and post-implementation phases are core issues for the success. It is hoped that through concerted action, with the available resources of national governments, international organizations, and people, it may be possible to meet the challenges and opportunities encompassed in watershed management.

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WATERSHED HYDROLOGY AND GIS APPLICATIONS

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1.0 HYDROLOGY

The term Hydrology refers to the Science of water. In a broad sense, the Hydrology can be defined as an Applied Science, which links Atmosphere, Hydrosphere, Lithosphere and Biosphere. The Science of Hydrology includes the scientific examination and appraisal of the whole continuum of a hydrologic, or water cycle. To define hydrology as a science of water resources assessment and management, Ad Hoc panel on Hydrology of the Federal Council for Science and Technology, United States (in 1959) recommended the following definition: "Hydrology is the Science that treats of the waters of the Earth, their occurrence, circulation, and distribution, their physical and chemical properties, and their reaction with their environment, including their relation to living things. The domain of Hydrology embraces the full life history of water on the Earth".

Hydrology touches every human life in some manner. Modern applications of hydrology are often concerned with floods and flood plain management. Changing land use patterns such as urbanization, deforestation etc. has aggravated flooding, and as a result, flooding is higher and more spread in some areas than before. Drought is the other hydrological extreme. To those people who depend on water for crops and livestock, the role of hydrology is most important. Increasing population and the accompanying increase in industry have provided tremendous sources of pollution for our water resources.

There are many other applications than those mentioned previously. Industry throughout the world has an important concern with hydrology. Agriculture is dependent on irrigation for the production of food and fibre. Highways, rail, roads and other commercial entities require bridges to span streams and rivers. Navigation of streams, harbors and seas has always been a basis for commerce. Water sports are an important part of life of many people. The fishing industry and recreational fisherman have a vital interest in providing water compatible with fishing. These demands by people, government and industry provide unlimited opportunities for application of hydrology.

2.0 HYDROLOGIC CYCLE

The hydrologic cycle describes the continuous circulation of water throughout our environment as it moves from the oceans, to the atmosphere and to the land, eventually returning to the oceans once again. It has no beginning or end, as water evaporates from the oceans and the land and becomes a part of the atmosphere. The evaporated moisture is lifted and carried in the atmosphere until it finally precipitates to the earth. The precipitated water may be intercepted or transpired by plants, may run over the ground surface and into streams or may infiltrate into the ground. The intercepted and transpired water and the surface runoff return to the air, through evaporation. The infiltrated water may percolate to deeper zones to be stored as groundwater, which may later flow out as springs or seep into streams as runoff (base flow) and finally evaporate into the atmosphere to complete the hydrologic cycle.

The hydrologic cycle is driven by the energy of the sun and the gravity of the earth, and proceeds endlessly with or without human intervention. This is actually made up of a series of complex processes and storages. Processes refer to how we describe the movement of water between the various storage components:

- Surface runoff
- Infiltration, groundwater recharge
- Discharge
- Groundwater flow

It can also involve a change in phase:

- Precipitation (vapor to liquid or solid)
- Evaporation and transpiration (liquid to vapor)
- Condensation (vapor to liquid)

Schematic presentation of the hydrologic cycle often lump the ocean, atmosphere, and land areas into single component. Yet another presentation of the hydrologic cycle is one that portrays various moisture inputs and outputs on a watershed scale, as shown below.

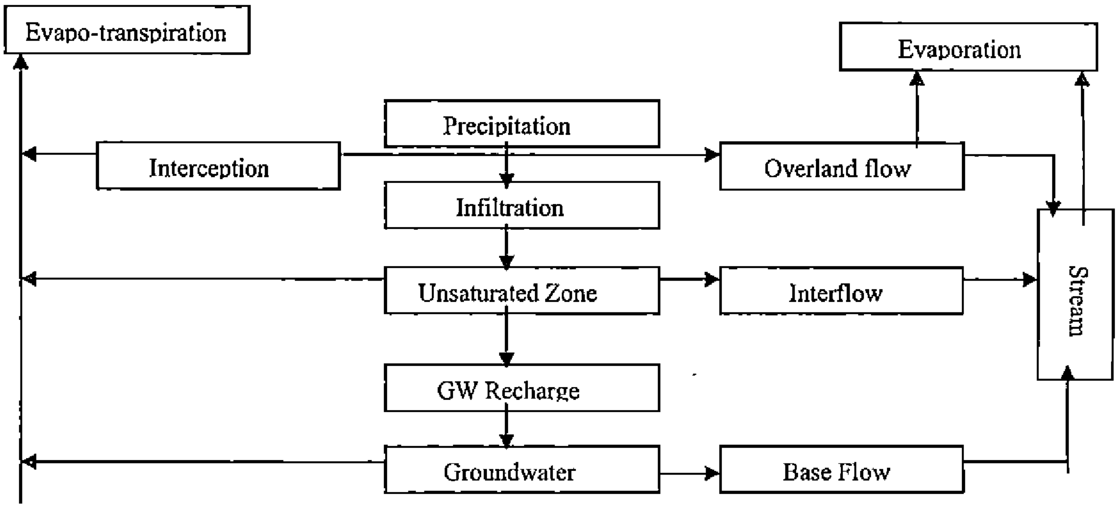
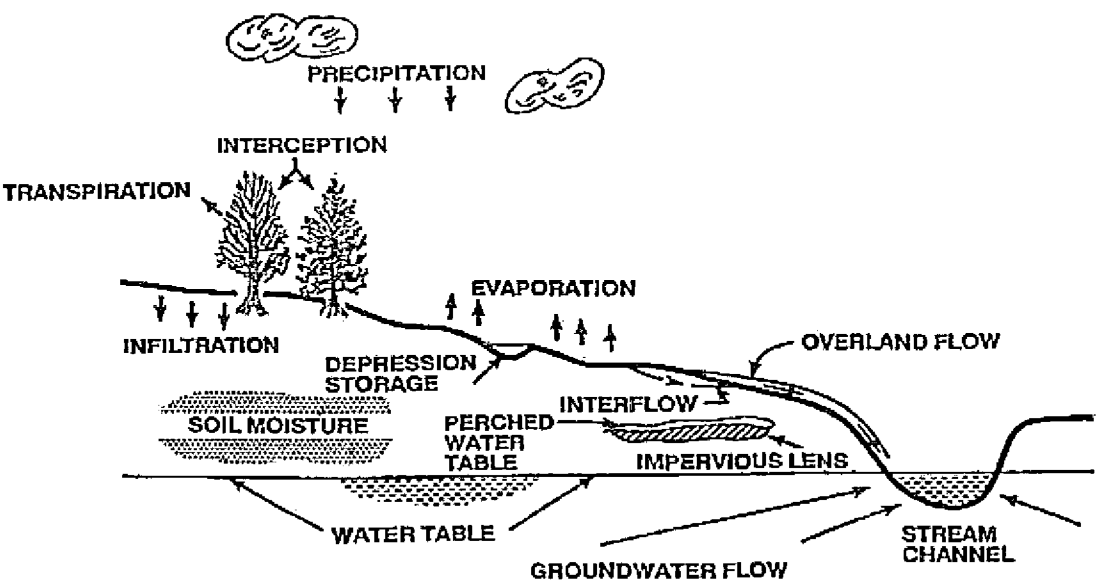


Figure 1. Schematic Representation of Hydrologic Cycle



Major pathways of precipitation and the runoff phase of the hydrologic cycle.

Table 1: Quantities of Water in the Phases of the Hydrologic Cycle

Sl. No.	Item	Volume Km³	Percent of total water	Percent of fresh water
1.	Oceans	1,338,000,000	96.5	
2.	Groundwater Fresh Saline	 10,530,000 12,870,000	 0.76 0.93	 30.1 -
3.	Soil moisture	16,500	0.0012	0.005
4.	Polar ice	24,023,500	1.7	68.6
5.	Other ice and snow	340,600	0.025	1.0
6.	Lakes Fresh Saline	 91,000 85,400	 0.007 0.006	 0.26 -
7.	Marshes	11,470	0.0008	0.03
8.	Rivers	2,120	0.0002	0.006
9.	Biological water	1,120	0.0001	0.003
10.	Atmosphere water	12,900	0.001	0.04
11.	Total water	1,385,984,610	100	-
12.	Fresh water	35,029,210	2.5	100

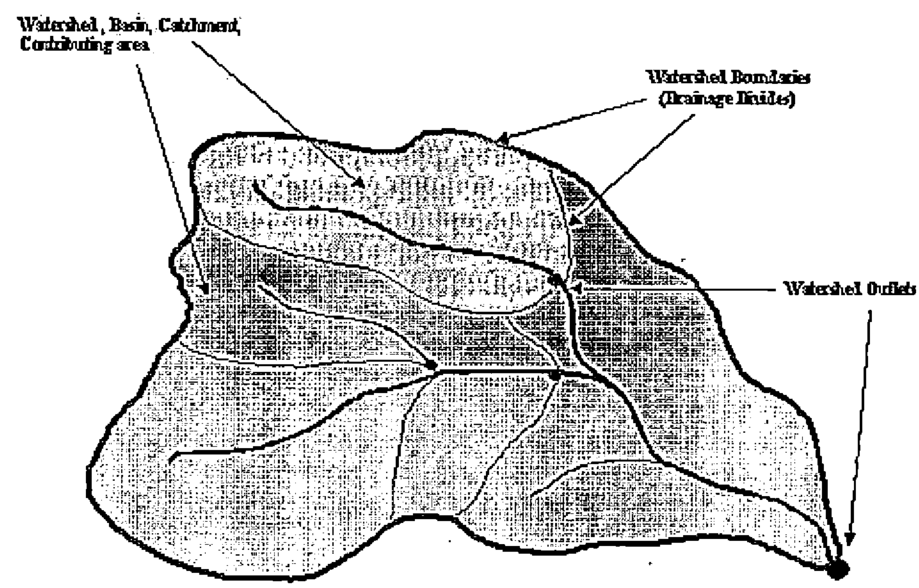
(Table adapted from World Water Balance and Water Resources of the Earth, UNESCO, 1978).

3.0 WATERSHED

Watershed is a natural area, which collects rain or stream waters and discharges it through a common outlet at its minimum elevation (the watershed mouth). The area of the watershed is generally determined from the topography or watershed divide. The divide represents the highest elevation points along the watershed perimeter. The functions of a watershed includes:

- Captures precipitation, its characteristics influence how much is captured
- Stores water once it infiltrates into soil (important to plants)
- Slowly releases water into streams, rivers, oceans

Various activities within a watershed impact runoff and quality of water leaving the watershed. Therefore it is important that the water resources must be managed at a watershed level rather than other boundaries.



Resources management within a watershed is a long term activity and its ultimate aim is the comprehensive development of the watershed so as to result in better productivity by proper utilisation of water and land for overall welfare of the people living in that area. But the formulation of the guidelines for such a project requires thorough knowledge about the watershed, the inputs to the watershed, energy outputs, the relationship between inputs and outputs, and the responses of the watershed for various management activities.

Watershed is an open system. It has boundaries, energy inputs to regulate the hydrologic system and hydrological responses or outputs. Watershed functions as a hydrologic system in which the relationship between the input (rainfall) and output (stream flow) is determined by the intermediate processes (evapo-transpiration, infiltration, soil moisture storage, etc.) and characteristics of the watershed surface (topography, soils, land use pattern, geology, etc.).

The energy inputs of the watershed are divisible into two groups. These are, climate above the surface and tectonic activities below its surface.

The hydrological responses of a watershed are also divisible into two groups. These are hydrological responses through the watershed mouth (channel runoff, sediment load, quality of water; etc.) and through the watershed surface (evaporation, transpiration, overland flow, infiltration, erosion, etc.).

The hydrological responses in particular and the entire hydrological system of a watershed in general, are largely controlled by the watershed personality or the watershed characteristics. The watershed characteristics are divisible into two groups. These are natural (lithology, geology, soils, vegetation type and density, land forms of different genetics, etc.) and anthropogenic or man made (land use type, population density, dams, irrigation tanks, rural and urban settlements, and other built up structures).

Without a thorough understanding of controlling geographical factors and operating hydrological cycle, it is not possible to develop a model for watershed resources management. A watershed management programme can be broadly explained by the following steps:

- Delineation of a watershed
- Defining a watershed
- Defining energy inputs to the watershed
- Defining watershed outputs/responses
- Correcting the watershed

After closely monitoring and analysing the inputs and outputs of a watershed, one should evaluate whether some sort of management is required or not and if needed, the extent and type of management.

3.1 Watershed Characteristics

Responses of a watershed always depend on the watershed parameters or watershed characteristics. Hence to study the responses of a watershed and to evolve a model for the watershed, it is absolutely necessary to know the watershed thoroughly. A geomorphological study is also advisable where the land forms, the slopes, the stream network and the natural processes are dealt with. Various geomorphological parameters, which have mostly been used can be broadly classified as those describing:

- Linear aspect of channel system: Various parameters which involve length of channels in different ways are grouped under this category
- Aerial aspect of channel system: The parameters which are governed mainly by the area of the drainage basin are classified as area aspects of the basin
- Relief aspect of the basin: Relief aspects are the function of the elevation or elevation difference at various points in a watershed or along the channels.

3.1.1 Size

Drainage area (A) is probably the single most important watershed characteristic for hydrologic design. It reflects the volume of water that can be generated from rainfall. The volume of water available from a watershed as runoff would be the product of rainfall depth and the drainage area, by assuming a constant depth of rainfall occurring uniformly over the watershed. Thus the drainage area is required as input to models ranging from simple prediction equations to complex models.

Table 2. Watershed Classification Based On Size

Sl. No.	Watershed Area (km^2)	Watershed Classification
1.	> 1, 000	Catchment
2.	400 - 1,000	Sub-catchment
3.	40 - 400	Watershed
4.	20 - 40	Sub-watershed
5.	4 - 20	Mini-watershed
6.	< 4	Micro-watershed

3.1.2 Length & Shape: Watershed length is usually defined as the distance measured along the main channel from the watershed outlet to the basin divide. The length is usually used in computing a time parameter, which is a measure of the travel time of water through a watershed.

The shape controls the length, width ratio, which affects the runoff characteristics. The longer the watershed, the greater is the time of concentration and hence more time is available for the water to infiltrate, evaporate and were utilised by vegetation. A circular watershed would result in runoff from various parts of the watershed reaching the outlet at the same time. An elliptical watershed causes the runoff to be spread out over time, thus producing a smaller flood peak than that of the circular watershed.

3.1.3 Slope: Flood magnitude reflects the momentum of the runoff. Slope is an important factor in the momentum. Watershed slope reflects the rate of change of elevation with respect to distance along the principal flow path. Watershed slope (S) is computed as the difference in elevation (ΔE) between the end points of the principal flow path divided by the hydrologic length of the flow path (L).

3.1.4 Hydrological Soil Cover Complex: A combination of a specific soil and a vegetative cover is referred to as a soil cover complex and a measure of this complex can be used as watershed parameter in estimating runoff. Soils can be classified according to their hydrologic properties.

Group A (Low runoff potential): Soils having high infiltration rates even when thoroughly wetted, considered chiefly of sands or gravel that are deep and well to excessively drained. These soils have a high rate of water transmission.

Group B (Moderately low runoff potential): Soils having moderate infiltration rates when thoroughly wetted, moderately deep to deep, moderately well to well drained, with fine to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C (Moderately high runoff potential): Soils having slow infiltration rates when thoroughly wetted, with a layer that impedes the downward movement of water, or of moderately fine to fine texture. These soils have a slow rate of water transmission.

Group D (High Runoff Potential): Soils having very slow infiltration rates when thoroughly wetted, clay soils with a high soil swelling potential; soils with a high permanent water table; soils with a clay pan layer at or near the surface; and shallow soils over impervious materials. These soils have a very slow rate of water transmission.

3.1.5 Drainage Characteristics: A large drainage density (The drainage density is defined as length of drainage channel per unit area) creates situation conducive for quick disposal of runoff down the channels.

3.1.6 Climate: Climatic parameters like precipitation, humidity, temperature, wind etc. affect the functioning of watershed. Intensity, duration and frequency of rainfall greatly influence the watershed hydrology.

3.1.7 Time of Concentration (T_c): Time of concentration is the time required for a particle to travel from the watershed divide to the watershed outlet. The equations, which are used in the calculation of T_c require river course length (L), average slope of the watercourse (S), and a coefficient (k) representing the groundcover. Commonly used equation is the Kirpich's equation. Kirpich equation, $T_c = k\ (L / S^{0.5})^{0.77}$

4.0 MAJOR COMPONENTS OF HYDROLOGIC CYCLE

4.1 Precipitation

It is the primary source of fresh water supply and its records are the basis of all water resources development and management projects. Precipitation from the atmosphere to the earth's surface will only occur under certain conditions. The conditions necessary are;

- cooling of the incoming air until it is supersaturated with water vapour,
- condensation, which requires the presence of tiny nuclei, and
- coalescence of water droplets to form particles which are large enough to fall to the ground as rain or snow.

Cooling of moist air to a sufficient extent, to produce condensation occurs when the air is lifted. Rainfall can be classified according to the lifting mechanism into;

- Orographic rain, where the lifting is due to flow over a mountain barrier,
- Frontal rain, where the lifting is due to the relative movement of two large air masses (warm air over cold air), (Cyclonic storms, where, movement is from high to low pressure area), and
- Convective rain (thunderstorms), where the lifting is due to local heating of the ground and violent uplift of air over a localized area.

The aerial or spatial distribution of precipitation is related to meteorological and topographical factors. Rainfall is recorded using a network of rain gauges and is usually recorded on a daily basis and in certain cases in an hourly basis. Rainfall can be measured using an ordinary raingauage, automatic recording raingauge, radars, remote sensing, etc. Rainfall data can be defined in terms of depth, intensity, duration, time distribution rainfall (hyetograph), and return period.

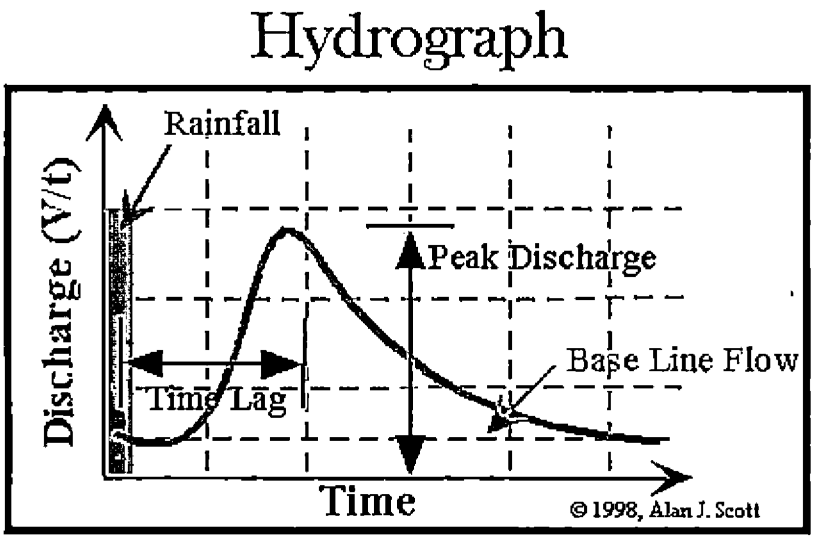
Average rainfall over a specified area (watershed, taluk, district, state) can be computed from point rainfall observations by Arithmetic Average method, Theissen Polygon method, Isohyetal method, etc.

4.2 Runoff

This is the most important component of the hydrological cycle, which forms the major part of the water resources available for the use, apart from the ground water resources. When the rate of rainfall exceeds the interception and infiltration rates, water starts accumulating on the ground and then to move down the slope as overland flow. Depending on the soil conditions and topography, overland flow changes into flow through small rills and gullies, which joins together to form small streams. Runoff depends on the physical characteristics of drainage basin (such as area, shape, elevation, slope, drainage network, soil, land use, etc.)

Total runoff can be roughly estimated by subtracting the losses (infiltration and evaporation) from the amount of rainfall. Total runoff through a stream can be divided into surface runoff and base flow.

Continuous river gauge-discharge monitoring has to be performed to get an idea of the total discharge flowing past a river cross section. This can be done in a daily basis or continuously using an automatic recorder. Time distribution of discharge is called a hydrograph.



Discharge can be estimated using empirical formulae developed by various investigators for different regions/river basins. Many mathematical models are presently available, which predicts runoff from the rainfall records and catchment characteristics. Unit hydrograph, synthetic hydrograph, etc. are the runoff estimation methods using hydrograph approach.

4.3 Evaporation and Transpiration

Evaporation is the process by which a liquid is changed to vapour. Evaporation takes place from a water surface when the atmosphere above it has a relative humidity less than 100 %. The prime energy source for evaporation from water is solar radiation. It depends on the wind speed, degree of turbulence in the air, as well as the vapour pressure difference between the water surface and air.

Transpiration is the process by means of which water passes through a living plant into the atmosphere as water vapour. A plant transpires during the growing season and it is an important component in the hydrologic cycle in vegetated areas. The term evapo-transpiration is often used to indicate the combined effect of water evaporated from the soil surface and transpired from the soil moisture storage through plants.

Apart from mathematical expressions to compute evaporation (by knowing the temperature, vapour pressure, solar radiation, wind speed, etc), field measurement of evaporation is done as the evaporation from pans of standard size. Evapo-transpiration can be measured using Lysimeters.

4.4 Infiltration

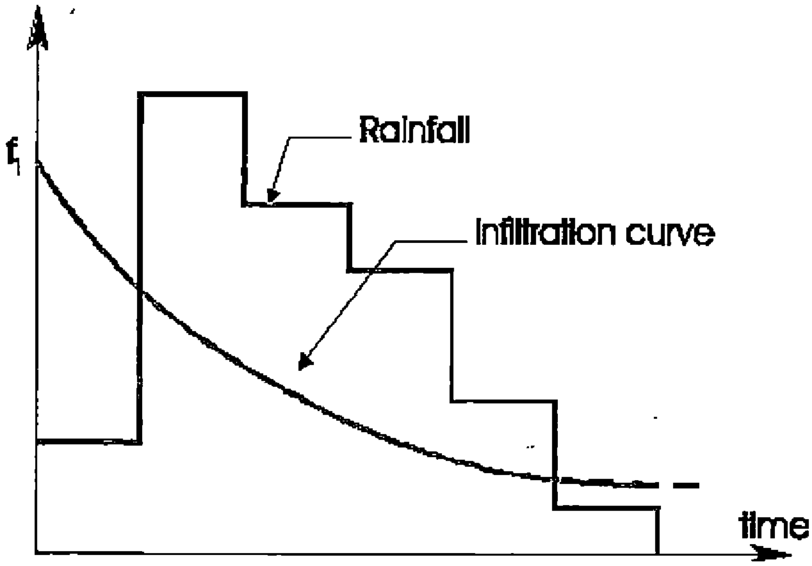
Infiltration is the movement of water into the soil through the surface of the ground. When rain falls after a long dry spell, infiltration occurs initially at a high rate. But, as the rain continues, the rate of infiltration decreases and ultimately reaches a constant value. Infiltration is one of the important components of the hydrologic cycle, since it divides the rainfall into runoff and groundwater.

Infiltration depends largely on the properties and state of the soil, ground cover, topography, intensity and duration of precipitation, etc. It is one of the most difficult elements of the hydrological cycle to quantify. It can be measured in the field using infiltrometers, permeameters, or rain simulators.

A curve denoting infiltration rate or cumulative depth of water infiltrated against time is called an infiltration curve. Horton (1933) established a simple exponential relation between the rate of infiltration and time, the infiltration rate being maximum f_0 to start with, falling off to a constant rate f_c. The infiltration capacity curve satisfies the equation

$$f_t = f_c + (f_0 - f_c)e^{-kt}$$

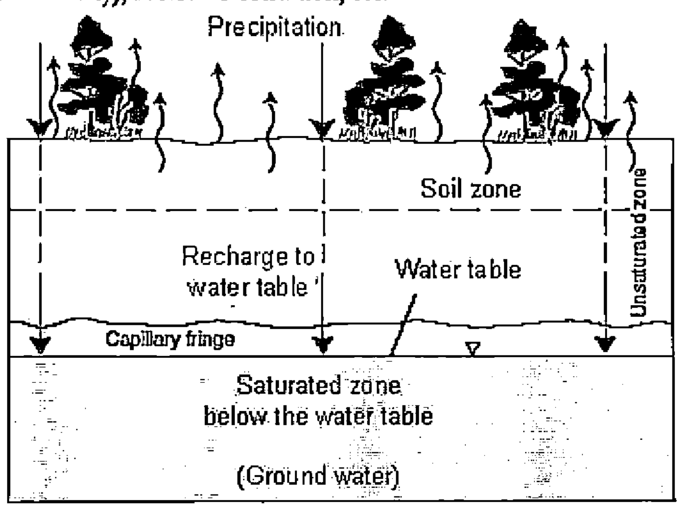
f_t = infiltration rate at time t
f_0 = initial infiltration rate at time 0
f_c = final infiltration rate
k = constant, depending on soil and vegetation



The other mathematical equations, which represent infiltration are, SCS, Holtan, Green-Ampt, Philip, Richard, and Kostiakov approaches

4.5 Percolation

Part of the infiltrated water flows laterally (subsurface flow or interflow) through the unsaturated soil zone and reaches shallow streams or other storages. Percolation denotes the movement of water to the deeper saturated zone through unsaturated zone, where it reaches the groundwater. Percolation depends on the characteristics of unsaturated zone such as porosity, permeability (hydraulic conductivity), moisture condition, etc.



4.6 Unsaturated (Vadose) Zone

This zone is the link between surface and underground hydrologic processes. It also controls the amount of precipitation that enters the soil or remains on the surface. The water in this zone can remain in storage, move downwards by gravity to the groundwater, or move upwards through evaporation or transpiration. In the vadose zone, some pores contain water, some are partially filled, and some are empty. The space not occupied by water is filled by air. This zone acts as a reservoir containing water for vegetation growth, and as a conduit for water moving down to recharge groundwater.

A complete evaluation of water in soil requires knowledge of the energy status of water in soil. The energy status of water is expressed through soil-water potential. The total-soil water potential is formally defined as the mechanical work required to transfer water from soil to a standard reference state, where the total soil-water potential is zero by definition. In soil science and hydrology, soil-water potential is mostly expressed in energy/volume (J/m^3; bar) or energy/ weight (head, cm or m).

There is a relationship between the amount of water held in soil and its energy status. This relationship is unique for each soil and is called as the soil-water characteristic curve or soil-water retention curve. Two points on the water retention curve are of special interest. They are Field Capacity (FC) and Permanent Wilting Point (PWP). When the soil moisture content of a layer reaches the point at which the force of gravity acting on the water equals the surface tension, gravity drainage ceases. This soil moisture content is the field capacity of the soil. It is the maximum amount of water that the unsaturated soil can hold against gravity. In other literature, field capacity is often defined as the water held at 333 cm (0.3 bar) tension. If the soil moisture drops too low, the remaining moisture is too tightly bound to the soil particles for the plant roots to withdraw it. The permanent wilting point is the soil-water condition at which movement of soil water to plant root is too slow to keep up with transpiration losses, and plants do not recover upon wilting. The permanent wilting point is different for different soils and is generally taken around 15,000 cm (15 bar).

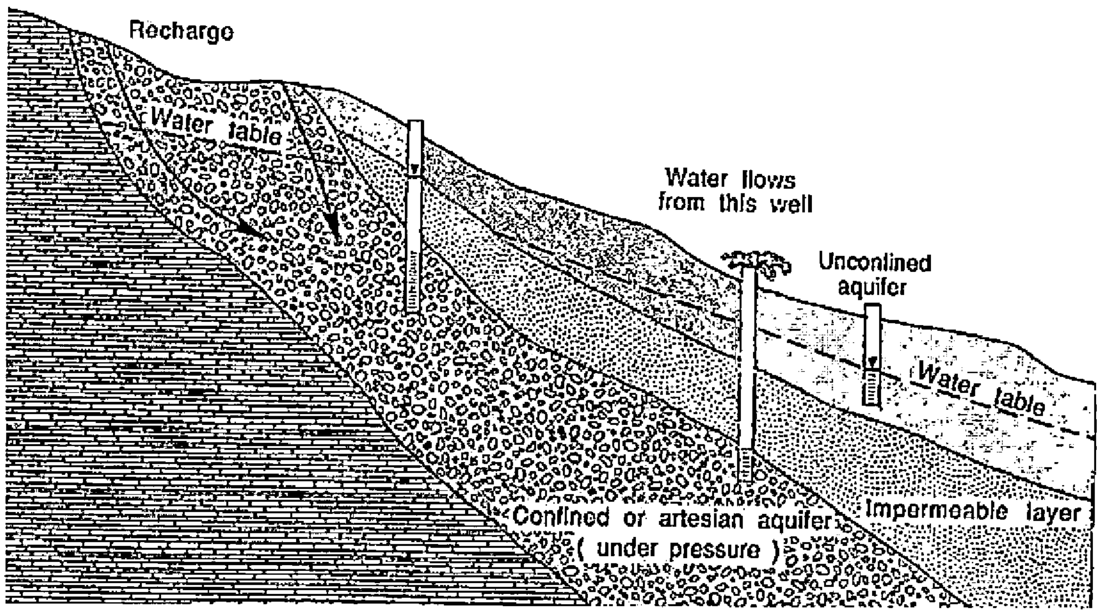
Soil moisture status of the vadose zone can be determined by gravimetric method, using tensiometers, neutron probes, etc. The soil water retention curve for different soils can be estimated in the laboratory using a pressure plate apparatus.

4.7 Groundwater

It is the water contained in the saturated zone of soil. Water bearing formations of the earth's crust act as conduits for transmission and as reservoirs for storage of groundwater. The geologic formations control the occurrence, movement, quality and availability of groundwater. The water table (phreatic surface) separates the saturated and unsaturated zones. The pressure at the water table is atmospheric. The water table level will fluctuate and may be directly related to precipitation. Porosity and permeability of the underlying strata is the controlling factor for the storage and movement of groundwater.

The zone of saturation consists of rocks with different water bearing and water yielding properties. Aquifers are geological formations, which are sufficiently porous to store large quantities of water and permeable enough to transmit it in quantities that can be economically exploited. Aquicludes are low permeability formations which contains water, but incapable to transmit significant quantities. Aquitard is a low permeability geologic formation, which contains water and can transmit it slowly from one aquifer to another. Aquifuge is an impermeable unit, which can neither contain nor transmit water.

An aquifer may be roughly divided into two major categories, unconfined aquifers and confined aquifers. Unconfined aquifers, also known as phreatic or water table aquifers, are characterised by an upper unsaturated zone and a lower saturated zone.



A confined aquifer, also called an artesian or pressure aquifer consists of saturated porous materials, such as sands and gravel, which are sandwiched between two formations of low permeability. They usually occur at a depth, and tend to be relatively well protected from contamination. Water in a well penetrating such an aquifer will rise above the base of the upper confining formations; it may or it may not reach the ground surface. The water level in a well penetrating a confined aquifer is the hydrostatic-pressure level of the water in the aquifer and is called as the piezometric or potentiometric surface. If the piezometric surface is above ground level, the confined aquifer will yield a flowing well.

The hydrologic equation based on the law of conservation of matter, as applied to the hydrologic cycle, defines the total water balance. Groundwater balance deals with aspects of balancing various components of groundwater recharge and discharge, with storage changes in the groundwater basin. Many of the streams and lakes are fed by groundwater during lean periods. This can be extracted to augment surface water resources. The study of hydrologic cycle would not be complete without an understanding of the exchanges of water between ground and surface supplies.

5.0 GEOGRAPHICAL INFORMATION SYSTEM (GIS)

A GIS is a composite of computer based decision support tools for the integration of spatial data from different sources and for the analysis, manipulation and display of these data. It is therefore, an excellent tool for the management of large bodies of spatially extensive data with all the advantages of a computer environment; precision, consistency and absence of computational error. Once a geographic database is established, its analyses allow us to study real world processes by developing and applying models.

This powerful tool holds a very large potential in the field of regional and micro-level spatial planning particularly in watershed planning and management. A GIS can help pull together various types of disparate data such as remote sensing data, census data, records from different administrative bodies, topographical data and field observations to assist researchers, planners, project officers and decision-makers in resource management. Creation of a spatial database is the first step in watershed planning. This is followed by spatial analysis to help identify problem areas and finally, to chart out various steps towards mitigating the identified problems. By taking a watershed as the spatial unit of study, appropriate physiographic and morphometric parameters can be taken into account to enable proper watershed level resources management.

5.1 GIS Applications in Hydrology

Hydrology is an area, which can greatly benefit from integration with GIS. It provides a level of automation for hydrological analyses that have not been seen before. Power of latest hydrological models is their ability to simulate watershed behaviour for different scenarios involving changes in input parameters, such as impact of land use, on discharge, water quality, etc. But the major problem with such models is the time requirement for the data preparation and computation of hydrological parameters. A GIS database containing land use, soil type, topography, and other related data could be interfaced with these models for an effective application. In the early days, GIS were mainly used as hydrological mapping tools. With the advent of sophisticated mathematical models requiring large input data, GIS play an important role. Further, integration of remote sensing with GIS have enabled the efficient generation of input parameters required by these watershed models.

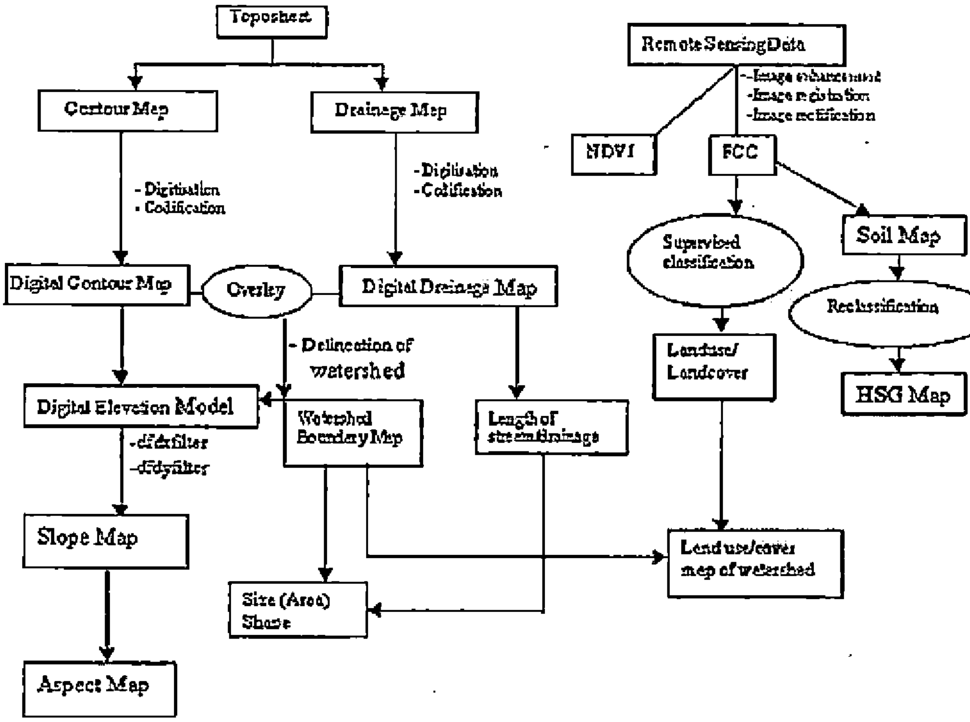
The types of data that can be used alongwith GIS can be of lumped in nature, physically distributed or a combination of both. Lumped hydrological model require parameters such as curve number or morphological characteristics, which can be extracted through a GIS. Physically distributed models require a larger amount of parameters at denser intervals, such as small grid level, which can be substantially facilitated with the aid of a GIS. Due to its efficient data handling capabilities, GIS is increasingly being used as an interface and data manager for hydrological models.

Recent advances in remote sensing and GIS provide very useful information in undertaking the integrated resource analysis. Satellite remote sensing provides reliable and accurate information on natural resources, which is pre-requisite for planned and balanced development at watershed level. These two new technological tools have emerged to meet ever-increasing demand for more precise and timely information.

5.1.1 Watershed Management Information Data Base: The function of an information system is to improve one's ability to make decisions. An information system is that chain of operations that take us from planning the observation and collection of data, to storage and analyses of data, to the use of the derived information in some decision making process. GIS can be an information database, which contains spatially referenced watershed and hydrological data in different formats and collected from different sources. A GIS can analyse these data and convert it into information required for various developmental and management activities. A watershed information database system consists of the following data types:

- remote sensing data
- collateral data
- base maps and toposheets
- hydrological data
- meteorological data
- socio-economic and institutional data
- field data

5.1.2 Extraction of Watershed Characteristics: GIS provides a digital representation of the watershed parameters and resource characteristics used in the hydrologic modeling. The information database in GIS environment enables the easy extraction of various watershed characteristics required for the hydrologic models. The following flow chart shows the steps involved in the computation of different watershed parameters through a GIS.



GIS is a tool for storing, analysing, and manipulating huge amounts of geographic information. Most of the morphological characteristics are geographic in nature. Therefore, the computation of these characteristics can be done easily and efficiently through a GIS with various data layers representing watershed boundary, drainage, contours etc.

5.1.3 Land Use/Cover Detection: The information of land uses/cover patterns, their spatial distribution and changes are the pre-requisite for making watershed development plans. These are dynamic features over space and time and it is difficult to get real time information through conventional means. In recent years, satellite remote sensing techniques have been developed, which are of immense value for preparing an accurate land use map and monitoring changes at regular periodic intervals of time. Remote Sensing offers multi-temporal repetitive data for identification and quantification of land surface changes, and therefore, greatly enhances capability of a GIS in updating map information on a regular basis. These techniques are having an immense potential for preparing an accurate land use map and monitoring change detection at regular periodic interval. Such studies can be used to assess the impact of watershed developmental activities.

5.1.4 Watershed Prioritization: Integration of Remote Sensing and Geographical Information System (GIS) Techniques provides reliable, accurate and update data base on land and water resources, which is a pre- requisite in identifying runoff potential and soil erosion zones and to identify the state of watershed and to suggest suitable sites for water harvesting structures.The various data layers such as land use/cover, soil texture, slope and runoff potential can be generated by analyzing the satellite data in the GIS environment. The potential areas for various soil and water conservation measures can be identified by using the decision rules formulated as per site suitability criteria for these structures.

5.1.5 Hydrologic Modeling: Prediction of surface runoff from a watershed is one of the most useful hydrologic capabilities of a GIS system. The prediction may be used to assess aspects of flooding, aid in reservoir operation, or aid in prediction of water borne contaminant movement. This leads to a situation wherein the majority of new watershed models to be having a GIS component or a GIS interface for input data management. Different rainfall-runoff models based on curve number, unit hydrograph (UH), instantaneous unit hydrograph (IUH), geomorpholocal instantaneous unit hydrograph (GIUH), or having calculation of watershed abstraction based on soil and land use characteristics, are being greatly benefited with the integration of GIS.

5.1.6 Flood Plain Zoning: The use of remote sensing and GIS has become an integrated, well-developed and successful tool in disaster management, as we are having our own earth observation programs, and the requirement for hazard mitigation and monitoring rank high in the planning. In disaster prevention phase, GIS is used to manage the large volume of data needed for the hazard and risk assessment and to prepare flood plain zoning maps. In disaster preparedness phase it is a tool for the planning of evacuation routes, for the design of centers for emergency operations, and for integration of satellite data with other relevant data in the design of disaster warning systems. In the disaster relief phase, GIS is extremely useful in combination with Global Positioning System in search and rescue operations in areas that have been devastated and where it is difficult to orientate. In the disaster rehabilitation phase GIS is used to organise the damage information and the post-disaster census information, and in the evaluation of sites for reconstruction.

5.1.7 Soil Erosion Modeling: Empirical soil erosion models use the parameters denoting watershed slope length and steepness, soil erodibility, rainfall erosivity and crop practices and management types, which are geographical in nature, to estimate average soil loss from a watershed surface. Computation of these factors can be done efficiently using geographical information system (GIS) with various data layers representing watershed boundary, slope, rainfall distribution, land use and management practices, and soils. The combined data layers of a GIS allow the calculation of soil erosion per pixel. In physically distributed models, the grid-based information stored in a GIS, on watershed soil, slope, and land use/management, can be directly transferred to the soil erosion model, which computes the erosion and deposition rates at various points on the watershed boundary.

5.1.8 Groundwater: Remote sensing with its advantages of spatial, spectral and temporal availability of data covering large and inaccessible areas within short time has become a very handy tool in assessing, monitoring and conserving groundwater resources. Satellite data provides quick and useful baseline information on the parameters controlling the occurrence and movement of groundwater like geology, lithology/structural, geomorphology, soils, landuse/cover, lineaments etc. The remote sensing technology and GIS tools have open new paths in groundwater studies. The integration of the two techniques enhanced the automation of geologic exploration, mapping and identification of groundwater aquifers or groundwater potential zones. Furthermore, GIS offers easy solutions of groundwater impact assessment problems and better visualization of different scenarios.

5.1.9 Water Quality: Integration of GIS and remote sensing to water quality have mainly concentrated on Non-Point Source Pollution (NPS). By inputting non-point source pollutant export coefficients based upon land use and soil type into the GIS attribute tables, non-point source loading rates can be determined for the watershed. Mapping of water quality parameters can also be done in a better way using GIS, using its interpolation functions.

5.1.10 Reservoir Sedimentation: The reservoir surveys carried out using the conventional equipments are time consuming. During such lengthy survey process, the siltation pattern and the bed levels of the reservoir will also be get changed. So, in order to update the sediment measurement techniques, to introduce latest technology available in the field and to overcome the difficulties faced in the conventional methods, methodologies were developed by the integration of GIS and remote sensing.

DELINEATION AND CHARACTERISATION OF WATERSHEDS – MORPHOMETRIC ANALYSIS

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A watershed is a natural hydrologic entity and it covers a specific aerial extent of land based on the reference drainage channel, usually a stream or river. It may cover from less than one hectare to thousands of hectares depending on the size of the stream, the point of interception of the stream, the drainage density (length of drainage channel per unit area) and its distribution. For the purpose of discussions on concepts, frameworks, and strategies in a holistic approach, we need to make distinctions between village-level micro-watersheds, sub-catchments, catchments, river basins, and international river basins that traverse different climatic zones and countries. Delineation of watershed is the process of demarcating a geo-hydrological entity encircled by a distinct ridgeline and surrounded by many such entities that form a major unit for the sake of administrative and technical feasibility considering homogeneity of basic resources and production. Before delineating a watershed, the size of the proposed entity should be decided.

Stream net - work and stream order

Water flowing downstream from an upslope region is in the form of small fingertip tributaries. All the small fingertip tributaries contribute to the flow by joining a main stream, and the flow continues till it reaches the end of the drainage cycle. The entire network of streams is characterised by the formation of links such as exterior link, interior links, nodes or junctions. The primary fingertip tributaries are the exterior links. The primary tributary may join another tributary and form an interior link. A node or junction is formed by the intersection of exterior - exterior link or exterior-interior link. The point at which water flows out of an area is called the outlet or pour point. This is the lowest point along the boundary of the water shed.

For ease of mapping we can assign a numeric order to links in a stream network. The smallest fingertip tributaries are designated as first streams as they are fed by overland flow and they have no upstream source. Where two first order streams join, a second order stream is formed and when two second order stream join we get a third order stream and so forth. When a first order and second order join it will retain the order of second. Depending on the order of streams watersheds also can be classified and based on this the proper interventions can be planned. For lower order streams cheaper interventions are only needed where as check dams and other structures will be needed for higher orders only (fourth order or higher usually). Other characteristics studied are

1. Bifurcation ratio Ratio between first to second 2-3 ideal , 5 good
2. Drainage density Total length / Area - if more good – use same unit for calculation
3. Length breadth ratio less than 3 ideal
4. Discharge time

Hierarchical classification of watersheds

In India, at the national level, watershed, the All India Soil and Land Use Organization do delineation in five stages. Although the terms, watershed, catchments, river basin, drainage basin, considered synonyms in the hierarchical classification their sizes differ. The watershed is the smallest unit in the national atlas. At the regional level, watershed is further delineated into sub-watershed, mini-watershed and micro-watershed. The smallest unit in the district atlas is taken as micro-watershed. This is a common term for village level watershed accepted in watershed planning. The classification of watersheds used by All India Soil and Land Use Organization is given below.

National Watershed atlas divides, India into 17 sheets of 1:1m scale. Central Water and Power Commission and Ministry of Agriculture divided India into Six drainage systems

1.Indus
2.Ganges
3.Brahmaputhra
4.Drinage into Bay of Bengal (except 2 & 3)
5.Drainage into Arabian sea except 1
6.Ephemeral drainage of Rajasthan

Water resources region: The ultimate in the hierarchy of watershed is the Water Resources Region. Six such water resources regions have been identified for the entire nation based on total surface runoff yield, and numbered in clockwise direction based on the works of Dr. AN. Khosla (Khosla, 1949). The features of these six water resources region and sub units are given in table

Hierarchical Order of classification and the number of sub units

Regions	Basins	Catchments	Sub-catchments	Watersheds	Total area (Lakh Ha)
1	7	12	51	302	308.22
2	4	22	126	836	820.15
3	4	14	55	330+	291.33
4	8	34	175	1150	1130.48
5	8	26	78	513	429.51
6	4	4+	15	106+	273.41
Total 6	35	112+	500+	3237+	3253.1

River basins: These are drainage areas of major rivers of India having a size ranging from 50,000 – 3,00,000Km^2.
Catchments: Drainage areas of major tributaries with size ranging 10,000 – 50,000Km^2
Sub catchments: Area ranges between 2,000 – 10,000Km^2
Watershed: These are the drainage basins of small rivers or rivulets. The aerial extent may not exactly match with that of the area given in the hierarchical classification (500-2000 km^2). For instance, Kerala with its 44 rivers is delineated into 44 watersheds. The Periyar watershed (14P) has an area of 5029 km2 while the area of Manjeswar watershed (44M) is only 49.88 km^2 Altogether 3237 watersheds have been identified.

Micro Delineation

Unit	Size in ha
Sub -watershed	10,000 –50,000
Milli -watershed	1,000 – 10,000
Micro -watershed	100 –1,000
Nano -watershed	<100

Micro watersheds: Micro watersheds are usually based on an important small streams or a group of streams (especially in the hilly areas). Micro-watershed is usually taken as an ideal unit for agricultural purposes. For the project preparation and implementation based on watershed area development approach in the villages, a micro-watershed of size 100 - 1000 ha is usually taken up. The ideal size would be about 500 ha area.
Nano watershed: These are drainage areas of small streamlets within a micro-watershed. These are units of less than100 ha.

Delineation of water sheds

For the proper watershed planning, watershed boundaries (divide lines or ridgelines) have to be found out and a watershed map according to scale must be drawn along with key information. Before delineating a watershed, the size of the proposed entity should be decided, A systematic sub-division of the catchment area up to sub-watershed can be achieved in stages following the hierarchy of the stream order. In the first stage, divide whole of the catchment area of a river into sub-catchments by following the major streams and important tributaries on a drainage map of 1: 1 million or 1: 250,000 scale drawn from the survey of India, topographical maps.

Then divide each sub-catchment into watersheds following distinct tributaries and streams within each sub-catchment. Base maps for such delineation could be 1:250,000 to 1:50,000 scales. Further, sub-divide the watersheds into sub-watersheds. These could be in the scale of 1:50,000. The areas of such sub-watershed may vary from 10,000 to 20,000 ha. Further sub-division of a sub-watershed into milli watershed is made for agricultural purposes especially for soil conservation programmes which are to be done entirely on watershed basis and this is known as micro level delineation of watershed.

There may be large number of small streams, which drain directly into the main stream. This presents difficulties in demarcation during all the above stages. To overcome this, a group of such streams may be combined into sub-catchments, watersheds, and sub watersheds according to the sizes already mentioned.

Codification of watershed

A national codification system is followed to avoid usage of the same symbol for different watersheds and to alleviate the ambiguity in indicating the same watershed by different agencies by different symbols. This will also greatly help national level policy, decisions on fixing priorities for individual as well as integrated development programmes. The codification of the delineated hydrologic units is done following the hierarchy of bigger, hydrologic units to smaller units moving downstream upwards. Alphanumeric, codification using digits and alphabets is used.

Regions	Basins	Catchments	Subcatchments	Watersheds	Sub watersheds
1,2,3---	A,B,C	1,2,3	A,B,C	1,2,3,	a,b,c,

The following connotations are commonly used for the watersheds of Kerala. Kerala State with its 44 rivers is delineated into 44 watersheds; The 44 watersheds are usually numbered from the south along with the first capital letter of the name of the respective rivers. Each major watersheds divided into sub water sheds in clockwise direction and is numbered with Arabic numerals serially in the sub-catchment occurs on right or left side of the main drainage. This is further divided into micro-watersheds and is numbered in clockwise direction, with small alphabet.

Coding of a tributary of Bharatha puazha (a river in Kerala)

Region	Basin	Catchment	Subcatchment	Watershed	Sub watershed
5	C	20	B	1	a

Thus the code will be **5 C 20 B 1 a**

Procedure of delineation of micro-watersheds

Watershed development programmes at the village level must be planned taking micro-watershed (about 500ha) as a unit. Delineation of micro-watersheds can be done in many ways. The most common method is to use a topographic map (toposheet). Other methods include watershed atlas, aerial photographs, topographical survey, and reconnaissance survey.

Topographic sheets or top sheet

In our country national surveying and mapping organization is the Survey of India. They prepare topographical maps on various scales, 1:1million, 1: 2,50,000, and 1:50,000, or 1:25,000. These are restricted and secret category files. However, they give authentic information on physical and cultural features of the area using unique symbols and signs. These maps clearly depict the network of contour lines and drainage pattern. The details are, however, dependant on the scale of the map. Smaller the scale of the map, lesser the details it contain. In contour maps of I:25,000, contour lines at 10 m intervals are shown. In 1:50,000 scale map, contours at 20m interval are given and other land cover information such as water bodies, wet lands, cultivated areas, forest areas, settlements, wet lands road net works, wastelands etc are also given. . The streams, tanks, and lakes serve as very good guidelines for delineating watersheds. Before delineating a watershed, the size of the proposed unit should be decided. For a micro watershed, it should be around 500 ha. Determine drainage units of this much dimension. Although 500 ha is a general norm, and if on actual survey, a watershed is found to have slightly less or more area, it may be taken up. In certain cases, it may not be possible to find watersheds of this much dimension. Watersheds may be small, especially in hilly areas. In such cases, small contiguous watersheds with an approximate total area of 500 ha can be taken up..

A tracing paper is laid over the toposheet and the ridgeline or the divide line of the watershed is first traced starting from a point, which is usually the outlet for runoff from that particular area of land, keeping in view the streams which contribute water to that selected point A line is traced from this point along with the ridgeline until it joins the same point. While tracing this line, the loops of contour should be considered for properly locating the boundary line. This line encircles the area of the watershed and delineates it from the adjacent watersheds.

Aerial photographs

Aerial photographs of 1:6000 or 1:4000 scales are taken as the 4-5 enlargements of these photographs provide the prints sufficiently enlarged for proper delineation.

Watershed atlas

In many states, watershed atlas has been prepared, sometimes up to micro watershed level. In Kerala, Kerala State Land Use Board in collaboration with Kerala State Remote Sensing and Environment Centre has prepared watershed atlas for the entire 44 rivers, i.e., 44 watersheds. Sub watersheds and various micro watersheds are also depicted on the watershed atlas. Micro watersheds are prepared in the scale I: 5000 or I :4000. The maps contain, ridge lines or boundary lines, main roads, administrative boundaries, water bodies and main places. It also contains general information on soil and water resources in the watersheds. Watershed atlas may be used to prepare resource maps on cadastral maps of scale 1:4000.

Delineation of watershed is also possible by actually conducting a topographical survey. A point on the drainage course is taken as the starting point. Contour lines of smaller intervals are traced out on cadastral maps. The loops formed by the contour lines, physical features, and the drainage lines help in delineating small watersheds of required size.

Reconnaissance survey: Small watersheds can be delineated on the cadastral map of the identified area directly by reconnaissance survey with reference to survey numbers and physical features. A particular point in the drainage course is taken as the starting point. One person can walk in the opposite direction of the flow of the main stream until the highest point. the ridgeline, is reached. A second person standing at the lower end of the stream may guide the first person to move a bit up or down to locate the highest point by looking at the sky line. A mark with a boulder can be made at this point. Similarly, the process is repeated for all the branches of the stream to obtain roughly the boundary of the upper reaches of the watershed. Some minor adjustments may become necessary and it can be made by noting the direction of overland flow during rainfall. By walking along the divide line of the watershed and observing the physical features, the ridgeline is marked and joined it back with the starting point.

Resource Inventory for watershed planning: The resources in the watershed, both natural and human made and various socioeconomic factors, which influence the implementation of watershed development programmes, must be gathered and analyzed before chalking out a comprehensive watershed plan. Data on the existing status of the natural resource base-land, water, vegetation, energy, live stock, fisheries and their distribution pattern, ownership, utilization pattern, etc. must be collected. Participatory techniques are useful for an overall assessment of these resources. Many of the information could be gathered from block level or Panchayath level resource maps, if they were already prepared, or from records available there. Secondary data can be gathered from various sources such as the Departments of Agriculture, Animal Husbandry, Forestry, Soil survey and Geology, various University Departments and Libraries. Climatic data may be obtained from Meteorological stations of Indian meteorological Department, Agricultural University Stations, Irrigation Departments, etc, If nearby stations are not present, direct observations can be made by establishing different equipments. As much information on surface and groundwater potential shall be collected from Irrigation Department, Central Ground water Department, etc. Thematic map on water resources gives information on wells, ponds, and depth of water table. If such information is not available, direct observation has to be made. In watershed development programmes, people's participation must be ensured not only in collecting data but also its implementation. As it is a continuous research and action process by the local community, the participatory technique used is "Participatory Rural Appraisal (PRA).

Direct observation: By direct observation, observable phenomena and processes are assessed within their natural surrounding. For instance, water table, stream flow, runoff yield, sediment yield, etc. must be observed and measured. Experienced personnel with subject matter knowledge are required to measure some of the parameters especially those related to hydrology.

Resource mapping: For resource mapping two methods are generally employed. They are the modified participatory resource mapping or the BGVS (Bhatath Gyan Vigyan Samithi) approach and the PRA method. The important characteristics studied in all these methods should include information relating to Climatic, Physical, Biological and socio economic resources along with infra structure and other external influences.

Climatic details include observations on Rainfall, Temperature, Humidity, Sunshine hours, Wind velocity and directions monthly, Evaporation and evapo-transpiration and any other relevant adverse climatic conditions if any.

Physical Factors/Resources include

- Size: It help in computing many parameters like precipitation receipt. Larger more heterogeneity
- Shape: Shape differs based on morphometric parameters like geology and structure. It decides length width ratio affects runoff
- Physiography Land form: Topography/Relief, Ruggedness, Slopes. These are vital in land use planning. Slope affect flow and erosion.
- Geology includes observations on Rock formation, Parent material, Stratigraphy
- Water : surface, subsurface, Ground
- Soil studies make observations about Type, Depth, Land Capability class etc.

THE WATERSHED PLANNING PROCESS

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A watershed area has the upper reaches, the intermediate reaches, and the lower reaches. In the upper reaches, the land would be relatively poor; and at the lower reaches, it would be better and fertile. The treatment to be given to the watershed also differs accordingly. Poorly planned land use activities in the uplands or upper reaches may adversely affect the productivity and environmental quality of the lowland portion of a watershed. In spite of numerous historical lessons, massive soil erosion from deforestation and subsequent land misuse continue to take place. Watersheds cannot be improved by land users and local communities alone. Watershed management programmes require external financial and technical assistance for planning, design, and construction of the necessary physical structures. It needs the active participation of agronomists, soil scientists, water engineers, forest and livestock experts, and extension specialists.

In most developing countries, lack of sufficient data on climate, soil, and hydrology of small watersheds constitute a major obstacle to proper planning. Where baseline data are readily available, Geographic Information Systems (GIS) and Global Positioning Systems (GPS) could be efficient and accurate tools for planning, on both at watershed and farm level. For example, GIS can be used to locate various land treatment practices and identify users in watersheds. Assessment can then be made to indicate to what extent the watershed has been treated to an acceptable level. The GPS can be used to design mechanical or vegetative terrace systems.

The following factors are important in the planning of watershed management

- It requires close collaboration among farming and non-farming communities, government agencies, and research institutions.
- Appropriate incentives must be provided to local farmers, if the improved practices involve changes in traditional land use.
- Initial investment from local and national governments is needed for conservation measures and public education.
- Economic incentives must be created through greater transfer of resources from downstream to upstream, in order to improve upstream conservation measures.
- Impact assessment must emphasize the long-term benefits rather than the short-term gains.
- Knowledge on the following is essential for the proper design and management of watershed activities: physical attributes like topography and soil type; rainfall characteristics; drainage pattern; natural vegetation and its distribution; present land use and land tenure; land policies of the government, social and cultural characteristics of local communities; and potential collaborating technical institutions and government agencies.

Phases and steps in watershed management

Participation and integration are the key characteristics of modern watershed management. It is more people friendly and process based than the traditional watershed management. It fit into the farmers pace of life rather than functioning at the convenience of development agencies, as was the case in the traditional approach. In the past, watershed management was aimed at soil, water and probably forest conservation only. Now, its aim is poverty alleviation and overall human development through natural resource management. As we all know, the old methods were extensionist and scientist led, but now it is farmer led, based on indigenous knowledge and culture of local people. Earlier, it was top-down planning including monitoring and evaluation. Now, planning, monitoring and evaluation are participatory.

In the conventional approach, land use was strictly based on land capability. In the modern approach, land use is based on land suitability and people's needs or preferences. It aims to empower people. It is multi-sectoral and multi disciplinary. In the old approach, engineering structures were given undue importance and got priority. In the modern integrated approach, agronomic, bioengineering and agroforestry methods are prioritised. People's initiatives are always encouraged. Farming system approach and common property management approach are other features. Moreover, the emphasis is to base small watersheds as units of management rather than large watersheds.

Planning and execution of management programmes for watersheds, in general, go through three different phases, viz., *Planning phase, Implementation phase,* and *Follow-up phase.* Normally, a model watershed management project requires a minimum of five years to show some results and another five years to consolidate the benefits. About one year is required for the planning phase. The planning phase is also useful for rapport building and implementation of entry point activities.

Phase 1. Planning phase: The planning phase or the preparatory phase is very important; as during this phase, resource inventory, defining challenges and opportunities, analysis of the causes of the problems, development of alternative solutions, developing objectives, and documenting data and decisions are done. It is useful for rapport building and implementation of entry point programmes. This process of planning can be broken into three stages.

Stage 1. Get familiar with the watershed

- Understand the people, their interests, and institutions
- Determine size, boundaries, soils, topography and other features
- Determine how the watershed is used at present

Stage 2. Ensure people's participation

- Implement some entry point programmes
- Identify and contact partners/stakeholders
- Forms different groups
- Divide work and responsibility
- Identify and manage conflicts
- Obtain local funding and other resources

Stage 3. Determine priorities for action

- Gather and analyse the data
- Assemble maps and data
- Evaluate water quality
- Assess land use
- Recognize and document problems
- Analyze the causes of the problem and their effects
- Determine goals and objectives
- Development of alternative solutions of the problem
- Select critical areas for attention

As the success of watershed management programmes is dependent on the level of people's participation, Participatory Rural Appraisal (PRA), the most popular PLA method wherein a continuous research and action process by the local community and the outside experts functioning as facilitators, are employed for resource inventory and appraisal.

Include provisions for some entry point activities (EPA). The major purpose of this activity is to meet a part of the felt needs of the community, develop rapport with people and to build the capacity of watershed association, watershed committee, self-help groups and user groups involved in the implementation of the programmes.

Phase II. Implementation phase: Once the problems have been recognized and priorities listed, it is possible to implement various alternatives. This phase involves three stages.

Stage 1. Conduct educational programmes

- Identify and understand target audiences
- Develop specific messages
- Combine communication approaches, channels, and media

Stage 2. Provide assistance

- Target technical assistance
- Provide financial assistance
- Build social support and recognition

Stage 3. Ensure implementation

- Select the best watershed management alternatives
- List ways or strategies for implementation
- Determine how to measure progress
- Implement the selected alternative solutions

Select the most relevant technique. Ideally, the steepland portion of watersheds should be left to forest or other forms of natural vegetation. However, where the soil and climatic conditions are suitable, well-designed and carefully managed structures such as bench terraces may prove ecologically sustainable.

Introduce the most important techniques in the first instance. Alternate measures are planned as per priorities; treatment measures are applied initially to critical areas so that these areas are restored to the pre-deterioration stage. Take the existing traditional or indigenous systems as the starting point. Identify the critical gaps and encourage the beneficiaries to adopt/adapt solutions for them through various alternatives. In the implementation phase, there must be room for midterm corrections.

***Phase III. Withdrawal and Follow-up phase*:** In the programme provisions must be there to take care of the various community assets created such as water harvesting structures, forest plantations in common lands, fish ponds, etc. Post –project maintenance is an important activity. The follow-up phase takes care of the general health of the watershed and ensures normal working. Special attention is paid to the critical areas restored during the implementation phase. Evaluation of the projects implemented can be taken up during this phase.

- Install a mechanism to continue with monitoring and evaluation
- Provide protection against all factors that might cause deterioration in watershed conditions.
- Due attention shall be paid to improve the crop production systems, forest management and production, forage production and management, socio-economic conditions, etc.
- All the factors that would sustain the watershed and people living therein, for instance, health and family planning, nutrition, etc. should be continued.
- All community assets created under the project shall be transferred to the water association for its operation and maintenance.
- As a follow up to the various management programmes, measures for overall improvement in the watershed must be continued.

Watershed development plan

The watershed development plan should be a comprehensive document containing information for all-round development of the watershed. The report normally includes the following parts.

1. *Introduction*: The report should start with an introduction. Include a general background and administrative history of the area.

2. *General features of the watershed*: A location map of the watershed and watershed atlas must be included. Name of the watershed, village, Panchayat, block, Taluk, assembly constituency, and district shall be mentioned. Various offices, and financial institutions, educational institutions,

health centres, etc. in the area may also be mentioned. Socio-cultural and historical background may also be included in this part.

3. *Watershed resource appraisal*: The development aspirations of the people must be linked to the resource capability and environment of the local area. Therefore, it is important to depict the resource appraisal correctly. The resource appraisal of the watershed must be done correctly. The information collected through PRM, transect walk, socio-economic survey, secondary data review, discussions with subject matter experts, etc., shall be described under the following heads

- Land resources
- Water resources
- Land use and vegetation
- Human resources
- Environmental appraisal

At least the thematic maps on land use and assets, water resources, land capability maps, and environmental appraisal may be prepared.

4. *Description and analysis of land based enterprises*

- Field crops
- Perennial crops
- Vegetables
- Livestock
- Fisheries
- Others

5. *Description and analysis of non-land based enterprises*: Watershed community include not only the farmers but also other people engaged in traditional occupations such as handicrafts. Goldsmiths, ironsmiths, potters, petty shop owners, tailors etc. are some such sections. Industries may also be present. An account of these enterprises and their problems may also be included.

6. *Benchmark information on watershed for impact evaluation studies in future*: Governments and several donors are spending huge amounts of money for the development of watersheds. They would like to know the impact of their funded programmes. This is possible only if bench mark information is available

7. *Watershed development plan*: This is the most important part of the proposal. The resource appraisal and environmental evaluation will indicate the resource capability of the area, major problems and sectors of intervention. Problems may be prioritised in consultation with the villagers. The evaluation of the watershed management programme is done based on two parameters. Whether the objects of management, i.e., alleviation of drought, flood control, sediment control, increased availability of ground water, increased stream flow, water supply, etc. are achieved and also financial returns. In respect of financial returns, a benefit: cost ratio of 1.5:1 shall be the minimum target.

Wetlands are part of the watersheds. In most cases, they act as the drainage points. Conversion or filling in of wetlands results in irreparable damages to the ecosystem. It affects watershed residents, plants, and animals in many ways. Wetland conservation should be a part of the watershed management programme.

Sand mining and levelling of small hills and hillocks for soil mining are two other recent issues in the watersheds, which must be properly addressed.

Another major problem is the alignment of roads and construction of buildings in the watershed. Most often, these are constructed arbitrarily ignoring the principles of natural resource management. Each of these must be analysed and corrective measures taken.

There should be more emphasis on rainwater management, particularly water conservation, and integrated nutrient management. Adoption of better land husbandry, which represents a shift in emphasis away from soil conservation for its sake to a more holistic approach, may be the best option.

Shortage of fodder is a big issue faced by the farmers. Fodder production programmes should be a mandate of the watershed management programmes. Although afforestation is a major component of the programmes, it is not getting enough importance. Locally acceptable species of trees shall be included. Fodder trees such as gliricidia and subabul shall also be included.

Watershed development plan can be organised as follows

- Analysis of problems and potentials
- Organization of community set up at the village level for implementation of programmes
- Capacity building of community members
- Rehabilitation and conservation measures of natural resources
    - Private land resources
    - Common land resources
    - Water resources
- Diversification and intensification of existing farming system through the adoption of proven technologies in
    - Filed crops
    - Perennial crops
    - Vegetables
    - Livestock
    - Fisheries
    - Others
- Integration of Indigenous technical knowledge (ITK) with exogenous technical knowledge (ETK).
- Livelihood support for non-land based enterprises
    - Existing enterprises
    - New enterprises
- Phasing of financial allocation over the project period for each component and subcomponent- Budget estimates for each component and subcomponent need be given
- Expected contribution from the participants
- Modalities for implementation, review, monitoring, auditing, etc.
- Timeframe for various activities under the project
- Withdrawal strategy and follow up action plans

As a part of the watershed development pan, detailed annual action plans should also be prepared.

Suggested programmes for strategic plan

The programme must target four major components, namely, conservation and development of natural resources, increased water yields, improved management of farm production system, and improved management of non-farm based livelihoods. Some programme measures are indicated below. Separate measures are suggested for conservation measures, water harvesting and production systems. All the measures suggested are indicative in nature. The actual details of treatments can be decided in consultation with the beneficiaries taking into consideration the capability of land, and needs and aspirations of the people.

1. ***Conservation and rehabilitation of natural resources in private lands*:** Lands that can be tilled or cultivated are the *arable lands*. These will be under the possession of individuals. As mentioned already, adopt the principle of land husbandry for the conservation of natural resources. Water conservation should get more importance than soil conservation. With respect to soil, soil productivity shall be the objective. Agronomic and biologic practises should get preference to mechanical measures in a conservation programme. People go for costly mechanical protection works, only if the crops grown are high value crops. In mountainous slopes, agronomical practises alone or mechanical protection alone will not give the desired

effects. In steep land farms (<20%), special measures are needed for protecting the soil and conserving water.

Agronomic/Biological methods: The following are some of the measures usually mentioned as "agronomic" or biologic. The nature and type of measures to be selected is based on the basis of percentage of slope, crops grown, soil characteristics, socio-economic conditions, etc.

Contour farming: Contour cultivation; Contour planting
Selection of crops
Crop geometry
Cover cropping
Conservation tillage
Organic manures
Mulching
Crop residue management
Changes in cropping pattern: crop rotation, multiple cropping, etc.
Grassed waterways and channels.
Strip cropping
Grass strips
Border strips: Boundaries of farms established with hedges of perennial vegetation esp., Pothappuullu, vetiver or any tuft forming grass.
Hedges/ Barrier strips: Involves a single or double row of closely growing grass established on the contour, for example: vetiver hedges, hedges with lemon grass(Cymbopogon flexuoses), hedges with Pothappullu (Themeda cymbaria), or such grasses.
Turfing the sides and tops of bunds.
Geotextiles for slope stabilization
Puertorican terraces with vegetation
Pasture development
Riparian filter strips
Afforestation on steep slopes and denuded hillocks
Promotion of farm forestry practices
Alley cropping/ hedege row intercropping e.g., Gliricidia, Subabul, Hedge Lucerne, Calliandra
Sloping Agricultural Land Technology (SALT)

Mechanical measures: Mechanical or physical measures of erosion management are designed to reduce runoff rate and its velocity. Some are very simple to construct but most of them are expensive and require constant maintenance and repair. If erosion can be curtailed adequately by good land husbandry or other cheap, cost effective techniques, mechanical measures need not be attempted. Select appropriate measures.

Contour bunding
Graded bunding
Broad based terraces
Ridging and tied ridging
Bench terraces (level or irrigation, reverse sloping, outward sloping)
Self-convertible bench terraces (Puertorican, California, Fanya juu, etc.).
Step/ strip terraces
Intermittent terraces (Plantation terraces/ Platforms)
Crescent bunds / Half moons
Conservation terraces/ Zing terraces
Stop-wash lines
Contour stone walls
Hill side ditches or contour trenches -continuous or staggered
Diversion drains

2. ***Conservation measures for common land resources***: In watershed management programmes, common land resources would also get due attention. Integrated development of these areas is necessary for the ecological health of arable lands and the drainage lines. Common

lands include cultivable wastelands, barren and wastelands, permanent pastures and grazing grounds. These lands are often under the possession of government and are common property resources. Because of this reason, sometimes, it may be ignored. However, management measures for private lands alone ignoring common lands will not yield the desired results. Peoples group or Non-Governmental organisations or local self-governments can take the lead in implementing management measures for these areas.

- Conservation of soil and water
- Contour vegetative hedges
- Infiltration pits
- Contour trenches to conserve moisture
- Ponds
- Grassland development
- Natural regeneration of existing biomass through social fencing
- Plantation of new seedling in the treated area
- Social forestry
- Over seeding of grasses and legumes for forage and pasture development.
- Afforestation: Planting of shrubs for fodder and fuel, planting of multipurpose trees in silvi-pastoral systems, etc.
- Regulation of grazing.

Control of gully erosion: Gully erosion is the most severe form of rainwater erosion. In India, gullies are commonly called *nalla.* A gully is a steep sided eroding water course, which is subjected to intermittent flash floods. There are about 4.0 million ha of lands in India affected by gully erosion.

A moot point is whether the importance it receives as a part of watershed management is justified? As Hudson (1981) stated, in terms of damage to agricultural land or reduction of agricultural production, it is not very important for the simple reason that most land subjected to severe gully erosion is of little agricultural significance. Of course, it may be important as a source of sediment in streams, rivers and dams. Gully erosion as a problem is mostly found in semiarid climates unsuitable for any serious agriculture, or on soils with adverse physical or chemical properties. Besides, gully control is expensive and difficult and the cost of reclamation usually exceeds the value of the land! Remember the old dictum of "prevention is better than cure" and follow better land husbandry measures. It is always better to use the limited resources for preventing future gullies than curing existing ones. Therefore, invest the resources only in areas where it pays at least in future.

Select suitable techniques based on the severity of problems. The treatments suggested for gully erosion control are of two types.

- Check dams of various types
- Vegetation lined waterways

Check dams are also called drop structures. There are several types of check dams, depending on the objectives and can be planned to (1) stabilize waterways, (2) store excess water, or (3) trap sediment. When the check dams are constructed for trapping sediments they are called *sediment storage dams, sediments traps or soil traps.* For gully control, check dams are constructed with the third objective of trapping sediment, and porous check dams are constructed. This include live check dams, brushwood dams; single row post brushwood dams, double row post brushwood check dams, dry stone masonry, loose rock check dam, wire bound loose rock, single fence rock, double fence rock and Gabion check dams.

3. ***Rain water management for increased water yields:*** This includes water harvesting, ground water recharge and water storage structures. Under water harvesting, both *in situ* and *ex situ* water harvesting are involved.

In situ water harvesting

- Infiltration pits/rain pits
- Contour trenches
- Mulching

- Trapezoidal bunds
- Contour stone bunds
- Basins/centripetal terraces
- Pit planting
- Husk burial
- Contour vegetative hedges
- Flooding in paddy fields

Rain water storage structures

- Farm ponds :
    - *Dug-out farm ponds* suited for flat topography,
    - *Embankment ponds* for hilly and rugged terrains with frequent wide and deep water courses;
    - Dug-out -cum-embankment ponds for medium topography.
- Percolation tanks
- Small earthen dams
- Rock-filled dams
- Sand dams
- Small weirs/check dams
- *Nalla* bunds
- Sub-surface dams/dykes

Off-stream storage of water

- Catch water drain
- Rectangular tanks
- Ring tanks
- *Godha* system for the high ranges

Roof top water harvesting

- Storage tanks for direct use
- Storage in dug wells
- Recharge pits/trenches
- Utilization of dried up wells for recharge

Artificial ground water re-charge: Sub-surface techniques

- Recharge shafts
- Injection well
- Recharge well
- Subsurface dyke/dam
    - Percolation wells with shaft or wells

Water surplussing and grade stabilization structures

Water weirs in bunds, drop spillways, drop inlet spill-ways, chute spill-ways, grass outlets, and emergency spill-ways, diversion drains and water ways.

4. ***Treatment of drainage courses or lines*:** Drainage lines include rivers, rivulets, streams, and other such drainage points. Control of stream bank erosion shall be a major activity. The following works are suggested.

- *Clearing drainage congestion*
- *Revetments*- Maintain the river bank in its existing position
    - Vegetative measures e.g. *Pandanus*, reeds, vetiver, *Desmostachya* (Attudharpha)
    - Grass reinforced with geotextiles (geonets, geomats, cocologs, etc.)
    - Bitumen impregnated geomats below higher water level
    - Live woody cuttings
- *Bank armouring using*
    - Rip-rap
    - Gabion
    - Concrete structure

- Spurs and Groynes
    - Protection, aggradation, or deflection spurs- Structures that project in to the riverbed from the bank to prevent lateral erosion- Usually permeable spurs made of timber or pre-fabricated metal frames are used
- *Retaining Walls*
    - Dry stone walls
    - Masonry walls
    - Crib structures
    - Gabion structures
    - Reinforced earth structures: Using a reinforced medium– geotextiles, gabion wire, timber grid, metal strips, etc.,

5. ***Improved management of farm production system*:** This involves the following three main activities in various farm production systems such as agriculture, horticulture, livestock and fisheries.

- Testing/demonstration of new technologies,
- Diversification of existing farming systems,
- Adoption of proven technologies

Some examples:

- Farming Systems Approach (FSA): Diversify production systems depending on the land capability, irrigation potential, soil characteristics and climatic conditions, for example, crop rotation, multiple cropping, and mixed farming.
- Use of improved planting materials
- Integrated nutrient management(INM)
- Integrated pest management (IPM)
- Integrated Pest Management (IPM)
- Low External Input Sustainable Agriculture (LEISA)
- Good Agricultural Practices (GAPS)

Livestock husbandry: Livestock rearing is an integral part of the rainfed farming systems almost everywhere in India. Specific measures must be planned to regulate the livestock population and to increase their productivity. The following measures can be included in the project.

- Mixed farming as a part of the homestead farming system
- Backyard poultry
- Backyard pig farming utilizing food wastes
- Rabbit rearing
- Production of fodder on cultivated lands
- Improvement of livestock health and quality
- Better animal health care facilities and preventive vaccination
- Milk co-operatives and milk processing facilities
- Livestock population control through castration of scrub bulls and other means.

Inland Fisheries

- Fish farming in ponds, lakes
- Mixed farming in rice fields

Sericulture

- Sericulture can be promoted through planting of mulberry and rearing of silkworms.

6. ***Improved management of non-farm based livelihoods (for landless and marginal farmers):*** These are the measures for landless and marginal farmers. These include adoption of proven technologies in existing livelihoods and starting of new microenterprises. Some such areas are agro-processing works, basket making, rope making, oil extraction, carpentry, black smithy/gold, leather works, pottery, ceramics, handicrafts, handlooms, tailoring, khadi and stationary/petty shops

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AGRONOMIC MEASURES IN WATERSHED MANAGEMENT

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Soil and water are the two major natural resources, the management of which greatly affect the social and economic structure of our villages and the country as a whole. The most serious problems in the management of these resources are erosion of topsoil and run off inflicting permanent damage to the land and water systems. Soil conservation means a way of keeping everything in the soil in its place. It is a combination of controlling erosion and maintaining soil fertility. Earlier, the focus has often been on trying to keep the soil at its place by plot-level activities only. At present, the attention has switched to landscape level approaches, especially on a watershed basis where in the role of biomass or vegetation in reducing erosion is also considered. Various soil conservation practices, in general, involve managing soil erosion and its counterpart process of sedimentation, thereby reducing its negative impacts on the ecosystem.

Soil and water conservation are always considered together. Many measures are directed primarily to one or the other, but most contain an element of both. Reduction of surface run-off by structures or by changes in land management will also help to reduce erosion. Many of the water harvesting structures conserve soil also. Similarly, reducing erosion will usually involve preventing splash erosion, or formation of crusts, or breakdown of structure — all of which will increase infiltration, and so help water conservation. Measures such as contour bunds as practised in India not only conserve soil but also water increasing infiltration.

Before planning for soil and water conservation, remember that erosion is part of the long-term geological cycles of mountain formation and decline, which occurs everywhere, and is an essential part of soil development. Therefore, attempts to reduce erosion to zero level are likely to fail. An optimum degree of soil conservation or maximum tolerable soil loss, however, can be targeted. This critical limit is not uniform for all soils and differs based on several factors as discussed under the Universal Soil Loss Equation.

Scope of soil conservation agronomic practices

Soil conservation measures are generally grouped as agronomic or biologic and mechanical or engineering measures. Mechanical measures of erosion control are designed to reduce runoff rate and its velocity. These structures break the slope length and degree of slope either through surface soil movement, changing topography of land or through constructing some structures. A combination between agronomic measures and good soil management can influence both the detachment and transport phases of the erosion process, whereas mechanical methods are effective in controlling the transport phase but do little to prevent soil detachment. Soil conservation relies strongly on agronomic methods in combination with a realistic soil management whilst mechanical measures play only a supporting role. Agronomic practices of land husbandry are considered cheap, environment friendly and easy to adopt than engineering measures. In moderately sloppy areas, the need of mechanical measures can be dispensed with, if suitable agronomic measures are adopted. The principle is to intercept the rainfall and reduce their splash effect by various practices.

Terminologies may be confusing. Some people classify the ***biological*** measures into ***agronomic*** (crop), ***agrostological*** (grass) and ***agroforestry*** (crop plus tree) measures. Sometimes, these are also mentioned as "***bionomical***" measures. The practices such as Puertorican terraces with grasses, wherein living plants and plant parts are used alone or in combination with engineering structures are sometimes called "***bioengineering***". Bioengineering measures are a new breed of slope protection measures, which are getting increased attention as they are found to be more sustainable than the civil engineering structures. In a bioengineering method, living vegetation either alone or in combination with non-living plant materials or soft engineering structures is used to stabilise and protect slopes from erosion. It is a hybrid technology of integrating vegetative methods with normal engineering practises to obviate much of the problems from engineering structures.

The first step in water erosion is detachment of soil particles resulting from the impact of raindrops followed by transportation through runoff water. Soil conservation agronomic practices help to reduce the impact of raindrops through interception, and thus reduce splash erosion. These practices also help to increase infiltration rates and thereby reduce runoff and overland flow. Reduction in runoff and soil losses is achieved through land management practices; choice of crop and crop management practices, and associated agronomic practices such as mulching and crop residue management.

Agronomic measures are more effective in low rainfall areas, permeable soils, and in loss sloppy areas. In heavy rainfall areas, erodable soils and in long, steep slopes, these measures have to be strengthened with mechanical measures. That means, soil conservation and agronomy goes hand in hand with mechanical measures such as contour bunding or bench terracing adopted on agricultural land. Generally speaking, soil conservation agronomic practices on agricultural land is second line of defence, the first being mechanical or engineering measures to arrest soil erosion immediately. This approach aims to optimize moisture retention, help conversion of surface run-off into sub-surface flow to improve re-charge, reduce soil erosion and enhance long-term production and productivity, especially of vulnerable and degraded lands.

In the Universal Soil Loss Equation, the factors that we can control are the C factors and P factors of a site. In the equation, A=RKLSCP, there is a characteristic combination of rainfall factors (R), erodibility factors (K), and slope gradient factors (LS) that we cannot control. The factors R and K are natural and we are still not in a position to manipulate them. These factors represent the erosion potential for that particular site.

The agronomic practises take care of the crop management factor 'C' in the Equation and the techniques such as bunds and terraces represent the P factor (support practice). The factors L (length of slope) and S (magnitude of slope) are also amenable to manipulation. C factor management (cover) techniques are more effective than P factor (support practice) techniques. For example, a bare soil usually has a P and C factor of 1.0, which has no effect in the equation of preventing erosion. This can be reduced to 0.5 through appropriate mechanical structures. The crop management factor, C, has much more importance in reducing erosion than these factors. The worst crop management practice may give a value of 1.0 for C factor; however, a better management can reduce it to 0.05 or even lesser under a grass cover (Dhruvanarayana, 1993). The use of C factor techniques can reduce the soil loss on a given site to less than 10 per cent of that of bare soil. That means, soil loss can be reduced drastically as compared to other factors. In short, agronomic practises which are comparatively easy to adopt, less costly and environment friendly would have tremendous influence in reducing erosion and consequent soil loss than any of the factors.

The P factors are much less effective than C factors. However, combining C factor techniques with P factor techniques especially those alters L and S factors too can do wonders in easily erodable sites.

In general, all the agronomic methods involve some sort of management, either land or crop, and do not require much earthwork, leveling, or altering slope. In this account, all the soil conservation measures, which involve some managent of soil or vegetation, is described. The nature and type of measures to be selected is based on the basis of percentage of slope, crops grown, soil characteristics, and socio-economic conditions.

Contour farming

In contour farming, rows are orientated across the slope and thus act as a barrier to the downslope flow of water. As machinery also works across the slope, it creates ruts that act as small dams. Contour farming reduces runoff and, therefore, soil erosion. Its effectiveness, however, decreases with increase in slope gradient and slope length, and intensity of rains.

Contour farming is considered as a basic soil conservation measure to be adopted in sloppy areas along with other conservation treatments. On steeper slopes, runoff may concentrate in the furrows, and if it breaks through may cause serious erosion. If the rainfall exceeds the surface detention capacity of the contouring system, concentrated runoff flowing downstream without any checks can lead to accelerated erosion and even severe gullying. Therefore, contour farming alone is not sufficient to control erosion on steep long slopes with erodible soils; and it must be supplemented by other methods. It is most effective on 0.5 to 9.0 percent slopes. In fact, up to a slope of 0.5-2.0 percent, only contour farming is needed as a soil conservation measure. Contour farming on fields as steep as a 9.0 per cent slope will cut erosion rates by half.

Contour cultivation, a major part of contour farming, implies that the direction of the cultural operations being done is across the slope, that is, almost on contour lines. All the cropping techniques follow contour lines. Tillage and planting across the natural slope create a series of ruts, which act as mini-embankments holding back water until it can soak into the ground. The barriers may look small individually, but as their number is large, their total effect is immense in reducing runoff.

Tools, which help to lay out contours easily, include specially designed levels and devices. The full benefits of contouring are obtained if all the field operations are done on the contour. However, because of slope irregularities, it may not always be possible to exactly stay on the level. When laying out the system, smoothen the curves at ridge tops and drainage ways, and square the rows with field edges to eliminate 'point-rows'. These adjustments should maintain a 0.5 to 1.0 per cent grade along the rows. A grassed waterway may then be considered to carry surface water down the slope.

On longer slopes, contouring can be effective by using it in combination with conservation tillage, terraces, strip cropping, or contour buffer strips. Contour cultivation should be practised as a supplemental measure in areas where mechanical measures with no change in the original slope are adopted such as contour bunding. The contour ridges or bunds erected in long slopes will serve as a good guide for contour cultivation. However, in gentle slopes, there is no necessity of ridging or bunding. In such places, contour cultivation and planting will take care of the erosion control.

Contour farming involves the following steps

- Marking of contour guidelines
- Contour ploughing
- Aligning seedbeds or rows along the contour
- Sowing on the contour
- Do all the after cultivation operations on the contour

Establish two or three contour guidelines that run across the farmland using simple levelling devices such as a water tube level, line level or by a hand level about 50 m apart. Usually, two persons are needed for marking guidelines. The person using the level stands at the edge of the field and sighting through his level, direct the second person to move up or down the slope until he/she finds the right position in the field where the second person is at the same level as the first person. The second person marks the spot with a peg. In a small field or on a uniform slope, only one guideline is usually necessary. In fields with uneven slopes or on long slopes, more than one guideline will be needed. After laying out the guidelines on the contour like this, the farmer can start ploughing. All the farming operations are done parallel to these guidelines.

Contour planting

In the tropics, because of the high pressure of population and non-availability of suitable lands for cultivation, farming is generally attempted in high slopes too. However, tree crops, which require minimum cultivation, only must be planted. Crops such as rubber, cashew nut, oil palm, coffee, tea, cardamom, pepper, etc. are suitable for this purpose. In states such as Himachal Predesh, apples and such fruit trees are also planted in the sloppy lands. On plain or nearly level lands, square or triangular system is usually adopted for planting lay out. On the contrary, contour system of planting is the most suited one for undulating and hilly terrains.

In contour planting, the planting points are marked on contour lines. Please note that when measuring distances in a field, reference is always made to horizontal distances. In flat or slightly sloping areas, the horizontal distances can be measured directly. Nevertheless, in steep sloping areas, it is not correct to assume that the distance along the gradient or the ***slope*** *distance* (the distance measured over the ground surface) is the horizontal distance. For smaller slopes, it may not make much difference, if we go for field approximation and use the side of the angle (slope distance) instead of the tangent (horizontal distance), as the differences are negligible. However, for slopes steeper than 10° (17%), horizontal distance must only be measured. For instance, at 10° slope, the slope distance will be only 1.5 per cent greater than the horizontal distance, but at 20° (36%) slope, the slope distance will be 6.4 percent greater than the horizontal distance. At 45° (100 %), the slope distance will be 30 per cent greater than the horizontal distance. Therefore, for slopes above 10°, field approximation of horizontal distance by measuring slope distance is not correct.

To start with, a vertical line, which should act as a base line, is marked out from top to bottom to divide the blocks into almost equal parts. This line must be at right angles to the contours down an average slope. Along the line, guide pegs are put at intervals equal to the appropriate row-to- row distance. Starting from the top most pegs, guide pegs are marked perpendicular to the vertical base line. From each of these points, planting lines can be marked out. Once the guide lines are aligned and marked, it is possible to commence marking of the planting using a Dumpy level. For smallholdings, hand levels (for example, Abney level), line level, A-frame or any of its variants can be used for this purpose.

If the distance between contour lines does not vary greatly, it will be possible to maintain a fairly uniform planting density by varying the spacing between the planting points in the rows. This is possible only on lands with uniform slopes. Where the slope or gradient increases, contours will converge, and where the slope is less steep, they open out. Therefore, it is needed to stop a contour line where the contours come too close and to start intermediate contours when the rows become too wide. The minimum distance between two lines should not be less than $2/3^{rd}$ and the maximum not more than $1\ 1/3^{rd}$ of the proposed distance.

Conservation tillage

Conservation tillage is a system of seedbed preparation based on the concept of minimum soil disturbance and maintenance of crop residue mulch. It is a general term that includes a number of tillage methods, used alone or in combination, to control erosion caused by both wind and water. In contrast to conventional tillage, reduced tillage practices are employed in conservation tillage. Mulch cover is an important component of conservation tillage. In general, the dominant factor in determining the effectiveness of conservation tillage practices is the amount and distribution of crop residue left on the soil surface. The practice of inter-cultivation or after-cultivation, which is done using secondary tillage implements, is mainly for controlling weeds. Instead of resorting to secondary tillage, weed control, a major function of secondary tillage, can be achieved through use of herbicides or by slashing, growing cover crops and suppression by mulches.

Conservation tillage is a general term given to a variety of tillage systems that vary from those that merely reduce excess tillage to the no-tillage systems, which permits direct planting in the residue of the previous crop and uses only that localised tillage necessary to plant the seed. A major objective of conservation tillage is to keep some plant residues on the soil surface. Crop residues and mulches help to reduce both erosion of soil and water runoff. Roughness of the ground and clods created through tilling increase water absorption and reduce water runoff velocity. Ridging on the contour also substantially reduces runoff velocity and soil loss. Studies showed that conventional tillage systems leave only 1-5 per cent of the soil covered with crop residues. Reduced tillage systems commonly leave 15-25 per cent soil covered, while with no-tillage system, 50-100 per cent of the land remains covered.

In *minimum tillage* or *zero tillage* systems, two broad group of conservation tillage, simple implements such as hoes and digging sticks are used to prepare land and plant crops. For weed control, herbicides are used. However, all the plant residues, including weeds are recycled into the soil.

Traditional tillage systems generally increase porosity of the topsoil and reduce barriers to infiltration of the soil surface. However, it normally interrupts the continuity of the macro-pores in the soil and can reduce deep infiltration, especially if a 'plough-pan' is formed. On the other hand, reduced tillage systems implemented on soils, which have never been ploughed or compacted by the use of heavy machinery, generally maintain the high infiltration rates of virgin soils. Nevertheless, a problem can arise during the transition period from traditional tillage systems to reduced tillage systems. Initially, a period of reduced infiltration may be experienced until new continuous macro-pore system is re-established by the activity of earthworms and other soil organisms.

Crop geometry

Crop geometry means the arrangement of plants in the field. With the same plant-to-plant distance, we can have different geometry. Along with optimum plant population, crop geometry is also important to have an optimum crop cover. Although a dense population reduces soil losses, it may increase crop evapotranspiration demand and nutrient requirements. A denser plant population may lead to severe moisture and nutrient stresses from soil and consequent crop failures under rainfed conditions. This is further decided by the duration of crop and period of moisture stress. In this respect, cross sowing is a better proposition than normal sowing. Similarly, triangular method of planting may be more effective than rectangular or square system of planting as this can be done without increasing plant population. On sloppy areas, however, systems where more number of plants could be accommodated in a row are preferred, and planted using the method of contour system of planting. For example, general spacing for cashew is 7.5 – 10m, but for contour planting, usual spacing is 8m X 4m.

Selection of crops

On a soil conservation point of view, it is common to divide crops into two categories, viz., soil degrading and soil protecting crops. This concept of "soil-degrading" or "protective" crops is according to the speed at which they cover the soil. However, this factor of covering capacity largely can be improved by appropriate cropping techniques. Crop cover or canopy is one of the most important factors, which affect soil loss dramatically. Generally, grasses and legumes provide better cover and protection to land. Consequently, the soil and water loss is reduced by growing grasses and legumes. Grasses generally protect the soil better than pulses or root crops such as cassava, although crop protective capacity can be improved a great deal by early planting in relation to the periods of heavy down pour. For example, Stylo (*Stylosanthes* spp.) reaches the same covering capacity (95%) as Guinea grass (*Panicum maximum*) but two months later.

Crops such as groundout and maize cover the soil very poorly in the first two months reaching only 80 per cent at the end of the third month. Nevertheless, as their life cycle is rather short (about 4 months), for the remainder of the year, the bare soil is exposed to splash erosion unless there are weeds to cover the soil and absorb raindrop energy. Against this, Guinea grass (*Panicum maximum*) and many other grasses that grow in large tufts can cover the soil in one month. Other plants seen as degrading are simply grown in a way ill suited to providing ground cover. This applies, for example, to tobacco, which is widely spaced in order to produce more leaves that are beautiful. This problem can be solved by mulching the spaces between such poor cover crops. It is obviously not possible to use mulch under cotton, another 'soil degrading crop', which takes at least two months to cover the soil. It is compounded by the fact that cotton normally will not leave any trace of organic matter in the soil for organic recycling as its leaves are grazed and the stalks and roots are carefully pulled up and burnt. In fact, degradation in this case is due to a combination of lack of plant cover and organic imbalance.

Some plants are described as 'soil degrading' because they cover the soil slowly, for example pineapple and cassava, which gain by only 10 to 20 per cent of cover per month. Now, this 'soil degrading crop' concept is not fully endorsed. The growth dynamics of plant cover varies considerably depending not only on the type of plant but also on cropping techniques like spacing, date of planting, fertilizer applications, etc., and climate especially rainfall and light. An ill-managed maize crop produced 15 times more soil loss than a well-managed maize crop under identical conditions (Hudson, 1957). Even a well-managed maize crop produced less soil loss than an ill-managed pasture. Thus, erosion depends not only on what type of crop is grown but also on how it is grown.

Some crops are particularly prone to erosion because of the way they are grown, like clean-tilled row crops. Closely growing crops such as grasses and good canopy producing crops such as legumes suffer less erosion hazards. However, under the modem scientific management, where new cultivars are tried, crop characters like duration and canopy can be modified or to some extent regulated. While choosing a crop, a critical consideration of crop canopy and root factors is need.

Plant architecture- a main consideration in the selection of crops

Plant architecture is one of the most important factors, which affect soil loss dramatically. Although plant canopy can be manipulated through crop geometry, plant population, fertilisation, etc., attempts should also be made to select suitable crops for maximum cover. The architecture of plants can also affect the development of gullying and erosion. Big plants with leaves that channel water toward the trunk operate as funnels, and water thus collected at the foot of the trunk can start to shear through the ridges, which will then drain off all the water contained in the furrows, giving rise to a gully. This occurs particularly with crops like pineapple, and to a lesser extent with crops like maize. The other type of architecture is that of umbrella-like plants, which send drops of water outwards and thus scatter their energy; banana and cassava are examples here.

Root factors

The influence of root formation must also be considered in the selection of crops. Plant roots acts as good binding factors in the soil. Grasses, in general, reduces soil erosion, improve soil structure and all this is due to good canopy and excellent binding force shown by the grass roots. Close to grasses, legume roots also help in improvement of soil structure perhaps due to higher root mass, and root secretions, which help in binding of soil particles. Fasciculate surface roots hold the surface of the soil. Plant with tap-roots behave differently. They grow in volume occupying the soil macropores and thus reduce infiltration, but they later rot, leaving tubes stabilized by organic matter, thus encouraging infiltration.

Changes in cropping pattern

Cropping pattern must be adjusted to suit the terrain and agro-ecological conditions of the field. The yearly sequence and spatial arrangement of crops or crops and fallow on a given land area is called a *cropping pattern. Cropping system* is actually a function of cropping pattern in relation to farming resources, farm enterprises, and available technology.

Multiple cropping can be defined as the intensification of cropping in time and space by growing two or more crops in the same of piece of land in a year. This is done through ***inter cropping, sequential cropping*** and/or by ***relay cropping.*** Several forms of multiple cropping especially mixed and intercropping are practised mainly as an insurance against the possible loss of one or more crops due to some unforeseen calamities. Mixed cropping is a traditional and age-old practice with Indian farmers. This is also found to be very effective in covering the land continuously, and thus, protecting the soil from the beating action of raindrops and the resultant erosion of soil. However, obstruction to agricultural operations, particularly in standing crop is a serious drawback of the system.

Well-planned crop rotation helps in soil conservation and preserves soil fertility. Crop rotation involving incorporation of legumes with cereals in a sequence to take advantage of different feeding zones, both for nutrients and water is the most ideal. Crop rotation also offset disadvantages of monocropping in controlling insects, pests and diseases etc. But introducing crop rotation often requires a change from traditional methods. The new system may require new markets, for example, as existing markets may change if grain crops are lost for a period of years. Farmers may be reluctant to adopt new cropping patterns without market incentives.

Strip cropping

Strip cropping is a term given to a variety of cropping techniques primarily used for soil and water conservation. To put it simply, it is the growing of two or more crops simultaneously in different strips wide enough to permit independent cultivation but narrow enough for the crops to interact agronomically. Here, the aim may not be sustainability in production but conservation of soil and water. It is generally effective on gentle slopes on rolling terrain. This practice reduces the length of slope and retards the velocity of run off. Considerable re-silting occurs in the strip occupied by the low growing soil conserving crops like cowpea, soybeans, Stylosanthes, Pueraria etc. alternated with soil-exposing crops. Crops like maize, rice, sorghum, tapioca, root crops etc. are considered as soil-exposing crops.

The effectiveness of strip cropping varies according to their width, the crop mixture, and the amount of concentrated runoff. They act as filters, slowing down the runoff flow, causing a fall in its competence and hence the sedimentation of coarse sand and organic matter - and allowing its infiltration rate to rise. These filters are very effective when there is a mixture of pulses and grasses, and when the soil surface has a large number of stalks or roots per square metre

Contour strip cropping: It is the practice of growing soil exposing and soil conserving crops in alternate strips of suitable widths established on the contour. These contour strips facilitate the performance of all farm operations on the contour.

Field strip cropping: Field strip cropping involves the planting of crops in more or less parallel rectangular strips across fairly uniform slopes, but on exact contours. This is suitable for gentle slopes with soils of low erodibility only and seldom practiced in humid tropics.

Border strip cropping: Boundaries of land holdings and farms are often established with hedges of perennial vegetation especially vetiver, Pothappuullu, and other tuft forming fodder grasses. Sometimes, these are reinforces with hedges of shrubs and trees. These strips of vegetation also minimize the risks of erosion.

Barrier strip cropping(hedge strips): These type of strip cropping involve a single or double row of closely growing grass established on the contour to provide protection against runoff. Runoff velocity can be reduced drastically by establishing hedges with grasses or shrubs on the contour at regular intervals. These hedges can increase the time for water to infiltrate into the soil, and facilitate sedimentation and deposition of eroded material by reducing the carrying capacity of the overland flow. The hedge strips serve as porous filters. These may not reduce runoff amount but can drastically decrease soil loss.

A wide range of grasses is used as hedges. Vetiver hedges, hedges with lemon grass (*Cymbopogon flexuoses*), Pothappullu (*Themeda cymbaria*), etc.are examples of this type. Live shrub or tree hedges staggered on alternate lines over a strip 50 to 100 cm wide act in a way similar to grassy strips, although they tend to be less effective, at least during the first years.

Growing perennial shrubs as contour hedgerows is another commonly used form of vegetative hedge. This is also called contour hedgerow intercropping and is discussed under alley cropping.

Vetiver hedges: Vetiver grass is commonly recommended for growing hedge strips to control erosion. It has a deep, strong, and fibrous root system. It grows in large clumps from the rootstock and is propagated vegetatively through slips. The grass can be planted on the contour to establish protective contour hedges. Vetiver can also be established on earthen banks or bunds and on terraces to reinforce and stabilize these structures. Its thick root system prevents slope failure due to rifling, gullying, or tunneling. The establishment of continuous hedges of vetiver with no gaps provides maximum protection.

Although vetiver is promoted on a large scale, its acceptability and large-scale adoption in humid tropics is doubtful. They survive well in semi-arid regions where overgrazing is frequent. They produce siliceous, long-lasting mulch, but their forage quality is poor. However, the problem is the roots of the vetiver are the economically important part which yield an essential oil. In order to extract the oil, roots are to be removed resulting in the destruction of strips. Vetiver roots are also used for many other purposes such as fans etc. Therefore, wherever possible, it is better to use forage plants and grasses that are suited to local conditions. Pothapullu (*Themeda cymbaria*) is such a grass widely grown in Central Kerala on stone as week as earthen bunds. This is a hardy grass, which survive drought. Periodic defoliation of the grass will not destroy the strip.

Grasses whose seeds spread too easily into the fields should be avoided. Plants with tightly packed roots and numerous stalks will slow runoff more effectively than freestanding trees. Some other commonly used grasses for establishing vegetative hedges are *Brachiaria brizantha, Brachiaria decumbens, Brachiaria mutica, Cenchrus ciliaris, Melinis minutiflora (Molasses grass) Panicum maximum, Paspalum conjugatum, Pennisetum purpureum,* and *Setaria spacelata.*

Buffer Strip Cropping: Buffer strips are installed on a rolling topography with complex slopes where contour strips are difficult to establish. This is done by expanding the filler areas into a continuous buffer strip of fallow or a soil conserving crop. In the humid tropics, buffer strips are generally planted to cover crops and trees. In addition to controlling erosion, the cropped land in alternate strips in alternate years may regenerate soil fertility, improve soil structure, and restore productivity. The biomass produced in these fallow or buffer strips can be used as mulch, fodder, and for green manuring. Buffer strips are usually planted with quick growing and easy-to-establish forage legumes. In principle for buffer strip cropping, ground-creeping plants with rhizomes and many scattered stalks are more effective than large tufts of grass. If the latter is used, a light mulch of cut tufts must be left on the soil-surface to prevent water from flowing between the tufts and digging channels.

The buffer strip acts as a sponge, partially absorbing runoff waters; and as a comb, slowing down runoff so it will deposit soil from the cropped field above. Because of this, the runoff water infiltrates deeply, or at least slowed down so that it deposits the coarsest eroded sediments. This in turn maintains good porosity and leads to the formation of a small terrace at the rate of 5 to 20 cm per year, which as time passes transforms landscapes into a succession of gently sloping fields and banks protected by leafy growth.

Crop rotation

Crop rotation is a common practice for smallholder farmers. The system of growing different crop species in sequence on the same plot is called crop rotation. Well-planned crop rotation helps in soil conservation and preserves soil fertility. The different rooting pattern of different crop species planted may help on soil structure formation and improve water percolation. These cropping pattern can vary from year to year depending on market price or on soil and weather condition. Crop rotation involving incorporation of legumes with cereals in a sequence to take advantage of different feeding zones, both for nutrients and for water is the most ideal. Crop rotation also offset disadvantages of monocropping in controlling insects, pests, etc. Nevertheless, introducing crop rotation often requires a change from traditional methods. The new system may require new markets, for example, as existing markets may change if grain crops are lost for a period of years. Farmers may be reluctant to adopt new cropping patterns without market incentives.

Mulching

Mulching of open land surface is achieved by spreading organic stubbles, trash or any other materials. Mulching covers the soil with materials that reduce soil moisture evaporation and inhibit weed growth. Mulching minimise splash and influence of rain crops on bare surface and protects the soil from direct impact from rain. Mulches applied before the beginning of the rainy season can reduce soil erosion and runoff. Further, they build soil structure and protect soil excessive heating and to allow microbiological changes to occur at optimum temperature.

Polyethylene mulches have also been utilised for water harvesting and control of seepage. For arable crops, crop cover is a problem in early seedling stage, while the grasses and forage crops grown in rotation will greatly reduce the soil loss.

Spreading of organic residues instead of mixing (*stubble mulching*) them can help in reduction of soil and water loss to a considerable extent. Stubble mulching using different materials is found to be useful in controlling erosion by reducing the surface flow of water as well as bringing about various other favourable effects. They include reducing the evaporation of water from soil surface, increasing infiltration, suppression of weeds, improvement of soil structure etc.

Trash farming in which crop remains are cut, chopped and partly mixed in ground and partly left on the land surface is also a form of mulching. The limitation with mulching practice is the availability of plant remains for mulching purpose. As most of the plant remains are used as cattle fodder, farmers may not adopt this practise under the condition of scarcity of fodder. However, preparing dust mulch on the open land surface may be helpful in conserving soil moisture.

A tillage system that ensures a maximum retention of crop residue on the soil surface is called mulch tillage or stubble mulch farming. It is defined as a method of seedbed preparation that involves leaving crop residues or other mulching materials on or near the surface. When a grain crop is seeded through the mulch of a chemically killed cover crop, it is called sod seeding. If the cover is only suppressed temporarily or not killed, the system is called live mulch. A cover crop, usually a legume, is grown specifically to break the cropping cycle, to produce mulch material, to improve soil structures and to enhance soil organic matter content.

The best mulching materials have a high humus content, along with good infiltration rates and water storage capacity. Good mulching materials should be able to withstand the forces of runoff and stay in place. However, it must allow water to percolate into the soil. It must be slowly decomposing and last for several seasons. Ease of application, cheapness, low maintenance are the other characters to be looked into.

Cover cropping

Although mulching is a rewarding practice, the main difficulty associated with it is that of producing and transporting the mulch materials to the field. An alternative is to produce the materials on the spot along with the crop. Cover cropping is a good technique, reducing inputs, fertilizers and cropping operations while protecting the soil against the onslaught of rain and erosion. Eliminating runoff can perhaps allow water to be supplied to both crops, and hence reduce the competition between them. The system can be compared to the old method of green manuring, which consisted of introducing a crop when the fallow time came, and ploughing it in before the end of the rainy season. Part of this crop could be used by leaving the cover plant on the soil surface in the form of litter.

Cover cropping is mandatory to attempt farming in steep slopes. An important aspect of any of the mechanical soil conservation treatment for steep erosion prone slopes is that the land between the terraces must be planted to a vigorously growing cover crop. Several creeping legumes are used as cover crops. Cover crops have several advantages besides protecting soil such as weed suppression, soil temperature maintenance, organic matter addition etc. It involves the practice of growing crops, which possess good land covering capacity. The vegetative cover provided by the cover crops act as a barrier to flow of water, and the binding action of roots reduces the nutrient loss due to leaching and similar means. Leguminous crops like *Calapagaonium mucunoides, Pueraria phaseoloides, Centrosema pubescens, Mucuna bracteata, Mimosa invisa* etc. are the commonly grown cover crops. *Stylosanthes gracilis* is an excellent fodder cum cover crop. Cover cropping must be practised in all the tree crops in steep sloppy areas.

Some cover crops used for soil and water conservation in the humid tropics

Grasses
Carpet grass (*Axonopus compressus*)
Palisade grass (*Brachiaria brizantha)*
Signal grass (*Brachiaria decumbens)*
T grass (*Paspalum conjugatum)*
St. Agustine grass (*Stenotaphrum secundatum)*
Legumes
Calopo (*Calopogonium mucunoides)*
Centro (*Centrosema pubescens)*
Tropical Kudzu (*Pueraria phaseoloides)*

Tropical clover (*Desmodium triflorum*)
Mucuna (*Mucuna pruriens*)
Sannhemp (*Crotalaria juncea*)
Common stylo (*Stylosanthes gracilis*)

Townsville stylo	*Stylosanthey humilis*
Velvet bean	*Stizolobium deeringianum*
Pintoi	*Arachis pintoi*

Natural vegetative strips (NVS)

Natural vegetative strips (NVS) have proven to be an attractive alternative strategy for erosion control as they are so simple to establish and maintain. NVS are attractive as they mainly consist of 'no intervention'. When the land is ploughed along contour lines, certain strips of 40-50 cm wide are left unploughed, across the field on the contour. These strips are spaced at desired intervals down the slope and can be marked beforehand. The contour lines can be determined using any of the simple devices mentioned already. The recommended practice for spacing contour buffer strips has been to place them at every one-metre drop in elevation, but a wider spacing may be acceptable. The natural vegetation of the strips filters the eroded soils, slows down the rate of water flow and enhances water infiltration, making them very effective for soil and water conservation. They hardly need pruning maintenance compared with fodder grasses or tree hedgerows, and compete little with adjacent crops. They are efficient in minimising soil loss and do not show a tendency to cause greater weed problems for the associated crops, once plant succession favours the longer term survival of perennial species over the short-term production of typical weedy species.

Organic Manures

Organic manures in addition to supplying plant elements, improve the soil physical conditions as well. However, they have slow nutrient effects on the crops. The effect of chemical fertilisers by improving the vegetative growth of crop and crop canopy and consequent reduction in soil erosion is evident. Organic manures and green manures improve the rate of infiltration and soil structure thereby affecting soil erosion process. A small dose of farmyard manure may not influence the soil properties appreciably particularly in tropics under rainfed conditions. Unlike farmyard manure, green manuring is more important in view of improvement in soil physical conditions as decomposition occurs *in situ*. Green manuring is a common practice in irrigated or high rainfall tracts. In moderate or low rainfall areas, green manuring may mean loss of one season. However, this practice can be adopted for controlling weeds and addition of nutrients.

Organic matter addition can improve soil structural stability and resistance to rainfall impact. According to Wischmeier's nomograph, a 1.0 percent increase in organic matter in the surface horizon means that soil losses can be reduced by 5.0 percent for loamy soils due to improved structure and by 3.0 percent for clayey or sandy soils. However, this means incorporating considerable amounts of organic matter into the soil. Moreover, in humid tropical regions, most organic matter vanishes quickly, with less than 5.0 percent remaining in the soil as stabilized humus. On the other hand, if the same amount of matter is spread over the surface, it would act as a mulch and reduce soil loss by 60 to 99 per cent. Therefore, managing the biomass on the soil surface may be an alternate solution as it not only reduces losses through runoff and erosion losses considerably, but also recycles nutrients through the gradual uptake by plants throughout the rainy season. More details on organic manures is given in the section on organic manures.

Crop residue management

Crop residues left in the field after harvesting or incorporated from elsewhere influences the soil properties tremendously by way of its role in improvements in soil moisture and temperature regimes, enhancement of soil structure, and finally erodibility of soil. In addition, crop residue management is an ideal practise for recycling plant nutrients. Crop residues are an excellent local source for mulches, especially if they are not required for other purposes, such as animal feed, fuel, and roofing materials. In India, crop residues are usually fed to cattle. Therefore, not much importance is attached to crop residue management. However, in developed countries, management of crop residues is an important aspect in the context of organic farming and soil and water conservation. If limited supply and high costs are not a problem, crop residues should be tried. In addition to their ability to aid in erosion control, they add humus to the soil. Integrated nutrient management involving organic mulches and manures, biofertilizers, crop residues and chemical fertilizers will be the ideal nutrient management system in the watersheds.

In densely populated regions, the cutting of wood for fuel, and the use of crop residues and cowdung as cooking fuels, which should otherwise be availble for recycling, also contribute significantly to soil degradation on steeplands. For example, approximately 60 per cent of crop residues in China and 90 per cent in Bangladesh are removed and burned for fuel each year (Pimentel, 1993).

Agroforestry

Broadly speaking, agroforestry is any land use system, which includes both trees and agricultural crops on the same piece of land. In other words, it is the practise of agriculture and forestry on the same piece of land. It is a hybrid of both land management systems where the object is to obtain food grains, fodder, wood and other benefits. Agroforestry systems have existed in the tropics for centuries to yield food, feed, timber and energy. Agroforestry systems strive to maintain ecological balance and conserve the environment. Agroforestry can be divided into many sub-systems. When the emphasis is on timber and energy, the system is called a silvicultural system. When a food crop is integrated, the silvicultural system is called an agri-silvicultural system and it covers all systems in which land is used to produce both forest trees and agricultural crops either simultaneously or alternatively. When fodder crops and livestock are integrated, the silvicultural system is called a silvi-pastoral system. When the agri-silvicultural system, silvi-pastoral system and crop residues are integrated, such integration is called an agri-silvi-pastoral system. In this system, land is managed for the simultaneous production of agricultural crops, forest crops and for grazing domestic animals.

In the humid tropics, where the dense evergreen forest slows growth of shrub and grass layers, timber production is most common. However, in the sub-humid tropics where deciduous trees and plantation trees allow sunlight penetration for growth and production of the first and second layers, silviculture and agrisilviculture are more common. In the semi-arid tropics, where water is limiting, particularly during the dry season, agrisilviculture is less common, while silvipasture is more common. Silvipasture is most common in the arid tropics, where water and sun stresses are limiting. In the humid tropics, where grasses and ground legumes are more dominant, dairy cattle and buffalo are more common, while in the dry tropics where fodder shrubs and trees dominate, dairy goats are more common.

Riparian filter strips

Water loving trees and other plants that grow near the banks of streams, rivers and lakes function as riparian filter strips. Riparian filter strips, either natural or planted play many important riles in the ecosystem. In general these strips moderate floods, stream bank erosion and bank cutting, trap nutrients, enhance aquatic environment, yield wood an timber, store water and provide home for wildlife and enhance biodiversity.

Alley cropping/ hedgerow intercropping

Hedgerow intercropping also referred to as alley farming or alley cropping is a type of strip cropping or agroforestry practice in which fast-growing trees and shrubs are established on arable lands and annual food or forage crops cultivated in the "alleys" between the hedgerows.

The shrubs or trees are usually planted in rows of trees 4 to 6 meters apart with crops cultivated between the rows or in the alleys. The trees or shrubs managed as hedges are pruned periodically during the cropping phases to prevent shading of the companion crop and the pruning applied to the soil as green manure and/or mulch. This improves the organic matter status of the soil besides providing nutrients especially nitrogen. Hedgerows are allowed to grow freely to cover the land between cropping cycles, that is, when there are no crops. This management strategy seeks to maximize trees' service roles of nitrogen fixation, soil and water conservation, weed control and nutrient cycling. Hedgerow intercropping can lead to soil and micro-environmental improvements directly affecting associated crops. In addition, other tree products such as fuel wood and fodder feed can be obtained. They create a more favourable microclimate for crops by shielding them from drying winds. Hedges planted on slopes also anchor soil and form terraces, preventing the loss of precious topsoil by heavy rains and the overland flow of water.

In fact, alley cropping can be considered as an improvement over the traditional shifting cultivation where in the fallow phase took care of restoration of productivity of the soil that has been depleted of fertility during the cropping phases. Hedgerows are allowed to grow freely to cover the land between cropping cycles, that is, when there are no crops. Hedgerow intercropping; does not necessarily eliminate the fallow requirement. Because the tree component of the alley cropping system is kept on the land during crop production, it performs a semi-fallow function continuously. This means that cropping cycles can be lengthened and fallows shortened without degrading the soil and reducing system productivity over time. The attributes of the trees or shrubs selected as hedgerows create soil conditions similar to those in the fallow phase of shifting cultivation. In alley cropping, the cropping and fallow phases can take place simultaneously on the same land, which allow the farmer to cultivate the field almost continually without going for a fallow period to restore soil productivity.

Apart from its role on soil conservation, it enhances or diversifies farm products. Most of the trees selected for hedgerows are multipurpose trees. They may give additional products-manure, forage, and firewood. Alley cropping also improves utilization of nutrients, reduce wind erosion, modify the microclimate for improved crop production, improve wildlife habitat, and enhance the aesthetics of the area. The woody species grown are fast growing leguminous shrubs or trees that coppice vigorously. Alley cropping is adaptable in sub-humid to humid areas.

Hedgerow tree species for the tropics

The trees recommended for these systems are chosen for their multipurpose/multi product characteristics. They provide soil-improving services, are fast growing and produce a number of useful products. The most suitable tree species for hedge crow intercropping includes:

- *Leucaena leucocephala* — Subabul, Ipil-ipil, Leucaena, Peelivaka
- *Calliandra calothyrsus* — Calliandra
- *Glyricidia sepium* — Gliricidia
- *Sesbania grandiflora* — Agathi
- *Sesbania sesban* — Shevri
- *Flemingia congesta* — Wild hops, Flemingia
- *Cajanus cajan* — Pigeon pea

Gliricidia and Leucaena are most suitable for use in alley cropping as they can be easily established by direct seeding, withstand repeated cutting, coppice well, produce large amounts of biomass, relatively long lived and multiple uses such as green manure, forage and fuel wood. However, in acidic, low base soils, Subabul has not been as successful as species such as *Flemingia congesta*. Similarly, in acid soils, the performance of Gliricidia is better than Leucaena.

An inter hedgerow spacing of 4-6 m was found to be the most ideal for trees such as Subabul and Gliricidia. The recommended hedge consists of two lines of trees 50 cm apart. However, tree spacing within the rows should be as close as possible, usually 10-15 cm to form a solid hedge along the row. This helps to provide a more effective barrier to soil movement on sloppy lands besides favouring leaf production over stem. Close spacing encourages more leaf and smaller branch production. In general, alley cropping systems of two-row hedges and wider alleys are more productive than those of one-row hedges and narrower alleys. With two-row alleys, there is less tree-crop competition. Intercrops should be planted at traditional spacing. The space between crop plants and any one-tree row should not be less than 0.5 m.

On sloping land, hedgerows are densely planted (5-10 cm within rows) along the contours to form a barrier against soil erosion. Grass strips planted alongside hedgerows will create a more effective barrier. Although alley cropping is possible in all types of lands, it is more popular in sloppy lands, the major purpose being erosion control and soil conservation. In steep-sloping lands, the efficacy of hedgerows along contours in controlling soil erosion has been conclusively proved. The hedge rows act as a barrier as well as cover by the presence of pruning applied as mulch. in reducing soil erosion. Contour-planted hedgerows act as permeable barriers slowing the rate of water flow so that soil particles are deposited and infiltration of water into the soil is increased.

The build-up of soil behind hedgerows can gradually lead to the formation of terraces just like Puertorican terraces. The litter and pruning from the hedges cover the soil and effectively check the impact of raindrops and consequent runoff until they are decomposed. This cover effect has been attributed for most of the beneficial effects of alley cropping in controlling soil erosion. Competition for light may be a problem for successful crop production. However, in normal course judicious pruning of the trees during the cropping phase will take care of this problem.

Sloping Agricultural Land Technology (SALT)

One of the main problems facing agriculture in sloping lands today is that of soil erosion and the consequent decline in productivity. On the one hand, populations who live and make a living out of sloping lands are increasing, and on the other, the carrying capacity of sloping lands is decreasing. Sloping Agricultural Land Technology (SALT) has been identified as a promising technique to contain the degradation of these lands and to restore their productivity. It is a system that consists of alternative strips of annual food crops and strips of fodder shrub or tree legumes along the contour line of steep lands. This is primarily a soil conservation oriented farming system involving hedgerow cultivation of subabul on contour lines.

In the Philippines, where the system originated in the late 1970's, the land used is divided into 40 per cent for agriculture, 20 per cent for forestry and 40 per cent for livestock. It is basically an alley cropping or hedgerow intercropping technology developed for sustaining agricultural production on sloping lands. SALT has evolved out of the recognition that a sustainable agricultural system is necessary for long-term improvements in the quality of life. The technology is tailored to small family farms for growing both annual food crops and perennial crops. Alley cropping with subabul, also called ipil-ipil (*Leucaena leucocephala*), has been put to wide use in the Philippines and Indonesia. Contour rows of subabul are set up 4-6 m apart, which are in dense double rows. These hedgerows minimize soil erosion and maintain the fertility of the soil. When the trees are 1.5-2.0m tall, they are cut back to about 40cm and the tops are placed in the 3-5m alleys where the crops are growing. Their branches can be pruned several times a year; usually every 30-45 days, and the pruned leaves can be used as green manure or for composting. Field crops include cereals, legumes, forage crops, and vegetables, while the main perennial crops are cacao, coffee, banana, citrus and fruit trees.

When fully grown, the hedgerows bank the soil and serve as sources of fertiliser. The ability of nitrogen-fixing tree/shrub species to grow on poor soils and in areas with long dry spells makes them good plants for restoring forest cover on watershed slopes and on other lands that have been denuded of trees. Through natural leaf drop, they enrich and fertilise the soil. In addition, they compete vigorously with the coarse grasses that are common on degraded lands that have been deforested or depleted by excessive cultivation.

The recommended hedgerow species used in SALT are *Flemingia macrophylla, Desmodium rensonii, Gliricidia sepium, Leucaena leucocephala Leucaena diversifolia*, and *Calliandra calothyrsus*.

Modifications to SALT

The success of SALT was an incentive to improve the system further. So far, three more SALT systems have been developed: Simple Agro-Livestock Technology (SALT-2), Sustainable Agroforest Land Technology (SALT-3), and Small Agrofruit Livelihood Technology (SALT-4).

SALT I, the original SALT, focuses mainly on food crop production. It is simple in application, low in cost, but is an effective alley cropping technology with agricultural crops and trees or shrubs in a ratio of 3:1. Compared to traditional upland farming management practices, this technology not only decreases erosion substantially but also increases crop yield.

SALT II (Simple Agro—livestock Technology) is a simple modification of SALT I in the sense that it integrates livestock rearing with crop production. This model is primarily based on goat production with a land use of 40 percent for agriculture, 40 for livestock and 20 percent for forestry. Other livestock species such as cattle and sheep can also be raised. This technology can minimize erosion, improve soil fertility, and generate a good net income for an upland family. Hedgerow species that are palatable, high in protein, fast coppicing and high yielding are recommended for planting. The hedgerows can be pruned regularly between 0.5m to 1.0m above the ground for animal forage.

SALT-III (Sustainable Agroforest Land Technology) focuses on the conversion of non-productive marginal land into economically productive land to supplement production from other SALT models. It is based on small-scale reforestation integrated with food production. Of the farm area, about 40 percent is used for crops and 60 percent for forestry. In other words, this model is a mixture of SALT I, SALT II, and a separate plot of land to produce valuable timber. Farmers owning landholdings of about two hectares can use this model. This "food-wood" intercropping can effectively conserve the soil, thereby providing food, wood and income to the slopeland farmer.

SALT IV (Small agro-fruit livelihood technology) integrates fruit crops and other perennial crops into the system. To improve hill agriculture and economics, commercialisation of hill agriculture is required. Thus, horticulture is a promising option with comparative advantages. Its main objectives are to produce food, increase cash income, and promote soil conservation in a limited area of slope land around 0.5 ha.

Over the years, several interesting modifications have been made in the SALT-4 system. For example, whole farmlands of the farmers are planted with plantation crops or fruit crops and double hedgerows are developed in between on the contours to allow natural formation of terracing and to maintain fertility. Several instances have been recorded in which farmers made modifications according to their convenience. Some liked to plant the entire area with fruit trees and planted crops in between, while others proportioned their land according to their landholding and access to markets for selling fruits.

Seeing the success of the SALT systems, other Asian countries have also developed similar upland farming systems. In almost every case, some type of agroforestry system is being used. By using SALT, small-scale upland farmers in the tropical Asia can conserve soil, reduce their purchases of commercial fertilizer, increase their farm yields and income and become generally self-sufficient.

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CONCEPT OF 'SUITABILITY' IN WATERSHED PLANNING - A CASE STUDY OF 'ATTAPPADY' WASTELAND COMPREHENSIVE ENVIRONMENTAL CONSERVATION PROJECT, KERALA

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The Global situation of rampant poverty, unemployment, a multitude of problems connected to ecological degradation and dwindling economic growth is highly alarming for rebasing our developmental efforts on a need-based eco-economic perspective. It is especially so for a country like India, with a multitude of diversities in the socio–cultural setting and massive commitments to the affluent Nations and Multi-National Corporations, in various techno-economic fronts. It is ripe–time for the Third–world countries to become self-dependent and evolve appropriate developmental strategies, providing due weightages for traditional wisdom and effective peoples participation. The concept of 'Suitability' of developmental interventions in scientific resource management is an area yet to be explored for tangible results, especially for the under-developed or developing countries.

Any critical appraisal of the Global efforts for environmental regeneration staged at Stockholm (1972), Rio-de-Janeiro (1992) and its decadal review held at Johannesburg (2002) will revel that these international efforts could not give us due promises for an ecologically clean world with harmonious co-existence of Man. Another major lacuna of these efforts was that it did not pay heed to the much aspired aspect of the concept of 'Suitability', while much was deliberated upon 'Sustainability' and 'Subsidiarity', the two catch – words still lingering in many such august assemblages. But, it has to be noted here that the concepts of River-basin development, Catchments Planning and Watershed Development were included for deliberations in the 'Agenda 21' of the Rio-summit. But the protocols generated out of the above global efforts did not pay due regards to the "Concept of Suitability", a more relevant one for holistic eco-economic development. The efforts taken by India in this regard is also much meagre, even while the growth rate under Agriculture and allied sector is dragging much behind with 1.2 percent. Annual growth rate of food grains' yield has declined from 16 percent in 1991-1996 to 2.1 percent in 2001-'5. Further the average size of operational holding has declined from 1.28 ha in 1970-71 to 1.41 ha in 1995-'96. These situations highlight the necessity of introducing a more scientific approach for planned development of our resources. The concept of 'suitability' of interventions on a need based resource management has very high value in the above context. But it has to be mentioned here that Kerala, a small state in Peninsular India can be proud of the humble contribution of sustaining or introducing this concept in one of its Internationally aided Project viz. Attappady Wasteland Comprehensive Environmental Conservation Project (AWCECP) (JBIC – Japanese Bank for International Co-operating aided Project). This Project has certain, special features such as introduction of 'suitability' concept, participatory eco-restoration, utilization of innovative technologies connected to Remote Sensing, Application of GIS packages and introducing a system of participation of Volunteers, Animators etc. The above aspects make the Project Planning under this programme worth to consider as a Case Study.

The Project

The Japanese aided Project "Attappady Wasteland Comprehensive Environmental Conservation Project spreads over the whole land of Attappady falling under the Tribal Development Block for an area of 745 square Kilometers in Mannarghat Taluk of Palakkad District. It forms a part of the Nilgiri National Bio-reserve with the total area of 5200 sq. km.

Objectives of the Project

The Covenant between the Govt. of India and the Japanese Government agreed upon defines the Projects objectives as –

"Ecological restoration of degraded wasteland in Attappady and development of replicable models of participative eco-restoration, so as to prevent further degradation and promote sustainable methods of livelihood for the local people (with special emphasis on tribal population) and in harmony with the resource base".

The total Project cost is 6338 Million Yen (Rs. 219.31 crores), of which the loan component from Japanese Bank for International Co-operation (JBIC) is 5112 million (176 crores) to be repaid by the Government of India with 2.1 percent interest. The state share is Rs. 43.31 crores. The State Government is expected to repay the loan portion to Government of India at the rate of 12.6 percent in 20 years after the completion of the Project.

The State Government had constituted a Society viz. Attappady Hills Development Society (AHADS) and registered it as No. 390 dt. 31.10.1995, under the Societies Registration Act 1860 for implementation of the Project. The Management of the Project at state level was entrusted to the Rural Development Department, Government of Kerala, with a High Power Committee for formulation of policies and crucial decisions connected to the Project Planning and Implementation. At the Project level, a Governing Body (GB) with the Secretary to Govt. – Rural Development Department as the Chairman was constituted with members including the local MP, MLA, District Panchayat representative, Panchayat Presidents at Block and Grama Panchayat level, nominated local people and the officials of various Developmental Departments. Further, a Technical Committee with the Chairman, Science and Technology and representatives of various scientific organizations as members was constituted to help and guide the Project Implementation. Yet another body to work on par with the Project was an International consultant, Nippon koei, a Japanese firm, appointed by the State Government.

A brief description of the Project area

Location: The Project area spreads over 745 km^2, in Mannarghat Taluk of Palakkad District bordered by the Tamil Nadu State in the North and the East and Mannarghat Block in the South and the West. The location is between 10° 55' 10" and 11° 14' 19" North Latitude and between 76° 27' and 11" and 76° 48' 8" East longitude. It forms a degraded patch of land within the Nilgiri National Bio-reserve.

Terrain condition and drainage: The terrain condition is undulating to very steep ranging between 450m and 2350 m above MSL. The main river Bhavani enters from the northern boundary and runs for 29 km, to drain out to Pilloor Dam located near the eastern boundary in Tamil Nadu. The tributaries joining Bhavani in the Kerala portion are Siruvani, Kodungarappallam and Varagar. About 40 percent of the land mass can be considered as an extension of the Deccan plateau and forms a rain-shadow to South West monsoon with average precipitation of 913 mm per annum. The Western slopes are in receipt of copious precipitation sometimes exceeding 4000 mm per annum. Average temperature varies from 23° C to 33° C.

Geology and Soils: Geologically Attappady lies in the Attappady–Mettuppalayam shear gone. The rocks are of Pre-Cambrian origin and belong to hornblende, gneiss, biotite gneiss quartz-feldspar, biotite schist and quartz intruded into various rock types. The Nine Soil associations identified are (i) Arali-Bhavani (ii) Chittoor-Attayampathy (iii) Gilsi-Thekkupanna (iv) Mamana-Thavalam (v) Rock-out crops-Vattakkallumalai (vi) Rock-outcrops-Elathodu (vii) Thenkurissi-Ponnani (viii) Vattakkallumalai-Sethumadai and (ix) Vattakkallumalai- Rock-outcrops.

Land Use: Land use categories in Attappady are given below.

Category of land	Area (Sq. Kms.)
Forest land	444
Agricultural land	158
Fallow / Waste land	129
Water bodies	11
Roads and embankments	3
Total	**745**

The Western slopes carry tropical wet-evergreen type of vegetation as against the humid-deciduous to xerophytic type of vegetation in eastern slopes. There are large patches of denuded lands deserving greening both in the Western and Eastern slopes. While the Western portion, is under rainfed or irrigated crops such as Paddy, Arceanut, Coconut, Tapioca, Banana, Ginger, Turmeric and Vegetables, the Eastern portion, mostly under Tamilian farmers are mainly under dry-land agricultural crops such as Chamai, Maize, Ragi, Groundnut, Sunflower, Pulses, Cotton, Sugarcane etc. Land management in general among the tribal folk is peculiar and they adopt a peculiar system of cultivation called Tribal Agriculture (Kothukadu Vyavasayam) in which they sow different seeds simultaneously in one and the same field on minimum tillage. They harvest grains, pulses and vegetables when the individual crop matures. The main advantage of this system is that there develops a micro-climate within the cultivated lands with crops enjoying reasonable co-existence. The pest and disease infestation in such lands are very much minimal. Not much has been studied about Tribal agriculture in the aspects of eco-economics. The Wastelands are highly degraded showing tendencies of desertification.

Demographic features and aspects of past developments

Attappady is considered as a Tribal tract consisting of three tribal clans viz. Irulas, Mudugas and Kurumbas. The second half of the 20th century indicated massive immigration to this area from other parts of the state and the neighboring states of Tamilnadu and Karnataka. The population growth trend is as given below.

Population Details

Year	Tribal folk	Percentage	Settles	Percentage	Total
1951	10,200	90.27	1,100	9.73	11,300
1961	12,972	60.44	8,489	39.56	21,461
1971	16,536	42.20	22,647	57.80	39,183
1981	20,659	33.19	41,587	60.81	62,246
1991	24,228	27.09	65,206	72.91	89.434

During 1967-68 there were only 138 tribal hamlets (99 Irula, 23 Muduga and 16 Kurumba). At present the total number of hamlets is 176. The social living of the tribes was governed by an oligarchical system with Oorumoopan (the tribal chieftain), Kuruthalai (the Minister or the Chief orderly of the Chieftain) Mannookkaran (a mystical personality capable to predict weather and perform rites connected to cultivation and folk activities) and Bhandari (the Treasurer)

The tribals had their habitations within the forest land and that they were having due access to forest usufructs, upto the time when forest Protection Act was strictly enforced on them during 1956. The enforcement of the Act weaned the poor tribals from their own happy environs, which they cherished with sumptuous food and freedom. They had sung songs and danced praising their own dieties and the lush greenery, mostly under their habitual intoxicants especially during full-moon days and such other auspicious occasions.

The tribal folk in general had no aptitude for farming. But the situation of having evacuated them from the forest land, forced them to cultivate or adopt their farming practices in the river embankments. The massive immigration of settlers prompted the tribal population to alienate their lands to the former turning themselves to be the labor class or wage employees of the settlers, and shifting to marginal lands, always suffering scarcity of water.

The settlers were dispersed with one house per holding. The settlers were also poor in their financial position and they also live a subsistence living. There is a growing trend among the settlers to relinquish farming and prefer to seek better employment opportunities, either to go abroad or seek some employment or other in the neighboring township of Coimbatore and Mannarghat, mainly on account of lesser returns from their lands.

The total house holds of Attappady are 14219 which includes landless too. There exists a total number of 11,405 operational holdings of which 6685 owns less than One hectare. The number of holdings between One and Two hectares is 2715. The people with land more than Two ha are 2005. Some recent documents show that 458 families do not possess any land at all. A study conducted by the Tribal Development Block shows that 5158 families are Below Poverty Line (BPL), which includes 2558 Scheduled Tribes, 576 Scheduled Castes and 2024, Settlers.

With regard to infrastructural facilities also, Attappady is very backward, even after much conserted efforts from the part of the Tribal Development Block, instituted as early as 1961, the Grama Panchayat and various Developmental Departments. Out of 176 tribal hamlets only 37 hamlets have bore wells 28 hamlets the dug wells. The Kerala Water Authority could provide drinking water facilities only for 26 hamlets. There are only 4 Kindergarten schools, 15 Primary Schools 5 Upper Primary schools and 6 High Schools. There are only 4 Government Allopathic Hospitals, 3 Ayurvedic Hospitals and 2 Homeopathic Hospitals. Electricity is available only to 26 hamlets and the connection to households is only about five hundred.

Two major Governmental Programmes include the ongoing Tribal Development Block Programmes, which expended about Rs. 25 crores as under different activities and the Soil Conservation Works under the centrally Sponsored Scheme of Soil Conservation in the catchments of RVP Kundah (Kerala portion) which expended Rs. 13.44 crores during the period of 30 years from 1667-'68 to 1997-'98. The efforts taken by Agricultural Development was much meagre to the tune of Rs. 3 crores during the part 10 years.

Various aspects furnished above are indicative of the general backwardness of Attappady and the prospective chances opened with the introduction of the AWCECP.

Eco-restoration Plans

The State Government vide order No: G.O. (MS) 14/96/RDD dt. 08-08-'96 entrusted the work of Detailed Survey and Designing of Project activities at a cost of Rs. 105 lakhs to Centre for Water Resources Development and Management, (CWRDM) Kunnamangalam, Kozhikkodu.

The CWRDM divided the total landmass of the Project area into 15 Development Units (DUs) and drew up proposals under the following headings viz.

i. Soil, Water and Bio-mass Conservation
  - Agronomy measures, mainly modification of vegetative cover
  - Mechanical measures, mainly contour terrace walls and trenching

ii. Water Resources Development
  - Mainly Check dams, Tanks / Ponds, Wells, Drip irrigation

iii. Income generating activities (to be identified)
  - Cottage Industries, Livestock farming and Fruit Processing

The Project Report (Eco-restoration Plans) produced by the CWRDM was presented to the aforesaid Technical Committee and the International Consultant (Nippon Koei). Then AHADS had already held Seminars and Workshops to evolve the opinions of the Tribal Chieftains, Local Leaders, Environmentalists and the Local Non-Governmental Organizations (NGOs) and their aspirations and perspectives were already documented. The inconsistencies with the proposals by the CWRDM with the above, prompted the Technical Committee to recast the Project giving due considerations for the outcome from the above Seminars and Workshops. Accordingly, the Implementing Agency of AHADS came forward with a new Approach and Strategy. This approach involved scientific Watershed Management utilizing Remote Sensing

Data generated by the State Land use Board (in collaboration with the National Remote Sensing Agency, Hyderabad and the All India Soil and Land use survey organization, Bangalore) and utilization of the GIS Packages (Arc-info) for evolving "Appropriate and "Suitable" interventions with location specificity.

A brief outline of the Strategy for Resource Planning in the AWCECP is furnished below.

Strategy of Resource Planning

1. The whole process of planning was started with the holding of workshops with participation of various scientific organizations, Ecologists and Planners.
2. On the basis of the recommendations of the above workshops the whole landmass of Attappady was delineated into 146 Micro Watersheds.
3. Local youth with genuine interest in the Project were accepted as Volunteers, with a structural composition of 50 percent Tribes and 50 percent Settlers, with gender equity, to function as a linking force, between the AHADS and the stakeholders.
4. Necessary training programmes were conducted for the Volunteers on various aspects of the project and the principles of Watershed Management and Eco-restoration.
5. User Associations (UAs) and Ooru Vikasana Samithis (OVS) were constituted and the same were registered under the Societies Registration Act.
6. Detailed discussions were made with the International Consultant on the proposed strategies and approaches.
7. Participatory Rural Appraisal (PRA) exercises were conducted utilizing the services of the competent scientists of the Kerala Agricultural University, the International Consultant and the Volunteer force.
8. Perspective Plans for individual Micro-Watersheds were evolved following the steps below.

    a. Generating basic information on eco-economic parameters for subsequent correlation and interpretation.
    b. Analysis of Thematic Maps such as (i) Drainage map (ii) slope map (iii) Land use capability / Irritability map (iv) Hydro- geological map (v) Land Use / Land cover map (vi) Transport network / Resource map and (vii) Village map showing particulars of Individual holdings.
    c. Thematic maps mentioned above were sequentially super-imposed so as to evolve particulars of the prevailing ecological scenario of the micro-watershed in general and the individual holdings in particular.
    d. Existing Productivity, Potential Productivity and co-efficient of improvement in each micro-unit within Micro-watersheds were drawn up in the aspects of Soil and Water, Bio-mass development and Socio-economic situation and possibilities! The parameters for soil-water Potential Productivity were (i) Soil Moisture content (ii) Drainage (iii) Effective Soil depth (iv) Texture and structure (v) Mineral Resources (vi) Base Saturation (vii) Cation Exchange capacity and (viii) Organic matter content. The aspect under Bio-mass development included Canopy Density and that for Socio-economic productivity were (i) participation of the beneficiary family in the developmental efforts of different Departments (ii) Adoption of innovations (iii) creativity of the beneficiary families and (iv) Economic status. This exercise was done with the help of GIS packages.
    e. Suitability of varied interventions were determined with reference to the accepted package of practices at the level of each individual unit.

9. On the basis of the above studies a Matrix was developed indicating the best intervention (together with ideal alternatives) on technical grounds.
10. The above Matrix with space for generating the proposed modifications was got printed for it to be taken to the individuals for detailed discussions and recording the proposals from the beneficiaries, which exercise was called 'Iterative Survey'.

11. Proposals of individual stakeholders were reexamined for incorporation within the technical admissibility.
12. Detailed Perspective Plans, with permissible financial lay-out were drawn up on the basis of the above exercises for each unit.
13. The next activity was constituting Interest Groups (making people or beneficiaries of identical interests joining together) with due involvement of Project Staff and the Volunteers.
14. Detailed Micro-planning for each Micro-watershed and finalizing the report showing project interventions, phasing of activities in accordance with Ombro-thermic diagrams and Detailed Budgeting.

15. Implementation of Programmes by the UAs and OVS are undertaken only on executing specific Memoranda of understanding (MoU) and providing financial support as Advance payments for commencement of activities it to be adjusted on completion of Programmes partially or in full.

The advantages of the above Planning Strategy include (i) Determination of Potentials and suitability for selected interventions (iii) Determination of investments for each individual plot with due rationality (iv) Evolving a scientific model for Socio-economic interplay with echo-economic dynamics (v) Integrating the technological innovations with the local wisdom and (vi) protection of the concept of "suitability" in watershed management, for making it a replicable model in similar situations.

LAND RESOURCE MANAGEMENT OPTIONS FOR SUSTAINABLE AGRICULTURAL PRODUCTION

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Land resources have a critical role to play in human support systems involving not only food, but fuel, water and other necessities of life. The ever increasing pressure on scarce land due to rise in population has made governments of developing countries assign high priority to land management issues to minimize degradation and optimize production.

Sustainability : Sustainability has been the basic concept in Land resource management, since farmers have always to pass on land to the future generations in a condition fit for their sustained use.
Sustainability (simplified definition): Sustainable land use is that which meets the needs of present land users while conserving for future generations this basic resource on which many of the production support systems depend.

Land resource issues

Land resource issues relating to sustainability vary with major climatic regions and have been well documented. Some of the major issues relating to major climatic zones are.

1. *Humid tropics.*
   - Alternatives to shifting cultivation
   - Soil erosion (water erosion0
   - Maintenance of fertility after forest clearance
   - Maintenance of high productivity under swamp rice cultivation.
   - Efficient management of perennial crop production systems of small holders
   - Forest clearance and fragmentation
   - Conservation of biodiversity
2. *Semiarid and Arid zone.*
   - Water shortages and competetion between uses.
   - Lowering of ground water table
   - Water management, rain water harvesting,efficiency of water use,dry land farming
   - Making provision for drought years
   - Problems of irrigation management,salinisation
   - Overgrazing,water and wind erosion.
   - Livestock nutrition and watering during dry season.
   - Encroachment of arable cultivation onto grazing lands
   - Fuel shortage, food sufficiency.
3. *Steep and Alluvial lands.*

   Steep Lands
   - Soil erosion, finding methods for sustainable use of fertile soils on sloping lands
   - Watershed management
   - .Forest clearance and biodiversity Conservation

   Alluvial lands
   - Maintenance of soil fertility and high productivity both in swamp rice and dryland cropping.
   - Problems of irrigation management,water table lowering,water use efficiency, salinisation
   - Shortages of fodder,fuel in predominantly cultivated landscapes

Land resource surveys and monitoring

Survey of land resources are needed to avoid costly mistakes and to improve efficiency of investment in agricultural development programmes. Planners and decision makers are seldom aware of the significance of natural resource management the, corner stone of sustainability. This message has to permeate the whole fabric of development from planning through implementation to monitoring change.

Land quality monitoring a new task for soil surveyors

High input intensive agricultural practices have resulted in rampant deterioration in land quality through degradative processes. Measurable criteria with potential to make comparisons between areas and to monitor changes over time are needed for soil erosion, decline in soil fertility, water reserves, biological activity, and other soil health parameters to determine severity of land degradation. This adds as a new task to soil surveyors..

Remote sensing techniques and GIS

The advent of remote sensing techniques using satellite imageries allow monitoring of land resources on a large scale. GIS allow an overlay of a series of mapped set of information in the form of digital maps. It also allows monitoring of changes in land use extent of degradation and has immense potential for planning large and small areas. The information from satellite imageries, GIS and other databases are so vast, enabling a wide range of applications and interpretations relating to land resource management.

Land use planning

In land use planning watershed has been identified as the unit to focus all development activities. Watershed development projects have been successfully implemented in many States in India. The strategies involve, holistic development, of the watershed through programmes aiming at poverty alleviation, based on demands of the participating community. Equally important is the focus on maintenance of land quality. The concept of integrated farming involving livestock, fisheries and other components suitable to the area have to be identified.. The fundamental concept of bottom up approach' involving the local community/beneficiaries at all stages of planning, execution, and monitoring of the project is important.

Management interpretations based on Soil Survey data for Agronomic Use

The identified delineated watershed incude lands of various land capability classes. Management strategies for agronomic use are mainly made based on interpretations of soil survey data. Some of the major interpretations are.

1. *Soil productivity:* Crop productivity levels of various identified classs of land vary. A high level of management provides necessary drainage, erosion control, protection from flooding, and provide all agronomic and plant protection strategies required for the crops. For irrigated crops irrigation systems adapted to the soil/crop has to be chosen. Good quality irrigation water based on the needs of the crop has to be provided.

2. *Irrigation:* The most favourable soils are deep, level, well drained with good surface permeability and high available water capacity. Important consideration for design of irrigation system, includes feasible water release rates, ease of land levelling, erosion potential, equipment limitations, soil surface characteristics, gravelliness and rockiness. Rooting depth is another important factor. A shallow root zone, low AWC, Shallow ,sandy and gravelly soils, require more frequent irrigations and split fertilizer applications., than deep fine textured soils. In respect of chemical characteristics,salinity is important and increases with

landscape positions like valleys and toe slopes where salts tend to accumulate and aggravate hazards of salinity.

3. *Drainage*: Soils with intermediate/poor hydraulic conductivity require subsurface drains. When there is excess of surface water, shaping the surface allows runoff and reduces downward movement. Rockiness, stoniness, slope, and presence of physical barriers affect installation of drainage system. Similarly unstable soils with abundant silt tend to clog subsurface drains. Acid sulfate soils with sulfides get oxidized on exposure, causing acidity. Peat/muck soils with anaerobic iron also clog drainage lines through precipitation of iron oxides.

4. *Erosion control*: The erosion control measures are decided mainly based on the identified land Capability Classs. In some cases a single practice will be sufficient to provide adequate control while in others a combination on engineering and agro techniques will be required.

5. *Prime and Unique farm lands*: Prime farm lands have best combination of chemical and physical characteristics suited for raising a wide variety of crops. Unique farm lands on the other hand have the potential for raising specific high value crops the choice of which will have to be made based on careful considerations on its suitability, market potential, post harvest processing,value addition. etc.

Research and Technology

A revolution in Agricultural technology is the need of the times. Although production increase is vital, maintenance of land quality without degradation is equally important. The technology developed must be affordable, geared to the needs of the farmers. Farm level demonstration of the technology alone will help in its dissemination and has to be convincingly effective.

Summing up

Land resources play a critical role in human welfare. Land is no longer abundant and its production potential is fast depleting. This calls for strategies to produce more food and other farm products under conditions of diminishing per capita arable land and irrigation water. Sustainability of production systems with maximum use efficiency of limited inputs is the only panacea to meet the needs of the future generations. The ultimate responsibility lies in the people and governments. Awareness and the will to bring about a change can alone pave the way to realize the dream of ushering in prosperity in the agriculture sector in the years to come.

WATER HARVESTING AND GROUND WATER RECHARGE IN WATERSHEDS

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Introduction

Soil, water, vegetation, animal and human resources are the natural endowments of a region deciding its productivity. Continued exploitation of these natural resources and utter ignorance on their susceptibility has already caused unimaginable damage and posed a serious threat to future survival of mankind. An immediate halt to this process of deterioration, through integrated watershed development, is the prime need of the hour to sustain the productivity and to maintain the ecological balance.

In India, watershed approach is mainly concentrated in rainfed agriculture, which is a complex, diverse and risk- prone technology and is characterized by low levels of productivity and low input usage. Nearly 72% of our agricultural land is under rainfed condition and they contribute 42% of our production. The productivity of any crop mainly depends on two natural resources, namely, land and water. Therefore, conservation of these two natural resources is essential for sustainability of rainfed agriculture.

In most parts of the developing world, the climate is characterized by seasonal rainfall. The total amount of rain in a year is often quite high and would in most parts be sufficient for the needs of people living there. The seasonality however, implies that during the dry season, surface water is not available and shallow dug wells and ponds dry out because of sinking ground-water levels. This has an effect that the women and children have to transport water from sources at long distances to their homes. In addition, the available water is becoming inferior quality due to higher pressure on the perennial sources from people and cattle, thus creating serious health problems. The seasonal variation in the natural availability of water creates a need for storage of water. If water can be properly conserved during the rainy season for consumption during the dry season, the above-mentioned negative consequences can be avoided

Watershed management for sustainable water resources

The term watershed has derived from a German word, *Wassesbede* meaning dividing lines. The piece of land from where all the rainwater drains out to a common outlet is called a watershed. The rainwater from the inside of the border of a watershed flows to a common outlet and from the outsides of this border, rainwater flows to another drainage line.

Watershed management is the integration of technologies within the natural boundaries of a drainage area for optimum development of land, water and plant resources to meet the basic needs of people and animals in a sustainable manner. Watershed management has been defined by Striffler (1979) as "the analysis, protection, repair, utilization and maintenance of drainage basins for optimum control and conservation of water with regard to other resources". In its broadest sense, it implies prudent use of soil and water resources. Good Watershed management implies that more rainfall will be retained on the land, which will contribute to better local water supplies to increase agricultural production, to develop better forest and grasslands, and thereby improve the income from land and ensure higher living standards

Availability and requirement of water

Water covers seven-tenths of globe surface; only less than one percent of it is fit and available for human use and consumption. The world's total water resources are estimated at 1.37 x 10^8 mham (million hectares meter) of which 97.2 per cent is salt water of the sea and 2.8 per cent fresh water. Out of this 2.8 per cent fresh water, 2.2 per cent is available as surface water and 0.6 per cent as ground water. Of the 2.2 per cent of surface water, 2.15%, ie almost three quarters of fresh water is in the glaciers and ice-caps of Artic and Antarctic and 0.01 percent is available in lakes, rivers and reservoirs and 0.0001 percent in streams. The rest is water vapor and the soil moisture. Hence the total fresh water on earth, located in lakes, streams, rivers and ground is estimated to be around 8 million cubic kilometers of which only 30,000 cubic kilometer per year i.e. 0.36 per cent of the world's total fresh water is accessible to man. In India, the total annual rainfall over the country is 370 mham. Based on the assessment of the runoff in different river basins, the surface runoff of the country works out to 185.8 mham. The total rechargeable ground water resources in the country are computed as 43.19 mham. The present water use and projected future demands for irrigation, domestic, energy, industrial and other uses in 2000, 2025 and 2050 are given in Table.1 (Bhatia, 1999).

Table.1. Present and projected future demands of water in India for various purposes

Sl.No.	Purpose	Demand in year (bcm)		
		2000	2025	2050
1	Domestic use	33	52	90
2	Irrigation	630	77	1000
3	Energy	27	71	150
4	Industrial use	30	120	64
5	Others	30	37	40
	Total	75	1050	1344

Need of water harvesting and ground water recharge

In India, the per capita water availability came down from 5300 m³ in 1955 to 2200 m³ in the early nineties against the world's average of 7400 m³ and Asian average of 3240 m³. Besides, the distribution of water resources in the country is not at all uniform. The per capita availability of water in some of the east flowing rivers of Tamil Nadu is as low as 380 m³, while it is as high as 18400 m³ in the Brahamaputra basin. As per UN standards, the countries with annual per capita water availability of less than 1700 m³ are considered as water stressed and those with less than 1000 m³ as water scarce (Consgrave, 2000). Simulation studies conducted as a part of World Water Vision, have shown significantly increased water stress in more than 60% of the world by the year 2025 including large areas of Africa, Asia and Latin America under the development scenario for Business–As-Usual (BAU) (Aleamo et al., 2000). The fresh water requirement by 2025 will be almost at par with exploitable water sources. Thereafter, additional supply will be necessary. Otherwise, the present gap between supply and demand will go on widening and the country needs to create storage of atleast 600 bcm against the existing storage of 174 bcm, with 75.42 bcm from projects under construction and 132.3 bcm being contemplated (Baatia, 1999)

Improper management or over exploitation of ground water and its inadequate replenishment has led to gradual decline of water table in many parts of the country rendering a huge number of wells in dry state. In India, from 1981 to 2000, ground water level has decreased by 4m. To overcome such a situation, bore wells and tube wells are drilled to greater depths. Water taken through tube wells and other sources is 2 times than water recharged during rainy season This has further complicated the situation in some areas where higher concentration of hazardous chemicals such as fluorides, arsenic and nitrates are observed, in addition to lowering the water table. Discharge of untreated effluents into surface water streams and lakes by industries resulted not only in contaminating these surface waters but also the ground water bodies. In coastal areas, over exploitation of ground water resulted in seawater intrusion thereby rendering ground water bodies saline in these areas. In Gujarath, tapping of excess water through tube wells caused salt-water intrusion 7 km inwards. In northern side of Gujarath and Southern side of Rajasthan, excess water tapping caused the mixing of fluoride in the ground water. In west Bengal, Arsenic is mixing with ground water. According to an estimate, 3 out of 5 persons in the developing countries do not have enough pure drinking water.

It is expected that ground water extraction may reach to the level of about 62 bcm by 2025 and to about 80 bcm by 2050 leaving very little or no water for further extraction (Chadurvedi, 1999).

During last few decades, world population has tripled and the use of water for human purposes has multiplied six fold. Leading experts on water resources are warning that the world is fast heading towards "a water shock" which may even dwarf the oil crisis. Experts also fear that shortage of water is likely to be so acute in future that next world war may well be fought over disputes relating to sharing of water resources among various countries. Today, about 80 countries comprising 40% of world's population suffer from serious water shortages (UN, 1997). Hence, large-scale development of ground water has assumed critical importance in the socio-economic advancement of the country and is a vital factor in promoting production of land through assured supply of water.

Anil Agarwal, former director, Centre for Science and Environment pointed out that how much rain we get is not at all important; question is how much of it we are harvesting. He also said that there is no village in India that cannot meet the basic drinking, cooking and reasonable irrigation needs through rainwater harvesting. Identification and promotion of simple, reliable and environmental friendly technologies are necessary to overcome the above problems. Reviving the traditional practices of water harvesting using scientific method is potential option.

The concept of rainwater harvesting lies in tapping the rainwater where it falls. A major portion of rainwater that falls on the earth's surface runs off from streams to rivers and finally to the sea. An average of 20% of the total rainfall recharges the ground water aquifers. Therefore, most of the rainfall goes waste in the form of runoff. The technique of rainwater harvesting involves catching the rain from localized catchment surfaces such as roof of a house, plain and sloping ground surface etc. The rainwater that falls on this catchment is diverted into dugout ponds, vessels or under ground tanks to store for long periods.

Methods of Water harvesting and Ground Water Recharge

Reducing the ground water draft and/ or increasing the ground water recharge can check the decline of water table. Soil and water conservation works can contribute immensely to ground water recharge. Depending on the approach, it is divided into Vegetative or agronomic methods and mechanical (engineering/artificial) methods.

Vegetative or agronomic methods

Mixed cropping: Developing intercrops that do not compete with the main crop is a good soil and water conservation method. That is, planting coconut arecanut, mango, jack, papaya as top layer trees; banana, pepper, cocoa, coffee, guava, sapota as second layer plants; turmeric, ginger, vegetables, elephant foot yam, fodder etc as third layer plants. When intercrops spread their canopy, they prevent soil erosion and make more rain to percolate. It not only ensures effective utilization of sunlight & water but also greater productivity of land.

Growing legumes and grass: In a land having lesser depth of top soil, perennial or tree crops cannot be cultivated and the only crop that we can raise is legumes or grass After the first rain, the land is to be moderately dug with the help of a fork and seeds of legumes/grass is to be broadcasted. When the plants grow up, their roots check the soil erosion and facilitate infiltration of water to deeper layers. The legumes help to increase the fertility by fixing atmospheric nitrogen

Contour cultivation: When all the normal cultural operations are done across the slope, the contour furrows and plant stems thus created would form a multitude of mini barriers across the flow path of the runoff, which improves vastly the in-situ detention storage. This in turn increases the opportunity time, and, hence, the infiltration of rainwater into the soil profile, thereby the quantity and velocity of runoff and its erosive potential are greatly reduced. Contour cultivation remains most effective on the moderate slopes of 2 to 7% and deep permeable soil and its effect decreases as the land slope become very flat or very steep.

Mulching: For a farmer, the first practical step towards water conservation is enriching the land with more and more organic materials to the land in the form of dry leaves. Mulching the land with agriculture wastes reduces soil erosion, evaporation and excessive heating; controls weeds and increases the water holding capacity & permeability of soil. Since it retains moisture, provides organic material and darkness; the microbial activity increases considerably which help to improve the soil health. Continuous mulching for three years in Sarang, Kerala; helped to bring the degraded soil back to fertility. Studies at Dehradun at 8% slopes have shown that use of

mulch @ 4 tonnes/ha in rows of corn considerably reduced the soil loss from 36.5 tonnes/ha to 6.2 tonnes/ha and runoff from 49% to 22% of total rainfall (Khybri et al., 1983).
Cover Crops: Cover crops do the same work as mulching. If legumes are used as cover crop, it gives an additional advantage of adding nitrogen to the soil. *Pueraria phaseoloides, Calopogonium mucunoides, Mucuna bracteata* etc are some of the cover crops used in Rubber plantations.
Vegetative barriers (Fig.1.): In small slopes, live fences of suitable crop (vetiver, gliricidia, hibiscus) will help to check the soil erosion. It also facilitates water infiltration through the air gaps created by its profuse roots. Hence, vegetative barriers encourage *in situ* moisture conservation and ensure silt less overland flows. Compared to mechanical bunds and trenching, planting vegetative barriers is easy, less laborious and does not need any maintenance (Katyal and Das, 1994).

Mechanical methods

Contour bunds (Fig.2): In contour bunding, narrow based trapezoidal bunds are constructed on contour to impound runoff water behind them so that all the stored water is absorbed gradually into the soil profile for crop use. Contour bunds are suitable for areas with lesser rainfall (< 600 mm) and permeable soils upto a slope of 8%. It can be followed upto a slope of 20%, but the height of the bund might have to be increased or bunds of lesser heights at lesser vertical distance are to be provided.

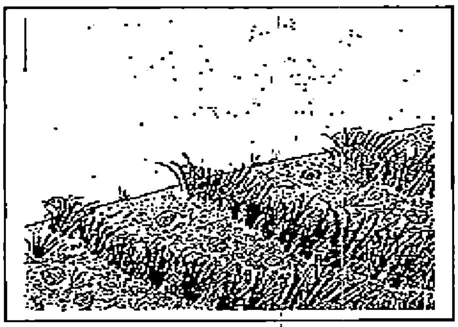

Fig.1.Vegetative barriers

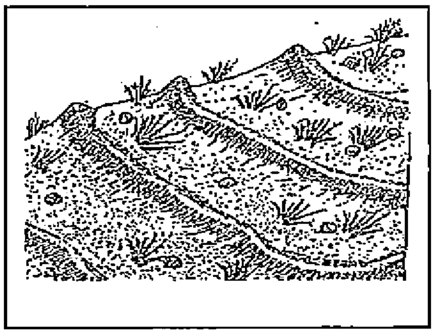

Fig.2.Contour bunds

Contour trenches (Fig.3): In areas of heavy rainfall, the bunds may not be sufficient to stop the runoff. Continuous or staggered trenches (of 2m length, 0.5m width and 0.5m depth) are ideal for these regions. While digging the continuous trenches, few walls are to be provided, which help to reduce the damage due to the slight errors in marking the contour lines. Contour furrows would form mini barriers across the flow path of runoff, which improves vastly the detention storage and increase the opportunity time and hence the infiltration of rainwater into the soil profile. This reduces the quantity and velocity of runoff and hence erosive potential of the rainwater.
Graded bunding or channel terraces: Graded bunding or channel terraces are constructed in high-rainfall areas (>600mm) where excess water is to be removed safely out of the fields to avoid stagnation of water, and hence, damage to the crops. Graded bunds are recommended even in lesser rainfall areas where the soils are highly impermeable or clayey in nature. In graded bunds, the water flows in a graded channel constructed on the upstream side of the bunds at non-erosive velocities and is led to safe outlets or grassed waterways.
Infiltration pits: Digging infiltration pits are common in coffee estates and rubber plantations. In between the rows of crops, pits of 1.5m long, 45cm deep and wide pits are dug. Pits are always dug on contour lines, across slope. The pits in the second row catch the runoff from untreated area of the first row. Once in two years, silt, dry leaves etc are to be cleared from the pit and put to the plants which help to increase the efficiency of infiltration pits and increase the growth and yield of plants.
Terracing (Fig.4): Terracing is recommended in areas having slopes above 30%. Terracing checks the soil erosion and percolates the run-off. It reduces the length of slope and velocity of run-off is not allowed to attain a critical value, which initiates scouring. Depending on type of soil,

climate and crop requirements, terrace may be constructed level or sloping outward or inward and with or without mild longitudinal grades. Level terraces are generally practiced where rainfall is good and paddy is cultivated. The outward sloping terraces are recommended for areas with relatively lower rainfall and shallower soils. Generally this is practiced as an intermediate step in the construction of either level or inward sloping terraces. The inward sloping terraces are suitable for high rainfall areas with deep permeable soils. While constructing the terraces, instead of going for big steps by keeping the vertical distance between the terraces higher, it is advisable to have more terraces with less vertical interval.

Construction of terraces is not only expensive but the soil also gets disturbed in the process owing to which the subsoil gets exposed resulting in poor crop yields in early years. Puertorican type of terraces eliminates these problems. In the Puertorican type of terraces, vegetative barriers are provided on convenient lateral grades and the soil in between the terraces is cultivated in such a way as to induce the progressive leveling of the area in the course of a few years (Fig.5.)

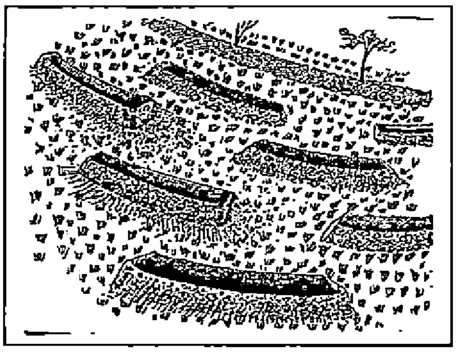

Fig.3.Continuous/staggered trenches

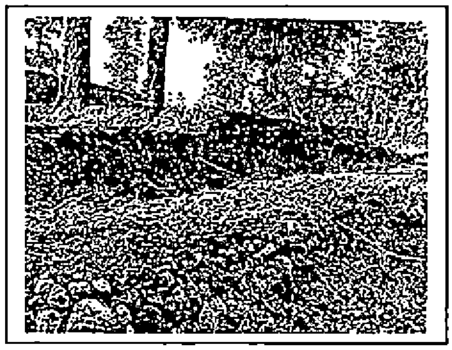

Fig.4. Terracing

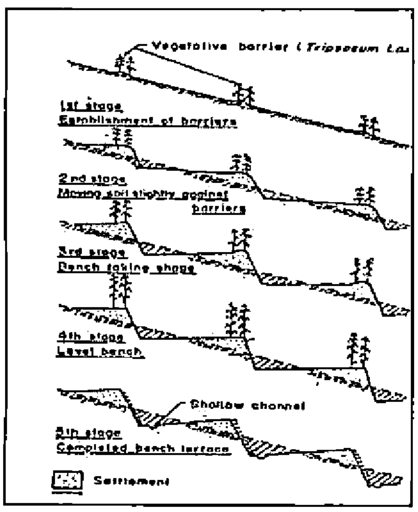

Fig.5. Puertorican type of terraces

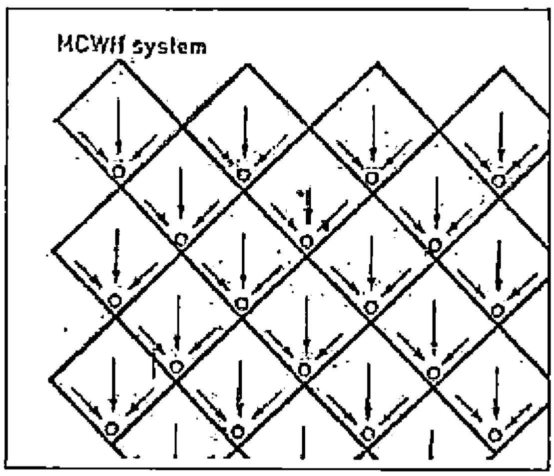

Fig.6. Micro Catchment water harvesting

Micro-catchment water harvesting: Micro catchment is a very small watershed varying from 100 to 300m² designed to collect runoff for the consumptive use of a single tree (Fig.6). Micro-catchment water harvesting (MCWH) method is suitable for areas having less quantity of annual rainfall. A bund having a height of 15cm is raised around each catchment. At the lowest point of each catchment, an infiltration pit of 30-40 cm deep is made and a tree is planted in it. It involves the collection of surface runoff from the catchment and storing it in the soil profile of the basin located downstream. Even a light shower causes ponding in the basin. Areas where rainfall is more than 300 mm per year and soils that develop crusting on the surface as a result of impact of raindrops are suitable for MCWH (Singh, 2000)

Gully plugs: If proper care is not given, runoff will create gullies. To check further erosion and to improve the land, gully plugs are useful. Depending on the speed and quantity of runoff, the distance between the gully plugs has to be properly decided. Locally available materials like stones, sand bags, plant leaves, branches etc can be used for this.

Rooftop rainwater harvesting system: Rooftop rainwater harvesting can be used either for storage of rainwater runoff in tanks for domestic needs or for recharging the ground water or both. Though the practice of rooftop water harvesting is an age old one, systematic collection and storage of water to meet the drinking water needs of the family is of recent times. The popularity of this practice is limited by the costs involved in collection by gutters/pipes and storage in iron or masonry tanks. Use of ferrocement technology in construction of storage tanks help to reduce the overall cost of these domestic systems

Such a system usually comprises of a roof, a storage tank and guttering to convey the water from the roof to the storage tank. In addition, a first flush system to divert the dirty water, which contains roof debris collected on the roof during non-rainy periods and a filter unit to remove debris and contaminants before water enters the storage tank, are also provided (Fig.7). The filter unit is a container or chamber filled with filter media such as coarse sand, charcoal, coconut fiber, pebbles and gravels to remove the debris and dirt from water that enters the tank (Table.2). The container is provided with a perforated bottom to allow the passage of water. The filter unit is placed over the storage tank.

Table.2. Details of filter media

Material	Thickness (in mm)	Position
Gravel of 20 mm size	50	At the top
Charcoal	50	
Coarse sand	50	
Coconut fiber	50	
Pebbles of 10 mm size	10	
Gravel of 20 mm size	50	At the bottom

The capacity of the storage tank determines the cost of the system and reliability of the system for assured water supply. The capacity of the tank is calculated as:
Capacity (Q) = (n x q x t)
Where, n = number of persons; q = consumption, litre per capita per day, lpcd
t = number of days or dry period for which water is needed

Roofs made of corrugated iron sheet, asbestos sheet, tiles, slates or concrete can be utilized for harvesting the rainwater. In a given area, rainwater runoff volume depends upon the roof area and it should be enough to generate design runoff volume for the storage tank. Runoff per unit roof area can be computed by multiplying total average rainfall (in mm) over the preceding wet months or monsoon (P), as per the climatic conditions with the runoff coefficient (f)(Table.3). The amount of water available from the rooftop will be obtained by multiplying the runoff per unit area with the total roof area in m^2 (A).

That is, water available from roof top (lit) = P x f x A

Table.3. Runoff coefficient of various roofs

GI sheet	0.9
Asbestos	0.8
Tiled	0.75
Concrete	0.7

After storing the harvested water in the ferrocement tank, the overflow water can be used for recharging the ground water. It can be recharged to the existing open well/tube well, ponds/pits and abandoned tube well/open well. If there is no drinking water scarcity, no need to construct the storage structure and the harvested water can be directly fed to the above mentioned water sources (Fig. 8). Care must be taken to see that water should pass through filter media before putting into the water sources.

At Chellanam, a coastal panchayat of Kerala, the local people developed a very low cost method of roof water harvesting. This method does not require any tank. If sweet water is slowly released on saline water, the former stands as a separate layer on the top of the former. This is because of the lower specific gravity of sweet water as compared to the saline water. Based on this, people of Challanam have standardized a method that costs only about 2500 to 4000 rupees. The local panchayat gives 50% subsidy. This method has spread to more than 250 hectares in a short span of 2 years. This method was found suitable only in coastal belts where water table is shallow and water is saline (Padre, 2002).

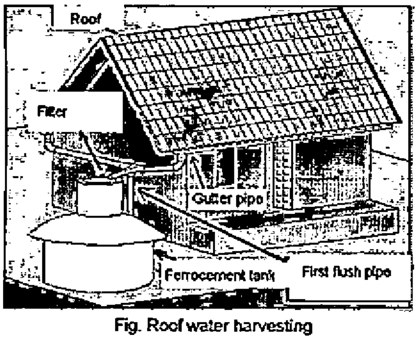

Fig.7. Roof water harvesting

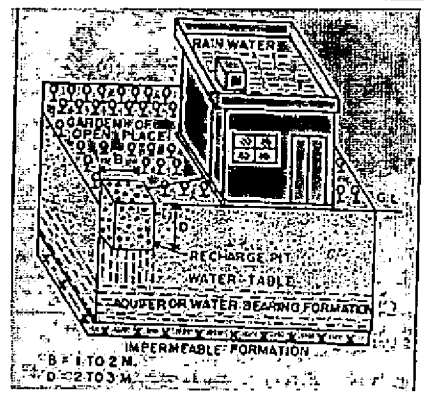

Fig.8. Recharging harvested roof water directly to ground water storage

There was only 2 feet water in the well of a farmer of Shekhpat Village, Jamnagar District. After recharging the well (in the year 1994) with flooded water from the nearby river, the water level rose to 8 feet in the next year itself (in the year 1995). In the year 1996, it reached 20 feet. Now his annual income has increased by 20,000 (Padre, 2002)

Percolation pond/ tank: Percolation ponds/tanks are small water storage structures constructed to harvest runoff from the catchments and to impound for longer time to facilitate percolation of impounded water into the soil substrata both vertically and laterally, thereby recharging ground water storage in the zone of influence of the ponds (Fig.9). This will help to increase the yield of wells, especially on the downstream side of the pond. The water stored in the Percolation ponds can also be used for irrigation and drinking purpose of the animals. Besides, it will check soil erosion, reduce flash floods and keep the drought at bay. *Madaka* of Karnataka and *Johads* of Rajastan are good example for percolation tank (Padre, 2002).

Construction of percolation ponds/percolation tanks is being advocated since long time in order to arrest the excess water that runs away from the cultivated fields. Even small sized tanks have been reported to be successful in conserving the runoff water in hill areas (Shrivastava, 1983). In plain areas, efforts have also been made in the past to conserve water at suitable places during the monsoon period and to utilize this stored water during limiting moisture condition or stress period. The success of this system mainly depends on the subsurface soil properties. It is very effective in highly permeable and unconfined aquifers. The natural depressions, existing dry or abandoned wells/tanks etc can be converted into percolation ponds/tanks. Surplus water from reservoirs, storm water, tank, canal etc. can be diverted into these structures to directly recharge the aquifer. The recharge water is guided through a pipe to the bottom of well, below the water level to avoid scouring and entrapment of air bubbles in the aquifers. Water should pass through filter media before putting into dug wells. Some times, it may dry up in few months. But by that time it would finish the job expected of it. Since these ponds are constructed to recharge nearby ground, its benefit will be obtained in all the water sources around it.

Percolation ponds can also be made by constructing suitable bund across natural streams and nallas. This will collect, spread and impound surface water to facilitate infiltration and percolation of water into the sub-soil for augmenting ground water recharge. These types of structures are suitable in alluvial and hard rock formations where the rocks are highly fractured and weathered.

Percolation tanks with wells and shafts can also be constructed as a combination of surface-cum-sub-surface recharge structure to recharge deeper aquifers where shallow or superficial formations are highly impermeable or clay. Recharge wells with filter can be constructed in percolation tanks and stored water admitted through recharge well to recharge deep aquifers (Sarma et., al, 2002)

Percolation ponds have been constructed extensively in the states of Tamilnadu, Andhra Pradesh, Karnataka, Maharashtra, Gujarat and also in many other parts of the country by state government agencies under various Soil and Water Conservation Schemes, Drought Relief Programme and Rural Landless Employment Guarantee Programme.

In Jalgaon district, the recharge through six percolation tanks was about 681 thousand cu m (TCM), with a rise in water level from 1to 5 m. The benefited area was 545 ha. In Amaravati district, the recharge through three percolation tanks has been about 298 TCM, with a rise in water level from 4 to 10 m. It has benefited an area of about 280 ha (Sarma et. al., 2002)

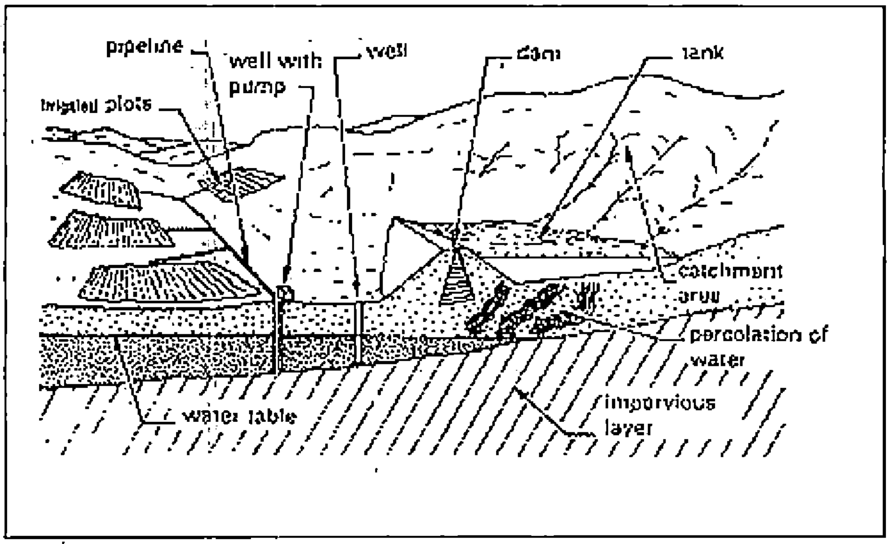

Fig.9. Schematic view of recharge through percolation tank

Check dams / Subsurface dams: Today, most commonly used method of storage of larger quantities of water is surface storage by dams. This method, however, have serious disadvantages, the most important being high pollution risks and heavy evaporation losses. The contamination of surface waters in rural areas of developing countries is practically impossible to avoid and evaporation can be limited only at high costs, by using sophisticated methods which is not appropriate at village level.

If the natural flow of ground water could be obstructed by constructing an impermeable layer (subsurface dyke) from the bedrock, it could arrest the ground-water flow and augment the recharge of ground water and hence raise the water table (Fig.10). Subsurface dams can be constructed in rivers, slightly sloping rice fields and in sloping land having impermeable layer (either hard rock or thick clay) underneath within a depth of 3 to 10m. The top level of the subsurface dam should be 50cm below the lowest ground level point Subsurface dams can be constructed by masonry, concrete, polyethylene sheet, sand-cement-bentonite mix etc. If a series of subsurface dyke/check dams are constructed across the river, it retards the flow of water from rivers to sea and increase the period of water flow in a river. Check dams help to increase the levels of water bodies in the surrounding areas. As a result, a considerable portion of the soil on either side of the river, which was not getting water earlier, gets recharged with water. During summer season, when water level in the river goes on declining, the land from both the sides starts draining a portion of water to the river by gravitational force. This process helps to increase the water flow in the river. In the case of small streams, check dams can be constructed by using different kinds of locally available materials like stones, earth, tree trunks, polythene bags filled with river sand. In case of comparatively wider rivers, masonry or concrete check dams are to be constructed.

There are many advantages of storing water under ground as compared to surface storage.: the evaporation losses are eliminated and the pollution risks are very low, in fact, the water may even be purified due to filtration and self-purification; no land is wasted by covering water: there is no risk of silting, vegetal fill-up and spreading of malaria; experience show that construction costs are low and the need for maintenance is negligible; indigenous materials can be used for the construction and it can be carried out by local people; no need of construction of water conveyance system; the benefits will be available in the wells in the zone of influence of check dam. Hence, in a state having steep topography and non-availability of waste lands, the most suitable method of water harvesting is the construction of subsurface dams at suitable locations.

Artificial recharge through four check dams in JNU and IIT, New Delhi created storage of 4600 to 22180 cum. Water levels in the wells recorded a rise of 0.8 to 9.9 m and an area of 75 ha has benefited. A subsurface dyke (160m length and 5m deep using plastered brick and tar felt sheets) constructed across a small nala in State Seed Farm, Ananganadi, caused considerable increase in the availability of ground water on the upstream side (Sarma et. al., 2002).

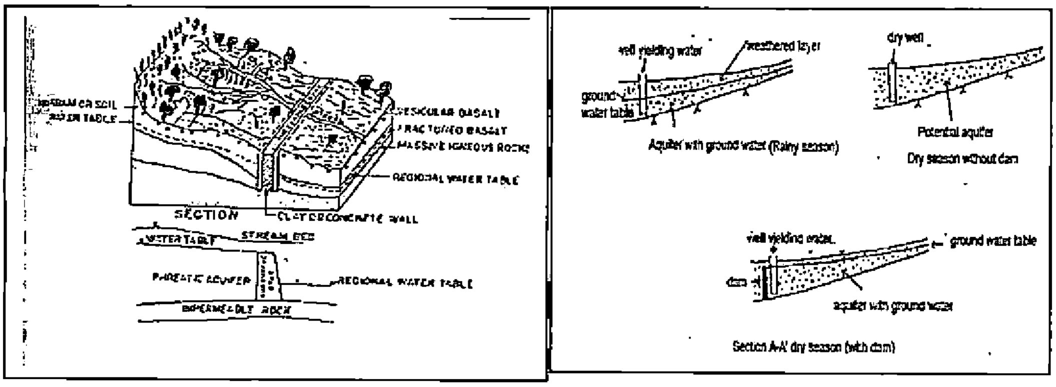

Fig.10. Recharge through subsurface dams

Using Termite Hills: Termite hills have several underground tunnels dug out in different directions. One or two of them usually touches the water table. It is by this way they bring droplets of water on their mouthparts for mound construction. Based on this fact, series of termite mounds are taken as indicators for water divining by some people. Roof water can directly feed to it. If run-off water is used to feed to termite mounds, water should be filtered with the help of filtering unit. This is to avoid the silts blocking the termite tunnels in the long run. Termite mound can intake a very large amount of water and can infiltrate it to a very large area of subsoil in a short time. When a farmer in Kasargod district, Kerala diverted the run-off to a termite hill situated near his house, in the very next season, his well that used to dry up during the summer months, was containing good amount of water (Padre, 2002).

Studies on the effect of soil-water conservation and ground water recharge

According to central Soil and Water Conservation Research Training Institute, Dehradun, 5334 million tones of soil are being eroded annually. Of this, 29% is being permanently lost to sea, 10% is deposited in reservoirs as silt, 61% displaced from one location to another. This study warns that present annual average loss of topsoil is approximately 16 tonnes/ hectare; which is far above the permissible limit of 4 tonnes/ hectare. The National Bureau of Soil Science and Land Use Planning (NBSS & LUP) has estimated that 57 % of the land area in India (187.7 M ha) is potentially exposed to various degradation forces (Sehgal and Abrol), 1994) of which 45% (148.9 M ha) is affected by water erosion. Wind erosion, chemical and physical deterioration are responsible for 4.1, 4.2 and 3.6 % of soil degradation, respectively. Water erosion poses most serious problem, resulting in soil loss of about16.35 t/ha/yr, and overall loss of 5.3 billion tonnes of top soil annually in the country (Dhruvanarayana and Rambabu, 1983). Singh and Bhardwaj (1986) revealed that the annual loss due to erosion is about 1665 thousand million cubic metres of river flow and 6000 m tonnes of soil along with huge quantities of other valuable elements. It is estimated that about 2.5 m tonnes of nitrogen, 3.8 m tonnes of phosphorous, 2.6 m tones of potash are lost every year from our country, which is perhaps more than their production in India

National Committee on Integrated Water Resources Development pointed out that the loss of storage capacity due to silting of tanks has deprived the country a whopping 5,000 crore rupees as capital loss (Padre, 2002).

For the nature to produce top soil, generations are required. But unfortunately most of the people do not take this issue of soil erosion seriously. With the harvesting of rain where it falls, run-off gets checked. So wherever rain water harvesting measures are implemented, soil erosion also stops. Soil management is crucial for maximum water intake, which can be achieved by providing a cover over the soil surface, and by increasing surface roughness thereby reducing runoff and increasing porosity. Practices, which maximize soil organic matter, tend to increase soil stability (Singh, 2000). Grasses have been found to control soil erosion, improve soil structure largely due to their good canopy and excellent binding force of the roots. Next to grasses , legume roots help in improvement of soil structure owing to higher root mass and root secretions. Run off studies conducted at Dehradun, on silty clay loam soil, with 160000 mm annual rainfall proved that grasses are the best soil protecting vegetation. Very little water, soil and nutrients were lost from soil under grass cover, while bare fallow produced maximum soil loss (Gupta et al., 1963). We can bring the degraded soil back to fertility with continuous mulching for three years (Padre, 2002).

Pathak and Laryea (1992) observed that creating surface roughness is an important aspect of increasing infiltration and reducing runoff and soil loss. Three levels of surface roughness ie, scoops (small depressions on soil surface), tied ridges and flat seedbeds, were tried on Alfisols. As compared to flat seedbeds, scoops reduced runoff by 69% and soil loss by 53%. In case of tied ridges, runoff was reduced by 39% and soil loss by 28%.

In Dehradun region, runoff observations on a 55 ha agricultural watershed treated with contour/field bunds have shown that runoff volume and peak flow were reduced to 62 and 40%, respectively of the values from fields before treatment (Ram Babu et al., 1980). Contour farming resulted in the reduction of runoff by 54% to 40% of rainfall and of soil loss from 50 tonnes to less than 20 tonnes per hectare during the rainy season at Dehradun. (Tejwani et al.,1975). In Ootacamund region, with 25% slope, when contour farming was practiced (where potato crop was raised), soil loss was reduced from 40 tonnes to 15 tonnes per hectare (Dhruvanarayana and Prasad; 1989). In the Nilgiri hills, it was observed that on areas with an average slope of 20%, bench terraces with lengths of about 100m, longitudinal grades in the range of 0.2 to 0.8% and inward grades greater than 1% conserved the soil and soil moisture more efficiently and also produced better yields of potato (Dhruvanarayana and Prasad; 1989).

In GR Halli watershed, cotour trenches of 1.5 to 3m length and 0.3m width was constructed and tree plantation was established by planting the plants in staggered manner. This practice, not only stabilized the soil erosion from steep slopes but also significantly reduced surface runoff and increased deep percolation in the watershed area (Patnaik et al, 1986).

Soil conservation measures implemented at seven watersheds (Table.4) were gauged at appropriated sites to assess the runoff and sediment yield. The study revealed that 28.5 to 66.6% of runoff was conserved within the watershed which otherwise was going out of the area prior to construction of soil conservation structures (Sastry, 2001).

Table.4.Effect of soil and water conservation measures on runoff and sediment yield of the watersheds

Watershed	Runoff as a percent of rainfall		Sediment loss (t/ha/yr)	
	Pre	Post	Pre	Post
Bazar-Ganiyar (Hariyana)	7.3	3.5	N.A	8.5
Behdala (HP)	30	10.0	12.0	7.0
Bunga(Hariyana)	30.0	21.6	768.0	435.0
Chhajawa (Rajastan)	50.0	18.5	N.A	10.6
GR Halli (Karnataka)	1.4	1.0	1.4	1.0
Joladarasi (Karnataka)	N.A	6.7	12.0	2.3
Siha (Hariyana)	N.A	1.5	N.A	9.7

If the forest is dense, in an area of 2500 mm rainfall, it can pass down 1000 to 1500 mm of rain. One hectare of forest can store about 6 to 7 lakh tones of water after filtering it. The topsoil itself can hold 1.2 lakh tonnes of water. Decline of forest cover is the major reason for lowering water table, increasing draught, and an alarming rate of soil erosion (Padre, 2002). Table.5. shows the amount of water infiltrated into the soil under different land cover.

Table..5.Rainfall, Runoff and Soil moisture storage in profile under different land cover.

Land cover	Runoff (mm) from 1106 mm	Water infiltrated into the soil (mm)
Fallow land	782	324
Grass cover	372	734
Tree + grass	66	1040

Water level in the well of a farmer's field at Kannur district, Kerala was only 1 feet during the month of May. After the construction of water harvesting structures (roof water and rain water harvesting) in the year 1994, the water level in the well rose to 3 feet in the very next year (1995). The levels in the subsequent years were 4 feet in 1996, 5 feet in 1997 and 6.5 feet in 1998 and thereafter, summer water level has been stabilized at that level. Total amount he had spent on rain water harvesting was only Rs. 700 (Padre, 2002).

Yadav et al (1991) in a study of comparison between developed and underdeveloped catchments has reported that runoff and peak discharge rate were less in developed catchments. The development included terracing, field bunding, and check dam construction.

Evaluation of the impact of watershed development carried out under Western Ghat Development Programme show that there is an improvement in lean flow in the thodu, reduction in water table fluctuation in the wells and reduction in soil loss due to erosion. The evaluation study also indicated the importance of people's participation for the success of watershed development (Varadan, 1998).

Water table fluctuations in recharged wells was much less as compared to the non-recharged wells. Even in low rainfall years the drop in water table was less than 50% in recharged wells than that in the non-recharged wells.

In the WDP area, yield of dug well increased by 70 per cent from 264 gallon per hour to 446 gallon per hour due to the recharge effect from water harvesting structures. Among the nine dug wells, which completely dried up before the program, four wells got recharged. The yield of bore wells inside WDP area was 1150 gallons per hour before the WDP and increased by 24 percent to 1426 gallons per hour after program implementation.

The integrated watershed management has great influence in augmenting the ground water recharge. The observations at Achulu micro-watershed in Kabbalanala revealed that the net returns which were negative in bench mark year from arable land improved substantially in the subsequent year (Table.6) (Krishnappa et al., 1994)

Table.6. Effect of watershed management at Achulu micro-watershed in Kabbalanala

Year	Rainfall (mm)	Net cropped area (ha)	Gross cropped area (ha)	Production (t)	Net returns (Rs. '000)	Employment (man days)
1986-87 (bench mark)	732	28.4	30.4	15.7	-1.40	2041
1987-88	787	28.4	31.6	41.2	79.47	2993
1988-89	697	28.4	32.9	35.2	71.11	3396
1989-90	907	28.4	33.4	48.4	86.13	3558

Studies conducted at some watersheds showed that even after increase in the number of wells and amount withdrawn from them, water table in the aquifers remained at a higher level from their initial status (Table.7). This effect was achieved due to the runoff conservation within the watershed area by various conservation structures. For example, in the Chhajawa watershed, before the initiation of the project, there was only 16 wells, pumping time of which was only 2 hours and irrigated area per well was 2 ha. 10 years after the implementation of the project, the number of wells increased to 54 and average irrigated area per well was found to be 7 ha. The pumping time of the wells also increased to more than 6 hours (Sastry et. al,2001).

Table.7. Impact of the Soil and water conservation structures on the ground water recharge

Watershed	Surface storage created (ha-cm)	Observed rise in ground water table (m)*
Bazar-Ganiyar (Hariyana)	79.0	2.0
Behdala (HP)	18.0	1.0
Bunga(Hariyana)	60.0	1.8
Chhajawa (Rajastan)	20.0	2.0
GR Halli (Karnataka)	6.8	1.5
Joladarasi (Karnataka)	4.0	0.2
Siha (Hariyana)	42.2	2.0

- Average rise in the water table for the period, 1984- 1997.

All the soil and water conservation measures should be done on a watershed basis starting from the highest point of the area (ridge line) to the outlet of the natural stream. Large-scale development of ground water has critical importance in the socio-economic advancement of a particular region, which is a vital factor in promoting the production of land through assured supplies of water.

Each one of us has a responsibility towards water. Instead of keeping our hopes on Government to deliver water, we have to convince ourselves that water is our problem. If each one contributes a little to bring up our declining water table, the problem can be solved sooner than we have expected.

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RAINWATER HARVESTING AND CONSERVATION STRUCTURES IN WATERSHEDS

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1. Introduction

Water scarcity will be one of the major threats to humanity during the current century, which has hardly sets its course ahead. As the available water resources taken from streams, rivers and ground water will not be sufficient in most dry areas of the world to cover the needs of domestic, agriculture and industry. Since ancient times, farmers and herders in tropics and subtropics have, under widely varying ecological conditions, attempted to 'harvest' water to secure or increase agricultural production. Water harvesting systems of various forms were prevalent in India during the time of ancient civilizations. Many civilization existed near the banks of rivers. Even the oldest literature Rigveda mentioned a lot on the rational and judicious use of water from wells, tanks, ponds, canals etc. Interestingly, in Arthasastra, Kautlya was entrusted with the responsibility of constructing dams, reservoirs, wells and ponds for the kingdom. Similarly, bylaws regarding orientation of ponds to store and conserve water efficiently and their maintenance have been specified in Vraht Sanhita. Wide ranges of indigenous irrigation techniques have also been reported from the olden time along with water harvesting.

Rainwater and Floodwater Harvesting have the potential to increase the productivity of arable and grazing land by increasing the yields and by reducing the risk of crop failure. Rainwater Harvesting techniques are relatively cheap to implement compared to flood water harvesting and can serve as an alternative to irrigation water from other sources. Water harvesting reduces the pressure on groundwater and also saves in energy cost in pumping.

Many successful water harvesting projects have been found to be on farmers' experience and trial and error rather than on scientifically well established techniques, and can therefore not be reproduced easily. Agricultural extension services have often limited experience with it. Further, conflicts between upstream and downstream users complicate the issue.

In the recent years some methodological and technological developments have taken place in the discipline of water harvesting. Application of hydrological and watershed models, remote sensing data and GIS tools, efficient irrigation techniques are some of them. A watershed approach should be practiced to make the water harvesting programmes more scientific, equitable and to avoid social conflicts.

2. Rainwater harvesting and conservation structures: Different methods and approaches

2.1 *In-situ rainwater harvesting*: Water collection and conservation where it is received through rainfall is termed as in-situ rainwater harvesting. Hence, all the measures in this category include simple interventions but spatially spread out. Many methods can be practiced to collect and conserve rainwater in an in-situ fashion depending upon the terrain, rainfall conditions and the objective of conservation. The commonly used and simple measures in this category are:

2.2.1. <u>Pits and basins</u>: Small pits of 60 x 60 x 60cm can be made to collect and infiltrate the overland flow. This measure is very effective in augmenting groundwater recharge in moderately sloping lands. The deeper the pit the effect of recharge will be better, however, it may lead to fall of humans or animals and consequent fatalities. About 1 to 4 nos of pits can be provided in 40m^2 depending upon the rainfall intensity and duration. Provision of basins for perennial / annual crops can act as a substitute to pits. In sloping lands, basins can be provided with crescent shaped bunds on the down slope side of the plant base.

2.1.2 <u>Contour trenching</u>: The intervention involves construction of trenches across the slope (along the contours) and interception of overland flow and its consequent recharge. Trench can be given a depth of 30 to 45cm and a width of 45 cm. Continuous or interrupted trench may be adopted. In the case of interrupted trenches, length of the trench can go up to 3m and can be made in line or staggered in the down direction. Trenches are provided in more sloping areas where pits may not be very effective.

2.1.3 Contour and graded bunds: Bunds of about 60 to 75cm height are provided along the contours. The section of the bund will be trapezoidal with the side slope varying according to soil type .These intervention can be given in moderately sloping lands having moderate infiltration rate. Generally provided in a slope range of 2 to 10%. Intensity of the rainfall and infiltration characteristics of the soil is two important design considerations. Design of the bund involve deciding the vertical and horizontal interval of the bund and the bund cross section.

2.1.4. Terracing: It is generally adopted for lands having a slope greater than 10%. Continuous sloping land is converted to tabletop or near tabletop benches by cut and fill operations. Each bench will be a few meters wide depending upon the original land slope. Higher the land slope, narrower is the bench width. At the outer end of each bench, a small shoulder bund is provided to give mechanical protection to the edge of the bench and also to prevent overland flow crossing from the upper bench to the lower one. There are three types of bench terraces depending upon the slope provided to the benches of terraces: a) sloping inward bench terraces b) level bench terraces c) sloping outward bench terraces. Sloping outward bench terraces are used in places where rainfall is less. In high rainfall areas sloping inward terraces will have to be provided. Quantum of earthwork involved in the construction of sloping inward terraces will be most compared to the other two types. In general, terracing is a costly measure but at the same time it is the most reliable from the point of view of soil erosion.

2.1.5 Vegetative contour barriers: It is possible to prevent / slow down the overland flow and sediment flow by providing vegetative hedges across the slope at regular intervals. The vegetative barrier can be made of grass, shrubs or trees. There are different options for vegetation to choose from. Their choice depends upon the terrain, soil and main crop characteristics. This measure can be recommended only to gently sloping areas.

2.1.6 Agronomic measures: Runoff and consequent soil loss is very much correlated to agronomic practices adopted in that land parcel. As a rule all cultural and inter cultural operations has to be done across the slope and never along the general slope. Commonly adopted agronomic practices are:

Contour cultivation: It consists of carrying out all agricultural operations like tillage, planting and intercultural nearly along the contour. Contour cultivation will reduce the overland flow velocity and soil loss. Row crops are ideally suited for this. Guiding contour lines can be marked on the field with the help of dumpy, hand level or even an A- frame. Subsequent operations are done making use of this guidelines.

Strip cropping: consists of growing different crops in alternate strips across the slope. Strips of main crop, which maybe erosion permitting, will be followed by erosion resisting secondary crop.

Crop rotation: refers to growing different crops in different season so that it will help in meeting the objective of water conservation and erosion prevention.

Mixed Cropping: is the practice of growing different crops in the same season.

Conservation tillage: various tillage operations such as mulch and deep tillage will help in soil and water conservation.

2.2 *Direct Surface Runoff Harvesting*: In direct runoff harvesting, concentrated form of surface runoff will be collected and stored or conserved for reuse. Different practices under this category are:

2.2.1 Roof water collection: Rainwater falling over roofs of building can be collected before it reaches the ground. Hence, very pure water can be obtained depending on the cleanness status of the roof. This water can be used for domestic purpose. In high rainfall areas large quantity of water can be expected from the roof of even a small building. For instance, in the sate of Kerala, with an annual rainfall of 300cm, about 300m^3 of water can be collected in a year. Large institutional buildings can provide considerable amount of water and this water can be used for non domestic purposes also. Water intended for domestic use must be collected in closed tanks, where as if the use is other than domestic, storages can be done in lined open ponds.

2.2.2 Embankment type and dugout type ponds: Ponds are very effective and age old water harvesting structures. There are two types of ponds depending upon the mode of construction; embankment type and dugout.

- Embankment type ponds, also called as tanks, can be planned in valleys by connecting it by a bund. A large storage capacity can be created with less earthwork and low unit cost. Runoff coming from upslope areas can be collected and the storage reservoir can be utilized to meet the water requirements in dry season.
- Dugout type ponds, on the other hand will be formed by excavation and is suitable for small scale storage. Low lying areas with light to medium hard soil can be chosen for excavation. Seepage and evaporation are two issues to be addressed in pond management.

2.2.3 Percolation pond: Percolation ponds are small water collection and storage structures, which are constructed to collect the runoff from a small catchment. These structures are constructed on the upland areas where it collect water during monsoon season and store it over a period of time. The main objective of percolation pond is groundwater recharge, hence, a major part of the stored water will be allowed to infiltrate and augment groundwater storage. The impounded or stored water in the percolation ponds can also be used for irrigation and other purposes.

2.3 ***Runoff or stream flow harvesting***: Water harvesting on a relatively large scale is put under this category. Different large scale water harvesting measures, which are ex-situ in nature, are given below.

2.3.1 Gully plugging / Check dams: Gully plugging means constructing an obstruction across a small drainage channel either by heaping loose boulder, brushwood or by any similar means. This will facilitate flow chocking and velocity reduction. Sedimentation will take place on the upstream side of the plugged section of the channel and will improve the bed condition. A series of gully plugging measures will be needed to protect a considerable stretch of the channel.

Check dams are small dams made of gabions, masonry or concrete. It can be constructed across small to medium streams. Check dams will function in several ways to improve the water availability of a region. Impounded water can be used for domestic, agriculture or industry. A considerable portion of the storage will move down the soil surface and enhance groundwater storage.

2.3.2 Water diversion: Water can be diverted from streams by making diversion structures and leading the water away from the natural course. Diverted water may be used directly for irrigation or it may be stored to meet several water needs. Masonry or cement concrete weirs are the commonly used diversions.

2.4 ***Subsurface flow harvesting***: Shallow groundwater moves laterally and joins with small drainage channels or streams. Subsurface dikes are used to check the lateral flow of groundwater and improve the quantity and longevity of groundwater availability in the surrounding. Subsurface dike consists of an impervious barrier constructed beneath the land surface and across the general land slope. Small dikes can be made of concrete or masonry. For large ones, plastic film will be an ideal choice.

3. Conclusion

The importance of rainwater harvesting and conservation measures is on the increase as the threat of water scarcity haunts the human life. Water harvesting and conservation is the need of the hour. However, there is no unique means or formula for water harvesting. Water harvesting methods will vary very widely from one situation to another. A water harvesting engineer will have to consider the rainfall characteristics, soil and land limitations, characteristics of water needs, economic, environmental and social issues before zeroing in on a specific method.

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DECENTRALIZED PLANNING FOR AGRICULTURE THROUGH LOCAL SELF GOVERNMENTS IN KERALA: PERSPECTIVES AND EXPERIENCES

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While excessive concentration on decision-making and authority limits the scope and extent of participation of people, decentralization, on the other hand has many positive connotations such as participation of local people, autonomy and transparency of decision-making, accountability, use of locally available resources etc. It is undoubtedly a departure from the bureaucratic rigours of development administration since it allows delegation, devolution of powers and deconcentration (Conyers and Hills 1984). Decentralization as a prominent approach towards local development got evolved from three converging forces such as growing disillusionment with the results of centralized control of development activities, the need for participatory management of development programmes to ensure growth with equity strategy of 1970s and the realization that the diversified and complex government activities can not be planned and administered by a central authority (Cheema and Rondinelli, 1983). Of late, the spiral of economic decline that has ensued structural adjustments has created the pre conditions for decentralization and local initiatives, largely taking over all local development activities.

Among the developing countries, India has gone far ahead with decentralization through a comprehensive legislation that rendered the age-old institutions of *Panchayats* mandatory organisations with well-defined roles in local governance including developmental planning and implementation. Enactment of the 73rd and 74th constitutional amendments that took place in the year 1992 has revivified these moribund village institutions and established a three-tier *Panchayati Raj* system, with local governments at the village, block and district levels. In addition to the conventional roles of collection of taxes, licensing and implementation of a few citizen services, these local governments can now creatively involve in planning, implementation and monitoring of developmental programmes for the respective local area through an array of institutional mechanisms such as grama sabhas, technical advisory committees, monitoring committees, district planning committee etc. As Alagh (1995) observes, the institutional structure of the local government system in India is so equipped to effectively implement developmental programmes for the rural poor in the context of the participatory approaches that are discussed currently.

Decentralized Planning in Kerala: The Context of Genesis and Evolution

Kerala had been the forerunner of decentralization with several earnest attempts to bring about legislations in this regard even as early as 1957, the year in which the state was formed. However, it was in the wake of the above-mentioned constitutional amendments that the state passed a comprehensive Panchayati Raj Bill in 1994. Emboldened by the provisions of the constitutional amendments the state resolved to make full use of the potential of decentralization through a thorough reorientation of its developmental machinery towards participatory development, which includes decentralized planning and implementation of local level development programmes through the Local Self Government Institutions by providing them with adequate financial as well as human resources and well-defined administrative capabilities. In fact, this has been perceived as a mechanism to address at least partially the issues of sustainability of the enigmatic development of the state in the social sector, which is marked by high indices of social development that are comparable with only those of the developed economies (See Dreze and Sen, 1995). Kerala ventured into this seemingly queer exercise of institutionalized participatory planning and implementation of development projects to strengthen the fragile spots in its economy such as the deplorably low productivity of important crops, growing apathy among cultivators, structural decay of the industrial sector, rapid deterioration of power situation and overburdening of the eco system. For instance, agricultural sector alone had been going through the most difficult times, with 50 per cent of rural population depending on agriculture, and the average size of holdings has decreased from 0.36 ha to 0.31 ha over a decade. The area under food grains, particularly rice, has reduced by 4.5 lakh ha over two decades from 1970. Community mechanisms such as group farming that have been established as remedies to the declining food grain production had also failed.

Attempts by Kerala towards decentralized planning have attracted development thinkers the world over, as it has raked up several contentious issues involved in the current development deliberations, such as the scope of increasing production and productivity of the small scale producers and resource less farmers at the local level, declining role of public sector in developing the poor, organizational linkages possible at the local level, extent of real participation as against the theoretical presumptions on people's participation, problems in devolving funds and authority to the grassroots level, role definition of various development agencies, new institutional arrangements that are required to cushion the impact of globalization, etc. to name a few.

Features of Decentralized Planning in Kerala

Decentralization has redefined the development orientation of the local bodies in the state as the committee on decentralization constituted by the Government of Kerala in 1999 observes: local authorities in Kerala as in mo st parts of the world have been concerned with activities, which could be termed more *welfarist* than developmental. Importance was always given to provisions of civic amenities and in rendering other social services. But now, with the constitution laying down the twin objectives of the local self-government system as promotion of economic development and social justice, several changes, which would reflect a development orientation, have to be brought about in the structure and functions of the local governments and the development agencies that can be linked with them'. The constitutional amendment espouses the idea that the Local Self Government Institutions have a critical role in originating plans including the state and national plans. The successful campaign launched in Kerala for participatory planning has thrown up invaluable methodological lessons in local planning, of course with flexible provisions for local initiative and innovation.

Decentralized planning has undergone major phases of evolution and growth, as a mass campaign programme at the beginning of the Ninth Plan period, that involved synergy of a large number of volunteering individuals and institutions and later as a an institutionalized programme which is being increasingly integrated into the system of governance by LSGIs. A well laid out procedure for decentralized planning and formulation of developmental plans with the participation of the people and other stakeholders and fully integrating the process of vigilant monitoring which is fuelled by the intense political activism in the society has been evolved. Further, Kerala has gone far ahead by putting in place necessary mechanisms to ensure fiscal empowerment as well as organizational empowerment for the grass roots level institutions. We shall now briefly examine the features of decentralized planning in Kerala with special reference to the mechanisms integrated into it to address the problems of the resource less farmers. The major characteristics of decentralized planning as envisaged and implemented in Kerala shall be summarized as follows:

Fiscal decentralization

Decentralized planning and implementation of local level development projects was introduced in the Ninth Plan, and a landmark decision that preceded this action was to allot more than a third of the state's plan resources to the local governments, with the rural local governments getting about 83 per cent share in accordance with the rural population. The most striking feature was that the quantum of plan funds earmarked for local governments is the highest in the country. Around 90 per cent of the Plan funds is given practically in an untied form to the local governments to prepare their own schemes and implement them within certain broad policy frame work, which stipulates that at least 40 per cent of the funds (10 per cent in urban areas) should be invested in productive sectors, not more than 30 per cent (50 per cent in urban areas) should be invested on infrastructure and atleast 10 per cent should be earmarked for the gender sensitive schemes and which has fixed a consensual upper ceiling for subsidies in different categories of schemes (Kerala State Planning Board, 2002). Moreover, the entire plan is investible and development oriented, as it does not carry any establishment costs. In order to ensure the explicit nature of plan allocation to local bodies, all the plan grants due to local governments are separately budgeted in a document given as Annexure VI of the state budget. Since it is passed by the legislature it is non- divertible for other purposes by the executive. Contrary to universal practice, it is the Grama Panchayat, which get the bulk of the grants with nearly 70 per cent of the rural share going to them and the district and block panchayats only sharing the remaining 30 per cent more or less equally. Every single rupee devolved to the LSGI whether under plan or other categories is given as per a transparent formula and there is no room for patronage or partisanship in allocation of resources to local governments. A definite procedure for the flow of funds has also been designed and operationalised. The fund flow would be in installments. See Table 1 for the details of allotment of plan funds to the LSGIs and expenditure during the ninth plan and tenth plan. There has been substantial increase in the allotment of funds to LSGIs during these plan periods, which enabled them to undertake grassroots level developmental initiatives.

Table 1. Allotment and expenditure of the plan funds for LSGIs during ninth and tenth plan

Year	Amount released (Rupees in Crores)	Expenditure Rupees in Crores)
1997-98	745.20	698.61
1998-99	910.33	590.87
1999-00	830.50	941.49
2000-01	761.38	740.70
2001-02	657.05	484.40
Total	**3904.46**	**3456.07**
2002-03	994.48	536.10
2003-04	1438.15	1345.85
2004-05	1163.72	930.63
2005-06	1375.00	Not available

Source: Various publications of the Kerala State Planning Board

Administrative decentralization

As discussed earlier, another conspicuous feature of people's plan campaign was the evolution and near perfect operationalisation of a concrete methodology for participatory planning for local level development, which is unique in such terms that it circumvents almost very functional constraint that might emanate from obscure definition of the roles of the stake holders involved in the programme. This methodology also takes into consideration the classical and scientific steps of developmental planning through an institutional mechanism, which is mandatory in nature. The structure and functions of local bodies have been reoriented in such a way as to facilitate decentralized planning, implementation and monitoring, with the following discrete functions:

Need identification: The felt needs of the community are identified through Grama Sabhas and Ward Sabhas, by means of a meeting of adult citizens of the ward. Being mandatory, the people's representative should ensure maximum participation of the citizens of that ward. It is observed that about 10-2 per cent of the rural population has participated in the meetings during the ninth plan. The meetings are held in a semi-structured manner with plenary sessions and sub group sessions, which deal with specific developmental issues. A status paper on each development sector which has already been prepared by the respective working group consisting of locally available experts, department personnel, people's representatives and a few citizens are presented for discussion, based on which the grama sabha reflects on each developmental issue. The decisions are recorded formally and forwarded to the local bodies. These deliberations form the basis of the developmental plan of the local body, which would be implemented ultimately by the development department under the scrutiny of the local body.

Situation analysis: Each local body in the state has come out with detailed analysis of the development situation of the respective area based on various primary and secondary sources of data. Exhaustive development reports have been prepared on the basis of this information and the local developmental concerns and demands that originated from the first special grama sabha (conducted during the inception of the decentralized planning programme) for every local body. These reports describe the status of development in each sector as per the available data, analyze the problems and point out the directions for further development. This is a one-time exercise for a plan period, which would be revised before the next five-year plan. Planning for agricultural development through LSGIs would be readily benefited by this activity as it facilitates realistic assessment of problems, quick appraisal of resources and objective prioritization in a participatory manner.

Setting strategies: The feed back of grama sabhas and reflections on the development report would be consolidated in a one day seminar held at the LSGI level in which participation of experts, elected members, representatives nominated by the Sabhas, practitioners from among the public is ensured. The developmental seminars suggest the broad priorities and the general strategies of developmental projects to be taken up for a particular year.

Projectisation: The ideas thrown up by the above three stages are translated into the form of projects by sectoral committees at the LSGI level. For each LSGI, there are about eight working groups dealing with different sectors of development. Each working group is headed by an elected member and is convened by the implementing officer of the concerned department. The vice - chairman of the working group is normally a non – government expert in the sector. The projects are prepared in prescribed formats that can record the objectives and fund sources, describe the benefits and physical targets in quantitative terms, outline the mode of execution, monitoring and evaluation and the phases of implementation.

Integration: While projects are formulated at the LSGI level, they cannot be either conceived or implemented independently, as there could be several components that overlap each other at different levels or tiers. For example, the local level plans may have to be integrated with the state plans and centrally sponsored schemes so as to use the resources obtained from various agencies. Similarly, establishing backward and forward linkages, horizontal integration between development departments, vertical integration between different tiers of local bodies are also required to avoid duplication of objectives and waste of resources. This would also facilitate integration of complementary components of various schemes, better targeting of beneficiaries and extensive spread of benefits. For example, a typical watershed management programme could have components like soil conservation, water harvesting, micro irrigation, bio mass generation, fisheries, animal husbandry, agro processing and even micro enterprises that can be implemented and monitored in an integrated manner.

Plan finalization and approval: Based on the allocation communicated, the concerned LSGI finalizes its plan for the year from among the projects formulated in different sectors and submits it to the DPC through the Technical Advisory Committees. The LSGI is free to take up any project, irrespective of its cost and subject of course to the priorities or projects; they can only ask for rectification. The DPC gives the formal approval to the plans after which the LSGI can start implementation. It is to be noted that the DPC also cannot change the priority of LSGI. It can only ensure that government guidelines are followed. Administrative approval for implementation is given project wise by the LSGI. Every LSGI has enormous powers of administrative sanctions subject only to the limits of its financial resources. The autonomy espoused in the principles of decentralization is reiterated in this process.

Implementation and monitoring: Implementation of the developmental plans is done through the implementing offices, or the local level units of the line departments, that have been transferred to the local bodies. The implementing officer, in consultation with the local body is vested with the responsibility of implementing development plans. Allocation of funds is subject to clearly laid out procedures that ensure transparency, responsiveness and accountability of the bureaucrats as well as the political leadership. Monitoring of the course of implementation of developmental projects also follows the preliminary elements of social audit or participatory evaluation. It leaves lots of rooms for public scrutiny of the progress of a developmental project, as the monitoring is done at several levels, at the official level by means of periodic reporting, and the people's level, by means of reporting at the grama sabha and by direct examination by the monitoring committees that are constituted for each project.

Impact of Decentralization on the Development of the Resource Poor: An Overview

It has been observed that the model of decentralized planning and implementation of developmental projects through local self-government institutions has made remarkable strides into the sphere of micro level development, particularly for the poor. In the farm sector, the benefits had been mostly for the small and marginal farmers than the large-scale farmers. The following is a brief review of the reports consolidated from around the state on the impact of decentralized planning and implementation as against the conventional development administration through development departments and the sporadic attempts hyped by NGOs.

- The formula based devolution of funds has ensured that funds have flowed to every nook and corner of the state including the hitherto outlying and backward areas, facilitating extensive public investment (See Table 2 for details of gross plan expenditure by LSGIs during the Ninth plan). Since the corner stone of Kerala's decentralization has been people's participation, which facilitate intervention by the interested citizens at all stages of the development process, there has been massive participation of common people in the planning process, through consciously built up awareness programmes. This has considerably widened the spectrum of utilization of development funds.

Table 2.Gross Plan Expenditure of LSGIs in the Ninth Plan

Sl No	Type of LSGI	Grant –in-aid	Total*
1	Grama Panchayats	1939.66	3340.71
2	Block Panchayts	498.29	1195.90
3	District Panchayats	505.65	863.35
4	Municipalities	303.09	468.26
5	Corporations	208.23	359.10
	Total	**3454.92**	**6227.32**

Total expenditure includes contribution from other sources such as own funds, state sponsored schemes, centrally sponsored schemes, co-operative finance, institutional finance , beneficiary contributions etc, the details of which are not provided here.

Source: Economic Review- 2003-04, Kerala State Planning Board

- Decentralization has also resulted in better targeting especially in the case of individual benefits by insisting on a due process in the selection of beneficiaries through grama sabhas. The quality of identification has certainly improved.
- Decentralization has unleashed a series of administrative reforms that are aimed at increased efficiency, transparency, social responsibility and accountability of pubic services. Already right to information, prescription of dire processes in giving of benefits, outsourcing of technical services, community management of assets and simplification of procedures have taken place. More reforms in the form of independent

regulatory institutions, improved management systems both financial and administrative, enhanced accountability mechanisms etc are in the offing.

- Demystification of the complex planning process has instilled among a large number of people and officials an increased awareness on efficient use of local level resources, as they experimented new methods of community level participatory methods for water shed management, labour banks, group farming, group based vegetable cultivation, self employment schemes etc.
- Integration of local level planning with various state sponsored and centrally sponsored schemes, including schemes for rural credit has ensured that every government sponsored developmental activity that take place in a locality would be implemented compulsorily in consultation with the local body.
- Local governments have done well in providing minimum needs infrastructure both to households as well as to communities. This is particularly true of housing, sanitation, and water supply, infrastructure of schools and hospitals and connectivity. Local governments have evolved good models in water supply, improvement of quality of education, improving agriculture productivity, etc. They have generally shown a preference for affordable technologies and appropriate solutions.
- Local government plans have shown a strong anti- poverty bias and more funds have flown to families below poverty line through local governments than what would normally have been. An Anti Poverty Sub Plan to take care of the population with absolute poverty and destitute has also been initiated with remarkable results as illustrated in Table 3.

Table 3. Selected physical achievements in Anti Poverty Sub Plan Projects implemented by LSGIs during 2002-03*

Sl No	Item	Unit	Physical targets
1	Area brought under cultivation	Acre	1651.04
2	Beneficiaries of vegetable cultivation	Number	132921
3	Distribution of tillers	Number	36
4	Removal of diseased coconut trees	Number	1518
5	Construction of cattle sheds	Number	985
6	Land brought under cultivation through watershed development	Ha.	109
7	Poultry- Egg rearing units	Number	544
8	Micro enterprises	Number	1114
9	Self employment units started by poor people	Number	783
10	Self employment units for destitute	Number	304
11	Distribution of land to landless	Number of beneficiaries	337

Figures include only the physical targets of projects formulated exclusively under Anti Poverty Sub Plan and not all the projects undertaken by the LSGIs.
Source: Economic Review- 2003-04, Kerala State Planning Board

Decentralization has taken special care about women and weaker sections of the society as well. Introduction of the mandatory Women Component Plan has been the reflection of absolute of commitment towards gender sensitive planning for women empowerment. Earmarking 10 per cent of the plan outlay for women has helped considerably the disadvantaged groups among women like widows, and has improved the provision of services, which are of direct benefit to women.

Decentralized Planning in Agriculture: Points of Intervention

The guidelines on decentralized planning and implementation in agriculture and allied sectors through LSGIs institutions explicitly declare that decentralized planning should promote local economic development by increasing production and productivity of small and marginal farmers and the traditional and small-scale industries with focus on employment generation and poverty reduction, natural resource management and integrated area development.

- In agriculture and allied sectors, agricultural extension including farmer oriented support for increasing production and productivity, watershed management and minor irrigation, dairy development, animal husbandry including veterinary care and inland fisheries have become *de facto* and *de jure* LSGI functions. Promotion of tiny, cottage and small-scale industries is mostly with the local governments. The government has set apart one third of the plan funds which comes to about Rs. 8000 crores for decentralized planning and implementation through LSGIs during the tenth plan period.
- It has been insisted that development interventions in agriculture and allied sectors and water use should be planned on a watershed basis in an integrated method. A massive campaign has been launched to delineate watersheds at the local level. The plan guidelines and the approach paper on decentralized planning in agriculture envision the formulation of integrated projects in agricultural sector that would facilitate multi sector integration and generation of maximum employment opportunities. The District Planning Committees have been directed to ensure the preparation of integrated plans rather than solitary projects by the local bodies.
- District level integrated plans with comprehensive geo referenced information on various resources-soil, water, vegetation, human etc apart from information on basic infrastructure and marketing channels, and innovative organizational mechanisms have to be prepared and employed for pooling the staggered resources for development planning in agriculture.
- The entire responsibility of poverty alleviation has gone to the LSGIs as all the centrally sponsored anti poverty programmes are planned and implemented through them. This leaves room for the preparation of location specific programmes exclusively for poverty alleviation.
- Local economic development to generate more jobs has been consciously attempted. It calls for focus on increasing agricultural productivity and value addition through post harvest processing. Paddy production has been given top priority. Waste /fallow land development and fodder development are also attempted through local bodies.
- It has been insisted that all anti poverty programmes should be as far as possible on the Kudumbasree[1] mode. Promotion of micro enterprises for the poor has been given special priority in the Kudumbasree programme. Kudumbasree provides training programmes for people below poverty line. Only those programmes which result in self-employment venture or which have an assured job market for wage employment are usually taken up.
- Kerala has the advantage of having organized every family identified as BPL into three tier structure of neighbour hood groups of 15 to 40 families at the local level networked into Area Development Societies (ADS) at the Panchayat/ Municipal Ward level and federated into Community Development Societies (CDS) at the level of the Village Panchayat/Municipality. Families are represented through a woman representative. As a policy this is seen as the next step of decentralization, of reaching out to the poorest through local governments and affords them the voice and the power in choice in so far as their development is concerned. Unlike other states of our country, Kerala has integrated the NHG, ADS and CDS with the local government system. They are envisaged not as parallel organizations, but as community wings of the local

[1] Kudumbasree is a prorgamme designed by the government exclusively for poverty alleviation by improving the entrepreneurial skills of women belonging to lower socio economic strata, working on micro finance through a network of self help groups.

governments, of course with well-defined autonomy. Government has given certain formal roles to CDS both in planning and implementation at the level of local governments. Basically the anti poverty sub plan is to be initiated by the CDS through a bottom up process starting from the NHG. It is these plans that are vetted and adopted by the local governments, again in active partnership with the CDS. Later in the selection of beneficiaries also the CDS has a critical role of prioritizing the applicants before seeking the approval of grama sabhas. The CDS has a critical role to play in the anti poverty programme in Kerala, particularly in preparing good quality programmes for the poor and also take part in community based monitoring of their implementation.

- Many village panchayats have undertaken panchayat level resource mapping in a bid to make data bases for local level development. Preparation of comprehensive development databases that would facilitate objective distribution of resources would be put to effective use with the completion of the computerization of LSGIs. Computerization of LSGIs is a flagship e- governance programme that tries to link up all the local bodies for better plan monitoring and administration of citizen services
- Looking at some of the specific measures, all the subsidy norms prescribed by NABARD and other agencies are distributed under the supervision of local bodies and are subjected to scrutiny by the grama sabhas and panchayat committees. To cite a few examples, fertilizer, including bio fertilizer and manure subsidy can be upto 50 per cent of the cost and can be given only to marginal and small farmers (marginal farmers- owns 1ha or less, small farmers- 1-2 ha) as the components of a larger integrated production improvement project for marginal farmers. Subsidies are not paid in cash to individuals or families. Vegetable seeds and paddy seeds are given free of cost and other seeds and seedlings can be given at 50 per cent subsidy. Machinery is given to farmer's cooperatives, registered padasekhara samithis, and free of cost after getting an agreement signed by them that it will be put to common use and will be promptly maintained.
- There is also a mechanism to establish linkages between various developmental agencies and rural banks for better administration of rural credit schemes. The local bodies facilitate identification of beneficiaries and disbursement of credit through the district level and block level banker's committee to explore the possibilities of operationalising potential linked credit plan.

Decentralized Planning in Kerala: Major Constraints and Challenges

Though decentralization has successfully contained many of the inherent problems of conventional developmental planning and implementation, it has not been truly successful due to several factors. Foremost of all, the outliers like Scheduled Tribes are still to gain from decentralization. In a scenario where one section of the poor lives off another section, decentralization seems to have certain inbuilt limitations. Similarly, the poorest among the poor need social safety nets particularly for food and health emergencies, which cannot be fully provided by local governments. Efficient use of natural resources at the micro level through innovative planning has also been limited.

Though decentralization has envisaged revival of the production sector, particularly agriculture and allied sectors, substantial improvement has not been registered in devising mechanisms to harness the efforts of the farming community in the form of a wider network of small and marginal farmers and small-scale producers. In spite of a vast net work of neighbour hood groups and community development societies not much headway has been made in tackling the growth stagnation in the productive sectors. The socio political reasons that prevent the smooth functioning of such network mechanisms to increase production in the agriculture sector has to be seriously reviewed.

With regard to financial support, integration of the flow of bank credit into local schemes has also been rather limited resulting more from banker's reluctance to deal with local governments than from inadequacies of project formulation. This has resulted in higher subsidies. In a state like Kerala where the number of educated poor is very high, the linkage with job markets through skill upgradation or identification of self-employment opportunities or small-scale production actitivities with assured markets have been substantially low.

There is also a tendency to spread resources thinly with preference being given to every electoral constituency whenever a developmental scheme is taken up. Distribution of assets and inputs, not necessarily productive has been common. Though there are provisions to ensure vertical and horizontal integration, it has proved difficult to achieve. Moreover, participatory aspect of planning is often limited to airing of needs and sharing of benefits rather than creating synergies in various fronts of development. The decentralization mechanism has not been successful in driving out the spectre of bureaucratic attitudes and lethargy from the administrative framework and usher in a pro active development culture, which would bring in tangible development through effective net working of people, enterprises and institutions.

Conclusion

The model of decentralized planning through the local bodies in Kerala has thrown open innumerable examples of local level resource mobilization, community resource management, participatory approaches, models of empowerment, models of transfer of technologies and models of institutional linkages, which can be emulated in any other developing economy. These new devices can be put to effective use to alleviate poverty and associated tribulations of the marginalized sections of the society, particularly the resource less farmers. The most striking feature of this kind of development intervention is the explicit social commitment shown by the government to support the poor with grassroots level mechanisms in a hostile global situation, which advocate downturn of governmental support to local development. Though there are overriding overtones of self-reliance and sustainability, it does not neglect the importance of state support as a major input to the development of the resource less. The decentralization exercise unfurled in Kerala satisfies all pre requisites for extensive people's participation and much more than that. It is unparalleled in terms of its reach and potential when compared to the sporadic and solitary developmental interventions by NGOs that are glorified as participatory. The process has become a part of governance in the state and is a natural culmination of the process of social transformation that has taken place over a long period of time. It is an alternative paradigm of development, which firmly reiterates the role of the government and integrates the concepts of decentralized development. It has vast potential to emerge as the most effective tool of development of the resource less in the developing economies and a weapon to confront the onslaught of the hostile policy prescriptions of globalization.

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PANCHAYATI RAJ INSTITUTIONS IN WATERSHED DEVELOPMENT

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The concept of development is evolutionary in nature. In 1950's immediately after independence, the planners put forth the concept of over all development of the community, without much consideration of the regional imbalances as well as the disparities within different social groups. This approach is called community development approach. In 1960's instead of community development approach we adopted the area development approach. The examples are IAAP and IADP. As an extension of this area development approach, special area planning was adopted in 70's. Programmes like DPAP and DDP were introduced as part of this.

DPAP (1974) followed the strategy and approach of integrated area development as envisaged by the Task Force constituted by the Planning Commission under the chairmanship of Dr. B.S. Minhas. The main objectives were :-

- Integrated development of agriculture with focus on conservation, development and utilization of land, water, livestock and human resources in an optimum manner.
- Providing more stable income and employment to the weaker sections of rural society.

Desert Development Programme (DDP) 1977-78 was started based on the recommendations of the National Commission on Agriculture (1974).

On evaluation it is revealed that both DPAP &DDP were implemented in a segmental and isolated manner, and watershed as unit area of development was given scant regard. Isolated implementation of wide ranging sectoral activities over widely disjoined areas of very small size failed to bring any noticeable impact and the programme objectives remained unfulfilled. The programme could not attend to peoples concerns, as the participation and involvement of the local inhabitants was missing. Despite substantial expenditure over Rs. 1700 crore under DPAP and about Rs. 550 crores under DDP till 1993-94, the appraisal of activities undertaken revealed discouraging outcomes. The 5.7 million hectares of area treated during the period under DPAP constituted only 10%of the total area to be treated. The area treated under DDP was 0.51 million hectares that accounted merely 1%of total programme coverage.

In 1994 a high level Technical Committee under the Chairmanship of Prof. C.H. Hanumantharao, suggested following corrective measures.

- Treatment and development of degraded lands should be taken up compulsory on water shed basis, convening contiguous micro watershed of 500 hectares.
- Participation of beneficiaries including women, SCs/STs and other weaker sections in planning and decision making activities.
- Development of areas through peoples own work plan prepared with the assistance of multi disciplinary technical team.
- Positive role of voluntary organizations for bringing about co-ordination between peoples organizations and district funding agencies.
- Transfer of programme assets to the community for maintenance and usufructs sharing among the beneficiaries.
- Creation of exclusive nodal watershed department in states.
- Unified approach and convergence of all the rural development programmes of various departments/ ministers to ensure a multiplier effect in area resource development and economic development of resource poor.
- Effectively monitor and evaluate the programmes to ensure their implementation in accordance with watershed approach and strategy.

Based on the recommendations of high level Technical Committee, the Ministry of Rural Development formulated the guidelines of watershed development in 1995-96.

In 2001 the guidelines were revised to provide role for Panchayath Raj Institutions.

Integrated Wastelands Development Programme (IWDP)

IWDP has been under implementation since 1989-90 by National Wasteland Development Board. The IWDP envisaged development of all the non- forest lands in the country. Wastelands are degraded lands which can be brought under vegetative cover with reasonable efforts and which are currently under utilized and which are deteriorating for lack of proper water and soil management. (Technical Task Group of Planning Commission, 1987). According to NRSA estimate (2000) the estimated area of wasteland in India 63.85 m.ha.

Objectives of Integrated Wasteland Development Programme (IWDP)

1. Developing wasteland/ degraded lands on watershed basis.
2. Promoting the overall economic development and improving source economic conditions of resources poor and disadvantaged sections.
3. Restoring ecological balance by conserving and developing natural resources (land, water and vegetative cover).
4. Encouraging the village community.
    a. To undertake sustained community action for the operation and maintenance of assets created and to further the development of potential natural resources.
    b. To adopt simple, easy and affordable technological solutions and institutional arrangements.
5. Employment generation, poverty alleviation, community empowerment and development of human and other economic resources of the village.

Peoples Participation

The guide lines for watershed development were revised in August 2001 to make them more focused and transparent. The guideline provides provision for people's organizations called watershed associations, watershed committee, Self help groups, User groups etc. But PRI's were not given any pivot role.

Role of Panchayath Raj Institutions (PRI)

With the 73rd and 74th Amendments to constitution of India, PRI's have been mandated with an enlarged role in the implementation of rural development programmes at the grass root level. Watershed development has been included in the list of subjects to be devolved to PRI's. Institutional frame work of Watershed Associates (WA) and Watershed Committees (WC) are parallel bodies at the village level as far as implementation of watershed programmes was concerned. There was very little co-ordination between then and the grama panchayth/ grama sabha. The PRI's are expected to perform far better than the watershed association/ committee as they are:-

- Equipped with the stationery rights and a mandate for natural resources planning.
- In a position to plan according to peoples wishes and integrate watershed management with wide development activities.
- In a position to draw the services of line departments in a integrated way and press for political pressure on line departments at higher levels.
- Potentially equipped with powers to impose local taxes or user charges. and
- Committed to making reservations"for the representatives of women and weaker sections as per the constitutional position.

With these objectives of empowering PRI's, Ministry of Rural Development incorporated suitable modifications to the guidelines of IWDP and launched a new initiative called Hariyali on 27th January 2003. These guidelines became operational from 1st April 2003.

Salient Features of Hariyali

- User communities were given the major role of planning, implementing and post project maintenance of assets created.
- The early system of watershed associate and waster shed committees were dispensed with and that role is vested with gramasabha.
- Involvement of multidisciplinary watershed development team for project formulation and implementation.
- Formation of user groups, SHG's to ensure peoples participation.
- Transparency and accountability ensured through gramasabha and grama panchayath.
- Adoption of low cost technologies and use of locally available materials
- Post project management and sustainability is ensured by maintaining watershed development funds created out of public contribution.

Important Concepts

Watershed Development Team (WDT): In order to avoid over emphasis on activities of a particular sector, it is proposed to have a multi disciplinary team of experts called Watershed Development Team (WDT) of at least 4 members. One member should be a woman and one should be from Social science background.
User Groups: Post project maintenance of assets created is to be done by user groups.
Self Help Group (SHG): In order to ensure equity, SHGs of land less /asset less poor belonging to the watershed is organized and encouraged to take up income generating activities and provision for revolving fund.
Watershed Development Fund: For maintenance of assets created, a provision of watershed development fund envisaged. 10%f the cost of project implemented in the private land (5%n case of SC/ST) and 5%f the project co st in common land is collected as WDF.
User Charge: The grama sabha can fix user charges for the utilization of natural resources from common land can be levied as user charge. 50% user charge is credited to WDF and the grama pancayath can utilise the 50%f other activities.
Funding Pattern: The unit cost for treating one hectare of water shed is fixed as Rs. 6000/- in the following pattern.

85% - Work Component
10% - Administrative Cost
5% - Community Mobilisation /Training.

Institutional Frame Work

Central	Department of Land Resources under Ministry of Rural Development.
State	Commissioner for Rural Development – Local Self Govt. Department.
District	District Panchayath/ DRDA – Approval of Micro Plan (Nodal Agency)
Block	Block Panchayath – Function as supports grama Panchayath in preparation of micro plans, training capacity building of functionaries. Promoters cost effective technologies. Monitoring and operation as maintenance.
Village	Grama Panchayath: Project Implementation – Maintenance of accounts – Gram Sabha – Approval of DPR at village level. Ensure transparency through periodic meeting. Dispute resolving etc.
User Groups	Maintenance of assets created using WDF.
SHGs	Income generating activities.

Monitoring: The Grama Panchayath should sent quarterly reports to Block Panchayath and Block Panchayath should send a consolidated report to DRDA/District Panchayath. The Government of India has introduced an online monitoring system and the DRDA should send the report to

Government of India on line. The state can also access the report from the network. Apart from the online monitoring, field monitoring is done through the Grama Sabha.

Integration with other schemes: Tthe amount for treating one hectare area is only Rs.6000/-. This amount is very meager for over all development of watershed. So it is necessary to integrate other rural development activities and schemes implemented through various line department and PRI's the programmes like Self Employment Schemes (SGSY), Wage Employment Scheme (SGRY/NREGS), Housing Schemes (IAY), Sanitation and other plans, schemes should be effectively integrated into the programme, so as to get full benefit to the stake holders.

Kerala Initiative in Watershed Planning:

During the 9th Plan period, a massive programme for watershed planning has been initiated in Kerala through local bodies. Watershed delineation and , preparation of watershed plan were undertaken by the Grama Panchayaths and Block Panchayaths. Grama Sabha were convened exclusively for watershed planning and each Block has prepared a comprehensive water shed plan. Later due to various reasons not much attention has been given. Now by the introduction of Hariyali the local bodies are showing interest in watershed planning. The documents prepared during 9th Plan was the basis for submitting project proposal for Hariyali to Government of India.

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PARTICIPATORY RESOURCE APPRAISAL AT MICRO-WATERSHED LEVEL

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Introduction

A comprehensive data bank and resource mapping is the basic need for the planned development of any area. In watershed development, it is more critical and crucial, it being an integrated approach to development. The integrated nature of resources is most well demonstrated in a watershed. The uniqueness of the inter linkage of land, water and biomass is manifested by watersheds, which not only control the diversity of earth surface, but also a definite determining factor of the economic structure of the society. The micro level planning will not be successful, if the resources of the region are not identified properly. This has to be identified accurately showing its existing spatial and social distribution, which ultimately help the planners engaged in resource planning to increase the rate of economic and social development by optimal use of the available resources of a region.

Watershed resources are for people, and without people they are meaningless. The ultimate aim of watershed development is to improve the living standards of the people residing in the area, by managing and conserving the resources and its optimal utilization, thereby maintaining ecological balance and sustaining productivity and development. The people determine the value of results of any development, on the basis of their needs and requirements. Hence the major component in watershed development is the people of the area.

Many of our developmental efforts in the past failed because of lack of people's participation. Several examples are there in front of us. Workable watershed development plans require not only viable, economic and adoptable technologies, but also the co-operation and participation of the people. Hence the watershed plans should clearly identify the roles of local people, their leaders and the local organizations.

Watershed development programmes could succeed and accomplish the objectives only if it is planned and implemented with the participation and co-operation of the people in the watershed area. This is possible if we could develop a sense of belongingness to watershed activities among the people, by involving people right from the start of the programme, especially in the planning stage. Once the plan recognizes the needs of the people, their problems and suggestions, they will consider it as their own programme and would render full support and participate actively. To this line, PRA tools are effective in planning watershed development projects and programmes. In addition to developing a sense of belongingness, it would create a feeling of empowerment among the people. PRA tools could also be used for implementing, monitoring, and evaluating watershed development projects.

What is PRA?

PRA is a process involving local people in the analysis and interpretation of local (rural) situation. In this the PRA practitioners interact with the villagers to understand them, learn them and learn from them. It is a semi-structured and relatively quick way of learning with the rural people about their situation, problems and opportunities. But it is more than just learning. It extends into analysis, planning and action. Thus PRA can be defined as a methodology to enable rural people to share, enhance and analyse their knowledge of life and conditions, to plan and to act.

The purpose of PRA may vary from enquiry about a specific aspect to investigate into one or more sectors or even to arrive at a comprehensive understanding about the socio-economic, and resource utilization and management aspects. This may even take place simultaneously. Thus it will lead to formulation of plans for participative integrated development of resources.

PRA exercises can be used in the field of watershed development, village level planning, tank rehabilitation, developmental programmes / projects etc. If the purpose is planning on integrated programmes like watershed development, then the various interest groups in the locality must be represented. The local residents are the key actors. They present and analyse their own situation, determine their preferences and priorities, and initiate a process towards sustainable development.

Methodology for PRA

The methodological basis of PRA centers on setting up a structured dialogue using a variety of methods, to share knowledge and analysis to develop practical actions. These methods are participatory, interactive, flexible, lightly structured, adaptable, exploratory, inventive and empowering. Greater emphasis has to be placed on helping external facilitators to question their assumption about local people and to develop more listening-oriented attitudes and behaviour. The current list of PRA methods comprises almost 30 different tools that can be used at various stages. It is the collection of these methods into unique approaches or assemblages that constitute systems of inquiry or interaction in PRA.

Some of the commonly used methods/tools of PRA are listed below.

- Timeline
- Transect walk
- Participatory mapping / modeling
  - Resource map
  - Social map
  - Resource flow map
  - Technology map
- Venn diagramming
- Seasonal calendar/ seasonal analysis
- Livelihood analysis
- Trend analysis
- Ranking and Scoring
  - Pair wise ranking
  - Matrix ranking/ scoring
  - Wealth ranking
- Semi-structured interviews

1.Time line:

It refers to a calendar of historical events from as far back as one can remember upto the present, in the life of a person, community, village, area, or institution depending on what history we wish to construct. It help us to trace trends through history, which would give detailed accounts of the past of how things have changed, the nature of change, and the reasons. Ultimately this exercise is helpful to get information on earlier problems experienced by the local people including natural calamities and out break of diseases, recurrence of the problems, coping mechanisms employed by the people, establishment of infrastructural facilities and the turning points in the history of the village/area. Normally the elders of the area will be the best source of information in this method.

2.Transect walk:

It is a planned walk with key informants / local people through an area, observing, asking, listening, identifying different zones, seeking problems and possible solutions. During the walk the facilitators and a group of villagers can discuss contrasts and changes in soil types, trees, crops and other resources of the area, as they walk across the area. Problems and opportunities are also noted. After the walk is complete, a transect diagram is drawn to illustrate physical, biological, agricultural, and ecological systems in the area. Transect walk is highly useful to have first hand information on natural resources of a village, the problems associated with them and to assess opportunities. It will give an insight into the terrain, land use, cropping pattern, soils, the spatial distribution of social groups etc. If done at the beginning of a project/ programme, the transect also offers a good possibility to get acquainted with the people of the area. Transect walks can also be used for refining data collected through mapping exercise.

How to do:

- Define the purpose of the walk
- Find key informants/ local people (who are knowledgeable, able to walk and willing to help)
- Identify the route. (Choose a path that will take the group through some of the diverse areas of the village)
- Finalise the aspects to be noted; prepare a checklist of questions and items to be observed.
- Assign tasks to team members.
- Make the walk.
- Observe, ask, and listen. Ask about what, when, where, who, why and how, and discuss problems and opportunities
- Make sketches during the walk (transect diagram). Record the observations. Note contrasts and changes and identify zones.
- Discuss the results with others.

Boundary transect is an important PRA tool having significant importance in the identification of ridge lines of the area. It provides a glimpse of the cropping pattern and topographical features of the area. For the above purpose a transect walk is conducted along the boundaries of the village or watershed along with some key informants from the area so that a clear idea about the cropping pattern, cultivation and management aspects as well as topographical details are obtained. This will serve in identifying the lacunae in the existing situation and therefore guide future developmental efforts.

3.Participatory mapping/diagramming:

Mapping various aspects of the village/ area by the participant villagers/ locals is one of the most widespread methods of PRA. In this, the local people, together in groups, make maps on the ground using locally available materials, like stick, rangoli powder etc. This can also be done in big chart paper, using pencils and sketch pens. These maps help us in understanding how people and resources are organized.

Villagers generally feel comfortable and find it interesting to draw maps of their own village. Maps drawn in participation of many villagers, draws a good deal of their collective local knowledge. There are many types of maps/diagrams like Social map, Resource map, Resource flow map, Technology map, ITK map etc. The most commonly used are Social map and Resource map.

Social map: This depicts the social set up of the area/ village i.e. it shows the settlements, the households and various other social institutions and community facilities. This will help us to see the class and caste patterns.

Resource map: This is drawing maps to depict the natural resources of a village/ area. It gives us an idea about the land, soil, water, trees, forests, and other such resources, their location in relation to the village/area, and from there on to an indication of how and by whom they are used.

How to do:

- Define the purpose of mapping.
- Collect area survey maps, land use capability map etc. and other related information.
- Make a check list of critical items
- Explain and discuss the purpose briefly.
- Try to involve a good number of villagers of different age groups.
- Select a suitable spacious place.
- Ask the people to draw the map with relevant details
- Allow the villagers to draw the map in their own style.
- Sit back and watch.
- Ask questions using the checklist, to achieve the purpose of mapping

4.Venn diagramming:

The sense of relations within the community and with the outsiders can be depicted using this tool. By this exercise we can know the local people's relationship and level of interactions with various individuals and institutions in relation to development. Thus it is helpful for identifying individuals and institutions important in and for a community and their relationships.

Community members use circles of varying size to show their internal relationships and their relationships with other individuals, organizations and institutions. The size of the circle shows the importance assigned and its proximity to the centre circle, which represents the community, shows the strength of the relationship.

5.Seasonal calendar/ seasonal analysis

Changes in weather and climate affect the way people live, work and move. For local people, especially farmers, it is important to note changes that occur in the weather from time to time. These changes greatly affect their activities and determine their agricultural output and nutritional status. Thus their activities are based on the seasonal calendar. It is the calendar of the people, depending on seasons. Community groups can easily prepare calendars and fill them with illustrations of various seasons, activities, production and other ways peoples lives are affected by weather and climate. If prepared, this calendar helps us in locating annual occurrences and events, linking up such events to their seasonality, and planning programmes on the basis of patterns that emerge. Examples of patterns could be: their calendar of agricultural operations, busiest and slackest months in the year, price fluctuations, seasonality of pest and disease out breaks, patterns of migrations, seasonality of requirement and availability of labour and numerous other such things

6.Livelihood analysis

It reveals the sources of income for people, and the occupational and economic categories prevalent in the area.

7.Trend analysis

This analysis is done to know the change over time regarding various aspects of the life of people. Changes in the cropping systems, land use patterns, proportions of different crops, yields, soil fertility, fertilizer use, pest incidence, animal population, hours of labour, labour wages, land erosion, land degradation etc. can be assessed using this PRA tool. It can be verbal or diagrammatic.

8.Ranking and Scoring

It reveals priorities and preferences. Here the local people are asked to rank/score items such as crops, varieties, breeds, income generating activities, etc. so as to identify their preference. While ranking gives the indication of relative preferences only, scoring quantifies these preferences. Some important Ranking/Scoring methods are

Simple ranking: It is used to rank order different items/attributes. The local people may be asked to rank order their problems, needs, strengths etc. using this tool, so as to prioritise them for planning

Pair wise ranking: This uses two items at a time for ranking, which enables easy choosing of one alternative over the other. Here the items are listed on both X-axis and Y-axis and their relative priority assessed against each other. The one that emerged more number of times will be the most preferred one.

Matrix ranking/ scoring: Here different attributes and criteria are listed in rows and columns, which are ranked/scored according to their relative importance/preference. The reasons for local preferences for an item would be better understood by using this tool.

Wealth ranking: It is used to categorise households according to relative wealth/well being. Wealth ranking is extremely useful for targeting beneficiaries of a programme. In addition, it helps the community feel a responsibility for those they decide less fortunate.

9.Semi-structured interviews:

This is an informal interview with the local people. It can be defined as guided conversation in which only the topics are predetermined and new questions or insights arise as a result of discussion and visualised analysis. Using this tool, we can interview the people to analyse variety of aspects of village life like the agricultural situation, the problems faced and the similar. Here it is desirable to get a cross section of the people of the locality. A checklist of the questions to be asked is to be prepared in advance. But it should not be a formal interview. It appears informal and conversational. It is a well-defined and systematic activity, with a set of clearly defined goals and guidelines. Unlike structured or formal interviews, it concentrates not only on the questions asked, but also on the context in which the interview takes place.

Combination of methods

The methods serve to understand four key themes that are central to agricultural systems and change. First, historical diagrams, seasonal calendars and daily activity diagram help to understand change over time, from long-term trends to the seasonal discussion of poverty, production and consumption, or daily activities.

These discussions reveal the dynamics of rural livelihoods. Secondly, changes in geographic space are explored using transects, farm sketches, flow diagrams, and social/resource maps and models. Thirdly, Matrix ranking and scoring, Venn and network diagrams draw out some of the complexities of decision-making which are rarely accessible through formal surveys and which enable researchers to appreciate farmers' different needs and preferences. Matrices are particularly valuable for generating local criteria for selecting and evaluating particular crop varieties or technologies, or priority activities. The fourth theme that includes system and impact diagrams looks at flows, flows of resources and information, flows of cause and effect.

It is not just the methods themselves but their combination and sequence that are particularly effective. For example, a set of resource models of a village, one of present conditions and one dating from a few decades earlier, can help to identify changes in land use patterns and practices, and their impact on land degradation. A third model of future situation can be added to assess what might happen if certain actions or actions are not taken. Transect routes can then be planned on the present model. This brings together local perceptions of spatial and temporal dimensions of land use change in a single analysis. Compare this process to a questionnaire survey, which must first analyse diverse perspectives before commencing the planning process. With PRA, these two stages are inter-linked – the iterative analysis leading to prioritizing of action points and planning.

Secondary data

For any given area, some information already exists that we could use. This information is usually available in government offices like Village offices, Panchayath Office, Krishi Bhavans, Block Development Offices, Cooperative Banks and Government. Organisations and Non-Government Organisations. The NGOs and special groups tend to have information that is more localized, covering a location or a social organization like religious bodies, church, mosque a sub-location, or even at ward level. The community itself may have some data, and even would know what type of information have been collected it. It is therefore very important that, before embarking on any information-gathering exercise, talk with people in community, leaders and extension workers to find out what has already been collected and is available.

Steps in the conduct of PRA

1. Identify the location
2. Define the purpose of PRA exercises.
3. Find out the number of PRAs to be carried out, and the methods to be used
4. Select the PRA-multi disciplinary teams.
5. Explain the specific objectives of each team. Assign tools/methods.
6. Have an overall idea of the locality and the people to be studied.
7. Date, time, venue etc. are to be finalized with the local leaders of the area.
8. Assign duties to each member of the team.
9. Reach the venue before time and do the necessary arrangements.
10. Explain the objectives of the exercise to the people gathered.
11. Divide the people into groups; each Multidisciplinary team can join the group.
12. Do the exercise
13. Join back and present the results in the plenary session.
14. Summarisation
15. Report preparation.

PRA - Multidisciplinary team

PRA session is to be facilitated by a multidisciplinary team. In that one person may act as the leader. One of the team members (Observer) should see that the process is going in the right direction. Some body in the team should record both the process and the contents

Some important points

- The success of PRA rests on the right attitude and behaviour of the PRA multidisciplinary team/facilitators. Be open and informal. Give respect and take respect. Facilitate, don't dominate. Hand over stick to the people.
- Make the exercise flexible and give chances for innovations.
- Don't allow any body to dominate in PRA exercises. Try to get participation of all the people gathered.
- Give due consideration to differences of opinion. Seek diversity.
- Cross check (Triangulate) the data collected.
- Avoid unnecessary probing. Collect only necessary information (Optimal ignorance).
- Don't expect too much precision for the data (Appropriate imprecision)
- The number of facilitators should not be too large.
- Need not use all the methods in a place. Use the methods, which are required to satisfy the purpose.

SUSTAINABLE AGRICULTURE AND ORGANIC FARMING

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The background

The ever-growing human and animal population coupled with the decreasing per capita availability of land and water; and other associated negative impacts on the environment consequent to unplanned developmental activities, have stretched the resilience of the natural resources to a level of catastrophe. The depletion and degradation of the natural resources at an alarming rate have not only caused decline in productivity but also have generated numerous environmental concerns. The compulsion to produce more has further compounded the problems leading to un-sustainability of the agricultural production system all over the world in general, and the developing countries in particular, necessitating a paradigm shift towards a holistic ecosystem management in an integrated manner for development of eco-friendly technologies.

Intensification of agriculture, an inevitable consequence of the compulsion to produce more, has put an enormous burden on the natural resources. Rapid and uncontrolled industrialization compounded by adoption of developmental programmes without due regard to their long-term adverse impact on the environment has been continuously eroding the basic resources. Development of efficient resource management strategies is therefore crucial for sustained agricultural production.

Limitation in land and water resources, increase in population, conversion of agricultural land to other uses, and persistence of hunger and malnutrition in several regions of the globe have heavily underscored the growing concern for issues related to sustainability in the agricultural production systems. Our past efforts to promote the use of fertilizers particularly of N and P have caused a clear shift in the soil fertility management characterized by over-dependence on chemical fertilizers which in many context was wrongly conceived as substitute to organic manure, probably due the unavailability of the latter. This has slowly but surely resulted in a decline in soil organic matter, optimum nutrient balance and consequently deterioration of physical, chemical and biological functioning of soils in many intensively cropped areas. It, therefore, calls for reversion of present chemical based soil fertility management strategy to the one based on integrated nutrient management strategy. The importance of micro-biological research which can create a revolution in the application of micro-biological processes into technologies for supporting sustainable agriculture and ecological harmony, needs to be recognized and promoted. The increased use of a variety of agricultural chemicals viz. pesticides, fungicides, weedicides, growth regulators etc has also to be viewed in same dimensions.

In the Indian scenario, the arable land availability will be reduced to 0.087 ha per capita if population is stabilized by 2050. The biggest challenge will, therefore, be to produce more food with less land demanding more water and other inputs to feed the millions. The factors, which have been responsible to usher in green revolution, are becoming subject to criticism for their second-generation problems. There is, however, option to integrate the recommended inputs with organic manure and bio-fertilizers. Besides shrinking resource of arable land availability, the water for agriculture shall be most limiting factor in the coming decades. The availability of energy and power will be other limiting factors for increased agricultural production. Thus, the key to meet these challenges lies in the integrated management of the natural resources like land (soil), water, energy and also the biodiversity, which is threatened, with extinction of some endangered species.

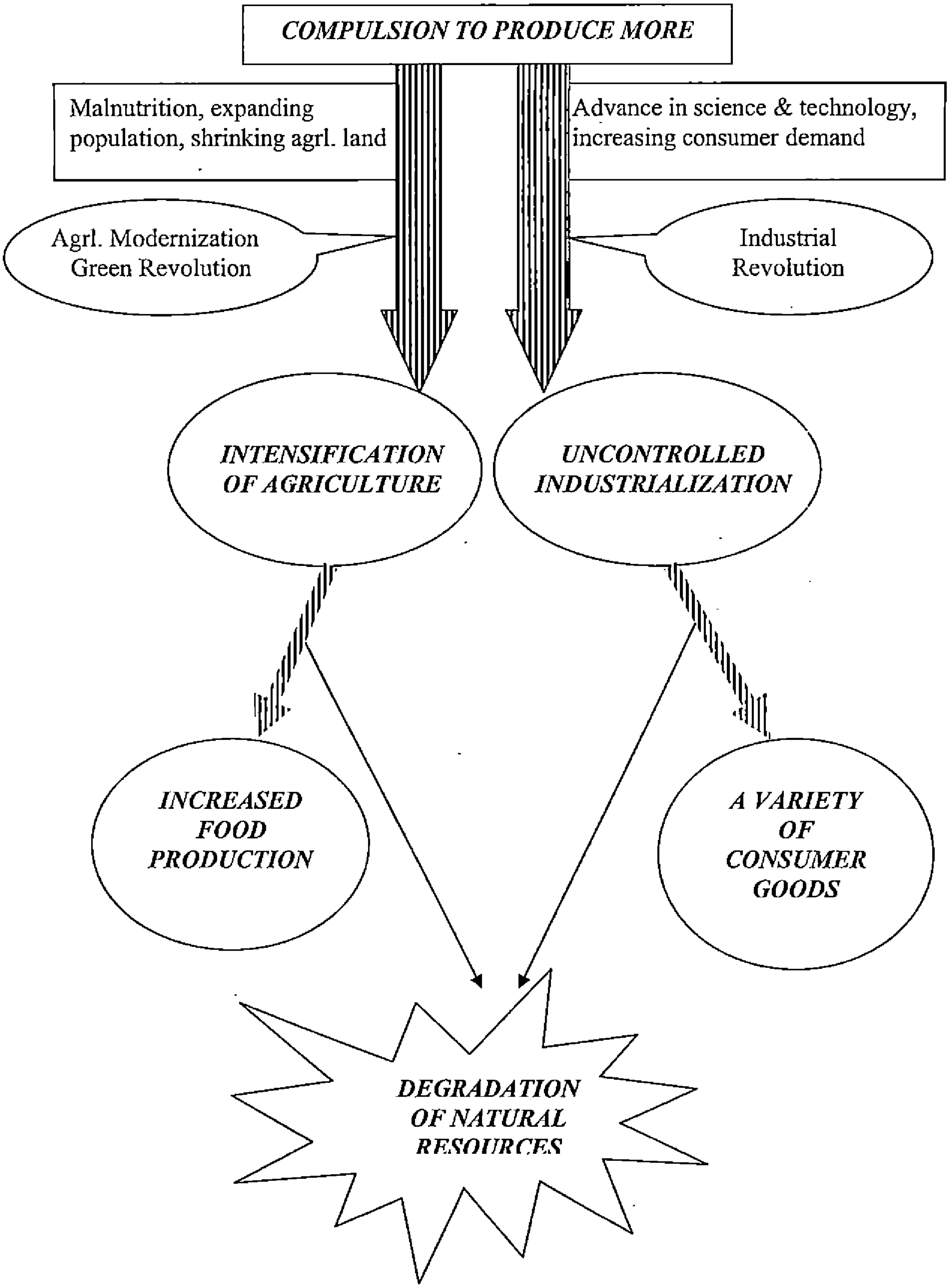


Fig 1. Derivation of present day agriculture reflecting the need for sustainable agriculture

Characteristics of Sustainable Agriculture

- Farming system based, not commodity based
- Recycling system, minimum depletion of natural resources
- Suitable to agro-ecological region, with planning based on rural resources at watershed / village level; group approach
- Defends technological gains already made which are environment friendly
- Makes new gains through innovative technologies, new frontiers of knowledge under close watch on their impact on environment
- Increases use efficiency of agricultural inputs through INM, IPM, seed quality, water management, energy management, efficient use of bio-diversity etc
- Involves processing, value addition and marketing network
- Identifies natural resource depleting factors and take precautionary measures against soil erosion, soil degradation, pollution of soil, water and environment, etc. through location specific technology
- Monitors changes in fragile eco-systems as early indicators of impact of new innovations
- Ensures blending of local adaptability, economic viability, social acceptability and resource conservation
- Does not damage the fabric of social-rural community
- Involves local groups and institutions in planning, monitoring and implementing processes for a close watch on sustainability

Definition of Sustainable Agriculture: In the simplest form, sustainable agriculture is defined as the practice of agriculture, which is ***economically, environmentally and socially viable.***

Organic farming

Very often the terms "sustainable agriculture" and "organic farming" are seen used as synonyms. But it should be clearly understood that they are entirely different concepts though some of the attributes are common. Both are eco-friendly and resource conserving. Organic farming advocates a total ban on the use of synthetic chemicals and does not always assure economic viability and hence sustainability.

What is organic farming?

Organic farming is a crop production method respecting the rules of the nature, targeted to produce nutritive, healthy and pollution free food. It maximizes the use of on-farm resources and minimizes the use of off-farm inputs. It is a farming system that seeks to avoid the use of chemical fertilizers and pesticides. Commitment to protection of nature is a pre-requisite for practising organic farming. In organic farming, the entire system (i.e. plant, animal, soil, water and microorganism) is to be protected.

Why is organic farming?

Organic farming produces healthy, nutritious and quality food; encourages and enhances biological cycles involving microorganisms, plants and animals; maintains and promotes long term fertility of soils; helps in soil and water conservation; maintains genetic diversity; minimizes all forms of pollution that may result from agricultural practices; uses on-farm resources as far as possible; preserves and enhances traditional and indigenous knowledge in farming, seeds and varieties; and considers social and ecological impact of farming systems. Now, the consumers prefer to consume natural/ethnic foods, particularly organic foods across the world. More over, they are ready to pay a premium price for such foods. The demand fore organic agricultural products is therefore increasing day by day.

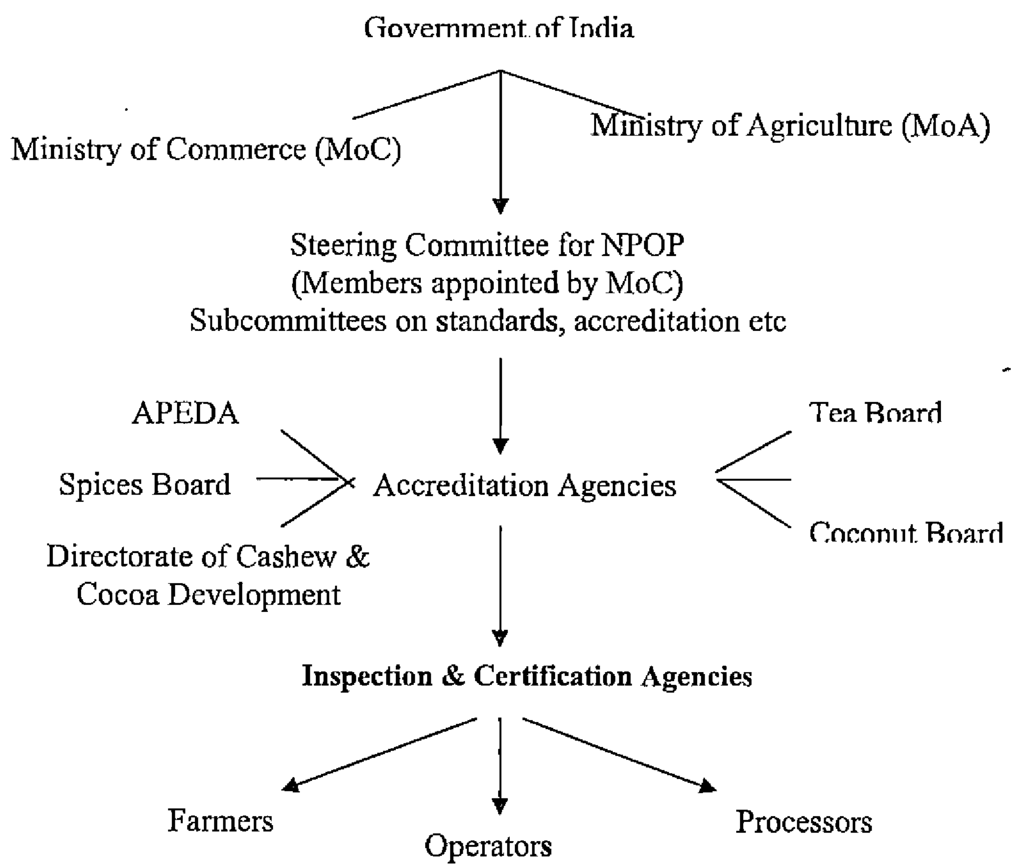
National Programme for Organic Production (NPOP)

The National Programme for Organic Production (NPOP) proposes to provide an institutional mechanism for the implementation of national standards for organic products through certification programmes for organic agriculture and products as per internationally approved criteria, thus encouraging the development of organic farming and organic processing. The programme includes *policies* for development and certification of organic products, *national standards* for organic products and processes, *accreditation* of programmes to be operated by Inspection and Certification-Agencies and *certification* of organic products.

Operational Structure of NPOP

The operational structure of NPOP is given in the following figure. The programme will be developed and implemented by the Government of India through its Ministry of Commerce as the apex body. The Ministry will constitute a Steering Committee for National Programme for

Operational Structure of NPOP



Organic Production, whose members will be drawn from Agricultural and Processed Food Products Export Development Authority (APEDA), Coffee Board, Spices Board and Tea Board and other government and private organizations associated with the organic movement. To advice the Steering Committee on relevant issues, sub-committees will be appointed whenever necessary. The Steering Committee will formulate a *National Accreditation Policy and Programme* and draw up *National Standards for Organic Products (NSOP)*, which will include standards for organic production and processes. National Accreditation Policy and Programme will be administered by the Accreditation Agency, which will define the overall policy objectives for the accreditation programmes and operations. The Steering Committee may amend the procedures whenever it deems fit. The National Accreditation Policy and Programme is subject to periodic internal review, which will be conducted by the members of Accreditation Agency who will advice the Steering Committee on such amendments.

Accreditation Agencies

The Accreditation Agencies will be constituted by the Government on the recommendation of the Steering Committee. APEDA, Coffee Board, Tea Board and Spices Board have already been recognized by the Government of India as Accreditation Agencies. Any other Government agency engaged in organic farming, which wants to be accredited, may apply to the Steering Committee for recognition as Accreditation Agency for the product dealt with by them. The work of the Accreditation Agency will involve drawing up procedures for evaluation and certification of the products, and formulating procedures for evaluation of the agencies implementing the programmes.

Evaluating Agency

Eligible Inspection and Certification Agencies implementing certification programmes will be identified by the Accreditation Agency with the help of an Evaluating Agency. Evaluating Agency will be appointed by the Accreditation Agency, which may consist of persons from within their organization or experts from outside. The evaluating agency will designate a Programme Manager for receiving and screening applications from certification programmes, for arranging evaluation visits etc. to ascertain the credentials of the programmes and of the implementing agencies. The Programme Manager will submit an evaluation report along with their recommendation to the Accreditation Agency for considering accreditation.

Accredited Inspection and Certification Agencies

Based on the recommendations of the Evaluating Agency, suitable Inspection and Certification Agencies will be accredited by the Accreditation Agency. These agencies should be well versed with the operating procedures, the NSOP and the international standards. Their programmes should have been in operation for at least one year and they should be able to provide the supporting documents.

Inspectors

The inspectors appointed by the accredited Inspection and Certification Agencies will carry out inspection of the operations through records maintained by the operators as per specified formats and also by periodic site inspection. Based on compliance to the standards and programmes, accredited Inspection and Certification Agencies will certify the organic status of products and operations, indicating their conditions along with their recommendations.

Accreditation Regulation 2001

These regulations shall apply to all certifying agencies in India which propose to engage, or are already engaged before the commencement of these regulations, in the certification of production and processing of organic crops/products under these accreditation agencies as organic.

No certificate granted by a certifying agency in respect of products as organic shall be valid unless the agency if accredited by the respective Accreditation Agencies.

The Accreditation Agencies will follow the approved accreditation criteria for inspection and certification as specified under the regulations.

Committee for Accreditation

A committee for accreditation of the respective Accreditation Agencies shall be constituted separately by the Govt. of India. This committee shall have the authority to conduct random or surprise field inspections, including analysis of samples drawn from the certified operators' (producer groups) farms.

Application for Accreditation

Applicants seeking accreditation as an agency or renewal thereof shall submit an application to the authorized officer in the form prescribed, available with Accreditation Agency along with fee prescribed for the purpose and specified in the regulations. When the Certifying Agency apply for accreditation from one of the Accreditation Agencies to cover multiple projects, some of them covered under different Accreditation Agencies, then that Accreditation Agency while considering such application will also associate technical expert from other Accreditation Agency under whom the particular products are covered.

An applicant shall deposit an accreditation fee along with the application form for accreditation. The Certificate of Accreditation will be valid for a period of three years. For renewal of Certificate of Accreditation, there shall be a renewal fee, which shall be remitted with the application for renewal. All accredited Inspection and Certification Agencies shall be allotted a specific accreditation number, which cannot be transferred or reassigned. On receipt of the application duly filled in all respects, together with the prescribed fee, the Accreditation Agency shall conduct a preliminary screening of all the applications. If the application is found in order, the Accreditation Agency shall arrange for field evaluation by a competent evaluator nominated by the Accreditation Agency. The Committee for Accreditation shall consider the application, along with the evaluation report. In case the applicant fulfills the prescribed criteria, the Committee shall give approval to the Certifying Agency. The Committee may, if considers appropriate, give opportunity to the applicant to fulfill/rectify any deficiencies found during the evaluation. In the case of non-approval, the same shall be intimated to the applicant in writing along with reasons thereof. On approval of Accreditation, the respective Accreditation Agencies shall intimate the Certifying Agency about the approval along with a copy of the prescribed Accreditation Contract. The Certifying Agency shall execute the contract on a non-judicial stamp paper of the value intimated to the applicant, within fifteen days, from the date of receipt of approval. On receipt of the contract duly signed by the authorized person of the Certifying Agency, the Accreditation Agency shall issue the Certificate of Accreditation within a period of fifteen days, from the date of receipt of the contract.

Updating and Renewal of Accreditation

Application for renewal of accreditation along with the fees prescribed shall be submitted by the Certifying Agency to reach the Authorized Officer 30 days before the expiry of accreditation period. The Chairman of the Accreditation Agency shall, however, have the power to condone any delay in submitting the said renewal application, in the events of a reasonable cause shown for the same. The renewal of the certificate for accreditation shall be based on the past performance of the Inspection and Certifying Agency and the Accreditation Agencies shall have the right to renew or reject such applications, at their absolute discretion. In the event of rejection of an application for renewal, the Accreditation Agency shall furnish the reasons for such rejections, in writing. The Chairman of the respective Accreditation Agencies shall be the Appellate Authority for deciding any appeal filed on account of any such rejection. The Ministry of Commerce, Govt. of India, shall be the competent Authority for entertaining all appeals. Decisions on such appeal shall be final and binding on both the parties.

Power to Issue Guidelines

The Accreditation Agencies shall have the powers to issue necessary guidelines to the Certifying Agencies for inspection and certification programmes, from time to time.

Logo: The *logo used under the certification programme will be called "India Organic". India Organic etched over the surface, is the seal that the product is organically produced and comes from India. All Accredited Agencies shall be entitled to use this logo for certified organic products. Use of the logo will be based on the fulfillment of the terms and conditions, contained under these regulations. Products marketed by any person can bear the National Organic Logo, only if the necessary certification is done by an Inspection and Certification Agency accredited by the Accreditation Agency.*

Termination of Accreditation

The Certificate of Accreditation granted to an agency shall be liable to be suspended for a specific period or permanently terminated in the event of violation of any of the clauses under these regulations and of such other directions issued by the Accreditation Agency or Govt. of India from time to time. Provided that in case of suspension, the Accreditation Agency shall have the powers to nominate any other Certification Agency to continue the work of certification in order to protect the interest of the operators. An appeal, if any, in respect of such suspension and/or termination of the Certificate of Accreditation may be filed with the Chairman of the respective Accreditation Agency within a period of 30 days from the date of issue of suspension/termination by the Accreditation Agency. The Ministry of Commerce, Govt. of India shall be the competent Authority for revision of the decision of the Appellate Authority. The revision shall be filed within 30 days from the date of issue of award on the appeal. However, the said periods for filing an appeal / revision can be condoned by the respective authority, in the event of a reasonable cause being shown.

Categories for Accreditation

Accreditation shall be granted for each category of products as follows: Organic agricultural production, organic processing operations, wild products, forestry, organic animal production and processing. The Certifying Agencies applying for accreditation should be actively engaged in programmes related to organic agriculture movement/production and their programmes should have been in operation for at least one year.

Reciprocity

National: Products certified by any accredited Certifying Agency will be accepted as organic by the other Certifying Agencies also.
International: For imported organic products, the authority for approval will be the Accreditation Agencies. It will decide on the approval of Inspection and Certification Agencies accepted in other countries. It will notify a list of such Inspection and Certifying Agencies.

Any Inspection and Certification Agency which wishes to re-certify any imported product or products with imported certified ingredients may apply to the respective Accreditation Agencies for inclusion of such products and the procedure for their certification in the certification programmes.

The National Standards for Organic Products (NSOP)

Inspection and Certification Agencies shall follow the national standards for organic products notified under the National Accreditation Policy and Programme. These standards will be reviewed by the Steering Committee for NPOP periodically. Revisions and amendments will be made as and when required in the meeting of the Steering Committee based on any proposal received by the advisory sub-committees as and when required. If any revision or amendment is approved by the Steering Committee, the accredited Inspection and Certification Agencies will be allowed a certain phase-in period before the amendments / revisions become effective.

Guidelines for Organic Production and Processing

Guidelines for specific crops in accordance with the National Standards for organic Products will be prepared by the respective Accreditation Agencies and will be submitted to the Steering Committee for approval.

Package of Practices

The respective Accreditation Agencies will prepare the package of practices for specific crop, specific to the region in accordance with the National Standards for Organic Products.

Issue of Certificates

The accredited Inspection and Certification Agency will issue Farm Certificates and Product Certificates certifying compliance to the national organic standards based on reports of inspection.

Certification procedures

Organic Certification is the fist and foremost step towards the organic farming practices. The organic products from the certified farms are having higher demand and attract a greater price in international trade. Fundamentally organic farming requires farming to be carried out with the use of natural farm inputs as against chemical synthetic farm inputs. The organic farming practice starts with the certification procedure and curing of the farm simultaneously. There are sets of guidelines and norms to be complied with, followed by the inspection by the certification agency before certification. These certifications are basically carried out on the basis of statutory certification norms (NSOP) and the voluntary/civil certification norms (as specified by the importing agency). Typically, the statutory certification norms (NSOP) are in line with the international / voluntary certification norms. Statutory certification norms for the leading and the most important organic foods consuming and importing markets

- European Economic Council (EEC) Regulation for organic foods in EU member states.
- United States Department of Agriculture (USDA) standards for organic foods in USA.
- Japanese Agricultural Standards (JAS) for organic products in Japan.

The generally accepted certifications from non-statutory agencies and associations are

- CODEX (FAO/WHO)
- IFOAM
- Naturland
- Demeter
- Soil Association

These are widely recognized across the three leading organic markets viz. US, EU and Japan and are trusted by a large section of importers and consumers and hence are as important as the statutory certifications.

In the year 2000, the Ministry of Commerce, Govt. of India, launched the National Program for Organic Production (NPOP) to ensure a focussed and well-directed development of organic agriculture. A National Steering Committee (NSC) comprising Agricultural and Processed food Products Export Development Authority (APEDA), Spices Board, Coffee Board and various other government and private organizations associated with the organic movement was set up to formulate the National Program for Organic Production (NPOP). National Steering Committee is entrusted with the preparation and approvals of

- The national standards
- Accreditation criteria for accrediting inspection and certification agencies
- Accreditation procedure
- Inspection and certification procedures

These documents were prepared on the basis of the guidelines evolved by the representative international organizations, viz., International Federation for Organic Agricultural Movement (IFOAM), EU Regulations and Codex standards.

The evaluating agency is appointed by the accreditation agency, consist of persons from the accreditation agency or experts from outside. The evaluating agency receives and screen the applications from the inspection and certification agencies for their certification programmes, The evaluating agency submits an evaluation report along with its recommendation to the accreditation agency for considering accreditation for the particular inspection and certification agency. Based on the recommendations of the evaluating agency suitable inspection and certification agencies are accredited by the accreditation agency. The inspectors are appointed by these accredited inspection and certification Agencies. They carry out inspection of the land and maintain records as per specified formats and also carryout periodic site inspection. Based on compliance to the standards and programmes, accredited inspection and certification agencies will certify the organic status or products and operations, indicating their conditions along with their recommendations.

Inspection and Certification Process

The following steps are to be followed for organic inspection and certification process

- Select an accredited inspection and certification agency
- The selection of agency is to be based on the acceptability of the exporter or exporting country and the standards prescribed by that country and other factors such as proximity of the agency to the farms, quotations for costs of the inspection and certification
- File application form detailing preliminary information about the size of the farm/ units, location of units, company activities, etc. to determine the cost of inspection and certification and based on application the cost of inspection and certification is determined and a contract regarding the same is signed between the producer and the agency.
- Based on the information provided by the producer, the agency carries out farm inspection on a mutually convenient day and time.
- The inspection includes:
    - Interviews with persons responsible for production
    - Physical inspection of fields, premises, processing equipment, storage area, etc Inspection of paper work, book keeping, etc
    - Testing for residue analysis is carried out if the inspector feels the need for the same.
- After fulfilling the necessary inspections, the agency provides the report of inspection and testing (if carried out). Based on the findings of the report, the agency decides whether or not to grant a certification.
- If certification is not granted then the agency provides the reasons for rejection. If only certain parts of the business can be certified, the agency does so, providing the producer with certain recommendations for the remaining parts of the business, which could not be certified.
- Each year following the official certification, the agency performs inspections to determine whether the requirements for certification are still met.

***Approved maximum tariff structure for certification** by NPOP*

Object of control	Details	Fees (Rs.)
Small farmers and Co-operatives	Travel and Inspection Report preparation Certification	12000/- per day 5000/- (consolidated) 5000/- per certificate
Small farmers and cottage Industry	Travel and Inspection Report preparation Certification	12000/- per day 5000/- (consolidated) 5000/- per certificate
Estate Manufactures and Exporters	Travel and Inspection Report preparation Certification	19200/- per day 5000/- (consolidated) 5000/- per certificate
Large and Medium sized processors	Travel and Inspection Report preparation Certification	16800/- per day 5000/- (consolidated) 5000/- per certificate

Source: M/s SKAL International; issued by APEDA (Ministry of Commerce & Industry, Govt. of India).

Leading Inspection and Certification Agencies in India

Following are the leading international inspection and certification agencies, which have so far been approved by most of the accreditation agencies in India.

Sl. No	Address of the accredited certifying and inspection agency	Contact persons details
1.	BVQI (India) Pvt. Ltd. Marwah Centre, 6th Floor Opp. Ansa Industrial Estate Krishanlal Marwah Marg, Off Saki-Vihar Road Andheri (East), Mumbai-400 072 (Maharashtra)	Mr. R. K. Sharma Phone No.: 022-56956300, 56956311 Fax No. 022-56956302 / 10 Email: scsinfo@in.bureauveritas.com
2	Ecocert SA (India Branch Office) Sector-3, S-6/3 & 4, Gut No. 102 Hindustan Awas Ltd., Walmi-Waluj Road Nakshatrawadi, Aurangabad – 431 002	Dr. Alexander Daniel Phone No.: 0240-2377120, 2376949 Fax No.: 0240-2376866 Email: ecocert@sancharnet.in
3	IMO Control Private Limited No. 1314, Double Road, Indiranagar 2nd Stage Bangalore-560 038. (Karnataka)	Mr. Umesh Chandrasekhar Phone No.: 080-25285883, 2520 1546 Fax: 080-25272185 Email: imoind@vsnl.com
4	Indian Organic Certification Agency (INDOCERT) Thottumugham P.O. Aluva-683 105, Cochin, (Kerala)	Mr. Mathew Sebastian Telefax:0484-2630908-09/2620943 Email: Mathew.Sebastian@indocert.org
5	International Resources for Fairer Trade Sona Udyog (Industrial Estate) Unit No. 7, Parsi Pandhayat Road Andheri (E), Mumbai – 400 072 (Maharashtra)	Mr. Arun Raste Phone No.: Tel: 022-28352811, 28235246 ext. 22 Fax – 022-823-5245 Email: irft@vsnl.com
6	Lacon Quality Certification Pvt. Ltd Chenathra, Theepany, Thiruvalla - 689 101, (Kerala)	Mr. Bobby Issac Telefax: 0469 2606447 Email: laconindia@sancharnet.in
7	Natural Organic Certification Association Chhatrapati House, Ground Floor Near P. N. Gadgil Showroom Pune-411 038, (Maharashtra)	Mr. Sanjay Deshmukh Phone No.: 020-25457869, 56218063 Fax: 020-2539-0096 Email: contact@nocaindia.com
8	OneCert Asia Agri Certification Private Limited, Agrasen Farm, Vatika Road, Off Tonk,, Jaipur-303 905, (Rajasthan)	Mr. Sandeep Bhargava Phone No. : - 0141-2720202 to 0141-2770342, Telefax No: - 0141-2720202 Email: info@onecertasia.in
9	SGS India Pvt. Ltd. - 250 Udyog Vihar, Phase – IV Gurgaon – 122 015, (Haryana)	Mr. Sudarshan Sharma Phone No.: 95124-2399990 to 98 Fax No.: 95124-2399764 Email: sudarshan_sharma@sgs.com
10	Skal International (India) A Division of CU Inspections India Pvt. Ltd. No. 191, 1st Main Road, Mahalaxmi Layout Bangalore – 560 086, (Karnataka)	Mr. Narayana Upadhyaya Phone No.: 080-23491928, 56966507 Fax no.: 080-23491935 Email: skalindia@eth.net
11	Uttaranchal State Organic Certification Agency (USOCA) 12/II Vasant Vihar, Dehradun-248 006, (Uttaranchal)	Dr. S. K. Malik Phone No.: 0135-2760861 Fax: 0135-2760734 Email: uss_opca@rediffmail.com

Sourse: APEDA

For Fees structures of the inspection and certifying agencies Please visit http://www.apeda.com/organic/

MONITORING OF POLLUTANTS IN FARMS AND FARM PRODUCTS

Dr.K.M.Durga Devi
Assistant Professor Sr. Sc.(Soil Science & Agricultural Chemistry)

It has become increasingly evident that various pollutants in an ecosystem affect and will continue to affect human, animal and plant life and even climate. Major substances which pollute our air , water and land are deposited matter such as smoke, tar , dust, grit etc ; gases like oxides of nitrogen (NO , NO_2); sulphur (SO_2); carbon monoxide, halogens (chlorine , bromine , iodine); acid droplets of sulphuric acid, nitric acid etc; fluoride, metals like mercury, lead, iron, zinc, nickel, tin, cadmium, chromium etc; agrochemicals-biocides (insecticides, herbicides, fungicides, nematicides, bactericides, etc) ,fertilisers, complex organic substances (benzene, ether, acetic acid, benzopyrenes etc); photochemical oxidants (smog, ozone, peroxyacetyl nitrate (PAN), nitrogen oxides, aldehydes, ethylene etc), solid wastes, radioactive waste and noise. Among the above-mentioned pollutants, pesticides, fertilizers, organic manures and farm waste account for major share in the deterioration of an agricultural land.

Persistence of chlorinated organic compounds in water has a special significance as they are picked up by plankton, fish etc. and in this process residues enter the food chain. Even though herbicides are less toxic substances compared to insecticides; they are also capable of polluting the environment. Since herbicides are sprayed rather early in the crop season, where the plant cover is little, major portion of the chemical enters in to the soil where it becomes a part of the life cycle. Hence these chemicals are supposed to be the major ground water pesticides. Quantitative measurements of pollutants are necessary before taking steps to control air, soil and water pollution

A. Air pollution

Air pollution from farms directly affects the environment through the production of gaseous nitrogen , hydrogen sulphide , methane , ammonia, carbon dioxide and particulate matter. Manure is the largest contributor to farm generated air pollution. A number of other factory farm components such as use of conventional animal feed , production of crops for animal feed also increase the production of gases and air borne particulates.

Analysis of air pollutants: It is very difficult to define and measure air quality. However, to evaluate the actual pollution of air, it is necessary to measure its quality.. The United States Environmental Protection Agency set national quality standards in 1971 as shown in the following table.

Table 1 Air quality standards for primary pollutants

Sl.no.	Name of the pollutant	Tolerance , ppm	Levels (microgram /m^3)	Relative toxicity
1	Carbon monoxide CO)	9.0(Not to be exceeded more than once per year for 8 hours period) 35.0(not to be exceeded more than once per year for 1 hour period)	10,000 40,000	1.00
2.	Sulphur oxides (SO_x)	0.50	1,430	28.00
3.	Nitrogen oxides(NO_x)	0.25	514	77.4
4	Hydrocarbons	_	19,300	2.07
5.	Particulates	--	375	106.7

Instrumental methods are widely used for air pollutant analysis.

Table 2. List of gaseous air pollutants and particulate matter analysed by different instrumentation techniques

Sl.No.	Pollutant	Instrumental technique
1.	NO_x	Chemiluminescence, Visible, UV and IR
2.	SO_x	Spectrometry, conductivity
3.	CO	Gas chromatography
4.	Hydrocarbons	Gas chromatography
5.	Aromatic hydrocarbons	Gas chromatography
6.	Metals	Atomic absorption spectroscopy
7.	Sulphates	Turbidimetry
8.	Ozone and oxidants	Visible and UV spectrometry
9.	NH_3	Spectrophotometry
10.	H_2S	Spectrophotometry
11.	Volatile pesticides	GC-MS
Particulate matter		
1.	Silicates	Chromatography
2.	Aromatic hydrocarbons	Chromatography
3.	Fluorides	Potentiometry
4.	Sulphates	Electron microscopy

Control measure: The proven technologies that can reduce the impact and total emissions of air pollutants from farms include better storage of manure, increased attention to nutritional needs of specific life stock, allowing cows to graze on pasture, reducing the release of toxicants by the proper use of fertilizers and pesticides.

B. Water pollution

Water pollution can be classified into four categories namely physical , chemical, biological and physiological pollution. Plant nutrients, pesticides, fertilizers, farm waste, manure slurry, sediments, plants and animal debris, drainage from silage, soil erosion containing mostly the inorganic materials are reported to cause heavy pollution to water sources. Frequent monitoring of water quality especially of drinking water by using standard methods of analysis is an integral component of pollution control programme. Water quality parameters like dissolved oxygen , biological oxygen demand , chemical oxygen demand , turbidity , solids , nitrogen and phosphates , are to be taken into primary considerations . Physical and chemical agents that are likely to accumulate in the biota of food chain are generally considered as toxicants and this category include heavy metals , pesticides and radioactive substances .

Nitrate problem: Urea, the major nitrogen fertilizer, is susceptible to various nitrogen loss mechanisms namely, ammonia volatilization, leaching and denitrification . Ammonia that emanates from agricultural fields contributes to acid rain, while nitrates produced in the soil contribute to contamination of ground water due to leaching of nitrates and ozone depletion due to release of nitrous oxide by denitrification process.

Analysis of water pollutants: Quantitative measurements of water pollution involve different types of examinations (such as physical, chemical, biological and microbiological) of water.

Table 3. International standards for drinking water (prescribed by WHO)

Substance	Maximum allowable limit
Standards of chemical and physical quality	
a. Toxic metals	
Lead	0.05 mg l^{-1}
Arsenic	0.05 mg l^{-1}
Barium	0.10 mg l^{-1}
Cadmium	0.01 mg l^{-1}
Chromium	0.05 mg l^{-1}
Selenium	0.01 mg l^{-1}
Cyanide	0.20 mg l^{-1}
b. Substances affecting health	
Fluoride	1.50 mg l^{-1}-
Nitrate	45.0 mg l^{-1}
c. Substances affecting potablility of water	
Total solids	1500 mg l^{-1}
Clour(platinum cobalt scale)	50.0units
Turbidity(turbidity units)	.25 units
Taste	-
Odour	-
Manganese	0.5 mg l^{-1}
Copper	1.5 mg l^{-1}
Zinc	15.0 mg l^{-1}
Calcium	200.0 mg l^{-1}
Magnesium	150.0 mg l^{-1}
Chloride	600.0 mg l^{-1}
Sulphate	400.0 mg l^{-1}1
Magnesium + sodium sulphate	1000.00 mg l^{-1}
Phenolic compounds	0.002 mg l^{-1}
pH range	Not less than 6.5 or grater than 9.2
d. Bacteriological examination	
Coliform bacteria	0

The ground water pollution by pesticides is a very serious and dangerous problem throughout the world .Atrazine was found in the ground and surface water in maize producing areas of South Africa. Atrazine, simazine, alachlor, carbofuran etc. have been detected in ground water a concentrations higher than the MRL. Herbicides and nematicides are supposed to be the major ground water pollutant pesticides as they are directly applied to soil.

Table 4. Properties of pesticides that indicate their high ground water contamination potential

Parameter	Value
Water solubility	> 30 mg l^{-1}
Hydrolysis half life	> 25 weeks
Photolysis half life	> 1 week
Field dissipation half life	> 3 weeks
Speciation	Negatively charged, fully or partially at ambient pH

An adhoc project on Evaluation of Kuttanad ecosystem for possible contamination by pesticides and toxic heavy metals was conducted at RARS, Kumarakom, Kerala Agricultural University during 1997-1999. The results revealed that mostly organo chlorines are present in the ecosystem and this is due to their long persistence.. Seasonal monitoring showed that the residue levels vary due to concentration effects during summer and dilution due to rain water during monsoons. However, the residue levels were much lower than the MRL. Environmental pollution due to heavy metals from fungicides is of little concern since their levels are also below the limits prescribed by WHO. 2,4-D residues were detected in higher levels in field water and river water. In ground water, it was near to the permissible limits during the punja season. Similarly carbofuran was detected at higher levels than the permissible limits in rice grain and straw.

Table 5. **Carbofuran and 2,4-D residues detected in different samples**

Sample name	Carbofuran		2,4-D	
	Maximum value	Sample %	Maximum value	Sample %
Field water (μg l-1)	109.0	20	8.70	17
River water((μg l-1)	36.0	20	5.40	13
Ground water((μg l-1)	2.0	16	0.09	8
Soil(μg g-1)	1.69	50	0.12	30
Sediment(μg g-1)	0.34	13	0.05	19
Rice grain(μg g-1)	0.75	30	-	0
Rice straw(μg g-1)	1.44	36	0.023	7

Source : KAU,2000

Control of water pollution: Ecosystem stabilization is the most scientific way to control water pollution. The principle involved in this technique include waste reduction at source, by reutilization, recycling and recharge of waste, waste water reclamation, removal of pollutants by adsorption, electro dialysis, removal of salts by reverse osmosis, use of water hyacinth, harvesting and removal of biomass, nutrient trapping , fish management, aeration , and use of chemicals(chlorination or ozonisation of waste water) etc.

C. Soil pollution

The problem of soil pollution differs from air and water pollution in the respect that the pollutants remain in direct contact with the soil for relatively longer periods. Fertilizers, pesticides, soil conditioning agents, farm wastes, soluble salts, food processing wastes and manure used in the farm, soil sediments are the chief sources of pollution .

a. Heavy metals: Indiscriminate land application of solid waste and waste water considering soil as nature's dispose- all is the main reason for heavy metal contamination of soil. The composition of sewage wastes, is highly variable depending upon the contributing source, method of collection and treatment procedure. In India, most of the raw sewage is a mixture of domestic, commercial and industrial activities. Therefore, although a large proportion of this waste is organic in nature, and contains essential plant nutrients, toxic elements may also be present in considerable amounts. The availability of these toxic substances (mostly heavy metals) is governed by the soil properties like pH and organic matter content, but the enhanced organic matter level due to application of waste generally results in increased availability of metals by forming organo metallic complexes. Plant species differ in their susceptibility and tolerance to heavy metals. The leafy vegetables and root crops accumulate larger amounts of heavy metals than grain crops. e.g. Spinach can absorb large amounts of Pb and Cd, where as wheat grains accumulate very small quantities of toxic heavy metals. The application of rock phosphate or its products to soil always implies the addition of a significant amount of lead and cadmium into the soil. In soils with coarser textures and acidic reaction , heavy metals applied through fertilizers are available more than in those containing large amount of clay and with alkaline reaction.

b. Pesticide residues: In almost all the soils that have been surveyed for insecticide residues in India, the most common chemical and the one that is found in the largest amounts is DDT, followed by HCH and Dieldrin. In a study at Punjab, out of 106 soil samples, 91 were contaminated with insecticide residues. The highest level of 0.08 mg per gram was found in the cotton growing areas. Nineteen percent soil samples indicated the contamination of soil samples with organo phosphates and carbamate insecticides.

The reactions, movements and degradation of insecticides affect the persistence of these chemicals in soils and determine the risk of soil pllution. Organophosphates persist in the soil only for a few days, DDT and other chlorinated hydrocarbons last from 3 to 15 years or even longer. Under certain conditions , toxicity from the accumulation of copper based fungicides may render the soil useless for growing crops. Similarly, the oxidation of sulphur contained in fungicides can alter the chemistry of organic matter in the surface horizon of soils in a way that decline in yield of some crop plants may occur.

Under Indian conditions, when a herbicide dose of 0.5 to 2.0 kg/ha is applied , it results in a build up of residues in the range of 0.25 to 1.0 mg/ kg which is safely below the potential residual effect. At several places in India, it has been observed that several herbicides including 2,4-D, isoproturon, oxyfluorfen, butachlor, pretilachlor etc. leave little or no residual effect on the crops . But the residues of fluchloralin, metabenzthizuron and atrazine were detected in amounts that could adversely affect not only crop plants but also several processes in soil leading to inefficient nutrient management and in turn reduced crop yields.

Management Strategies

1. Integrated Intensive farming system
2. Organic farming
3. Biotechnology
4. Integrated Plant Nutrient Management
5. Integrated Pest Management
6. Water shed management
7. Precision Farming Technology

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COMPOST ENRICHMENT
A NEED FOR TODAY AND TOMORROW

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"Nourish nature to nurture mankind" has been the guiding mantras in Vedic agriculture. But the introduction of high yielding varieties in mid 60's has been a major out break in Indian agriculture for increasing the food production. The high yielding varieties are heavy feeders of plant nutrients, thus possessing a major threat to ecological balance and heavy depletion. Various studies have reported the use of manures in combination with chemical fertilizers is significantly important to sustain the crop yields and soil health on long term basis. But the availability and production of organic manures is the limiting factor in today's agriculture. Composting is the technology being used by the farmers to produce organic manures and increase yields. Now professional growers are discovering that enriched compost is much better than conventional compost.

The conventional method of composting takes a long time to produce compost and it has low nutrient quality in order to over come this drawback composts are often enriched by addition of desirable nutrient element and inoculation of efficient microorganisms. Such enriched product is required for intensive crop production. Enrichment of compost helps to reduce the nutrient content per unit weight and decrease the period of composting making it more accept able to the farmers. The beneficial uses of enriched compost play a vital role in saving m money, reduce pesticides and conserve natural resources.

There are four different approaches in compost enrichment are a) Enhancement of nutrient availability to plants, b) Suppression of diseases in plants, c) Bio remediation of toxic soil d) Bio filtration of contaminated air.

Enrichment of Nutrient Availability to Plants

The conventional farm compost has the major nutrients in the proportion of 0.5 % N, 0.15 % P_2O_5 and 0.5 % K_2O. To enhance the nutrient availability from compost, it can be enriched with much substance such as inorganic fertilizer, organic amendment, microbes and earthworms.

Inorganic fertilizer

It has been found that organic nitrogen in the compost can completely substitute by inorganic nitrogen compounds like ammonium sulphate and urea, which are utilized equally effectively for decomposition. Thus low quality compost with low nitrogen on enrichment raise the total N content. This also opens up a vast field for utilization of large quantities of various organic waste materials and will be served as good quality compost to farmers. Different minerals like rock phosphate can be added layer by layer during coir composting @ 10 kg to get P enriched compost. The level of rock phosphate may be 12.5% to 25% depending on the P enrichment.

Organic amendments

During composting of the city garbage or solid wastes, certain organic substance that is rich in N and other nutrient element, can be mixed. The organic elements that can be mixed are 1) oil extract cake 2) food processing wastes, 3) press mud, 4) legume plants and weeds, 5) leaf materials, 6) poultry manure 7) silk worm wastes. The addition of organic wastes rich N, resulted in reduction of C/N ratio in a shorter time. Coir pith, waste from coir making industry can also be used for this purpose. In this study has been conducted in College of horticulture vellanikkara about co- composting.

In kerala water hyacinth is a serious problem in the water bodies, which in turn depletes the oxygen. Selective co-composting of the carbonaceous materials of wider C/N ratio with that of narrow ones along with other organic enrichners will provide readily compostable mixture of higher quality. The water bodies of our state are found to be highly polluted and even the adjoining paddy fields are severely affected by the toxic and harmful organic wastes. Excessive aquatic vegetation like water hyacinth impedes the flow of water in all kinds of waterways. Co-composting procedure was standardized as follows:

- An area of 5m length and 3m width in a shady place is to be selected
- Spread 100kg of coirpith approximately to a height of 2 cm
- Spread 1 bottle spawn (200gm) of *Pleurotus platypus* uniformly over the coirpith layer Cover the layer with another 100kg of coirpith
- On the surface of the second layer water hyacinth was spread uniformly to a height of 2cm.
- This process of sandwiching *Pleurotus sp* and water hyacinth alternatively with 100kg coirpith is repeated until the heap reaches 1m height. Avoid the entry of weed seeds into the composting bulk.
- The heap is periodically monitored to maintain moisture content of 200%
- At the end of 30 days the coir waste turns into black or dark brown mass of compost

Using the suggested eco-friendly method, the enriched manure (organic carbon: 24%, N: 0.94%, P: 0.5% and K: 1.2) with C.N. ratio 25:1 was produced from the original coir pith with C/N ratio 112:1. Along with water hyacinth of N content 1.4%, the other organic enrichners also contributed for this drastic reduction in C/N ratio. Another study was conducted Naija Nair (1997) to investigate the methodologies of coir pith compost through proper organic amendments and various bioprocessing and also to study the effect of best enriched coir pit compost on plant and soil. Here coir pith is the major study material along with the other three enrichners used. A) KPCL sludge, it is an industrial waste of organic origin produced by Kerala Chemicals and Protein Ltd., Thrissur. b) Cow dung c) Muncipal solid waste. Out of different treatments, the treatment in 1:1:1 combination found to have the lowest C: N ratio.

Microbial inoculation

The factors of composting are manipulated mainly to enhance the microbial activity where the rate of decomposition of the organic wastes is enhanced. Organic wastes may contain natural micro flora that bring about the decomposition under suitable environmental conditions. The microbial inoculation is considered when specific decomposition of the substance is desired. The microbial inoculation is done for selective degradation, phosphate solubilization and N fixation. Inoculation will accelerate the process of composting and enrich the nutrient concentration. The classical example is coir pith composting. Here pleurotus spp is effectively degrading the lignin and cellulose component in the coir pith .The coir pith compost preparation is as follows

Coir pith compost preparation

Select an area of 5m length and 3m width and spread 100kg of coir pith layer by layer approximately to a height of 1.0m. One bottle of spawn of pleurotus spp is uniformly spread over the coir pith layer. Cover the layer with another 100kg of coir pith. On the surface of this second layer one kg of urea is uniformly spread. This process is sandwiching the pleurotus sp and urea alternatively with 100kg coir pith is repeated until the heap reaches one-meter height .for this process of composting of one ton of coir pith, five kg of urea and five spawn bottles are needed. The heap is periodically monitored to maintain the moisture content to about 60%; this is achieved by sprinkling water. At the end of about 60 days the coir waste turns in to a black/dark brown mass of compost.

Some other examples of microbial inoculants are. Azotobacter chrococum which helps in nitrogen fixation, Aspergillus awamori is a phosphate solubilizer ,Pseudomonas ,a plant growth promoter, while Trichoderma harizanum –plant growth promoter &biocontrol agent.(Radhakrishna, 2003)

Enrichment with Earthworm

Ismail (1997) reported that the most commonly used earthworm for vermicomposting include exotic species like *Eudrillus euginae* and *Eisenia foetida* as well as the local earthworms like *Perionyx excavatus.* Earthworm can be used for compost preparation, which enriches the compost, and this process is called Vermicomposting. Pits measuring 2.5m length 1m width and 30 depths are dug and lined with bricks or stones. Then coconut husks are laid in 2 layers. After that one layer of coir pith or sawdust is spread to half-inch thickness and sprinkle water on it. This is the bedding material for vermicomposting. Over this half decomposed or easily decomposable organic matter and cow dung in 8:1 proportion is spread uniformly to 30cm thickness. To this mass earthworms are released at the rate of 100 worms per m2. It is better to add cow dung in the form of slurry. Organic matter-cow dung mixture should be added till the pit is full. Cover the pit with a wet sack. Maintain the wetness of sack by periodical sprinkling of water. Mix the materials in the pit once in a week for proper aeration. The compost will be ready in 30-45 days. Zacharia (1995) in her work , vermicomposting of vegetable garbages done at college of agriculture , Vellayani, used different types composts in the nutrient enrichment of vermicompost by inoculation with beneficial microorganisms. In the enriched compost the majornutrients NPK are found to be increased. The exotic earth worm *Eudrillus euginae* compost treatment with Azosirillum, Phosphorus solubilizing organism and one per cent rock phosphate gave maximum NPK content when compared with control treatment. Preetha (2001) studied the waste management from ayurvedic drug management units using earthworms. This takes a longer time for degradation as materials are different and this directly cannot be used. To make it in to a valuable one earth worms are used .

Plant disease control

Each year, more than 10 per cent of vegetables planted are lost to root rot alone. Additional crop losses are caused by other soil borne plant pathogens. Compost can help control plant diseases and reduce crop losses. Disease control with compost has been attributed to four possible mechanisms. a) Successful competition for nutrients by beneficial organisms; b) antibiotic production by beneficial micro- organisms; c) successful predation against pathogens by beneficial microorganisms; and d) activation of disease – resistant genes in plants by composts.

Scientists have enhanced the natural availability of compost to suppress diseases by enriching it with specific disease fighting microorganisms or other amendments. This enriched compost can be applied to crops infected by known diseases. Research has shown that tailored compost significantly reduced or replaced the application of pesticides, fungicides, and nematicides-which could adversely affect water resources, food safety and worker safety.

The second approach of compost enrichment is suppression of plant diseases. Both composts and compost teas are used for reducing incidence of diseases. Compost tea is a highly concentrated microbial solution produced by extracting beneficial microbes from vermicompost and/or compost. Compost or vermicompost is placed in basket as suspended in water or nutrient solution and the extraction process begins. Good quality compost tea can be brewed in 24 hours. Compost tea provides direct nutrition.

- As a source of foliar and soil organic nutrients
- As cheated micronutrients for easy plant absorption
- In a biologically available form for both plant and microbial uptake

Vermiwash and its uses

The aqueous extract of live column of vermicompost with earthworm activity is the product of interactive process of the bioagents and the substrate of compost material.

- Inhibition of spore germination
- Antagonism and competition with pathogens
- Induced resistance against pathogens

a. *Inhibition of spore germination*: The primary source of the effects observed with compost tea is apparently of a live microbiological nature. Inhibition of spore germination by the production of siderophores, which are low molecular weight, iron-chelating chemicals like Pseudomycins and Psuedobactins, which are produced by Pseudomonas, exert a powerful chemical suppressive effect on other organisms.

b. *Antagonism and Competition with pathogens*: Antibiotics have been produced by Bacillus subtilis and inhibit the germination and/or growth of many other fungi.

c. *Induced systemic resistance against pathogens*: Studies showed that the microbes whether pathogenic or not can cause the induction of internal plant defenses. For instance, by inoculating cucumber leaves with the fungus, Colletotrichum lagenarium, the infected leaf not only became resistant towards this fungus but also towards many other pathogens of bacterial and viral nature.

d. Studies have been conducted by Ryekeboer nad coosemans (1996) on the suppression of club root disease on cauliflower after the addition of biowaste compost to the potting soil. All the treatments except one control treatment were infested with spores of *Plasmodephora brassicae* in potting soil. A significant depression was found for higher doses of compost. The compost and compost teas influenced the soil physical characteristics and production. Effect of soil and foliar application of vermivash on the growth and yield of tomato was studied by Ranijasmine (1999). She also reported that 50% and 25% concentrations of Vermiwash could reduce the inorganic fertilizer dose to half of the recommended dose with out reduction in yield.

Bioremediation or Toxic Soil

The third approach of compost enrichment is the bioremediation of toxic soil. Bioremediation is a treatment process that employs microorganisms capable of degrading toxic contaminants for reclamation of the polluted sites. Certain microbes can digest organic substances such as fuels or solvents that are hazardous to humans. The microorganisms break down these products to CO_2 and H_2O_2 that are less toxic or non-toxic. Once the contaminants degraded, the microorganisms population is reduced because they have used all of their food source. Dead microorganism or small populations in the absence of food no contaminations risk.

Advantages of Bioremediation

- Help in treating contamination in a place
- To harness natural microbial process
- Help to reduce environmental stress

The soil containing about 3000 mg Kg^{-1} of dicamba herbicide was bioremediated to a non-detectable level in 50 days using wood chips compost at 1: 9 ratio of the compost and contaminated soil.The method saved time and money and resulted in an enriched soil.(Cole, 1997). Although bioremediation holds great promise for dealing with intractable environmental problems, specifically much needs to learned about hoe microorganisms interact with different hydrologic environments. As this understanding increases , the efficiency and applicability of bioremediation will grow rapidly.

Biofiltration of Contaminated Air

A biofilter is an engineered bed of soil or compost under which lies a distribution system of perforated pipe and layer of coarse distribution media. Biofiltration helps in the removal and oxidation of organic gases and volatile organic compounds from contaminated air by beds of compost or soil biofilter media that convert the organic compounds to CO_2 and H_2O. Contaminated air is blown into the perforated pipes and slowly diffuses up through the biofilter media. The contaminant molecules flow through the biofilter medial like pebbles in a stream until they settle out and are consumed by the microorganisms. The biofilter media retains no residue from the original organic compounds found in the contaminated air stream. This is due to the extremely efficient microbial ecosystem that exists within the biofilter media. Enhancing and maintaining this rich microbial ecosystem is what the biofiltration is all about. Studies have been conducted by sukesan (1997) on biofiltration of gaseous trichloro ethylene (TCE) using hydrocarbon-enriched compost as filtration matrix.

Five different finished composts were used as bed medium in batch scale bioreactors with 5 ppmv TCE in the headspace. All the five compost samples were enriched with propane or methane gas. It was found out that physical – chemical adsorption is responsible for immediate removal of nearly 75% of TCE added to the headspace. Enrichment of compost with propane or methane enhanced the removal of 85% of TCE at a retention time of 20 days. Significant differences observed in the TCE removal capacity between the compost types. Deciduous leaf debris derived compost removed >95% of TCE while >15% removal was observed in wood chips bark compost. Differences in response to enrichment and subsequent TCE removal were investigated. The microbial examination of hydrocarbon enriched compost showed that hydrocarbon enrichment corresponded to fold increase in number of propanotrophs and methanotrophs.

Conclusion

The management of organic matter decomposition process is very much significant in various ways. Composting for plant nutrient supply is one of the primary supplements to inorganic fertilizers. Proper composting of crop residues, farm wastes and industrial wastes by regulating substrate composition is essential for producing enriched composts that will provide enhanced nutrient availability in soil, suppression of diseases in plants, bio remediation of toxic soil and bio filtration of contaminated air.

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SOIL TEST CROP RESPONSE CORRELATION STUDIES FOR FARM IMPROVEMENT

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From the period of green revolution, fertilizers have played a key role in increasing food grain production in India. There is a strong relationship between fertilizer consumption and food grain production in the country over years. The consumption of fertilizer nutrients in the country increased drastically with corresponding increase in food grain production till early nineties. Nevertheless, here exists a wide gap between demand for fertilizers and their production that has necessitated their import leading to spiralling of fertilizer prices. Thus, fertilizers constitute one of the most effective and costlier inputs in increasing crop production and their rationalised use needs no emphasis.

The fertilizer recommendations of crops, generalised state level, are based on fertilizer trials conducted in research stations and in farmers' fields. Adoption of this fertilizer recommendation uniformly throughout a region does not ensure economy and efficiency in fertilizer use since variations in soil fertility are not taken into account. It leads to discrepancy in fertilizer use. Scientific and economic fertilizer use must take into account the soil fertility status as well as the crop needs. This has necessitated the formulation of fertilizer dose for crops based on soil tests. After soil testing, in order to interpret soil test values, peculiarities of both the soil and crop have to be taken into consideration. Different soils with given soil test values for nutrients differ in their capacity to supply nutrients to crops. Crops vary in their nutrient requirements and in their response to added nutrients in different soils. Soil test values should be closely correlated with nutrient uptake by crops and hopefully with the yield for making fertilizer recommendations. There comes the relevance of Soil test crop response correlation studies.

Soil test crop response correlation studies based on fertility gradient approach provides a basis for soil test calibration for site specific and situation specific formulation of fertilizer dose. In this approach, soil fertility variations are created in the same field. Actual soil test values for soil available nutrients are then determined in the laboratories and correlated with crop responses to applied nutrients as observed in the field. Accordingly, fertilizer prescription equations can be derived for recommending fertilizer doses for maximum yield, economic yield and specific yield targets of crops. Such soil test based recommendations ensure balanced use of soil and fertilizer nutrients for sustained crop production. The fertilizer prescription equations have to be test verified in farmers' fields before they are recommended for large scale adoption.

The environmental hazards caused by prolonged or heavy rates of mineral fertilization can be easily mitigated by optimising the fertilizers with judicious application of organics. The complementary use of organics and inorganics helps not only in increasing nutrient use efficiency but also in sustaining high yields of crops. Hence soil test crop response studies are being conducted under integrated plant nutrition system.

This project (All Indian Co-ordinated Research Project on Investigations on Soil Test Crop Response Correlations) was started in 1967-68 with 8 centres. Presently, STCR project is working with sixteen cooperating centres. The present location of the coordinating cell of the project is at Indian Institute of Soil Science, Bhopal. The project mainly conducts applied and some basic research work on the development of soil test based nutrient recommendations for crops and cropping systems in different states. The recommendations generated are then tested in the follow up trials at research farms or in a nearby village and also in the frontline demonstrations in .villages. The state soil testing laboratories are involved in the conduct of frontline demonstrations on farmers' fields.

Targeted yield concept strikes a balance between fertilizing the crop and the soil. The procedure provides a scientific basis for balanced fertilization and balance between applied nutrients and soil available nutrients. In the targeted yield approach, it is assumed that there is linear relationship between grain yield and nutrient uptake by the crop, as for obtaining a particular yield, a definite amount of nutrients are taken by the plant. One this requirement is known for a given yield level, the fertilizer needed can be estimated taking into consideration the contribution from soil available nutrients.

Prediction equations for the cropping sequence, was prepared by following the methodology outlined by Ramamoorthy and co-workers. It was done by developing post harvest soil test value prediction equations making use of the initial soil test values, applied fertilizer doses and the yields obtained or uptake of nutrients. The post harvest test values were taken as dependent variable and a function of the pre-sowing soil test values and the related parameters like yield/uptake and fertilizer nutrient doses. Prediction equations for post harvest soil test values were developed from initial soil test values fertilizer doses applied and the yield of crops/uptake of nutrients in order to obtain a basis for prescribing the fertilizer amounts for the crops succeeding the first crop in the sequence.

In STCR studies, the field experiment consists of two parts. In first part, generate artificially a large variation in fertility status by applying four graded dose of N, P and K fertilizers to four strips and by growing a gradient crop to stabilize the treatments. The P and K levels were fixed based on P and K fixing capacities of soils. In second part, test crops were grown following fractional factorial design with treatments consisting of varying levels of N, P, K; two to three levels of organic manures and absolute controls. The test crops were grown up to maturity and harvested. The yields of economic produce were recorded. The available NPK before initiation of the experiment and the concentrations of NPK in the plant samples collected at harvest were chemically analysed. Using the concentrations and yield data, the total uptake of NPK by the test crops were calculated.

These targeted yield equations were tested in follow up trials and frontline demonstrations on farmers' fields. In this section numerous examples where balanced fertilizer use based on targeted yield approach helped to produce higher crop yields and obtain higher benefit: cost ratios have been presented. These follow-up trials also revealed that soil test based recommendations help to efficiently use available resources, maintain soil fertility and practice integrated plant nutrient supply to crops. Soil Test Crop Response Correlation Project has generated targeted yield equations and calibration charts for targeting higher yield and recommending fertilizers on the basis of tests. Results are verified by conducting trials on farmers' fields to demonstrate the value of soil test based nutrient recommendations.

The trials conducted in various parts of the country have revealed the superiority of fertilizer application based on targeted yield approach over the semi-quantitative approach employed in the soil testing laboratories and generalised state level Package of Practices recommendation for the crop. In this approach, the fertilizer dose can be adjusted in accordance with and available resources of the farmer.

WATERSHED MAPPING AND ITS MANAGEMENT FOR SUSTAINABLE AGRICULTURE DEVELOPMENT

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Introduction

Demographic changes and economic growth exert strong and competing pressure on the finite natural resources. In India the net area devoted to agriculture is shrinking day by day due to various reasons. The size of land holding is becoming smaller and smaller. The 'waste land' is on the increase, mainly due to poor returns and the risk aversion of the people. Shiva (2002), reported that Indian farmers are spending more than Rs.1.32 trillion on seeds and chemicals under the globalisation regime. Considering these aspects, sustainable solution to hunger and poverty is possible only through the promotion of ecological, organic, biodiverse small farms which conserve the natural resource, use low cost and locally adaptable technologies.

As reported by McNeill (2000), it was the Report of the World Commission on Environment and Development (the Brundtland Report) published in 1987, which brought in the terminology of 'sustainable development'. Sustainability highlights the importance of appropriate allocation of limited resources at par with efforts for maintaining and expanding the resource base itself. This needs proper evaluation of the resources in terms of its problems and potentials. According to Venkataraman (2002), the future growth in agriculture have to necessarily come from increased productivity from a shrinking natural resource base through efficient management. Simultaneously conservation of natural resource must receive sustained attention. He also pointed out that our vision for growth should not be clouded by short-term gains, but must strongly focus on long term sustainability. Sustainable agriculture must be in harmony with the environment without exploiting and exhausting the natural resources. This can be achieved by proper conservation, development and management of natural resources through the process of watershed management.

Watershed Management

Watershed is a drainage area with well defined natural boundaries. A watershed can be considered as a hydro-geological and bio-physical entity. It behaves as an independent system in all ecological aspects. Each watershed has its own carrying capacity within which it limits its function. Singh *et al.* (1994) defined watershed or a drainage basin as a natural unit draining run off water to a common point. It can be demarcated based on ridge and gully lines. Yadav and Bhushan (2001) defined watershed as a hydrologic and geomorphologic area of land that drains to a particular outlet. Since water follows a definite course, watershed becomes an ideal hydrological unit for developmental activities. Sivanappan (2002) expressed watershed as an area from which runoff, resulting from precipitation flows past a single point into a large stream, river, lake or an ocean.

The developmental efforts on watershed basis undertaken by developed countries like USA, Germany etc. had revealed that this philosophy has scope for replication in varied situations prevailing in less developed nations also. Hence watershed as a globally accepted unit ideal for ensuring inter ecological linkages and it provides for integration and sustainable use of the basic resources namely land and water. It integrates the biophysical, social and economic inputs for optimum results from the developmental efforts undertaken.

Land Evaluation for Water shed Management

Any agricultural development activity to be made sustainable needs proper land evaluation. This will help for resource based planning process in crop selection and its management appropriate to each locality. Land evaluation involves the basic surveys of physiography, hydrogeomorphology, soils, vegetation, climate, socio-economic conditions etc. of an area. According to Beek (1981), these data are potentially useful to the farmers, planners, administrators and decision-makers.

Land evaluation for sustainable agriculture development can be best envisaged through the concept of watershed management. According to Sivanappan (2002) watershed has become an acceptable unit of planning for optimum use and conservation of soil and water resources. He also opined that it will help in preventing degradation resulting from interaction of physiographic features, it eliminates unscientific land use / inappropriate cropping pattern and reduces soil erosion, thereby improving the sustainable productivity of the land resources. Watershed management helps in enhancing the ground water recharge and also restoration of the eco-system.

In land evaluation, the biophysical parameters will be assessed in terms of their problems and potentials in order to adopt a particular land use or cropping pattern. Land evaluation for agriculture merely on the basis of one or two biophysical parameters do not yield realistic results.

According to Dent and Young (1981) land evaluation is the process of estimating the potential of land for alternative kinds of use. These include productive uses such as aerable farming, livestock production, forestry etc. together with uses that provide services or other benefits such as catchment area protection, recreation, tourism, wildlife conservation etc. As defined by the FAO (1983), land evaluation is the assessment of land performance when used for specified purposes. The first attempt of land evaluation was carried out in California during 1933 for taxation purpose. Later this was used for agricultural related activities.

Integrated land evaluation

The approach towards land evaluation besides productivity enhancement have other dimensions such as employment generation, innovativeness, people's participation, sustainability etc. Achievement of sustainability through agricultural development programme is very complex as it involves lot of human intervention besides the interaction of number of other physical, environment, economic and social factors.

Land evaluation, considering the biophysical and socio-economic factors, is essential for sustainable agriculture development in the present context. This is termed as 'integrated land evaluation'. The procedure of considering the biophysical factors alone for land evaluation did not yield the desired results and acceptability of the stakeholders of land. This gave rise to the concept of integrated land evaluation. This concept of land evaluation for crop suitability was introduced by FAO since mid seventies and updated periodically. Here the biophysical, social and economic factors are given due considerations.

As per the FAO guidelines (1983), the promising combination derived on the basis of biophysical factors can be subjected to analysis in terms of economic and social factors to confirm or modify their suitability in social and economic terms. Shao (1984) devised a land classification system on the basis of physical factors such as water, soil properties and current land use. This system consisted of five classes. This system was then used together with the social and economic factors to arrive at proper land evaluation.

Samanta (1991) opined that development of a more sustainable agriculture system can be achieved only through an 'integrated approach'. For the purpose, an understanding of the present farming and land use system and its development over time is necessary. Verheye (1991) reported that in the approach of integrated land evaluation besides physical resources, human and capital factors also needed consideration.

Johnson and Cramb (1996) introduced the integrated method of land evaluation that generates biophysical and economic measures of land performance using crop yield prediction, expert system and risk analysis.

Krishna *et al.* (2000) in their study considered factors such as physiography, irrigation, slope, soil depth, surface texture, ground water potential, production system, population density, literacy per cent and infrastructure status as factors of ecological-economic zoning for land use planning.

Remote sensing and GIS for watershed management

Efficient resource management system needs timely and reliable information or data, which can be achieved through intensive inventories of the present 'state of affairs'. The future also needs due consideration especially for those entrusted with the task of designing and implementing suitable plans for the conservation, development and management of available resources aimed at sustainable development. This calls for an appropriate 'Natural Resource Management System' for any nation. In this context 'Remote Sensing', acts as an effective tool in the generation of reliable and timely spatial information of the earth resources. However, it acts as only an effective means and not an end by itself. In the words of Varadan (1987), the capabilities of Remote Sensing have an important and evident relevance to Concurrent Tentative Synthesis and Continuous Monitoring in relation to a Holistic Approach to Development. Remote Sensing opens up a tremendous vista of possibilities teeming with opportunities and beset with pit falls. Sahai (1988) stated that remote sensing technique can play an unique role in promoting comprehensive, reliable and up-to-date information on the character, distribution, productivity and utilisation of natural resources.

Aerial photographs and satellite images are the remote sensing data bases mainly used for extracting valuable information on natural resources. With the availability of high resolution and multi-temporal remote sensing data, resource inventory and analysis can be carried out with considerable speed and precision. The method of analysis of data ranges from visual interpretation to advanced computer processing. Results of the studies by following authors highlight the relevance of remote sensing technology in land evaluation and natural resource management.

Reddy *et al.* (1990) used land evaluation for developing land use plans for land development and management. They used satellite remote sensing in combination with collateral and adequate ground truth for generating small scale land resource maps. Skole *et al.* (1994) reported that satellite remote sensing can be used for vegetation mapping in various tropical forests at different scales. Kar (2001) opined that remote sensing is a cost and time effective technology to identify, map, inventorying and monitoring physical resources information for watershed management.

Geographical Information System (GIS) act as an effective tool in storing, processing, analysis and querying of both spatial and non-spatial data base for the effective management of the natural resources. GIS helps in handling large volume of data to arrive at appropriate decisions on watershed management. Kar (2001) in another study of Yacharam watershed, Andhra Pradesh, revealed the usefulness of remote sensing and GIS technologies for providing up-to-date reliable and accurate information on different natural resources like existing land use / land cover, hydro-geomorphology, soil and topographical features of watershed. Patel *et al.* (2001) generated spatial database (thematic maps) on soils, slope and landuse from remote sensing data, topo maps and field survey. Spatial information was integrated using GIS to prepare resource maps on composite land use and land capability. Tomar *et al.* (2002) used integrated approach through remote sensing and GIS for generating site specific action plan for watershed management of Shipra watershed, Meghalaya. Satellite data was visually interpreted for land use, soil drainage, aspect and hydrogeomorphological information of the watershed. These information were integrated with socio-economic characteristics for generation of action plan. The action plan package consisted of plantations, silvipasture, agro-horticulture, agro-forestry, double cropping, grazing lands, aquaculture etc.

Spatial Crop Suitability for Water shed Management

Crop suitability evaluation is the process of assessing a land unit for a specific crop or a cropping pattern. From the earliest times, farmers have been deciding which crops are best suited for their land or as settlers where they can locate the land suited to the crops of their interest. This has often been a process of trial and error. In the era of modern planning, it has been recognized that a land cannot be simply rated from 'best' to 'worst' irrespective of the kind of use. Surveys in developing countries revealed short comings in the land capability classification. Hence procedures were devised for comparing suitability of land for different purposes.

The initiative for developing some measures of standardisation of the terminology of land suitability and its procedures was taken up by the FAO through a series of discussions from 1970 onwards and the results were incorporated in 'A Framework for Land evaluation' of 1976 and in the 'Guidelines : land evaluation for rainfed agriculture' of 1983. The end result of such type of land evaluation helps in generating 'suitability maps' otherwise termed as 'spatial suitability data' showing the suitability of each land mapping unit for specific kind of use or specific type of crop. These maps show whether a particular mapped area of land is highly suitable or moderately suitable or not suitable for a particular land use, cropping pattern or a particular crop. As opined by Dent and Young (1981), such data can be presented either as a single map with a tabular legend or as a series of individual suitability maps.

Sys (1985) had standardised the crop requirement parameters with respect to climate and soils for important tropical and sub-tropical crops. According to him this can be considered as a guideline and it has to be reviewed to suit local conditions and sometimes to varieties of crops.

Verheye (1987) conducted land suitability evaluation in major agro-ecological zones of European community for land use planning and nature protection. The system provided a basis of assessing the non-agricultural use and environmental protection. Dhandar and Subramanian (1991) suggested 'crop suitability models' for the west coast ecosystem of India to enhance the production and productivity. The models suggested were rice based cropping system, coconut based cropping system, arecanut based cropping system, mixed farming and integrated farming system with fish culture, livestock, poultry, rice and coconut.

Naidu and Hunsigi (2001) in a study on land suitability evaluation to assess the suitability of Karnataka soils for sugarcane crop, used FAO frame work for land evaluation of 1976 as well as the Soil Potential Rating (SPR) method developed by Mc Cormack during 1974. Study found that the SPR method based on yield criteria was a more realistic assessment approach than FAO method of climate and soil site criteria for crop suitability. Mandal *et al.* (2002) mapped at 1:50,000 scale the cotton growing soils of Nagpur district according to suitability classes based on modified Riquier's criteria developed from farmers yield. The study revealed that 57.5 per cent of area is highly suitable, 28.5 per cent moderately suitable, 5 per cent marginally suitable and 9 per cent unsuitable for cotton crop. Natarajan *et al.* (2003) generated small scale crop suitability map for Salem district of Tamil Nadu on the basis of land capability and land irrigability information. Samad (2004) developed a spatial crop suitability model through participatory and integrated land evaluation for a selected watershed in Thiruvananthapuram district, Kerala State.

Conclusion

Sustainable development through resource based planning helps productivity enhancement as well as environment conservation. Often this is ignored for short term and immediate benefits by mankind. Sustainable resource management especially at micro level needs spatial planning with the use of maps supported by other relevant data. This provides valuable information for location specific planning for sustainable development.

Spatial planning in the context of sustainable agriculture development can be achieved by the process of 'land evaluation'. Land evaluation in agriculture sector can be best envisaged through 'watershed approach'. For sustainable management and development of land resources, watershed must be considered as the unit of development. The concept of integrated approach of land evaluation can be applied in evaluating the problems and potentials of a watershed area. The technologies of remote sensing and GIS provide realistic and timely spatial/non-spatial data of the resources and hence can provide unique support for an evaluation and development of sustainable plans.

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LAND CAPABILITY CLASSIFICATION FOR WATERSHED MANAGEMENT PLANNING

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Soil and water are the most valuable and limited natural resources. Scientific management and judicious use of these natural resources by following suitable conservation practices are very much essential for sustainable production. Thus the basic knowledge of land capability classification is a pre-requisite and most important for planning, implementation and execution of soil and water conservation programmes. The basic principle of soil and water conservation is "to use the land according to its capability and treat the land according to its need".

Land Capability Classification is a systematic arrangement of different kinds of lands according to those properties that determine the ability of land to produce on virtually permanent basis, without causing damage to it due to erosion or other hazards. Land capability is the suitability of land for a specified use for maximum sustained production or returns.

Land evaluation is the process of assessment of a particular tract of land for specific purposes involving the execution and interpretation of data of natural resources, survey of soils, vegetation, climate and other related aspects of land in order to identify and make a comparison of the promising kinds of land uses. Several systems of land evaluation are used in soil survey programmes, the most important being land capability classification (Klingebiel and Montgomery, 1961) and FAO framework for land evaluation (FAO, 1976).

The USDA land capability classification is a general purpose land evaluation system useful for farm planning with bias on conservation. The land suitability classification is a specified land assessment system suitable for qualitative and quantitative evaluations.

Land use planning

Land use planning is the multi disciplinary approach to evaluate the land and alternative land use patterns for the purpose of selecting best possible choice in view of specific objectives. Land use planning is mainly based on physical criteria and a series of socio-economic considerations.

The physical land constraints are:

1. Climatological properties like rain fall, temperature, evaporation, day length, sun shine etc
2. Soil physical properties like soil depth, texture, compaction, permeability. Water holding capacity etc.
3. Soil chemical properties like nutrient availability, pH, base status etc.
4. Workability and trafficability governed by slope, rockiness, soil surface properties etc.

The socio-economic constraints include:

1. Sociologic and demographic conditions, technical know how etc.
2. Economic constraints like demand and consumption pattern, income status etc
3. Infrastructure constraints like transport, communication, administration etc.

Hence the land use planning requires to take options and to make choices between alternatives. This approach provides 2 major advantages.

I. First it assesses the suitability of soil for unlimited number of land uses.
II. Secondly it clearly indicates the nature of constraints that hamper optimal production of land.

Land capability classification

For optimum productivity, every unit of land should be managed in accordance with its inherent characteristics, capability, and limitations. Land capability classification is the grouping of land units into defined classes based on its capability and limitations. This classification is based on

- ✓ The inherent soil characteristics
- ✓ Environmental factors (Temperature & moisture)
- ✓ The external land features like slope, aspects and extent of erosion

This classification consists of 4 categories

1. Land suitability classes
2. Land capability classes
3. Land capability sub classes
4. Capability units

Land suitability classes: At this level the land is grouped into

i) Land suitable for cultivation ii) Land not suitable for cultivation

Land capability classes

There are 8 land capability classes. They are indicated by Roman numbers from I to VIII. Classes I to IV are suitable for cultivation and v to VIII are not suitable for cultivation. The gradation from class I to VIII indicate the increased limitation for crop production.

Suitable for cultivation
- Class I – very good land
- Class II – good land
- Class III – moderately good land
- Class IV – fairly good land

Not suitable for cultivation
- Class V, Class VI, Class VII – Suitable for pasture and grazing
- Class VIII → Suitable for wild life and watershed

Features of Land capability classes

Class I: Very good cultivable land, very deep and productive. Suitable for intensive cultivation of all climatically adopted crops

Class II: Good cultivable land with slight limitations of soil depth, salinity, texture, drainage or erosion that reduce the choice of plants.

Class III: Moderately good cultivable land. These soils has limitations of moderate erosion, soil depth, soil salinity and soil texture.

Class IV: Fairly good land, suitable for occasional or limited cultivation. Strong , very strong salinity, shallow depth, erosion, fine texture or excessive drainage. Such soils may not be economical to cultivate as they need intensive soil conservation and land management practices.

Class V: Not suitable for arable farming, but very suitable for grazing, have many limitations for the use of implements due to stoniness, or marshy condition.

Class VI: Well suitable for grazing or forestry, have moderate limitations of steep slope, severe erosion, limited soil depth, strongly gypsiferous, stony or sand dune areas.

Class VII: Fairly suitable for grazing or forestry, have limitations such as steep land subjected to erosion or very shallow stony soils having not enough available moisture

Class VIII: Extremely rough, rocky, arid, wet or extremely saline land suitable for wildlife recreation.

Factors determining classification

The external and internal or inherent characteristics of soil and land as well as environmental factors are to be taken into consideration while determining the capability of land

1. External features of land: Slope, Erosion features, Water-logging /wetness/marshy land etc.
2. Internal/Inherent soil characteristics: Surface soil texture, Effective soil depth, permeability and internal drainage, salinity and alkalinity, fertility etc.
3. Environmental factors

The land capability classes range from the best and intensive cultivable land to land I which has no value for cultivation, grazing or forestry, but may be suited for wild life, recreation etc. Thus lands under different capabilities can be classified into groups, classes, sub.classes and units from higher to lower level.

Land capability group: There are two broad groups

I. Land suitable for cultivation and other uses: This group includes four classes namely Class I to Class IV based on increasing intensity of hazards and consequent limitations of land use.

II. Land not suitable for cultivation: In this group there are four classes from Class V to Class VIII lands. These classes are very well suited to forestry, grassland and wildlife.

Increasing intensity of hazard and limitations of land use: The relative degree of limitations in land use with hazards is progressively higher from Class I to Class VIII (Table)

Suitability of land capability classes for different land uses

LC CLASS	Wild life	Forestry	Limtd grazing	Mod grazing	Intens. grazing	Lim. Cultvn	Mod Cultvn	Intens. Cultvn	Very intns Cultvn
I	✓	✓	✓	✓	✓	✓	✓	✓	✓
II	✓	✓	✓	✓	✓	✓	✓	✓	
III	✓	✓	✓	✓	✓	✓	✓		
IV	✓	✓	✓	✓	✓	✓			
V	✓	✓	✓	✓	✓				
VI	✓	✓	✓	✓					
VII	✓	✓	✓						
VIII	✓								

Land capability sub-classes: The land capability class is determined by the degree of limitations or intensity of hazard in land use. At this stage, it is not usable for planning, since only degree of difficulty is known. The kind of hazard or problem has not been identified. Within land capability classes, subclasses are determined by the kind of limitations in land use with hazards involved.

There are four land capability sub-classes and have the following priority:

Limitation/ hazards Symbol

(i)	Erosion and runoff	e
(ii)	Excess water/wetness	w
(iii)	Root zone limitations	s
(iv)	Climatic limitations	c

Sub-class (e) erosion and runoff: Susceptibility to erosion and past erosion damages are the major factors for placing soils in this sub-class. For example IIe will indicate moderate problems of erosion.

Sub-class (w) excess water/wetness: Includes soils where excess water is the dominant hazard in their use. Poor soil drainage, wetness, high water table and over flow are the criteria for classifying the land to this sub-class.

Sub-class (s) soil limitations within the rooting zone Includes land with soils which have such limitations as shallowness of rooting zone, stones, low moisture holding capacity, low fertility, etc. For example, IIs would indicate a moderate problem of stones affecting tillage or less effective soil depth.

Sub-class (c) climatic limitations Climate (Temperature/rainfall) is the major hazard in the use of land.

When the soils have two kinds of limitations the dominant one is shown first. Land capability sub-class is designated by the small letters, which follow the land capability class Roman numbers. For example, IIe, IIIw, IIs and IIc.

Land capability sub-classes provide information about the kind of conservation problem or limitations involved. The class and sub-class together provide the information about the type of limitation and kind of problem involved for, broad programme planning and conservation measures.

Land capability units: Land capability unit is the mal step in the land capability classification. Within each sub-class the land that is suited for essentially the same kind of management and the same kind of conservation treatment is designated as a land capability unit. Lands may have the same capability and sub-class but because of individual differences may not respond to the same treatment. In fact, the same treatment could be very harmful. Therefore, a land capability unit is essentially uniform in all major characteristics that affect its management and conservation. The sub-classes are further divided into units based on a specific management practice, to which crops respond. It is a grouping of one or more individual land units having similar potentials and limitations or hazards. These units are designated by ordinary numerals placed as subscript to the subclass letters.

1. Limitations of effective soil depth
2. Very heavy or light texture soil
3. Nature of material restricting root growth
4. Salinity or alkalinity

Thus the notations can be $IIIs_1$, $IIIs_2$, $IIIs_3$ etc.

Land capability sub classes: It is sub group of land capability classes. It indicate the kind of limitation in the management and use of the land such as erosion (e), climate (c), excess water (w), and soil limitation (s). It is indicated by adding limitation symbols to the capability class number. Eg. `IIe` - it indicate good cultivable land with limitation of soil erosion.

Land capability units: These are further sub divisions of the land capability sub classes. This classification is done for practical purposes. All the soils in a land capability unit are similar in characteristics and qualities to have similar potentialities and hazards

Importance of Land capability classification / Advantages of LCC

The classification of soils into capability groupings enables one to get the picture of

1. The hazards of soil to various factors which cause soil damage, deterioration and lowering of soil fertility.
2. It tells us about the various potentialities of soil
3. It enables the groping of land based on limitations for crop production. ie. Soils in one land capability class need similar management.
4. The system is simple and easy to present

Limitations of Land capability classification

1. In this classification more emphasis is attached to the limitations of soil rather than potential
2. It fails to classify the soils adequately for use other than arable use.
3. It cannot distinguish between an elite soil with no limitation and a unique soil that with many limitations are suitable for special kinds of land use.

LAND EVALUATION - PRODUCTIVITY RATING -PARAMETRIC APPROACH

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Land: A tract of land is defined as geographically a specific area of earth's surface. It's characters embrace all reasonably stable or predictable cyclic attributes of biosphere vertically above and below. This area including those of atmosphere, the soil and the underlying geology, the topography , the plant and animal population and the result of past and present human activity ,to the extend that these attributes exert a significant influence on present and future use of the land by man.

Land use: Any kind of permanent or cyclic human intervention to satisfy human needs for a complex of natural and artificial resources which together are called land use . This involves always specific areas and can be considered as a geographic concept.

Land use planning: The process of evaluation of land, alternative land use patterns and other physical, social and economic condition for the purpose of selecting and adopting the kinds of land use and courses of action best calculated to achieve specified objectives.
Before land use planning, one has to have an answer for two questions.

1. Where is the <u>best land</u> for the land use?
2. What is the <u>best land use</u> for this land?

Thus answering the above questions is nothing but, ***Land Evaluation***

Land evaluation is the process of estimating the potential of the land for alternative kinds of use. This includes productive uses such as arable farming, this livestock production forestry as well as uses that provide services or benefits like preservation fragile ecosystems, recreation, tourism, wildlife conservation. Land evaluation procedure compares the requirements of land use with the resources offered by the land assessment of land performance which is used for the specified purposes.

Land evaluation should answer the following basic questions

- How is the land currently managed and what will happen if practices remain unchanged?
- What improvement in management practices, with the present use are possible?
- What other uses of land are physically and economically and socially relevant?
- Which of these offer possibilities of sustained production or other benefits?
- What adverse effects physical, economic, social or environmental are associated with each use?
- What are inputs necessary for productive and alleviating the adverse effects?
- What are benefits from each use?

The evaluation process provides with a set of scenarios for decision by land use planners. Therefore land evaluation can be described as a step ahead of resources served and one which precedes land use planning. Thus land evaluation is the assessment of land performance when used for the specified purposes may be for

1. Irrigated farming
2. Forestry
3. Recreation
4. Urban development

Thus, we can say land development process involve the following steps

1. Inventory of land resources by survey , mapping and data collection
2. Land evaluation
    a. Classifying land
    b. Matching suitability to requirements of a particular land use
    c. Indicates the order of alternative uses
3. Land use planning- decision making
    i. Based on above information
    ii. And based on requirements of land use
4. Implementation- Results

Principles of land evaluation

The guiding principles of land evaluation are

1. Land suitability is assessed and land is classified with respect to the specified kinds of use.
2. Evaluation requires a comparison of the benefits obtained and inputs needed on different type of land.
3. A multidisciplinary approach is required.
4. Evaluation is made in terms relevant to the physical and economic and social context of the area concerned.
5. Suitability refers to use on a sustained basis.
6. Evaluation involves comparison of more than single kind of use.

Types of land evaluation

The result of land evaluation may be given in terms that are qualitative, quantitative physical or economic

Qualitative evaluation: The suitability of land for alternative purposes is expressed in qualitative terms only, such as highly, moderately or marginally suitable, or not suitable for a specified use. Qualitative evaluation is evaluation in employed mainly in surveys at a reconnaissance scale, or as a preliminary to more detailed investigation

Quantitative physical evaluation is one which provides quantitative estimates of the production or other benefits to be expected eg:- crop yields , rates of timber growth recreation capacity. This type of evaluation is most frequently carried out as the basis for economic evaluation. The drawback with this type of evaluation is that does not normally supply he basis for comparison between different forms of production.

Economic evaluation is one which includes results given in terms of profit and loss for each specified enterprise on each kind of land. Specific money values are applied to data from quantitative physical evaluation and there by obtaining the cost of inputs and value of production. Economic land evaluation is always required for project appraisal for most planning decisions and for private investments.

A further distinction in types of evaluation is that between *current* and *potential suitability*.

- *Current land suitability* refers to the value of land in it's present condition without major improvement.
- *Potential land suitability* refers to the value of land at some future date, if and when major land improvements have been carried out.

Levels of intensity and approaches

Three levels of intensity are common

1. *Reconnaissance* concerned with the broad inventory of resources and development possibilities at regional and national level.
2. *Semi detailed* levels concerned with more specific areas and aims such as development projects.
3. *Detailed level* concerning actual planning and design for farm level project.

Two approaches are commonly used

1. *Two stage approach*, with first stage being a qualitative land evaluation followed by a second stage of economical and social evaluation and
2. *Parallel approach* in which both land evaluation and socio economic feasibility carried out simultaneously

Land suitability classification

Land suitability classification is the process of appraisal and grouping of specific areas of land in terms of their suitability for defined uses.

Structure of suitability classification

1. Land suitability orders- reflecting kinds of suitability
2. Land suitability classes- reflecting degree of suitability within orders.
3. Land suitability subclasses- reflecting kinds of limitation within classes
4. Land suitability units- reflecting minor variants in management within subclasses

Land suitability orders

Order S-Suitable: Land on which sustained use of kind under consideration in expected to yield benefits which justify inputs without unacceptable risk of damage to land resources.
Order N-Not suitable Land which has qualities that appear to preclude sustained use of kind under consideration.

***Land suitability classes*:** The number of classes should be kept to the minimum necessary to meet the interpretation aims. Three classes are generally recognized within the order suitable and two classes in order not suitable.

Class S1 Highly suitable: Lands having no significant limitations to sustained application of given use.
Class S2 Moderately suitable: Land having limitations which in aggregate are moderately severe for sustained application of a given use.
Class S3 Marginally suitable: Land having limitstions which in aggregate are severe for sustained application of a given use.
Where additional refinement in necessary this should be achieved by adding classes and not by subdividing the classes. Within the order not suitable, there are normally two classes.
Class N1 Currently not suitable: Land having limitations which preclude the possibility of a given use with current technology at acceptable cost.
Class N2 Permanently not suitable: Land limitations are so severe as to preclude any possibility of use.

***Land suitability Subclass*:** Land suitability Subclasses reflect kinds of limitations and are expressed as lower case letters following the classes eg. S2m: Moisture deficiency; S3e:Severe erosion.

N1 (actually unsuitable and potentially suitable): Land units with very severe limitations which can be corrected
N2 (Unsuitable): Land units with very severe limitation which cannot be corrected.

The evaluation is carried out by the land characteristics with the limitation levels of the requirement tables.

The second method is more difficult and the approach is more accurate. According to the first method, a land unit with 1 or with 4 or even more S2 levels will be classified as S2, although it is clear that the land with 4 moderate limitations will have a lower a nor return as compared with the land with only one limitation. The second method considers land with several limitations of the same level as a lower class.

Parametric approach

The parametric approach is the evaluation of land characteristics consists in a numeral writing of the different limitation levels of the land characteristics in a numerical scale from a maximum (Normally 100) to a minimum value. If a land characteristic is optimal for the considered lad utilization type the maximum rating of 100 is attributed; If the same land characteristic is unfavourable a minimal rating is applied. The successful application of the system implies the respect of following rules;

1. The number of land characteristic to consider has to be reduced to a strict minimum to avoid repetition of related characteristics in the formula, leading to a depression of land index. Therefore, all land qualities expressed by one characteristics should be rated together. As such the single rating of texture should be done with regard to the capacity to retain nutrients, water availability permeability and one should avoid to introduce separate rating for these single qualities.
2. An important characteristic is rated in a wide scale (100-25), a less important characteristic in a narrower scale (100-60). This introduces the concept of weighing factor. Eg. Studying the suitability for irrigation the very important factor of texture is rated from 100-25, the less important factor of Calcium carbonate content from 100-80.
3. The rating of 100 is applied for optimal development or maximum appearance of characteristic. If, however, some characteristics are better than the usual optimal, the maximum rating can be chosen higher than 100. Eg. If the most common organic content of the crop 15 cm in a specific area varies from 1-1.5%, the rating of 100 is applied for that carbon level. Soils with more than 1.5% O.C.are attributed a rating of more than 100 for Organic Matter.
4. The depth to which the land index has to be calculated must be defined for each land utilization type. If one considers that for a specific land utilization type all horizons have a similar importance the weighted average of a profile section until the considered depth is calculated for each characteristic. If at the other hand one considers that the importance of a horizon becomes greater when his position is nearer to the surface, a different proportional rating can be given to the depth sections of the profile in such a way that they increase when approaching the surface. Therefore the profile can be subdivided into equal sections; to each of these sections one attributes a "depth correction index" (weighting factor) starting with a minimum value in depth and becoming gradually greater when approaching the surface section.

The depth to be considered should coincide with the normal depth of the root system in a deep soil. The weighting factors or depth correction indices suggested, are given in Table 1.

Table 1. Number of sections and weighting factors for different depths

Depth (cm)	Number of equal sections	Weighting factors
125-150	6	2.00-1.50-1.00-0.75-0.50-0.25
100-125	5	1.75-1.50-1.00-0.50-0.25
75-100	4	1.75-1.25-0.75-0.25
50-75	3	1.50-1.00-0.50
25-50	2	1.25-0.75
0-25	1	1.00

Example: application to textural appraisal of a soil profile for a deep rooting perennial crop.

Optimal depth : 150 cm

The profile texture is as follows:

0-30 cm : sandy clay loam
30-100 cm : clay
100-150 cm : loamy sand

The textural ratings are as follows:

Sandy clay loam : 85
Clay : 100
Loamy sand : 50

The textural rating of the profile calculates as follows:

Use 6 sections of 25 cm with weighting factors: 2 - 1.5 - 1 - 0.75 - 0.50 - 0.25

First section of 25 cm (0-25 cm): 25 x 2 x 85= 4,250
Second section (25-50 cm): 5 x 1.5 x 85 = 637.5
20 x 1.5 x 100 = 3,000
Third section (50-75 cm): 25 x 1 x 100 = 2,500
Fourth section (75-100 cm): 25 x 0.75 x 100= 1,875
Fifth section (100-125 cm): 25 x 0.5 x 50 = 625
Sixth section (125-150 cm): 25 x 0.25 x 50= 312.5

Sum: **13,200.0**

Textural rating profile: 13,200 : 150 = 88

The limitation scale as defined earlier can be complemented by a parametric approach leading to a combined limitation-parametric method of evaluation. The ratings to be selected for the different limitation levels are suggested in Table 2.

Table 2. Limitation levels and their ratings

Symbol	Intensity of limitation	Rating
0	no	100-95
1	slight	95-85
2	moderate	85-60
3	severe	60-40
4	very severe	40-0

Table 2. shows an example of a framework that can be used for the evaluation of land characteristics following the combined limitation-parametric approach.

The methodology suggests in the first place an evaluation of the climate, whereby the climatic characteristics are regrouped in 4 groups:

- characteristics related to radiation;
- characteristics related to temperature;
- characteristics related to rainfall; and
- characteristics related to relative air humidity.

For calculation of the climatic index the lowest characteristic rating of each group is used. This is because there is always a strong interaction between characteristics of the same group and also because they do not act together. The climatic indices are transformed to climatic ratings to be used in the total land evaluation

Table 3.. Framework for representation of the requirements for a specific land utilization type in terms of limitation levels and ratings

LAND CHARACTERISTICS	Land classes, limitation level and ratings					
	S1		S2	S3	N1	N2
	0		1	2	3	4
	100	95	85	60	40	25
CLIMATE (c)						
TOPOGRAPHY (t) - slope (%) WETNESS (w) - flooding - drainage PHYSICAL SOIL CHARACTERISTICS (s) - texture/structure - coarse fragments (vol. %) - soil depth (cm) - $CaCO_3$ (%) - $CaSO_4$ (%) FERTILITY CHARACTERISTICS (f) - apparent CEC (cmol(+)kg^{-1} clay) - sum exchangeable basic cations (Ca + Mg + K) (cmol(+)kg^{-1} soil) - pH in water - organic carbon (%) SALINITY AND ALKALINITY (n) - EC (dS/m) - ESP (%)						

The climatic index, as well as the land index, are calculated from the individual ratings. The calculation of these indices can be carried out following two procedures

1. ***Storie method***

$$I = A \times \frac{B}{100} \times \frac{C}{100} \times \ldots$$

(A, B, C . . . : ratings)

2. ***Square root method*** (Khiddir, 1986)

$$I = R_{min} \times \frac{A}{100} \times \frac{B}{100} \times \ldots$$

I = index
R_{min} = minimum rating
A, B, ... : other ratings besides the minimum rating

Suitability classes are arbitrary defined according to the value of the index;

Suitability class	**Land index**
S1	100-75
S2	75-50
S3	50-25
N	25-0

When we compare the results obtained by the limitation method with the results of the parametric method, we realize that in extreme cases classes obtained with one method may differe from classes obtained by the other method.

Indeed if we consider the maximum number of characteristic ratings as related to climate, topography, drainage, flooding, combined texture - coarse fragments - depth, and 3 fertility ratings (apparent CEC, basic cations or pH and organic carbon) for the humid (sub) tropics, we reach at a number of eight. In arid areas, the fertility characteristic ratings will be replaced by $CaCO_3$, $CaSO_4$ and salinity-alkalinity ratings to reach also a maximum of eight.

The maximum land index of an S1-land unit can be considered as 100. The lowest index could be the result of the lower rating 85 of 4 slight limitations, while the other 4 characteristics could present the lowest 95-rating of the 0-level.

In such case, the lowest index of the S1-land unit, defined according to the limitation method, will be:

Storie method: Land index = $85 \times 0.85^3 \times 0.95^4 = 43$
Square root method: Land index = $85 \times 0.853 \times 0.95^4 = 60$

The upper land index of an S2-land unit with one moderate limitation, and all other characteristics optimal will be the maximum rating of the moderate limitation level, being 85. The lowest value of the S2-land unit with 3 moderate limitations rated 60, could present the other 5 characteristics with the lowest rating, 85, of the slight limitation level.
This situation will produce following land indices :

Storie land index = $60 \times 0.60^2 \times 0.85^5 = 10$
Square root land index = $60 \times \quad 0.60^2 \times 0.85^5 = 24$

The upper land index of an S3-land unit presents the highest rating of the severe limitation level being 60 and all other ratings 100; the corresponding land index will be 60. If the lowest value is defined by 2 lower ratings of the severe limitation level, being 40, and all 6 other ratings as lower rating of the moderate limitation level, being 60, we obtain following indices :

Storie land index = $40 \times 0.40 \times 0.60^6 = 1$
Square root land index = $40 \times \quad 0.40 \times 0.60^6 = 5$

The highest land index of a N-land unit with an upper rating of 40/25, of N1 and N2 respectively, for the severe limitation level, and all other ratings 100, will be 40 or 25, respectively for N1 and N2. The lowest values will reach the zero-level.

The relationship between the calculated land indices and the corrected land indices is presented in graphs. Using these graphs, we can compute a corrected land index from each calculated parametric value. The corrected land indices permit a complete resemblance in the valuation results from limitation and parametric methods.

SOIL FERTILITY INFORMATION AT FARM LEVEL – A CASE STUDY

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The research programme was undertaken with the intention to generate data on the fertility parameters of the soil resources of the main campus, Vellanikkara and to utilise the data for further analysis of fertility constraints towards crop production. A detailed inventory on the fertility of soil resources of KAU campus and its consequent use in conjunction with new technologies generated would facilitate extrapolation of the technologies to other areas of similar soil characteristics within and outside the state. Delineation of the fertility constraints would also help in rational use of fertiliser resources for crop management within the campus.

A soil map of the main campus of Kerala Agricultural University prepared in 1976 at 1:4000 scale by the Soil Survey Wing of the Dept. of Agriculture, was available for further refinement. This map has series descriptions and records of some permanent features of the soilscape of the campus.

The total area of the campus is 384.56 ha. The inventory under report was carried out covering the 37 blocks, covering 380 ha of cultivated land. The physiography of the area is typical of a very old landscape, characterised by nearly level to gently sloping undulating plains with a few isolated hills formed due to the vertical movement of the tectonic process resulting in upheavals. The climate of the area is humid tropical with an average annual rainfall of 3324mm and temperature ranging from 20.8 to 36 °C. The major rock type observed in the area is granite gneiss. Water received from the Peechi dam through the Peechi canal forms good sources of irrigation for the area. Dug wells at different points and natural ponds in a few locations form supplementary sources of water. The area comprises Kerala Agricultural University Head Quarters, College of Horticulture, College of Forestry, College of Co-operation, Banking and Management, Radiotracer Laboratory, Vegetable seed production unit, Orchards, STCR Research Schemes, Instructional Farm, Central Nursery, Forestry Experimental Plots, Rubber Estate, Botanical Garden, Cashew Research Station, Pineapple Research Station, Pepper Research Schemes, Cadbury Cocoa Project, NBPGR Experimental Plots and Water Management Project. A variety of crops are cultivated in this part of the campus.

Major crops of the study area are Rubber, Coconut, Mango, Cashew, Guava, Pine apple, Banana, Cocoa, Minor fruits, Vegetables, spice crops etc.

In the base map, there are 3 soil series namely Vellanikkara I, Vellanikkara II and Vellanikkara III were delineated. The soil series were tentatively distributed into 12, 14 and 12 phases respectively for the current investigation on soil fertility.

A chain survey document of the main campus was referred for preparation of individual block maps of the campus. The block maps were then mosaiced to prepare the whole campus map at 1:2000 scale. Eighty meter grids were then laid on the base map measuring 1cm = 20 metres i.e. 4cm grids. Ammonia prints of the base map were used for field traversing and collection of samples. Sampling sites were located at 80 x 80m spacing using measuring tapes and rods.

Soil samples were collected from selected sites identified from the base map. Area occupied by buildings and roads were avoided. A 40cm deep pit was dug out at each sample site. Surface samples from 0-20cm depth and subsurface samples from 20-40cm depth were collected. About 1.5kg soil sample each, after uniform mixing, was taken in a polythene bag and labeled for transportation to the laboratory. The surface and subsurface samples were analysed by standard procedures to record their physical, chemical and electrochemical properties especially available nutrients and other fertility parameters.

Phase level mean tables of various soil physical and chemical parameters are provided in the ensuing text. The base map of the campus, prepared out of chain survey at 1: 2000 scale was scanned through an A_0 scanner and the raster image was digitised on-screen using Auto CAD Release 14. The original soil map of the campus was also computerised in the same way. Altogether 175 polygons covering 38 phases of the three soil series were digitised. The digitised maps were converted to DXF format and exported to PC ARC INFO software, which is a popular software used for developing Geographic Information Systems (GIS). The files were then subjected to topology building and the same were converted to PC ARC INFO coverages.

Phase level mode data on various soil characteristics generated during the study were attached to respective polygons in the PC ARC INFO coverages. Thematic maps were generated using GIS techniques.

The themes used for map preparation were organic carbon, available phosphorus and potassium. By overlaying these themes with crop layer, fertilizer recommendations based on soil fertility status can be made. The updating of fertility status may done for specific locations as per the requirement.

Soil resource mapping of Palakkad District, Kerala

Palakkad district of Kerala is one of the districts selected for comprehensive development under the *Rashtriya Sam Vikas Yojana* of the Government of India. The work was carried out by the combined effort of NBSS&LUP, KAU and Dept. of Agriculture. The main objective of this scheme is to address the problems in relatively backward districts especially those with low agricultural productivity. Agricultural development forms a large segment of sectoral development envisaged for the district. Rice is the most important crop of Palakkad district, which, consequently, is often described as the granary of Kerala. However, the average yield of rice is only 2209 kg/ha. Similarly low are the yields of other crops such as coconut, arecanut, cotton, groundnut *etc.*

The detailed soil survey was taken up in panchayats with more than 25 per cent of their geographical area under rice to generate detailed information on land and soil qualities. The data so generated shall form the basis for refining the existing fertilizer recommendation for rice. In addition, the study shall identify land- and soil-related constraints to crop production, especially availability of macronutrients and micronutrient availability from soils.

Elapully panchayat is one among the 42 panchayats selected for study in the district. To fulfill the objectives the detailed soil survey and soil fertility assessment of the panchayat were undertaken. The programme comprised mapping the soils at phase level and soil-fertility mapping. This report contains the findings of the study including the spatial distribution of different kinds of soils in Elapully panchayat and their plant nutrient fertility.

Location and other details: The panchayat is located towards the eastern end of Chittur taluk in Palakkad district. It lies between 10°43'02" and 10°47'35" North latitudes and 76°42'33" and 76°50'02" East longitudes. The panchayat is bounded on the east by Kozhinjampara and Nallepally panchayats, south by Nallepally and Polpully panchayats, west by Puthusserry, Marutha road and Kodumbu panchayats and north by Puthussery and Vadakarapathy panchayats. The total geographical area of the panchayat according to revenue records is 4,907 ha.

The landscape of the panchayat comprises low hills, valleys and nearly level plains. The state highway linking Palakkad and Pollachi town passes through the middle of the panchayat. The general slope of the land is north to south. River Korayar, originating in Tamil Nadu passes through part of the panchayat and then forms the northern boundary of the panchayat. Vandithodu, a stream, forms the southern border of the panchayat. The total population of the panchayat is 35,509.

Agricultural importance: he panchayat has long been agrarian. Most lands were single-cropped in the absence of irrigation facilities. Double-cropped lands were confined to small commands of tanks and to lands along the streams. Organic manures were the only source of plant nutrients. Large tracts of land were barren due to non-availability of water. Rice yields before nineteen forties were 0.6 to 1.2 tonnes per acre.

Scientific agriculture made inroads into the panchayat in the nineteen forties with supply of chemical fertilizers. Weirs were constructed across streams and irrigation facilities were created. When Walayar project was completed, the area under irrigation was increased. The land reforms paved the way for increased production and diversification of crops. The rice productivity increased to the level of 1.5 tonnes per acre.

Different major and minor projects together provide irrigation for nearly half the land area of the panchayat. Judicious use of the water can extend the area considerably.

Coconut is the dominant upland crop. It is also grown on bunds of rice fields. The details of land use are presented below:

Land use in Elapully panchayat

Land use	Area (ha)
Total geographical area	4907
Misc. tree crops	8
Cultivable barren lands	256
Barren land	26
Agricultural lands	4625
Rice (Viruppu)	1724
Rice (Mundakan)	1724
Coconut	800
Sugar cane	60
Banana	250
Pulses	80
Garden land	317
Vegetables	40
Tapioca	80
Mango	120

Climatic factors: Elapully panchayat in the eastern part of the Palakkad plains is one of the driest panchayat in the district. The climate can be described as dry subhumid tropical. The mean annual temperature of the panchayat is 27.7 °C. March and April are the hottest months with mean temperature of 31 °C and July is the coldest with mean temperature of 25 °C. July has the lowest mean monthly temperature in the year because of the SW monsoon rains.

The mean annual rainfall (1449.3 mm) exhibits variation over the years in the range 1140 to 1866 mm. Rainfall is received mainly from SW monsoon. The premonsoon rains received during April-May contribute 144 mm to the average annual rainfall. The mean SW monsoon rainfall is 1084.5 mm and ranges from 874 to 1332.4 mm. The SW monsoon sets in by the first/second week of June in the panchayat and extends to the first week of September. Second and third weeks of September are fairly dry. The NE monsoon starts by the second week of October and ends by second week of November and then tapers off. The average rainfall received during NE monsoon is 220.8 mm. December to March is the dry period, January being driest.

Survey Methods: Detailed soil surveys are made to provide information about the soils of specific geographical areas. The information comprises a description of the soils and data on their spatial distribution, and a discussion on their potentials, limitations and management for specified uses. Besides soil characteristics, information is provided on the external land features, the kinds of uses to which these soils are put to and other observations that have a bearing on the potential use.

The stages involved in detailed soil survey and generation of this report can be broadly grouped into (1) preparatory work, (2) field survey and mapping, (3) field review and correlation, (4) laboratory investigations, (5) soil fertility investigations, (6) digital data processing in a GIS and generation of maps, and (7) preparation of the report.

a.*Preparatory Work:* The detailed soil survey of Elapully panchayat employed the cadastral maps of the panchayat as base. Cadastral maps on which detailed soil survey of the panchayat is based were generated through conventional ground survey and depict cadastral boundaries (land parcels of specified ownership) with survey numbers, drainage and communication lines, and many permanent features. These maps procured from the Office of Survey and Land Records were scanned using optical drum scanner at 200 dpi, printed on a wide format printer and laminated on the back and provided to field parties for use as base map. Available reference material on geology, previous soil surveys covering the area, geomorphology, land use/land cover, etc., were collected before the survey was undertaken.

b. *Field Survey and Mapping*: The soil surveyor has undertaken an extensive traverse of the survey area and followed by soil profile observations along transects drawn across identified landforms (contiguous) and/or at random sites, supported by additional examinations in the field. During the course of traverse of the panchayat the soil surveyor identified and selected areas for taking up soil profile examination along transects. Transects were selected in such a way as to provide a picture of soil variation with landscape segments. Soil profiles were studied to record characteristics of the soils such as horizons, colour, texture, kind and amount of coarse fragments, size and shape of aggregates, consistence at various moisture contents, distribution of pores and plant roots, soil reaction and other features to enable identification of soils and, later, to grouping of similar soils.

On completion of each transect, the soil profile data were arrayed to group the profiles into soil series, the lowest category in Soil Taxonomy. Soil series are differentiated based on the kind and arrangement of horizons within the profile. The series is the most homogeneous class with individuals having similar horizons and soil properties and behaving uniformly for a given level of management. The map unit delineations in the detailed soil survey of the panchayat are phases of soil series. Division of the soil series into phases is based primarily on surface soil texture, slope, erosion, presence of surface stoniness/gravelliness, salinity, etc. Phases of the soil series were spatially delineated on the cadastral base.

c. *Field Review and Correlation*: Field review and correlation ensure uniformity, consistency and quality of soil mapping. Field reviews and correlations were carried out in three phases, initial, progressive and final. The main purpose was to verify the accuracy of landform delineation, establishment of soil-landscape relationships, and preliminary and progressive legends and related data. The soil series of Elapully panchayat were identified and correlated based on standard norms. A few typifying pedons were selected for identified soil series for working out range in characteristics following standard methods. While the soil survey was in progress, horizon-wise soil samples were collected from some of the soil profiles in the area, which were regarded as typical for the identified soil series. Progressive arraying of the soil profile data provided for final selection of a pedon as typifying the soil series. The arraying also helped in defining the range in characteristics of the soil series.

d. *Laboratory Investigations*: The soil samples upon arrival at the laboratory were processed. The sieved soil sample and coarse fragments were weighed to determine coarse fragment content by weight. The different parameters assessed were Particle size distribution, Cation exchange capacity and exchangeable bases, Soil reaction, Electrical conductivity, Organic carbon, Exchangeable acidity, Extractable acidity, Exchangeable bases, Available macronutrients like nitrogen, phosphorus, potassium, sulphur and micronutrients, Calcium carbonate equivalent and Lime requirement.

e. *Soil Fertility Investigations*: Composite surface soil samples were collected from each cadastral survey plot (parcel of land) for determination of soil reaction, electrical conductivity, and content of plant-available nitrogen, phosphorus, potassium, iron, manganese, zinc and copper. The sampling excluded parcels of land used for purposes other than agriculture.

The estimation of plant-available nitrogen in soil was made from the organic carbon content of soil assuming C:N of soil organic matter to be 10:1, and for other elements by direct estimation after extraction with appropriate reagents. The methods employed have been presented in the laboratory investigation section.

The criteria used for categorizing soils with respect to their soil reaction and plant-available nutrient levels are as follows: the soil reaction is classified as from Ultra acid (pH=< 3.5) to very strongly alkaline (pH=> 9.0), major nutrients as low-medium-high and available Zn & Cu as deficient and adequate. The micro-nutrient elements iron and manganese were found to be adequate in all the soils.

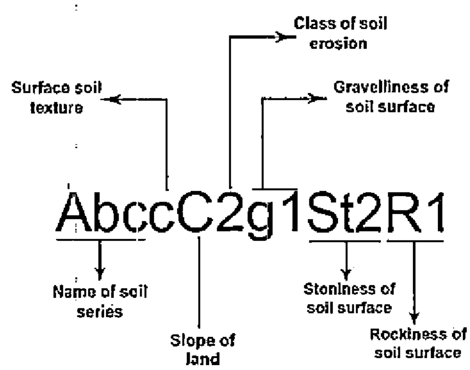
f. *Digital Data Processing*: The map data processing was carried out using a computerised Geographic Information System and related softwares. All the relevant data layers were assembled before map composition and checked for consistency and spatial correspondence. The map was composed using different data layers, legends were constructed and suitable layout was designed.

For the preparation of soil fertility map an additional program was developed using VB Script. The overlay of soil fertility map and soil map facilitated extraction of soil fertility information specific for each soil map unit (phases of soil series).

g. *Map Unit Composition*: Each map unit delineation on the soil map represents an area dominated by one major phase of a soil series. For series and phases of series there are precisely defined limits for the properties of the soils.

Explanatory notes on the symbols used in map units: The soil map units (phases of soil series) are depicted on the map by symbols that are indicate of name of the soil series, texture of surface soil, slope of the land, intensity of soil erosion, gravelliness/stoniness/rockiness and other features, if any.

For example, the map unit AbccC2g1St2R1 is a phase of Abc series. The first three characters (alphabetical) signify the name of the soil series, the fourth (lower case) indicates the texture of the surface soil, the fifth (upper case) indicates the slope of the land, the sixth (numeral) indicates the intensity of soil erosion, the seventh (lower case) together with the eighth (numeral) following indicates gravelliness on the surface, the ninth and tenth together (upper and lower case) with the eleventh (numeral) indicates stoniness and the twelfth (upper case) together with thirteenth (numeral) indicate rockiness.



Explanation of the symbols (alphabets/numerals) are presented in the following sections.

Soil Texture

Symbol	Soil texture
a	Sand
b	Loamy sand
c	Sandy loam
d	Loam
e	Silt loam
f	Clay loam
g	Silty clay loam
h	Sandy clay loam
i	Sandy clay
k	Silty clay
m	Clay

Slope class

Symbol	Slope %	Slope class
A	0-1	Level to nearly level
B	1-3	Very gently sloping
C	3-5	Gently sloping
D	5-10	Moderately sloping
E	10-15	Strongly sloping
F	15-25	Moderately steeply sloping
G	25-33	Steeply sloping
H	>33	Very steeply sloping

Erosion class

Symbol	Erosion class
e1	Slight
e2	Moderate
e3	Severe
e4	Very severe

Gravelliness

Symbol	Surface gravel (% areal cover)	Gravelliness class
g1	15-35	Slight
g2	35-50	Moderate
g3	50-90	Severe

Surface stoniness

Symbol	Stones (% areal cover)	Stoniness class
St1	15-35	Slight
St2	35-50	Moderate
St3	50-90	Severe

Surface rockiness

Symbol	Rocks (% areal cover)	Rockiness class
R0	<2	Negligible
R1	2 to 10	Fairly rocky
R2	10 to 25	Rocky
R3	25 to 50	Very rocky
R4	50-90	Extremely rocky
R5	>90	Rock outcrops

Additional Symbol: 'p' appearing at the end of a map unit symbol represents a phase of the soil series wherein the soils when wet are extremely slushy (locally termed *poondal padam*).

h. *Preparation of the Report*: The report gives brief description of the panchayat, the general agricultural land use and detailed descriptions of the overhead climate, methods followed and the map units represented in the soil map. It is oriented for easy extraction of information by the ultimate user, the farmer. Delineation of soil map units on a cadastral base facilitates extraction of soil information for each land parcel.

Criteria used for Fertility mapping

The criteria used for categorizing soils with respect to their reaction and plant-available nutrient levels are presented below:

Soil reaction (pH)

< 3.5	Ultra acid
3.5-4,4	Extremely acid
4.5-5.0	Very strongly acid
5.1-5.5	Strongly acid
5.6-6.0	Moderately acid
6.1-6.5	Slightly acid
6.6-7.3	Neutral
7.4-7.8	Slightly alkaline
7.9-8.4	Moderately alkaline
8.5-9.0	Strongly alkaline
> 9.0	Very strongly alkaline

Plant-available nitrogen content

Low	< 0.76% soil organic carbon
Medium	0.76-1.50% soil organic carbon
High	>1.50% soil organic carbon

Plant-available phosphorus

Low	< 10.0 kg P/ha
Medium	10.0 – 24.0 kg P/ha
High	> 24.0 kg P/ha

Plant-available potassium

Low	< 115 kg K/ha
Medium	115 – 275 kg K/ha
High	> 275 kg K/ha

Plant-available zinc

Deficient	< 1.00 ppm (when HCl was used as extractant)
Adequate	> 1.00 ppm (when HCl was used as extractant)
Deficient	< 0.60 ppm (when DTPA was used as extractant)
Adequate	> 0.60 ppm (when DTPA was used as extractant)

Plant-available copper

Deficient	< 1.00 ppm (when HCl was used as extractant)
Adequate	> 1.00 ppm (when HCl was used as extractant)
Deficient	< 0.12 ppm (when DTPA was used as extractant)
Adequate	> 0.12 ppm (when DTPA was used as extractant)

Lime requirement of the soils: Lime requirement was estimated for soils with acid reaction. The pH of the soil (1:2.5 soil:water) formed the basis. The general formula used was

Lime requirement (t $CaCO_3$ ha^{-1})= ΔpH x 0.3375

where ΔpH = required pH (6.5) – measured pH

Assumptions used were

1. Acidity equivalent = 0.1 meq per 100 g soil for 0.1 unit change in pH
2. Clay content of soil is 30 per cent

Cation exchange capacity of soil is 10 cmol (+) kg^{-1} soil.

Explanatory notes on Fertility map: This map provides information on classes of soil reaction and plant-available macronutrients and micronutrients for individual land parcels (with survey numbers) in the cadastral map. To know the soil reaction and nutrient content of a specific parcel of land, locate it on the map by its cadastral survey number, which is given by the first line of numerals above the vertical set of coloured boxes.

The available nitrogen, phosphorus and potassium contents of the surface soil are depicted as coloured boxes with the symbols N, P and K respectively to the side. The colour of the box for each nutrient indicates the availability: Red for low, Yellow for medium and Green for high availability. The levels of available copper and zinc are also depicted as coloured boxes, red for inadequate and green for adequate availability.

PLANNING FOR WATERSHED BASED DEVELOPMENT: EXPERIENCES AND PROSPECTS IN KERALA

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Abstract

The decentralized planning program through People's Participation is now being established in Kerala has set focused economic results at various levels of development. It is important at this stage to make these results sustainable. Hence it becomes necessary to address the issues of spatial planning in the biophysical environment. Therefore it is imperative to involve the eco-region into the planning system for conformity with natural laws. A micro watershed is an ideal development unit for achieving this objective. The Watershed approach represents the principal vehicle for transfer of rain-fed agriculture technology. A watershed is a geo-hydrologic unit draining at a common point by a system of streams, which makes it an ideal planning unit for conservation of soil, water and biomass; and encourage the sustainable development of the area by empowering people at the local level to manage their own resources. Watershed development provides immense scope for effective integration of different sectoral programs, primarily based on a 'ridge to valley' approach. It also enables clarity on issues like sustainability, equity and participation that are addressed in decentralized planning. A state wide effort has been initiated during the third year (1999-2000) of the 9th Plan, with people, their elected representatives, activists, non-governmental organisations, academicians and officials from agriculture and allied departments of the Government of Kerala for understanding their respective micro watersheds and preparation of a "Block Level Master Plan for Watershed based Development" in each of the 152 Block Panchayats of Kerala. This paper briefly highlights the significance, framework and organizational setup for the Watershed Based Development in People's Planning Campaign along with the program implementation, its present status, initiatives taken under the DSP for the Eleventh Five Year Plan in Kerala and Government of India's approach to the 11th Plan.

Key Words: *Decentralized Planning, Micro Watershed, Watershed Based Development, Participatory Approach, Land, Water, Biomass*

Introduction

As per the 73rd and 74th amendments, the then Government of Kerala, implemented the "Decentralized Planning" in the Panchayat Raj Institutions (PRIs) with effect from 2nd October, 1996 towards the last lap of the Eighth Five Year Plan. The Government succeeded thereafter, introduced the Ninth Five Year Plan as the "People's Plan Campaign (PPC) for Decentralized Planning" with functional, financial and administrative autonomy to the Local Self Governments (LSGs) of Kerala. This program was executed in six phases in which the first phase was devoted to participatory planning to identify local needs and building up grass-root level institutions (Grama Sabha), followed by the second phase where "Development Report" were prepared and presented in the "Development Seminar". The third phase was to setup the" Task Forces for Project Formulation and Preparation of the Shelf of Projects" while the fourth phase was to train the "Elected Representatives for the Formulation of grass root level plans". The fifth phase was for the "Preparation of the Higher Tier Plans of the Block and Zilla Panchayats" whereas the sixth phase was to identify the "Voluntary Technical Corps (VTC) for the appraisal of the plans submitted by the LSGs. After this phase the decentralized planning program became an administrative responsibility of the LSGs. It is true that, with the limited experience of the elected representatives and officials, many of the LSGs found it difficult to efficiently manage the functional, financial and administrative autonomy vested to them. In many of the sectoral projects, lack of forward-backward linkages and integrated approach has affected the quality of the output. Integration of projects on watershed basis had been proposed from the inception of the PPC, however, in practice watershed planning remained a mirage in the absence of adequate technical details, logistics and other support. Hence during the third year of the PPC, a major scheme has been introduced to implement through the Block Panchayats to delineate all the micro watersheds in Kerala and prepare their "Block Level Master Plan for Watershed based Development (BMPWD). This program successfully completed delineation of all the micro watersheds (area of about 500-600 ha) of the state (about 7000 micro watersheds) and prepared "Block Level Appraisal Reports" (BAR) for all the 152 Block Panchayats. The micro watershed reports were presented in the respective (?) "Samagra Vikasana Grama Sabhas" (SVGS) held in the month of November-December 2000 and identified about fifteen people (Watershed Study Team –WST) from each of the micro watersheds for conducting cadastral level primary data collection for the preparation of Vikasana Rekha and Action Plans.

After eight months of Kerala's unique approach to the Watershed based Development program, the Planning Commission of the Government of India, in its approach paper to the Tenth Five year Plan released on 1st September, 2001; under the Sectoral Policy Issues (3.9) summarizes that " Watershed Development Programs are being implemented by several departments of Government of India, often with different and conflicting guidelines. Even when approach or guidelines are common, sanction of funds is done by different departments and each does separate monitoring. The need for 'a Single National Initiative' has been felt for some time, and was also articulated in the 1999-2000 budget speech of the Union Finance Minister and in the President's address for 2000-2001. Evaluation reports have shown that watershed projects cannot succeed without full participation of project beneficiaries and careful attention to issues of social organization. This is because, success depends on consensus among a large number of users. Moreover, collective capability is required for management of common property and for new structures created during the project". The Hon. Chief Minister of Kerala, in his address to the meeting of the National Development Council convened by the Government of India and the Planning Commission on 12th September, 2001 at Vigyan Bhawan, New Delhi, suggested to "Introduce integrated watershed management practices in at least half of the nation's rain fed areas" with monitorable targets. The Tenth Five Year Plan of Kerala - Draft Guidelines, prepared by the State Planning Board (October 2001) visualize "an integrated view of land, water and biomass translating itself into watershed management with building blocks at the local government level built up to river basin level management plans.......". Also suggested that "in the case of water resources or biomass development, large irrigation schemes are no longer relevant. Appropriate micro level water harvesting, water conservation and water management has to be adopted". It is true that India is still a backward agrarian country and rural poverty alleviation program has to be based on rural resources like soil, water, biomass and manpower. It was the understanding of the necessity of converging these elements that gave birth to the concept and program of watershed development. The Government of India in its Eleventh Plan Aproach document, the chapter on "Sectoral Policies for the Eleventh Plan", Sub section 3.1(d) on "Water Management and Irrigation" specifically propose that *"Watershed management, rainwater harvesting and ground water recharge can help augment water availability in rainfed areas. Building structures for water management and managing them also provides opportunities for employment generation in rural areas. In addition the enhanced productivity of land will generate its own employment. The National Rainfed Areas Authority to be set up in the current year provides a vehicle for developing concerted action plans for rainfed areas in close consultation with state governments". It also states that "with an estimated 80 million hectares needing treatment, and average expenditure of Rs.10,000 per hectare, the total requirement of funds is about 80,000 crore. For this magnitude of funding to be feasible during the 11th Plan, it is absolutely essential; that these programs be converged with or at least supplemented by the Employment Guarantee Program funding local level schemes which conserve moisture and recharge ground water".*

Previous Work

Rich experiences has been accumulated over the past two decades through the untiring efforts of committed activists like Anna Saheb Hajare (Rale Gan Sidhi in Madhya Pradesh), P.N.Mishra (Sukhomajri in Haryana), Rajendra Singh (Ruparel in Rajasthan) and many others to give credence to the participatory watershed development concept in India. However this approach in the world is rare. It is important to note that the participatory watershed development programs are slowly picking up in the developing and under developed nations. The most important aspect of the program is the sustained community action based on watershed principle commonly known as "ridge to valley" approach. Thus watershed development is a program that evolved over a period of time and now identifies the integrated interaction between various Natural Resources belonging to a watershed, which is a natural phenomenon given rise to and generated by the flowing water. There are many watershed development programs undertaken in different parts of Kerala under the Westernghat Development Program (WDP), National Watershed Development Program for Rainfed Areas (NWDPRA), Drought Prone Areas Program (DPAP), National Wastelands Development Board (NWDB) and AHARTS, of which few are completed and the rest is in various stages of completion. However, it is not yet clear that how far these programs could achieve the objectives originally targeted. Hence it is explicitly argued that "Watershed Based Development" is one of the prime areas where the country and Kerala in particular may concentrate in the coming decades by integrating with Local Self Governments for achieving sustainable development as is envisaged in 11th Five Year Plan Approach documents of the Central and State Governments.

The Ninth Five year plan in Kerala opened the way for decentralized planning with people's participation at the LSGs. In order to re-enforce the ongoing local level development in the LSGs (Grama and Block Panchayats), preparation of a "Block Level Master Plan for Watershed Based Development (BMPWD)" has been formulated during the third year (1999-2000) of the decentralized planning program. This program is slowly picking up at present. The decentralized planning program in Kerala is in its Eleventh year of activity. Now the program on decentralized planning is established as an administrative responsibility of Local Self Governments (LSGs) in Kerala. Even though it brought in tremendous changes in the grass-root level attitude on development and social system in general, there exists scope and need for improvisation of procedure to stabilize the system ensuring sustainability, equity and participation. Hence now the r thrust is to be given for a holistic, resource based, spatial planning approach to improve the present system. It is in this context that the Watershed Based Planning and Development is considered to re-enforce the ongoing local level development program for which an associate campaign started to evolve development plans on the basis of micro watersheds (500 ha) and to prepare a "Block Level Master Plan for Watershed Based Development". The framework conceived here encompass all the capabilities of the ongoing plan campaign modulated within the intrinsic potential of a watershed based 'ridge to valley' approach requires preparation of the following for all the 152 Block Panchayats of the State.

1. A Watershed based Appraisal Report (WAR) at the Block Level,
2. A Development Report of each micro Watersheds (WDR) of the Block,
3. An Integrated and Perspective Action Plan for each micro Watersheds (WAP), and
4. A " Block Level Master Plan for Watershed Based Development" (BWMP).

The following were the institutional arrangement for the program.

1. Grama Sabha (GS) of wards falling within the boundary of micro watershed,
2. Watershed Study Team (WST) for each watershed (15 to 20) from Grama Sabha,
3. Watershed Committee (WC) for each micro watershed (6) elected from GS,
4. Watershed Development Council (WDC) constituted at the Block Panchayat Level,
5. Subject Committee of the Block Level Expert Committee (BLEC) on Watershed,
6. Subject Committee of the District Level Expert Committee (DLEC) on Watershed,
7. Established Institutes (both Govt. and NGO level) for imparting training (TOT),
8. Nodal Institute and State Level Faculty for Co-ordination and Training,
9. Core faculty in the People's Plan Campaign Cell of the State Planning Board, and
10. A State Level Implementation Committee.

The campaign for the preparation of Block Level Master Plan for Watershed Based Development was organized in the following three phases (Table 1)

Table 1 Flow chart showing institutional arrangement and their functions for the watershed based development program

Watershed Association - WA Neighbour Hood Group –NHG - - - - - - - - - - Watershed Study Team -WST Watershed Committee - WC	Total population within a Micro Watershed Area (MWS) All NHG's in a MWS - - - - - - - - - - 3 representatives from each NHGs (1 male, 1 female & 1 SC/ST)from both WST & WC	1. Primary data collection 2. Preparation of WDR 3. Preparation of WAP 4. WAP implementation
Watershed Development Council WDC	President (Chairman) and Secretary (Convenor) of BP, Presidents of all GPs in the Block, 3 reps. of TAC, (one each from Irrigation, Soil Conservation, Drinking water); 3 to 5 NGO's (one each from an NGO) working in WSD.	* 1. Over all responsibilities of leadership including training for WC in the BP 2. Preparation, modification improvements, if any needed in WAR 3. Assistance to the preparation of WDR 4. Assistance to the preparation of WAP and IA
Block Technical Support Group BTSG	4 members from Block TAC (Irrigation, soil conservation, drinking water & rural dev.) 6 members from WDAC Nodal agency's rep. be its convenor (RDD)	Function as the Technical support team to WDR, WAP, IA, etc.
Watershed Development Ad - Hoc Committee WDAC	6 Institutions to be identified and Secretary, Planning as the Chairman. Institutions may be Agriculture, Irigation and Soil Conservation Department of GOK, KWA,RDD,CWRDM&CESS	1. Preparation of guide lines for the activities under WSD program planning to undertake. 2. Planning of Block level training. 3. Program monitoring in these blocks

* Training to be given at WC level

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1. Organization, Orientation and Capacity building of the State Level Faculty, DLEC and BLEC Subject Committee on Watershed; and preparation of Watershed Appraisal Report at the Block Panchayat Level.
2. Identification of Watershed Study Team (WST) from Grama Sabha's and their training; WST's primary data collection and compilation. Election of Watershed Committee (WC) members from the Watershed Grama Sabha's and their training. WST and WC together prepare the integrated and perspective action plan for the micro watershed (WAP).
3. WDC along with DLEC/BLEC prepare the Block Level Master Plan for the Watershed Based Development of that Block Panchayat by compiling all the WAP's prepared in the micro watersheds of that Block Panchayat. This exercise will be through detailed discussions.

This program started in June 1999 (3rd year of the 9th Five Year Plan). First phase of the program implementation has been fully completed. The second phase has been initiated in which the Block Level Watershed Appraisal Reports were used for the presentation in the "Samagra Vikasana Grama Sabha's" (SVGS) during November-December 2000. The Watershed Study Teams (WST) were identified for each of the micro watersheds.

Strength and Weaknesses of BMPWD

Strength: The strength of the program has been (i) the timely co-operation of committed group of members from each Block, District & Block Coordinator's, KRP's, large number volunteers; the Secretary, Rural Development Department, the ADC (General)'s of each District and the smart functioning of the following efficient infrastructure; (a) A State Level Implementation Committee, (b) A four member group in the PPC Cell in the State Planning Board for the smooth functioning of the over all activities. (c) State level faculty for watershed development, (d) State Institute of Rural Development (SIRD), Kottarakkara as the nodal agency; (e) 151 Watershed Development Councils (WDC) and (f) Seven training centers distributed from south to north in Kerala (CESS, CWRDM, CPCRI, SIRD, IRTC, PASS and PDS) (g) Successful Completion of all the Block Level Appraisal Reports; (h) Successful completion of the "Samagra Vkasana Grama Sabhas" in all the wards of the Grama Panchayats and identification of about fifteen people from each of the micro watersheds for the conduct of the Primary data collection, preparation of Vikasana Rekha and action plan.

Weakness: The weakness of this program is listed below: (i) the organizational infra structure setup for this program is non functional as on today; (ii) the selection of the faculty at the respective Panchayats and capacity development for these faculty for imparting training at micro watershed level yet to be done; and (iii) the identified people in each of the micro watersheds were not given training for the collection of primary data in each of the micro watershed area. Hence they could not carry forward the work envisaged thereafter.

Guiding Principles

Sequence of activities and their operational modalities may vary from situation to situation and the guidelines are flexible so that the desired modification may be considered at different levels. The main elements of the guiding principles are as follows: Conservation of natural resources, integrated development of natural as well as social resources, in-situ moisture conservation, sustainable farming system, adoption of ridge to valley approach, due emphasis on production enhancement activities for land owners and livelihood support for landless families, democratic decentralization in decision making, transparency in transactions, mobilization of community at the village level, direct funding to the community, emphasis on "Government" participation in "Community's" plans, contributory approach to empower the community, building upon indigenous innovations, initiatives and ideas; equity for resource-poor families and empowerment of women, moving away from subsidy oriented development to self reliant development, convergence of activities/schemes of government and non-governmental organizations, etc. (extract from "WARASA" - NWDPRA Guidelines October, 2000)

Support Organizations

The role of Support Organization (SO) in Watershed Development Program is very important. The Rural Development Department (RDD) of the Government of Kerala may be considered as the Nodal Agency for this program. The SO can be Autonomous Centers as well as competent NGOs. A list of possible SOs having manpower and expertise in watershed development programs are listed below:

1. Centre for Earth Science Studies (CESS) , Thiruvananthapuram
2. Centre for Water Resources, Development and Management (CWRDM), Kozhikode.
3. Central Plantation Crops Research Institute (CPCRI), Kasaragod.
4. Integrated Rural Technology Centre (IRTC), an NGO, Mundur, Palakad.
5. PDS, an NGO, Peermade.
6. PASS, an NGO, Adoor.
7. RASTA, an NGO, Wayanad
8. SHREYAS, an NGO, Wayanad.

Program output

The following output in the form of reports and charts will be available with emphasis on conservation of soil and water, water for drinking and irrigation purpose.

1. "Watershed Based Appraisal Report" (WAR) of all the BPs are available.
2. "Watershed Development Report" (WDR) of each of the micro watersheds in BPs
3. "Watershed Action Plan" (WAP) for each of the micro watersheds in the BPs

With the assistance of Sectoral Committee Members of the Garama and Block Panchayat and Technical Advisory Committee Members of the Block and District Panchayats, WC,WA,US,NHG and NGO's, the program can be effectively implemented so that targets assigned as program output in each phases could be achieved.

National & International Financial Assistance

Financial assistance for "Watershed Development" programs in India shows increasing trend both by the National and International funding agencies. National Wastelands Development Board (NWDB) initiated a major step in 1985 for wasteland development through watershed approach.. The Drought Prone Areas Program (DPAP), the Desert Development Program (DDP) also adopted watershed approach in 1987.The Ministry of Rural Areas & Employment recommended that all the area development program under the Ministry should be implemented on watershed basis and the new guidelines which constituted in 1995 envisage active participation of Panchayati Raj Institutions, NGOs, Social Workers, etc. at the grass root level besides a high level of community participation and Technical support. The National Watershed Development Program for Rainfed Areas (NWDPRA) launched in 1995 by the Government of India under the Ministry of Agriculture is the fourth major program based on the watershed concept. CAPART has taken the initiative to promote voluntary action in this field and NABARD came on a big way for financing viable watershed development programs.

Many International funded projects on "Watershed Development " has been completed and many are in various stages of progress. International financial agencies like World Bank, Swiss Development Agency, DFID, Global Environment Fund (GEF), etc. may be approached with viable projects on "Watershed Based Development" for financial assistance. \

Conclusion

The Watershed approach represents the principle vehicle for transfer of rainfed agriculture technology. A watershed is a geographic area that drains to a common point, which makes it an ideal planning unit for conservation of soil, water and biomass; and encourage the sustainable development of the area by empowering people at the local level to manage their own resources. Watershed Based Development provides immense scope for effective integration of various sectoral programs, primarily based on a 'ridge to valley' approach. It also enables clarity on issues like sustainability, equity and participation that are addressed in the decentralized planning. It is proposed that Kerala' s Eleventh Five Year Plan approach may be a Watershed Based Development for sustainable development of the State and a role model for the nation.

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MANAGE YOUR COMPUTER

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Maintaining your computer is easy to do and will save you hours of frustration and expensive repairs. Frequently, people find that, when they thought they needed to upgrade or replace their computer because of its performance, all they really needed to do was to perform some maintenance on it. The most common difficulties are due to viruses and to pop up advertising.

The single most important maintenance task you need to do is to upgrade and update your virus protective software and its data files on at least a *weekly basis*. All virus protection software is virtually useless if the virus data files are old. All major virus protection software packages include a subscription for free updates and upgrades, and they all perform that task easily over the Internet, and each of them include automatic reminders to update the virus data files and reminders to scan your system for viruses. When the subscription expires, *renew it!* The most well known of these are Norton Antivirus, McAfee VirusScan, and PC-Cillin. The next important task is to check Windows Updates and install updates as they become available. The third task of importance is to update the data files of anti adware and spyware software, and to run that software so as to remove adware and spyware from your computer.

Daily: Shut down your entire computer system and turn off the power to all of it for at least 5 seconds before restarting it, once per day.

Weekly: 1. Check your antivirus software for updates to its virus data files, and for upgrades to its scan engine. Do not depend on any automatic update features to do this entirely for you. 2. Check Add/Remove Programs in Control Panel and compare against This list of adware and spyware and remove any programs which have a match in the list. 3. Check for data file updates for anti adware and spyware software and run the software so as to remove additional adware and spyware.

Monthly: 1. Perform a virus scan of your system using your antivirus software. 2. Check your hard disk for errors.

Quarterly: Perform a disk defragmentation.*

Annually: 1. Remove the cover of your computer and blow out the dust and debris using a can of compressed air available from any computer or office supplies outlet. Take special care to blow dust from all fans inside the computer. If there are any elastic bands anywhere inside the computer, remove them (nylon wire ties are fine). 2. Get a floppy drive cleaning kit and use it as directed. 3. Get a CD drive cleaning kit and use it as directed.

Mouse: When your mouse starts sticking or otherwise not working well, open the cover and remove the ball and clean it: Using the can of compressed air mentioned above, and blow the dust out of the interior of the mouse. Using tweezers, pen knife or other appropriate tools, clean the rollers of lint or other debris. When you reassemble your mouse, it will work like new.

Keyboard: Clean your keyboard only with a cloth dampened with a mild household cleaner. Take great care not to allow liquid of any kind to get into the keyboard itself, as that will destroy the membrane of the keyboard and ruin it.

Disk checking and defragmenting: Before attempting to perform either a disk error check (aka scandisk) and/or a disk defragmentation, it is necessary to close all programs and stop any running applications or applets. To do this:

1. Close all programs by either clicking the "X" in the upper right corner of their window, or from the task bar by right mouse clicking on their icon and selecting close or exit.
2. Close all items in the System Tray (rightmost portion of the task bar) by right clicking on each item and selecting close, exit or disable, whichever may apply. Caution: When attempting to shut down some items in the system tray, a window may appear asking whether or not you want that program to run automatically the next time Windows starts. In

most cases, the answer is "yes" unless it is something that you really don't want started every time you start your computer.

3. Invoke the Task Manager by holding down the Ctrl and Alt keys together and then hitting the Delete key *just once*. End each task shown *except* for Explorer and Systray by clicking the task to select it, then clicking End Task; some tasks may take several tries before they are finally ended, and some may show a window indicating that they are no longer responding - that's ok, just end them.

It is also recommended to disable or shut off any screen saver and to disable any power saving. To shut off the screen saver, RIGHT mouse click the desktop (not any icon on the desktop, just empty space there), and, under the Screen Saver tab, note what the name of the screen saver is for later on, then scroll upwards to NONE and select it. To disable power saving, open (double click) My Computer, then Control Panel, then Power Management; note down what the setting are now, then set each one to Never.

An alternative to the above method is to start the computer in Safe Mode. To do so, start tapping on the F8 key about 5 seconds after starting the computer until a menu appears. Use the down arrow on the keyboard to select the Safe Mode item in the menu and hit the Enter key. In Safe Mode, no device drivers will be loaded nor any programs run; that means that the screen will look different, there will be no sound and no modems, network cards, printers, etc. will be working. Any screen saver WILL work though, so you will still need to shut that function off before starting either error checking or defragmenting.

Disk Error Checking and Disk Defragmenter are tools associated with the hard disk drive (usually drive C:). The most common way to get to those tools are by right mouse clicking on the C: drive in My Computer or in Windows Explorer (not to be confused with Internet Explorer), and clicking on Properties. At the top of the properties sheet for the drive is a tab labeled Tools, and there they are. Error Checking (Scandisk) can be run in Standard mode, unless there is reason to believe there may be problems with the disk. Standard mode will take a few minutes to run, while Thorough mode will take several hours. After Error Checking is complete, run the Defragmenter, which WILL take at least one hour and perhaps several hours depending on the speed of the machine, size of the hard disk, and level of fragmentation of the hard disk. It's a good idea to start defragmenting at bedtime and find it finished in the morning.

After error checking and defragmenting have been completed, shut down the system and power it off before starting it again. Go back and set your screen saver to what it was before, and your power management to the values you noted down earlier.

Windows XP

The Windows Desktop: Using Windows XP is simple. First, you'll notice the large area on the screen, called the *desktop*, and the narrow band at the bottom, called the *taskbar*. Everything you can do on your computer appears inside frames that are called *windows*. You can open as many windows at one time as you like—and resize them, move them around, or restack them in any order.

Icons: The small pictures on the desktop are called *icons*. Think of them as doorways to the files and programs stored on your computer. Place your mouse over an icon. Text appears identifying its name or contents. To open the file or program, double-click the icon.

The first time you start Windows XP, you'll see only one icon-the Recycle Bin-where you can send files you wish to delete from your computer.

Shortcut icons are identified by the small arrow on the lower left corner of the image. These let you access:

- Programs
- Files
- Folders
- Disk drives
- Web pages
- Printers
- Other computers

Shortcut icons simply supply links to the programs or files they represent. You can add and delete them without affecting the actual programs or files

Taskbar: Every time you open a window, a button representing it appears on the taskbar. The button disappears when you close a window. The taskbar also contains the *Start menu* and *notification area*, where you'll see the clock. Other icons in the notification area can appear temporarily, showing the status of ongoing activities. For instance, the printer icon appears when you send a file to the printer, and disappears when printing is complete. You'll also be reminded in the notification area when new *Windows updates* are available to download from the Microsoft Web site.

Windows XP keeps the taskbar tidy by consolidating buttons when too many accumulate. For example, buttons representing individual e-mails are automatically grouped under a single e-mail button. Clicking the button lets you select a specific mail message from a convenient menu.

Start Menu: The Start menu appeared automatically the first time you ran Windows XP. You can return to the Start menu anytime by clicking the Start button on the taskbar. The Start menu contains everything you need to begin using Windows. From it you can:

- Start programs.
- Open files.
- Customize your system with *Control Panel.*
- Get help by clicking *Help and Support.*
- Search for items on your computer or the Internet by clicking *Search.*

Some commands on the Start menu have a right-facing arrow, which means additional choices are available on a secondary menu. Place your pointer over an item with an arrow and another menu appears.

The left side of the Start menu updates with links to the programs you use most frequently. At the top left are fixed or "pinned" items—shortcuts to things like your Internet browser and e-mail program.

Files and Folders: Each piece of work, or file, can be stored in a folder. Windows XP makes it easy to store files in the places that make the most sense. Place text, image, and music files in the folders titled My Documents, My Pictures, and My Music. Those folders are all easy to find on the right side of the Start menu, and they offer convenient links to the tasks you'll perform most often.

Windows: *Windows*—frames within the desktop—display the contents of files and programs.

Working with windows is easy when you know the basics. The name of each window appears at the top, in a title bar.

- Move a window by *dragging* it. Click the title bar and, while holding down the mouse button, move the mouse pointer across the computer screen.
- Shrink a window by clicking the *Minimize* button, located at the right-hand side of the title bar. This reduces the window to a button on the taskbar.
- Maximize a window by clicking the *Maximize* button, located to the right of the minimize button.This enlarges the window to fill the desktop. Click the button again to restore the window to its original size.

Inside a window, browse the menus to see the different commands and tools you can use. When you find the command you want, just click it.

If a program needs some information from you before it can complete a command, a *dialog box* appears. To enter information, you might need to:

- Click and type in a *text box.*
- Select a choice in a *list* by clicking the arrow button to show the list, and then clicking the item you want.
- Choose a single option by clicking a *radio button.*
- Place a check mark in a check box next to one or more options that you want.

If the contents of your file don't fit in the window, drag the *scroll bar* or click the *scroll buttons* at the side and/or bottom of the window to move the contents up, down, or sideways. To change the window size, click the edge of a window and drag the border to the size you want.

Control Panel: Customizing your computer settings is simple with Windows XP Control Panel. Open it by clicking Control Panel on the Start menu. From Control Panel you can:

- Change the way Windows XP looks and acts.
- Add and remove programs or hardware devices.
- Set up network connections and user accounts.

Ending Your Session: When you want to interrupt your Windows session and let someone else use the computer, go to the Start menu. Click Log off and then Switch User. Windows XP then will be ready to welcome a different user. When everyone's finished, go to the Start menu and click Turn off computer. The next time you log on, the Welcome screen will be the first thing you'll see. Just click your name, type your password if you have one, and you'll be back at the Windows desktop

Built-in Photo Sharing and Organization: With Windows XP, viewing photos and sharing them with friends, family, and colleagues couldn't be easier. Just plug in your digital camera and your photos appear instantly—ready for you to edit, e-mail, or print. You can even publish images directly to a Web site or save them on CD. Or send them to an online retailer for professional quality prints

Playing Music, Video, and CDs: Like listening to music and watching videos? Windows XP includes Windows Media Player, so it's a cinch to:

- Tune in Internet radio.
- Download music or movies from the Web.
- Watch streaming video broadcasts.
- Play your own CDs.

Windows Media Player makes it easy to create your own customizable *jukebox*. Just:

1. Copy your personal CDs onto your computer or download music from the Internet.
2. Arrange selections in any order you want.
3. Store the playlist.

The computer will play your selections back—one after another, in any order you choose, any time you like. You can even make your own CDs!

Optimized for Games and DVDs: The latest Microsoft® DirectX® technology gives you the enhanced power, performance, and reliability that make Windows XP great for playing computer games. Networking and Internet features let you challenge competitors across the hall or across the globe! Enjoy watching DVDs, too. The next time you and your laptop share an airplane trip, why not take along one or two of your favorites to watch instead of the in-flight movie?

Multiple Users: With Windows XP it's easier than ever to share a single computer among several users. Each person using the computer can create a separate password-protected account with personalized settings and private files. Multiple accounts can be active on the computer at the same time—switching back and forth is fast and simple. For example, if someone wants to check e-mail while you're working, they simply switch over to their account. There's no need for you to close your programs and log off. The other user won't see your files while they're working; and when you switch back you won't see theirs. You'll find the screen exactly as you left it.

Networks: Powerful and Practical: Is there more than one computer in your home or office? Connecting them into a network boosts the abilities of every computer on the system.Make team efforts out of big projects like creating reports and spreadsheets. Free up space on smaller computers by centralizing large files like photos and music on one computer, where they can be shared by everyone, even at the same time. Play multiplayer computer games on a whole new level, with each player on a separate computer! Save money by sharing hardware. Networked computers can share the same printer, scanner, fax, even the same Internet connection. Family members can surf the Web at the same time, from different computers, all on the same phone or other service line!

Let the Wizard do the Work: You don't need to be an expert—a *wizard* steps you through the entire process of setting up a network for your home or small business. Simply answer a few questions about the computers you wish to link, and the wizard does the rest. Once your network is up and running, Windows XP stays on the job, tracking changes and making adjustments automatically so you'll always get the best performance with the least effort.

Data Protection, Inside and Out: Windows XP contains powerful new features designed to keep your computer network running no matter what. Sophisticated protection software guards each computer's operating system, and also establishes a protective barrier, or firewall, that shields the entire network from outside hackers and viruses spread over the Internet.

Robust, Reliable, Compatible: Windows XP Professional marks a new standard in business software—combining enterprise-class performance and reliability with unprecedented ease of use. Built on the rock-solid foundation of Microsoft's proven Windows 2000 technology, Windows XP Professional contains all the features of Microsoft® Windows® XP Home Edition, and includes new and enhanced features designed especially for business and advanced use. Startup time is faster and your business programs will run better than ever before. See more of your work at one time by stretching it across several monitors. Or view two different programs simultaneously, on computers equipped with a dual interface display adapter. With Microsoft ClearType™ technology, screen contents are easier to read, especially on laptops. Windows XP Professional is world-ready with multilanguage support. Select among 24 languages—a very useful feature if your company spans the globe, with multilingual employees who use different languages but share the same computers. Use a laptop? The enhanced power management features in Windows XP stretch battery life. And with laptops *and* other PCs you get better control over how your computer uses power.

On the Road and Around the World: Read e-mail, view files, and run programs on your office computer from anywhere in the world. Windows XP Professional's advanced communication features put you in command of the latest mobile computing and cutting-edge wireless technologies. Use Remote Desktop to view the screen of a computer running Windows XP Professional, over the Internet, from any other computer running Windows XP. That means you can "go to the office" from your laptop, your home computer, or from a client's office on the other side of the globe. It's like being in two places at once! The secure wireless connections in Windows XP let you communicate and collaborate in real time—at the same moment things are happening—using voice, video, and instant messaging. There's no wasting time trying to hook up—you're automatically notified whenever another Windows XP-equipped wireless device is in range. Windows XP Professional allows up to 10 Internet or other file-sharing connections simultaneously. Network bridging allows communication over wireless, Ethernet, and home phone lines all at the same time. With Windows XP Professional, going mobile means no hassles. You're always connected!

More Secure; Easier To Manage: Windows XP Professional features a secure file system with encryption for sensitive information. Security-related administrative settings assure your system remains safe, secure, and private. Windows XP Professional is also designed for easy management. An enhanced backup utility, improved for easier use, makes it simple to regularly copy data onto magnetic tape, Zip® disks, and other storage media. Automated System Recovery can even restore your operating system in case of disk failure. Windows XP Professional can be deployed incrementally throughout your organization. Upgrading individual computers only as needed reduces costs and lets you take advantage of the new technology of Windows XP at your own pace. Business computers linked via Windows 2000 Server software are a cinch to upgrade and manage using Remote Installation Services and Group Policies. These features let you install, configure, and manage individual computers as groups rather than single machines, and monitor them from a centralized location at great savings in time and support costs.

CD Writing: Consider the floppy disk, which is now on the endangered species list, a victim of the larger, stronger, much more useful recordable CD. A single blank CD holds 650 MB or more (equivalent to more than 400 floppy disks), and you can use the CD format to store data and music for playback on all sorts of devices. Now that Windows XP includes built-in support for CD burning, a CD-R or CD-RW drive is an essential part of any PC, and the venerable floppy disk is passé.

Fix a Balky Burner: If you have a compatible CD burner, you shouldn't need to do anything special to get it working under Windows XP Home Edition or Professional. The core code that makes CD recording possible is enabled automatically when you set up Windows XP. If you're unable to record a CD, start the troubleshooting process by checking to ensure that the feature is properly configured:

Open My Computer, right-click the CD Drive icon, and then click **Properties**
Click the **Recording** tab to display the settings
If you don't see a **Recording** tab, then Windows XP doesn't recognize your CD burner's recording capabilities. Check the Windows Hardware Compatibility List to make sure your drive is on the list. If the drive is listed and you can play CDs, but no Recording tab is visible, you'll need to manually edit the Registry using the instructions in Knowledge Base article, CD-R Drive or CD-RW Drive Is Not Recognized as a Recordable Device.
Make sure the **Enable CD recording on this drive** check box is selected. This setting turns on the built-in CD recording features included with Windows XP. The only reason to disable this feature is if you always prefer to use a third-party program and want to avoid any possible conflict between that program and Windows XP.
Try a slower speed. Instead of choosing the **Fastest** setting, dial the burning speed back to 18X or even 8X. Your drive may be able to keep up with a less demanding pace.
And of course, don't overlook the obvious. You do have a blank CD in the drive and the drive is properly connected, right?

If the drive is configured correctly but you end up with coasters instead of readable CDs, check to make sure you've installed Windows XP Service Pack 1. Problems in the original release of Windows XP resulted in problems with certain CD-R drives; these issues were fixed in SP1.

Tweak Performance: Select a drive where you want Windows XP to store images of files you're getting ready to burn to CD. If you have multiple drives, select the one that has the most free space. In the CD Drive Properties dialog box, choose an available drive letter. If you have only a single drive C, of course, that's your only option. But on a computer with multiple drives, you can significantly speed up performance by choosing a drive letter other than your system drive. Don't underestimate the amount of disk space you'll need, either. When you drag files into the CD folder in preparation for burning a CD, you actually copy them to a temporary folder in your local profile. Then, when you begin the actual burning process, Windows creates a separate image file. If you've selected enough files to fill a CD to its full capacity, you'll need more than 1 GB of extra disk space. Defragmenting the disk where that image is stored can have a major impact on performance as well. The burning process can encounter hiccups if your image file is scattered in fragments across a nearly-full disk. Defragmenting regularly lessens the likelihood that you'll encounter problems.

Scanning

1. Place your document (photo, picture, etc.) on the glass panel and launch your scanning program. This will give you a preview of what's on the plate.
2. Your scanner probably gives you the chance to set some scanning parameters which use these terms or synonyms:

Colour setting: To scan the document as a colour image, select [Colour] or [High Colour] or [True Colour]. To scan it as a grayscale image, select [Grayscale].
To scan it as a black and white image, select [Black and White].

Image resolution: This is a **KEY step.** Resolution is usually expressed in dpi (dots per inch). The smaller the number of dpi, the smaller the file size AND the smallest it will show up on screen.... which is GOOD!

Scanning zone: The scanner scans the entire surface of the plate. You software might give you the opportunity to delimit the zone you want to include, thereby eliminating unwanted areas and already reducing your image size.

3. Scan your image: Now that your parameters are set, you can launch the final scan. Sometimes this is done by clicking on a "save" button or by selecting "File/Save" in the top menu bar.
4. Saving File options: There are many file formats available. Your choice will depend on 3 main criteria: file size, image quality, and use or destination.

Some Simple Hardware Techniques

To change the size of the virtual memory paging file: You must be logged on as an administrator or a member of the Administrators group in order to complete this procedure. If your computer is connected to a network, network policy settings might also prevent you from completing this procedure.

1. Open System in Control Panel.
2. On the Advanced tab, under Performance, click Settings.
3. On the Advanced tab, under Virtual memory, click Change.
4. Under Drive [Volume Label], click the drive that contains the paging file you want to change.
5. Under Paging file size for selected drive, click Custom size, and type a new paging file size in megabytes in the Initial size (MB) or Maximum size (MB) box, and then click Set.

   If you decrease the size of either the initial or maximum page file settings, you must restart your computer to see the effects of those changes. Increases typically do not require a restart.

   - To open System, click Start, click Control Panel, and then double-click System.
   - To have Windows choose the best paging file size, click System managed size.
   - For best performance, do not set the initial size to less than the minimum recommended size under Total paging file size for all drives. The recommended size is equivalent to 1.5 times the amount of RAM on your system. Usually, you should leave the paging file at its recommended size, although you might increase its size if you routinely use programs that require a lot of memory.
   - To delete a paging file, set both initial size and maximum size to zero, or click No paging file. Microsoft strongly recommends that you do not disable or delete the paging file.

To change the performance of foreground and background programs

1. Open System in Control Panel.
2. On the Advanced tab, under Performance, click Settings.
3. On the Advanced tab, under Processor scheduling, do one of the following:
   - Click Programs to assign more processor resources to the foreground program than the background program.
   - Click Background services to assign equal amounts of processor resources to all programs.

To open System, click Start, click Control Panel, and then double-click System. Choosing the Programs option will result in a smoother, faster response time for your foreground program. If you want a background task, such as a Backup utility, to run faster, choose the Background services option. The Programs option allocates short, variable time slices, or quanta, to running programs, while the Background services option assigns long, fixed quanta.

To specify the default operating system for startup

1. Open System in Control Panel.
2. On the Advanced tab, under Startup and Recovery, click Settings.
3. Under System startup, in the Default operating system list, click the operating system you want to start when you turn on or restart your computer.
4. Select the Display list of operating systems for check box, and then type the number of seconds you want the list displayed before the default operating system starts automatically.

- To open System, click Start, click Control Panel, and then double-click System.
- To manually edit the boot options file, click **Edit**. Microsoft strongly recommends that you do not modify the boot options file (boot.ini). Doing so may render your computer unusable.

To specify what Windows does if the system stops unexpectedly: You must be logged on as an administrator or a member of the Administrators group in order to complete this procedure. If your computer is connected to a network, network policy settings might also prevent you from completing this procedure.

1. Open System in Control Panel.
2. On the Advanced tab, under Startup and Recovery, click Settings.
3. Under System Failure, select the check boxes that correspond to the actions you want Windows to perform if a Stop error occurs:
    - Write an event to the system log specifies that event information will be recorded in the system log.
    - Send an administrative alert specifies that your system administrator will be notified.
    - Automatically reboot specifies that Windows will automatically restart your computer.
4. Under Write Debugging Information, choose the type of information you want Windows to record when the system stops unexpectedly:
    - Small Memory Dump records the smallest amount of information that will help identify the problem. This option requires a paging file of at least 2 MB on the boot volume of your computer and specifies that Windows will create a new file each time the system stops unexpectedly. A history of these files is stored in the directory listed under Small Dump Directory.
    - Kernel Memory Dump records only kernel memory, which speeds up the process of recording information in a log when the system stops unexpectedly. Depending on the amount of RAM in your computer, you must have 50 MB to 800 MB available for the paging file on the boot volume. The file is stored in the directory listed under Dump File.
    - Complete Memory Dump records the entire contents of system memory when the system stops unexpectedly. If you choose this option you must have a paging file on the boot volume large enough to hold all of the physical RAM plus one megabyte (MB). The file is stored in the directory listed under Dump File.

- To open System, click Start, click Control Panel, and then double-click System.
- You must have at least a 2-MB paging file on the computer's boot volume if you select Write an event to the system log or Send an administrative alert.
- If you choose either Kernel Memory Dump or Complete Memory Dump and select the Overwrite any existing file check box, Windows always writes to the same file name. To save individual dump files, clear the Overwrite any existing file check box and change the file name after each Stop error.
- You can save some memory if you clear the Write an event to the system log and Send an administrative alert check boxes. The memory saved depends on the computer, but typically about 60 KB to 70 KB are required by these features.
- If you contact Microsoft Product Support Services about a Stop error, they might ask for the system-memory dump file generated by the Write Debugging Information option.

Managing your computer's performance: Windows allocates resources according to its settings and manages devices accordingly. You can, however, change the way Windows uses processor time and computer memory to improve performance. You can also adjust the settings for your computer's visual effects.

Managing processor time: System processing is managed by Windows, which can allocate tasks between processors, as well as manage multiple processes on a single processor. However, you can set Windows to allocate more processor time to the program you are currently running. This can result in faster program response time. Or, if you have background programs, such as printing or disk backup that you want to run while you work, you can have Windows share processor resources equally between background and foreground programs.

Managing computer memory: When your computer is running low on RAM and more is needed immediately, Windows uses hard drive space to simulate system RAM. This is known as virtual memory, and is often called the paging file. This is similar to the UNIX swapfile. The default size of the virtual memory pagefile (named pagefile.sys) created during installation is 1.5 times the amount of RAM on your computer. You can optimize virtual memory use by dividing the space between multiple drives and removing it from slower or heavily accessed drives. To best optimize your virtual memory space, divide it among as many physical hard drives as possible. When selecting drives, keep the following guidelines in mind:

- Try to avoid having a pagefile on the same drive as the system files.
- Avoid putting a pagefile on a fault-tolerant drive, such as a mirrored volume or a RAID-5 volume. Pagefiles don't need fault-tolerance, and some fault-tolerant systems suffer from slow data writes because they write data to multiple locations.
- Don't place multiple pagefiles on different partitions on the same physical disk drive.
- You can choose to optimize your computer's memory usage. If you use your computer primarily as a workstation, rather than as a server, you can have more memory devoted to your programs. Your programs will work faster and your system cache size will be the default size that came with Windows XP. You can also specify to set aside more computer memory for a larger system cache, If your computer is used primarily as a server, or if you use programs that require a larger cache.

Changing visual effects: Windows provides several options to set the visual effects of your computer. For example, you can choose to show shadows under menus, giving them a 3-D look. You can tell Windows to display the entire contents of a window while you move it on your screen. To make large text more readable, you can choose to display the smooth edges of screen fonts. You can also enable the Web view in your folders, which will display a list of hyperlinked tasks and information on the left side of the folder window. Windows provides options for enabling all of the settings (for best appearance), or none of the settings (for best computer performance). You can also restore the original default settings.

System Properties overview: You can use System in Control Panel to do the following:

- View and change settings that control how your computer uses memory and finds certain information.
- Find information about hardware and device properties, as well as configure hardware profiles.
- View information about your network connection and logon profile.
- Report system and program errors to Microsoft or your system administrator when they occur.

You can change performance options that control how programs use memory, including paging file size, or environment variables that tell your computer where to find some types of information. Startup and recovery options indicate which operating system your computer uses when it starts and which actions it performs if the system stops unexpectedly. Information about hardware and devices is also available in System. Use the Add Hardware Wizard to install, uninstall, or configure certain types of hardware. Device Manager shows you which devices are installed on your computer and allows you to change device properties. You can also create hardware profiles for different hardware configurations.

Using Backup: The Backup utility helps you create a copy of the information on your hard disk. In the event that the original data on your hard disk is accidentally erased or overwritten, or becomes inaccessible because of a hard disk malfunction, you can use the copy to restore your lost or damaged data.

Open Backup

- To start Backup, click Start, point to All Programs, point to Accessories, point to System Tools, and then click Backup.
- The Removable Storage service must be started for Backup to work properly. For more information, click Related Topics.

- You can also use the Automated System Recovery Wizard in the Backup utility to help you repair your system.
- For information about using Backup, click the Help menu in Backup.

Power Options overview: Using Power Options in Control Panel, you can reduce the power consumption of any number of your computer devices or of your entire system. You do this by choosing a power scheme, which is a collection of settings that manages the power usage by your computer. You can create your own power schemes or use the ones provided with Windows. You can also adjust the individual settings in a power scheme. For example, depending on your hardware, you can:

- Turn off your monitor and hard disks automatically to save power.
- Put the computer on standby when it is idle. While on standby, your entire computer switches to a low-power state where devices, such as the monitor and hard disks, turn off and your computer uses less power. When you want to use the computer again, it comes out of standby quickly, and your desktop is restored exactly as you left it. Standby is particularly useful for conserving battery power in portable computers. Because Standby does not save your desktop state to disk, a power failure while on Standby can cause you to lose unsaved information.
- Put your computer in hibernation. The hibernate feature saves everything in memory on disk, turns off your monitor and hard disk, and then turns off your computer. When you restart your computer, your desktop is restored exactly as you left it. It takes longer to bring your computer out of hibernation than out of standby.

Typically, you turn off your monitor or hard disk for a short period to conserve power. If you plan to be away from your computer for a while, you put your computer on standby, which puts your entire system in a low-power state. Put your computer in hibernation when you will be away from the computer for an extended time or overnight. When you restart the computer, your desktop is restored exactly as you left it. To use Windows Power Options, you must have a computer that is set up by the manufacturer to support these features. For more information, see the documentation that came with your computer.

Managing power on a portable computer: Using Power Options in Control Panel, you can reduce consumption of battery power on your portable computer and still keep the computer available for immediate use. You can view multiple batteries separately or as a whole, and set alarms to warn you of low battery conditions. You can put your computer on standby, which turns off the monitor and hard disks to reduce battery power consumption. When you bring the computer out of standby, your desktop appears exactly as you left it. You might want to save your work before putting your computer on standby. While on standby, information in computer memory is not saved on your hard disk. If there is an interruption in power, information in memory is lost. You might also be able to put your computer in hibernation. The hibernate feature turns off your monitor and hard disk, saves everything in memory on disk, and turns off the computer. When you restart the computer, your desktop is restored exactly as you left it. The Power Options you see will vary depending on the exact hardware configuration you have. To use Power Options, the computer must be ACPI-compliant, which dictates that all components are capable of power management. If one or more components are not capable of power management, you might either not have ACPI functionality, or might experience erratic behavior.

Operation during commercial air travel: Some commercial airlines might request that you turn off portable computers during certain portions of the flight, such as takeoff and landing. To comply with this request, you must turn off your computer completely. Your computer might appear to be turned off while in standby mode. However, the operating system might automatically reactivate itself to run certain preprogrammed tasks or to conserve battery power. To prevent this from occurring during air travel, be certain to shut down your computer completely when not in use. For more information, click Related Topics.In addition, if your computer is equipped with a cellular modem, you must also ensure that this modem is completely turned off during air travel as required by Federal Communication Commission regulations. Failure to comply with these requirements could lead to civil or criminal penalties.

System Information overview: System Information collects and displays system configuration information for local and remote computers. This includes information about hardware configurations, computer components, and software, including signed drivers and unsigned drivers. When support technicians troubleshoot your system configuration, they require specific information about your computer. You can use **System Information** to quickly find the information that these technicians need to resolve a system problem. System Information saves data files in a native (.nfo) format. You can also open .cab and .xml files in System Information. When you open .cab files, you can view the contents of those files by using the Tools menu.

Using Disk Cleanup: Disk Cleanup helps free up space on your hard drive. Disk Cleanup searches your drive, and then shows you temporary files, Internet cache files, and unnecessary program files that you can safely delete. You can direct Disk Cleanup to delete some or all of those files.

- To open Disk Cleanup, click **Start,** point to **All Programs,** point to **Accessories,** point to **System Tools,** and then click **Disk Cleanup.**

Using Disk Defragmenter: You might need to be logged on as an administrator or a member of the Administrators group in order to perform some tasks. Disk Defragmenter consolidates fragmented files and folders on your computer's hard disk, so that each occupies a single, contiguous space on the volume. As a result, your system can gain access to your files and folders and save new ones more efficiently. By consolidating your files and folders, Disk Defragmenter also consolidates the volume's free space, making it less likely that new files will be fragmented. You can also defragment disks from a command line using the defrag command.

- To open Disk Defragmenter, click **Start**, point to **All Programs**, point to **Accessories**, point to **System Tools**, and then click **Disk Defragmenter.**

Removing unneeded files: When running an operating system as complex as Windows, you may not always know the significance of all the files on your computer. Sometimes Windows uses files for a specific purpose and then retains them in a folder designated for temporary files. Alternatively, you may have previously installed Windows components that you are no longer using. For a variety of reasons, including running out of space on your hard drive, you may want to reduce the number of files on your disk, or create more free space, if it can be done without harming any of your programs. Use the Windows Disk Cleanup Wizard to perform all of the following tasks to clear space on your hard disk:

- Remove temporary Internet files.
- Remove any downloaded program files (ActiveX controls and Java applets downloaded from the Internet).
- Empty the Recycle Bin.
- Remove Windows temporary files.
- Remove Windows components that you are not using.
- Remove installed programs that you no longer use.
- To start Disk Cleanup, click **Start**, click **Run**, and then type **cleanmgr**.

DATABASE CONCEPTS: DESIGN AND MANAGEMNENT OF RDBMS

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What is a Database ?

In the era before the 1960's large corporations and business houses maintained records on papers and sorted them in what we call office files. As the complexity and volumes of data grew rapidly, it became increasingly difficult to manage business records on paper. Imagine you are searching for a record in a room cluttered with files. This is time consuming. Computers gave a solution to the problem of data management. The data sorted in office files is now stored electronically in a computer. The software which manages data is called a DBMS (Data Base Management System). A DBMS performs the function of efficient storage and retrieval of data. It also provides facility for querying and reporting.

A database is a collection of information that's related to a particular subject or purpose, such as tracking customer orders or maintaining a music collection. If your database isn't stored on a computer, or only parts of it are, you may be tracking information from a variety of sources that you're having to coordinate and organize yourself.

For example, suppose the phone numbers of your suppliers are stored in various locations: in a card file containing supplier phone numbers, in product information files in a file cabinet, and in a spreadsheet containing order information. If a supplier's phone number changes, you might have to update that information in all three places. In a database, however, you only have to update that information in one place — the supplier's phone number is automatically updated wherever you use it in the database.

Components of a Database File

A *file* is a collection of related records. A *record* is a collection of related fields. Each *field* in the record gives a part of the information related to that record. A *Database* may consist of one or more files.

Consider the database file

Record No.	Emp Code	Emp Name	Date of Join	Dept.	Designation
1	A 003	Mohan T.T	19-04-2000	Acct.	Clerk
2	A 009	Nandan K	25-05-1995	Acct.	Peon
3	A 001	Vishal V.	21-04-2005	Acct.	Exec
4	A 011	Kamala H.P.	01-01-1990	Admn.	Mgr

This file contains 4 records (each row is called record). Each record is identified by its record No.

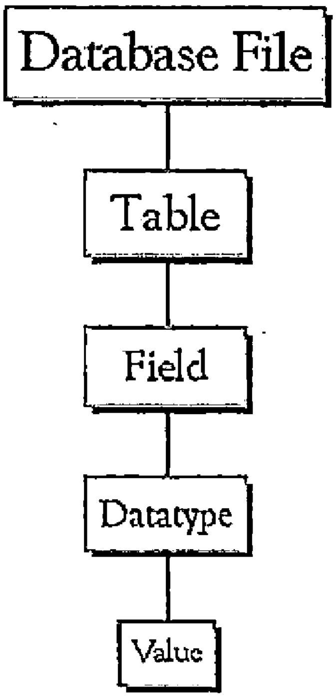
Relational Databases

Consider the company Fairdealers Ltd., having more than thousand employers. The company is fully computerized and has 10 departments. Each department stores the details of the employers. This lead to a repetition of data since each employee may sometime come in the 10 departments and hence all the data will repeat 10 times. In this case we make use of the relational database management system where it break down data into separate files and provide a relation between the files through a key field. In the case of the company given above the key field may be taken as the employee code where every one can easily call the details by just typing the employee code and can update if necessary. Thus data is not stored repeatedly in different places.

There are various database packages in the market. Some of them are dBASE III PLUS, Fovbase, FOXPRO, Clipper, ORACLE, INGRES, SYBASE, MS ACCESS.

Microsoft Access Description

Microsoft Access is a powerful program to create and manage your databases. It has many built in features to assist you in constructing and viewing your information. Access is much more involved and is a more genuine database application than other programs. First of all you need to understand how Microsoft Access breaks down a database. Some keywords involved in this process are: *Database File, Table, Record, Field, Data-type.* Here is the Hierarchy that Microsoft Access uses in breaking down a database.



Database File: This is your main file that encompasses the entire database and that is saved to your hard-drive or floppy disk. Example) StudentDatabase.mdb

Table:A table is a collection of data about a specific topic. There can be multiple tables in a database. Example #1) Students Example #2) Teachers

Field: Fields are the different categories within a Table. Tables usually contain multiple fields.
Example #1) Student Last Name
Example #2) Student First Name

Datatypes: Datatypes are the properties of each field. A field only has 1 datatype
FieldName) Student LastName
Datatype) Text

Starting Microsoft Access

Two Ways

Double click on the Microsoft Access icon on the desktop.

Or

click on Start --> Programs --> Microsoft Access

Creating New, and Opening Existing Databases

- Create a New Database from scratch
- Use the wizard to create a New Database
- Open an existing database (The white box gives you the most recent databases you have used. If you do not see the one you had created, choose the More Files option and hit OK. Otherwise choose the database you had previously used and click OK)

Create a database using the Database Wizard

1. When Microsoft Access first starts up, a dialog box is automatically displayed with options to create a new database or open an existing one. If this dialog box is displayed, click **Access Database Wizards, pages, and projects** and then click **OK.** If you have already opened a database or closed the dialog box that displays when Microsoft Access starts up, click **New Database** on the toolbar.
2. On the **Databases** tab, double-click the icon for the kind of database you want to create.
3. Specify a name and location for the database.
4. Click **Create** to start defining your new database

Create a database without using the Database Wizard

1. When Microsoft Access first starts up, a dialog box is automatically displayed with options to create a new database or open an existing one. If this dialog box is displayed, click **Blank Access Database**, and then click **OK.** If you have already opened a database or closed the dialog box that displays when Microsoft Access starts up, click **New Database** on the toolbar, and then double-click the **Blank Database** icon on the **General** tab.
2. Specify a name and location for the database and click **Create.** (Below is the screen that shows up following this step)

Tables

A table is a collection of data about a specific topic, such as students or contacts. Using a separate table for each topic means that you store that data only once, which makes your database more efficient, and reduces data-entry errors.

Tables organize data into columns (called **fields**) and rows (called **records**).

Create a Table from scratch in Design view

1. If you haven't already done so, switch to the Database Window You can press F11 to switch to the Database window from any other window.
2. Double-Click on **"Create table in Design view"**. *(DESIGN VIEW)*
3. Define each of the fields in your table.
    - o Under the Field Name column, enter the categories of your table.
    - o Under Data Type column, enter the type you want for you categories.
        - The attribute of a variable or field that determines what kind of data it can hold. For example, in a Microsoft Access database, the Text and Memo field data types allow the field to store either text or numbers, but the Number data type will allow the field to store numbers only. Number data type fields store numerical data that will be used in mathematical calculations. Use the Currency data type to display or calculate currency values. Other data types are Date/Time, Yes/No, Auto Number, and OLE object (Picture).
    - o Under the Description column, enter the text that describes what you field is. (This field is optional).

Primary Key

- One or more fields (columns) whose value or values uniquely identify each record in a table. A primary key does not allow Null values and must always have a unique value. A primary key is used to relate a table to foreign keys in other tables.
- **NOTE:** You do not have to define a primary key, but it's usually a good idea. If you don't define a primary key, Microsoft Access asks you if you would like to create one when you save the table.

- For our tutorial, make the **Soc Sec #** field the primary key, meaning that *every* student has a social security number and no 2 are the same.
  - To do this, simply select the Soc Sec # field and select the primary key button
  - After you do this, Save the table

Switching Views

To switch views form the datasheet (spreadsheet view) and the design view, simply click the button in the top-left hand corner of the Access program.

Datasheet View	Design View
Displays the view, which allows you to enter raw data into your database table.	Displays the view, which allows you to enter fields, data-types, and descriptions into your database table.

Entering Data

- Click on the Datasheet View and simply start "chugging" away by entering the data into each field. NOTE: Before starting a new record, the **Soc Sec #** field must have something in it, because it is the Primary Key. If you did not set a Primary Key then it is OK.

Manipulating Data

- Adding a new row
  - Simply drop down to a new line and enter the information
- Updating a record
  - Simply select the record and field you want to update, and change its data with what you want
- Deleting a record

Simply select the entire row and hit the Delete Key on the keyboard

Forms

A form is nothing more than a graphical representation of a table. You can add, update, delete records in your table by using a form.

NOTE: Although a form can be named different from a table, they both still manipulate the same information and the same exact data. Hence, if you change a record in a form, it will be changed in the table also.

A form is very good to use when you have numerous fields in a table. This way you can see all the fields in one screen, whereas if you were in the table view (datasheet) you would have to keep scrolling to get the field you desire.

Create a Form using the Wizard

It is a very good idea to create a form using the wizard, unless you are an advanced user and know what you are doing. Microsoft Access does a very good job of creating a form using the wizard. The following steps are needed to create a basic form:

1. Switch to the Database Window. You can do this by pressing F11 on the keyboard.
2. Click on the **Forms** button under **Objects** on the left side of screen
3. Double click on **Create Form Using Wizard**
4. On the next screen select the fields you want to view on your form. Most of the time you would select all of them.
5. Click Next
6. Select the layout you wish
7. Click Next

8. Select the style you desire...**HINT**: if you plan on printing your form, I suggest you use a light background to save on printer toner and ink
9. Click Next
10. Give you form a name, and select **Open the Form and enter information**
11. Select **Finish**
12. You should see your form. To adjust the design of your form, simply hit the design button (same as with the tables), and adjust your form accordingly

Reports

A report is an effective way to present your data in a printed format. Because you have control over the size and appearance of everything on a report, you can display the information the way you want to see it.

Create a Report using the Wizard

As with the Form, it is a very good idea to create a report using the wizard, unless you are an advanced user. Microsoft Access does a very good job using the wizard to create reports.

1. Switch to the Database Window. You can do this by pressing F11 on the keyboard.
2. Click on the **Reports** button under **Objects** on the left side of screen
3. Double click on **Create Report Using Wizard**
4. On the next screen select the fields you want to view on your form. Most of the time you would select all of them.
5. Click Next
6. Select if you would like to group your files. Keep repeating this step for as many groupings as you would like.
7. Click Next
8. Select the layout and the paper orientation you desire
9. Click Next
10. Select the style you desire...**HINT**: if you plan on printing your report, I suggest you use a light background to save on printer toner and ink
11. Click Next
12. Give you report a name, and select **Preview the Report**
13. Select **Finish**
14. You should see your report. To adjust the design of your report, simply hit the design button (same as with the tables), and adjust your report accordingly

Discussion

Using Microsoft Access, you can manage all your information from a single database file. Within the file, you can use:

- Tables to store your data.
- Queries to find and retrieve just the data you want.
- Forms to view, add, and update data in tables.
- Reports to analyze or print data in a specific layout.
- Data access pages to view, update, or analyze the database's data from the Internet or an intranet.

Store data once in one table, but view it from multiple locations. When you update the data, it's automatically updated everywhere it appears. To store your data, create one table for each type of information that you track. To bring the data from multiple tables together in a query, form, report, or data access page, define relationships between the tables. Customer information that once existed in a mailing list now resides in the Customers table. Order information that once existed in a spreadsheet now resides in the Orders table.

A unique ID, such as a Customer ID, distinguishes one record from another within a table. By adding one table's unique ID field to another table and defining a relationship, Microsoft Access can match related records from both tables so that you can bring them together in a form, report, or query. To find and retrieve just the data that meets conditions that you specify, including data from multiple tables, create a query. A query can also update or delete multiple records at the same time, and perform predefined or custom calculations on your data. To easily view, enter, and change data directly in a table, create a form. When you open a form, Microsoft Access retrieves the data from one or more tables, and displays it on the screen with the layout you choose in the Form Wizard or with the layout that you created on your own in Design view. A table displays many records at the same time, but you might have to scroll to see all of the data in a single record. Also, when viewing a table, you can't update data from more than one table at the same time.

A form focuses on one record at a time, and it can display fields from more than one table. It can also display pictures and other objects. A form can contain a button that prints, opens other objects, or otherwise automates tasks. To analyze your data or present it a certain way in print, create a report. For example, you might print one report that groups data and calculates totals, and another report with different data formatted for printing mailing labels. To make data available on the Internet or an intranet for interactive reporting, data entry, or data analysis, use a data access page. Microsoft Access retrieves the data from one or more tables and displays it on the screen with the layout that you created on your own in Design view, or with the layout you chose in the Page Wizard.

A table is a collection of data about a specific topic, such as products or suppliers. Using a separate table for each topic means that you store that data only once. This results in a more efficient database and fewer data-entry errors. Tables organize data into columns (called fields) and rows (called records).

For example, each field in a Products table contains the same type of information for every product, such as the product's name. Each record in that table contains all the information about one product, such as the product's name, supplier ID number, units in stock, and so on.

In table Design view, you can create an entire table from scratch, or add, delete, or customize the fields in an existing table. If you want to track additional data in a table, add more fields. If an existing field name isn't descriptive enough, you can rename the field. Setting a field's data type defines what kind of values you can enter in a field. For example, if you want a field to store numerical values that you can use in calculations, set its data type to **Number** or **Currency**.

You use a unique tag, called a primary key, to identify each record in your table. A table's primary key is used to refer to related records in other tables.

Field properties are a set of characteristics that provide additional control over how the data in a field is stored, entered, or displayed. Which properties are available depends on a field's data type.

A common field relates two tables so that Microsoft Access can bring together the data from the two tables for viewing, editing, or printing. In one table, the field is a primary key that you set in table Design view. That same field also exists in the related table as a foreign key. In the Suppliers table, you enter a supplier ID, company name, and so on, for each supplier. SupplierID is the primary key that you set in table Design view.

In the Products table, you include the SupplierID field, so that when you enter a new product, you can identify its supplier by entering that supplier's unique ID number. SupplierID is the foreign key in the Products table.

A select query is the most common type of query. It retrieves data from one or more tables and displays the results in a datasheet where you can update the records (with some restrictions). You can also use a select query to group records and calculate sums, counts, averages, and parameter query is a query that when run displays its own dialog box prompting you for information, such as criteria for retrieving records or a value you want to insert in a field. You can design the query to prompt you for more than one piece of information; for example, you can design it to prompt you for two dates. Access can then retrieve all records that fall between those two dates.

An action query is a query that makes changes to or moves many records in just one operation. There are four types of action queries:

- *Delete Queries* A delete query deletes a group of records from one or more tables. For example, you could use a delete query to remove products that are discontinued or for which there are no orders. With delete queries, you always delete entire records, not just selected fields within records.
- *Update Queries* An update query makes global changes to a group of records in one or more tables. For example, you can raise prices by 10 percent for all dairy products, or you can raise salaries by 5 percent for the people within a certain job category. With an update query, you can change data in existing tables.
- *Append Queries* An append query adds a group of records from one or more tables to the end of one or more tables. For example, suppose that you acquire some new customers and a database containing a table of information on those customers. To avoid typing all this information into your own database, you'd like to append it to your Customers table.
- *Make-Table Queries* A make-table query creates a new table from all or part of the data in one or more tables. Make-table queries are helpful for creating a table to export to other Microsoft Access databases or a history table that contains old records.

An SQL query is a query you create by using an SQL statement. You can use Structured Query Language (SQL) to query, update, and manage relational databases such as Access.

When you create a query in query Design view, Access constructs the equivalent SQL statements behind the scenes for you. In fact, most query properties in the property sheet in query Design view have equivalent clauses and options available in SQL view. If you want, you can view or edit the SQL statement in SQL view. However, after you make changes to a query in SQL view, the query might not be displayed the way it was previously in Design view.

After you've set up different tables for each subject in your Microsoft Access database, you need a way of telling Microsoft Access how to bring that information back together again. The first step in this process is to define relationships between your tables. After you've done that, you can create queries, forms, and reports to display information from several tables at once.

A one-to-many relationship is the most common type of relationship. In a one-to-many relationship, a record in Table A can have many matching records in Table B, but a record in Table B has only one matching record in Table A.

In a many-to-many relationship, a record in Table A can have many matching records in Table B, and a record in Table B can have many matching records in Table A. This type of relationship is only possible by defining a third table (called a junction table) whose primary key consists of two fields — the foreign keys from both Tables A and B. A many-to-many relationship is really two one-to-many relationships with a third table. For example, the Orders table and the Products table have a many-to-many relationship that's defined by creating two one-to-many relationships to the Order Details table. One order can have many products, and each product can appear on many orders.

In a one-to-one relationship, each record in Table A can have only one matching record in Table B, and each record in Table B can have only one matching record in Table A. This type of relationship is not common, because most information related in this way would be in one table. You might use a one-to-one relationship to divide a table with many fields, to isolate part of a table for security reasons, or to store information that applies only to a subset of the main table. For example, you might want to create a table to track employees participating in a fundraising soccer game. Each soccer player in the Soccer Players table has one matching record in the Employees table.

Good database design ensures that your database is easy to maintain. You store data in tables and each table contains data about only one subject, such as customers. Therefore, you update a particular piece of data, such as an address, in just one place and that change automatically appears throughout the database.

A well-designed database usually contains different types of queries that show the information you need. A query might show a subset of data, such as all customers in London, or combinations of data from different tables, such as order information combined with customer information.

This query retrieves the order ID, company name, city, and required date information for customers in London whose orders were required in April.

The results you want from your database — the forms and data access pages you want to use, and the reports you want to print — don't necessarily provide clues about how you should structure the tables in your database, because you often base forms, reports, and data access pages on queries instead of tables.

Before you use Microsoft Access to actually build tables, queries, forms, and other objects, it's a good idea to sketch out and rework your design on paper first. You can also examine well-designed databases similar to the one you are designing, or you can open the Northwind sample database and then open the Relationships window to examine its design.

Follow these basic steps when designing your database. The first step in designing a database is to determine its purpose and how it's to be used:

- Talk to people who will use the database. Brainstorm about the questions you and they would like the database to answer.
- Sketch out the reports you'd like the database to produce.
- Gather the forms you currently use to record your data.

As you determine the purpose of your database, a list of information you want from the database will begin to emerge. From that, you can determine what facts you need to store in the database and what subject each fact belongs to. These facts correspond to the fields (columns) in your database, and the subjects that those facts belong to correspond to the tables.

Each field is a fact about a particular subject. For example, you might need to store the following facts about your customers: company name, address, city, state, and phone number. You need to create a separate field for each of these facts. When determining which fields you need, keep these design principles in mind:

- Include all of the information you will need.
- Store information in the smallest logical parts. For example, employee names are often split into two fields, FirstName and LastName, so that it's easy to sort data by LastName.
- Don't create fields for data that consists of lists of multiple items. For example, in a Suppliers table, if you create a Products field that contains a comma-separated list of each product you receive from the supplier, it will be more difficult to find only the suppliers that provide a particular product.
- Don't include derived or calculated data (data that is the result of an expression). For example, if you have a UnitPrice field and a Quantity field, don't create an additional field that multiplies the values in these two fields.
- Don't create fields that are similar to each other. For example, in a Suppliers table, if you create the fields Product1, Product2, and Product3, it will be more difficult to find all suppliers who provide a particular product. Also, you will have to change the design of your database if a supplier provides more than three products. You need only one field for products if you put that field in the Products table instead of in the Suppliers table.

Each table should contain information about one subject. Your list of fields will provide clues to the tables you need. For example, if you have a HireDate field, its subject is an employee, so it belongs in the Employees table. You might have a table for Customers, a table for Products, and a table for Orders. When you decide which table each field belongs to, keep these design principles in mind:

- Add the field to only one table.
- Don't add the field to a table if it will result in the same information appearing in multiple records in that table. If you determine that a field in a table will contain a lot of duplicate information, that field is probably in the wrong table.

The database files in Access

The term "database" means different things depending on the DBMS used. For example in dBase IV, a database is a file (<filename>.dbf) containing a single table. Forms and reports are also stored as individual files with different extensions. The net result is a clutter of files.

In contrast, an Oracle database has virtually no relationship to individual files or individual projects. For instance, a database may contain many tables from different projects/applications and may also be stored split into one or more files (perhaps on Different machines).

Access strikes a convenient balance—all the "objects" (tables, queries, forms, reports, etc.) for a single project/application are stored in a single file.

Compacting a database

As the help system points out, Access database files can become highly fragmented and grow to become much larger than you might expect given the amount of data they contain (e.g., multiple megabytes for a handful of records). Compacting the database from time to time eliminates fragmentation and can dramatically reduce the disk space requirement of your database.

Renaming a database

It is often the case that you are working with a database and want to save it under a different name or save it on to a different disk drive. However, one command on the File menu that is conspicuous by its absence is Save As. However, when compacting your database, Access asks for the name and destination of the compacted file. As a result, the compact database utility can beused as a substitute for the Save As command. This is especially useful in situations in which you cannot use the operating system to rename a file (e.g., when you do not have access to the Windows file manager).

GEOGRAPHIC INFORMATION SYSTEMS TECHNOLOGY AND APPLICATIONS

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Introduction

We are presently positioned at the beginning of twenty first century with the fast growing trends in computer technology information systems and virtual world to obtain data about the physical and cultural worlds, and to use these data to do research or to solve practical problems. The current digital and analog electronic devices facilitate the inventory of resources and the rapid execution of arithmetic or logical operations. These Information Systems are undergoing much improvement and they are able to create, manipulate, store and use spatial data much faster and at rapid rate as compared to conventional methods.

An Information System, a collection of data and tools for working with those data, contains data in analog form or digital form about the phenomena in the real world. Our Perception of the world through selection, generalization and synthesis give us information and the representation of this information that is, the data constitute a model of those phenomena. So the collection of data, the database is a physical repository of varied views of the real world representing our knowledge at one point in time. Information is derived from the individual data elements in a database, the information directly apparent i.e. information is produced from data by our thought processes, institution or what ever based on our knowledge. Therefore in a database context the terms data, information and knowledge are differentiated. It can be summarized that the data is very important and added value as we progress from data to information, to knowledge. The data, which has many origins and forms, may be any of the following:

1. Real, for example the terrain conditions etc.
2. Captured, i.e. recorded digital data from remote sensing satellites or aerial photographs of any area.
3. Interpreted, i.e. landuse from remote sensing data.
4. Encoded i.e. recordings of rain-gauge data, depth of well data etc.
5. Structured or organized such as tables about conditions of particular watershed.

Concepts of Space and time in Spatial Information Systems

Spatial information is always related to geographic space, i.e., large-scale space. This is the space beyond the human body, space that represents the surrounding geographic world. Within such space, we constantly move around, we navigate in it, and we conceptualise it in different ways. Geographic space is the space of topographic, landuse/landcover, climatic, cadastal, and other features of the geographic world. Geographic information system technology is used to manipulate objects in geographic space, and to acquire knowledge from spatial facts.

The human understanding of space, influenced by language and cultural background, plays an important role in how we design and use tools for the processing of spatial data. In the same way as spatial information is always related to geographic space, it relates to geographic time, the time whose effects we observe in the changing geographic world around us. We are less interested in pure philosophical or physical considerations about time or space-time, but more in the observable spatio-temporal effects that can be described, measured and stored in information systems.

The handling of spatial data usually involves processes of data acquisition, storage and maintenance, analysis and output. For many years, this has been done using analogue data sources, manual processing and the production of paper maps. The introduction of modern technologies has led to an increased use of computers and information technology in all aspects of spatial data handling. The software technology used in this domain is geographic information systems (GIS).

A general motivation for the use of GIS can be illustrated with the following example. For a planning task usually different maps and other data sources are needed. Assuming a conventional analogue procedure we would have to collect all the maps and documents needed before we can start the analysis. The first problem we encounter is that the maps and data have to be collected from different sources at different locations (e.g., mapping agency, geological survey, soil survey, forest survey, census bureau, etc.), and that they are in different scales and projections. In order to combine data from maps they have to be converted into working documents of the same scale and projection. This has to be done manually, and it requires much time and money.

With the help of a GIS, the maps can be stored in digital form in a database in world co-ordinates (metres or feet). This makes scale transformations unnecessary, and the conversion between map projections can be done easily with the software. The spatial analysis functions of the GIS are then applied to perform the planning tasks. This can speed up the process and allows for easy modifications to the analysis approach.

TECHNOLOGY OF GIS

Any planning operation using GIS needs thorough understanding of technology by the personnel involved in handling data to evolve output for making plans and decisions. A brief description of how GIS works or technology is envisaged.

Definition

Numerous definitions exist for GIS. Not a single one is complete by itself as the users based on their needs define them all. Some of them are:

- An information system that is designed to work with data referenced by spatial or geographic coordinates. In other words, a GIS is both a database system with specific capabilities for spatially referenced data, as well as a set of operations for working [analysis] with the data. (Star and Estes, 1990)
- GIS is a powerful set of tools for collecting, storing, retrieving at will transforming and displaying spatial data from the real world. (Burrough, 1986)
- GIS is a database system in which most of the data are spatially indexed, and upon which a set of procedures operational in order to answer queries about spatial entities in the data base (Smith *et al.,* 1987)

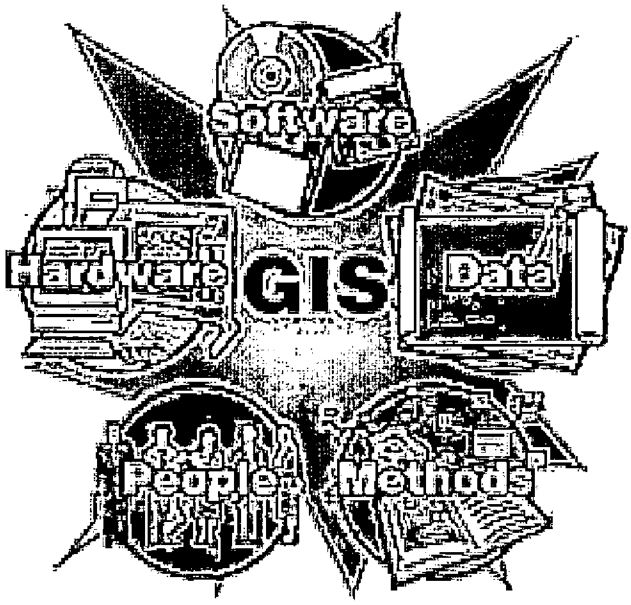
GIS is also defined as

- GIS is a computerized, integrated system used to compile, store, manipulate and output mapped spatial data.
- A computer based tool for mapping and analysing geographic phenomenon that exist and events that occur on earth.
- A GIS is an integrated set of hardware and software tools used f or manipulation and management of digital spatial and related attribute data.

All the above definitions are true but not a comprehensive one. A comprehensive definition should include the components of GIS and may be defined as "An organized collection of computer hardware, software, geographic data and personnel designed to efficiently capture, store, update, manipulate, analyze and display all forms of geographically referenced information." (ESRI, 1990)

Components of a GIS

A successfully working GIS has a series of components that operate in concert to make the system functional. A functional GIS integrates five key components. (FIG.1)



a. Hardware: It is the computer system on which GIS operates. A wide range of hardware from centralized computer servers to desk top computers used in stand alone or networked configuration serve as a host for the GIS software.

b. Software: GIS software provides the function and tools needed to store, analyse and display geographic information. Some of the commonly used software is Arc Info, Arc view, ISROGIS, ILWIS, GRASS, GRAM etc.

c. Data: Data in GIS refers to any information collected by software /personnel and/or manipulated to needs into layers, to give an entire picture to a geographic topic. It is the most important component and forms the backbone of GIS.

d. People /users: The term users refer to any individual who will use GIS to support projects/program goals or to an entire organisation that will employ GIS in support of its overall mission. USGS (1988) classified users into two:

   i. System users: They are those persons who have actual hands-on use of the GIS hardware and software. These persons have advanced technical skills in the application of GIS. They design, maintain, update and manage the system and develop plans for applying it to real world problems.
   ii. End users: They are those persons who do not have actual hands-on use of the system. They make use of the information products generated by the GIS. They may or may not be technically skilled but use GIS output to support project/ program. They can be individuals, groups or organisation using GIS output for supporting overall mission.

e. Methods: Methods refer to the rules and plans that decide the model and operational practices of GIS output by an end user. It is unique for each organisation.

GIS SUBSYSTEMS

A GIS has four main functional sub-systems. These are:

- i Data Input: A data input subsystem allows the user to capture, collect, and transform spatial and thematic data into digital form. The data inputs are usually derived from a combination of hard copy maps, aerial photographs, remotely sensed images, reports, survey documents, etc.
- ii Data Storage and Retrieval: The data storage and retrieval subsystem organizes the data, spatial and attribute, in a form which permits it to be quickly retrieved by the user for analysis, and permits rapid and accurate updates to be made to the database. This component usually involves use of a database management system (DBMS) for maintaining attribute data.
- iii Data Manipulation and Analysis: The data manipulation and analysis subsystem allows the user to define and execute spatial and attribute procedures to generate derived information. This subsystem is commonly thought of as the ***heart of a GIS***, and usually distinguishes it from other database information systems and computer-aided drafting (CAD) systems.
- iv Data Output: The data output subsystem allows the user to generate graphic displays, normally maps, and tabular reports representing derived information products.

Data

The most important component of any GIS is data and the primary function of a GIS is to manipulate and analyse data to generate derived output. GIS utilizes two data-types.

Data types

GIS technology utilises two basic data types.

- i Spatial data: describes the absolute and relative location of geographic features. It tells us where something occurs.
- ii Attribute data: describes characteristics of the spatial features. These characteristics can be quantitative and/or qualitative in nature. Attribute data is often referred to as tabular data. It tells us what occurs.

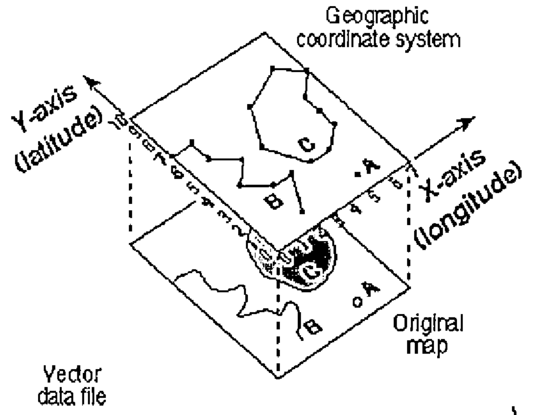
Every GIS provides the ability to store and manipulate both the spatial and associated attribute data.

Data models

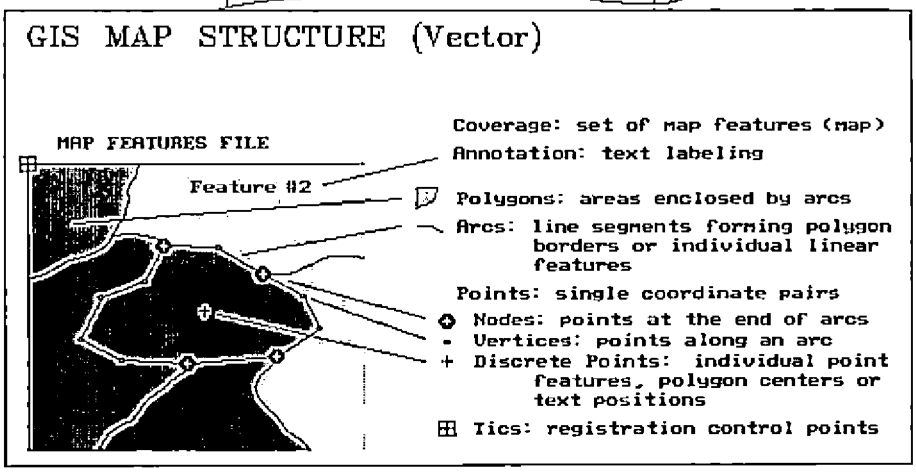
Data model is a set of logical definitions or rules for characterizing the Geographical data. The data model represents the linkages between the real- world domain of geographical data and the computer or GIS representation of features. Data model help not only in organizing data on geographical features but also help in capturing users perception of these features (Marble, 1982). All data models are approaches for storing geographic features in a database. Data models are used to simplify the data shown on map into a more basic form that can be easily and efficiently stored in the computer. Data models are of two types:

- i ***Spatial data model:*** Traditionally spatial data has been stored and presented in the form of a map. All spatial data models are approaches for storing the spatial location of geographic features in a database. The basic types of spatial data models for storing geographic data digitally are:

- *Vector data format*: A vector model stores all spatial data as primitive features or points, lines, and polygons. Vector storage implies the use of **Figure 2.** Vector representation of geographic data vectors (directional lines) to represent a geographic feature. Vector data is characterized by the use of sequential points or



ENTITY	X,Y COORDINATES	NAME
A	5,1	well
B	0,7; 1,7; 1,6; 2,5; 1,4; 2,3; 3,3; 2,1	stream
C	4,3; 5,3; 6,4; 6,5; 6,6; 7,7; 6,8; 4,7; 3,5; 4,3	lake



vertices to define a linear segment. Each vertex consists of an X coordinate and a Y coordinates. Vector lines are often referred to as *arcs* and consist of a string of vertices terminated by a *node*. A node is defined as a vertex that starts or ends an arc segment. One coordinate pair - a vertex, defines point features. Polygonal features are defined by a set of closed coordinate pairs. Attributes of vector units are stored in computer files as records or tuples that may be linked to them. The end result of converting a map to a vector data file is a GIS compatible -compatible digital data file. (Fig.2)

- *Raster Data Formats*: Raster data models incorporate the use of a *grid-cell* data structure where the geographic area is divided into cells identified by row and column. This data structure is commonly called *raster*. The location of each grid cell is defined by row and column coordinates with an associated attribute tag linked to each cell. The grid network defines location of the entities with each pixel associated with a square parcel of land on earth surface. A raster model stores spatial and attribute data together for sets of grid cells registered to the original map. The location of each grid cell is defined by row and column coordinates with an associated attribute tag linked to each cell. The end result of converting a map to a raster data file is a GIS-compatible digital data file. (Fig.3)

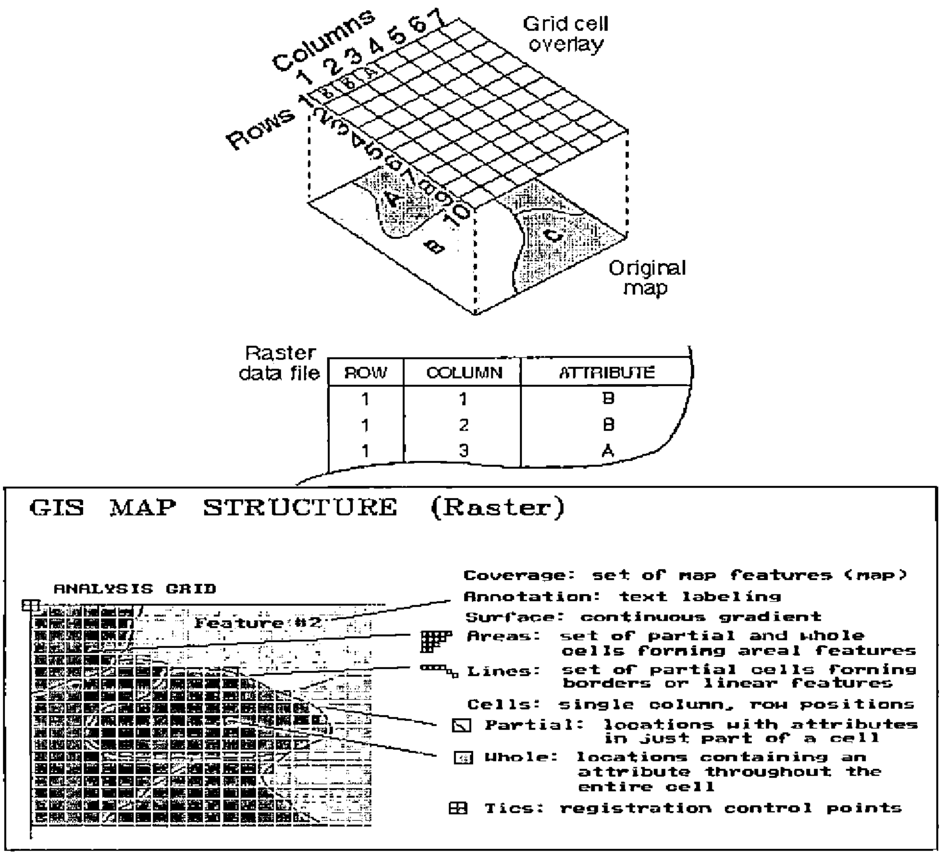


Figure 3. Raster representation of geographic data

ii ***Attribute data model*:** Attribute data model is used to store and maintain attribute data for GIS software. A variety of data models exist for the storage and management of attribute data . The most common are :

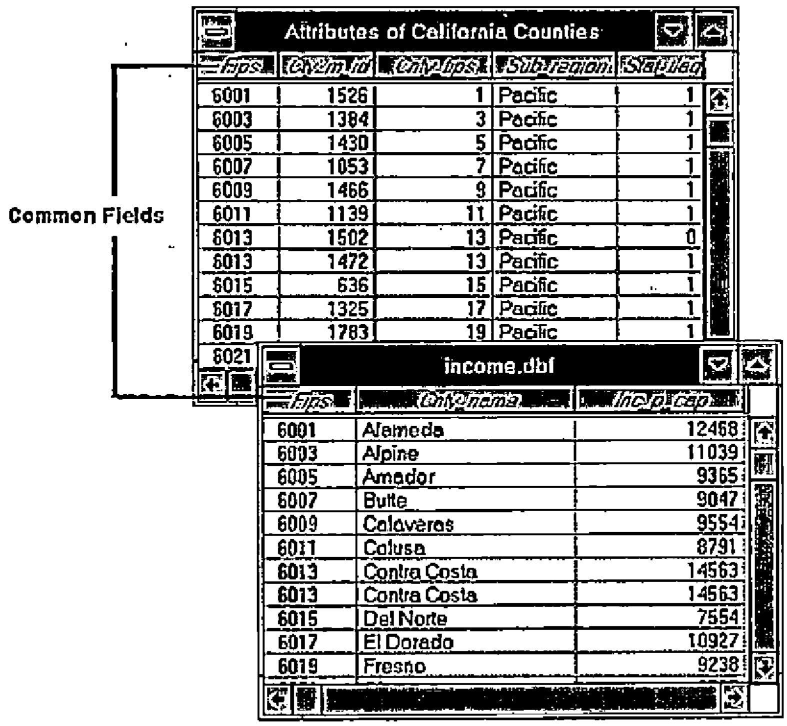
- *Tabular*: The simple tabular model stores attribute data as sequential data files with fixed formats for the location of attribute values in a predefined record structure. This type of data model is outdated in the GIS arena.

- *Hierarchical*: The hierarchical database organizes data in a *tree* structure. Data is structured downward in a *hierarchy* of tables. The hierarchical system assumes that each part of hierarchy can be reached using a key (a set of discriminating criteria) that fully describes the data structure and there is a good correlation between the key attributes and associated attributes the item may posses. Hierarchical DBMS have not gained any noticeable acceptance for use within GIS

- *Network*: The network database organizes data in a network or *plex* structure. Any column in a plex structure can be linked to any other. Network database structures are very useful when the relations or linkages can be specified beforehand. They avoid data redundancy and make good use of available data. Network DBMS have not found much more acceptance in GIS than the hierarchical DBMS.

- *Relational*: The relational database organizes data in *tables*. Each table, is identified by a unique table name, and is organized by *rows* and *columns*. Each column within a table also has a unique name. Columns store the values for a specific attribute. Rows represent one record in the table. In a GIS each row is usually linked to a separate spatial feature. Accordingly, each row would be comprised of several columns, each column containing a specific value for that geographic feature. This serves as the linkage between the spatial definition of the feature and the attribute data for the feature. The relational database model is the most widely accepted for managing the attributes of geographic data. In the relational design, data are stored conceptually as a collection of tables. Common fields in different tables are used to link them together. Data are extracted from a relational database through the user query known as Structured Query Language (SQL). A relational database format is shown in the Figure 4.

- Object Oriented: The object-oriented database model manages data through *objects*. An object is a collection of data elements and operations that together are considered a single entity. The object-oriented database is a relatively new model. This approach has the attraction that querying is very natural, as features can be bundled together with attributes at the database administrator's discretion.



Fips	[illegible]	Cnty_fips	Sub_region	[illegible]
6001	1526	1	Pacific	1
6003	1384	3	Pacific	1
6005	1430	5	Pacific	1
6007	1053	7	Pacific	1
6009	1466	9	Pacific	1
6011	1139	11	Pacific	1
6013	1502	13	Pacific	0
6013	1472	13	Pacific	1
6015	636	15	Pacific	1
6017	1325	17	Pacific	1
6019	1783	19	Pacific	1
6021				

Fips	Cnty_name	Inc_p_cap
6001	Alameda	12468
6003	Alpine	11039
6005	Amador	9365
6007	Butte	9047
6009	Calaveras	9554
6011	Colusa	8791
6013	Contra Costa	14563
6013	Contra Costa	14563
6015	Del Norte	7554
6017	El Dorado	10927
6019	Fresno	9238

Figure 4. Representation of relational data model

Spatial Data Relationships

The nature of spatial data relationships is of concern since the primary role of GIS is the manipulation and analysis of large quantities of spatial data. To date, the accepted theoretical solution is to *topologically structure* spatial data. It is believed that a topologic data model best reflects the geography of the real world and provides an effective mathematical foundation for encoding spatial relationships, providing a data model for manipulating and analyzing vector based data.

Topology

Topology is a mathematical approach that allows us to structure data based on the principles of feature adjacency and feature connectivity. It is in fact the mathematical method used to define spatial relationships. Without a topologic data structure in a vector based GIS most data manipulation and analysis functions would not be practical or feasible. Since most input data does not exist in a topological data structure, topology must be built with the GIS software. The topological model is utilized because it effectively models the relationship of spatial entities. The major disadvantage of the topological data model is its static nature

Data Sources

Data input into a GIS as mentioned are spatial data and attribute data. So their sources are also different. Data input into a GIS is digital data and is the most expensive part of the GIS. In any GIS data acquisition, data compilation and database development accounts for about 60 to 80 % of the cost incurred. A wide variety of data sources exist for both spatial and attribute data.

- *Attribute data sources*: Any textual, tabular, graphical data that can be referenced to the geographical feature serve as attribute data sources. Attribute data is usually inputted by manual keying or by a bulk loading utility of the DBMS software.
- *Spatial data sources*: Most commonly available spatial data sources are

    - Hard copy maps
    - Aerial photographs
    - Remotely-sensed imagery
    - Point data samples from surveys
    - Existing digital data files.

The most popular spatial data sources are the existing hard copy maps, or *analogue maps*. So the accuracy of the map inputted into the GIS decides the quality of the output of any GIS.

Map

The accuracy and quality of the map is a major factor deciding the output of any GIS. Therefore it need special attention or care while working with a map. Maps are fundamental tools used to portray spatial or geographic data. A map is a graphic representation of where features are, explicitly and relative to one another. A map is composed of different geographic features represented as points, lines, and/or areas. A geographic feature on a map is defined both by its location in space and by its characteristic features and therefore can be treated as a miniature model of the real world. The symbols and features used in a map describe its counterpart in real world and the map legend is the key linking the attributes to the geographic features. Any map portrays three kinds of information about geographical features. They are the:

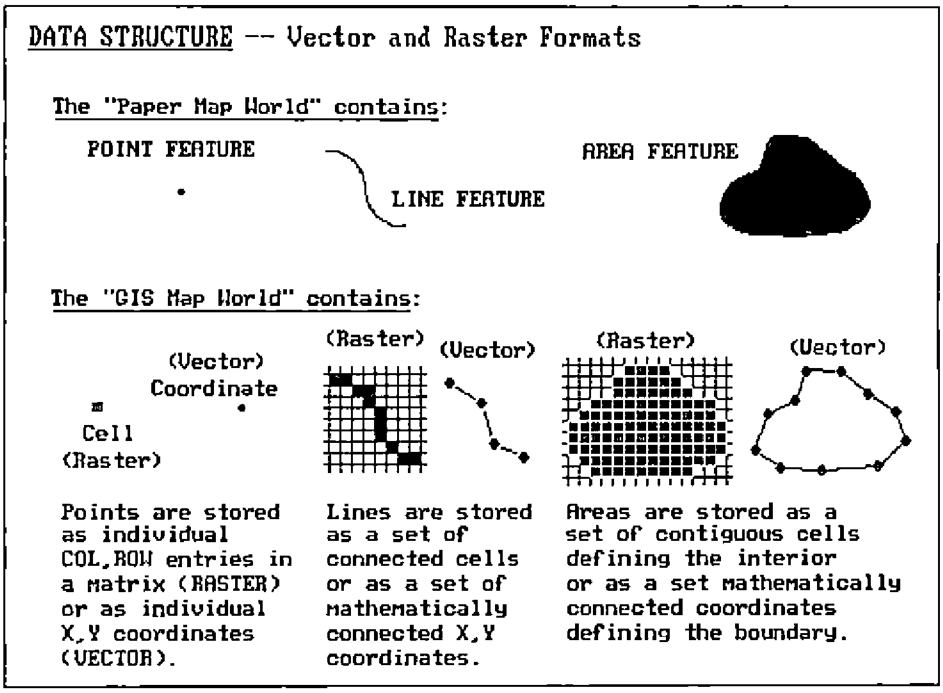
- Location and extent of the feature identified explicitly by reference to a coordinate system representing the earth's surface. This is where a feature is.
- Attributes (characteristics) of the feature describe or characterize the feature. This is what the feature is.
- Relationship of the feature to other features implied from the location and attributes of all features.

Characterizing Geographic features

All geographic features on the earth's surface can be characterized and defined by points, lines, and areas, i.e. a point, line, and/or an area can in principle represent every geographic phenomenon (**Figure 5**).

Figure 5. Characteristic representation of geographic features

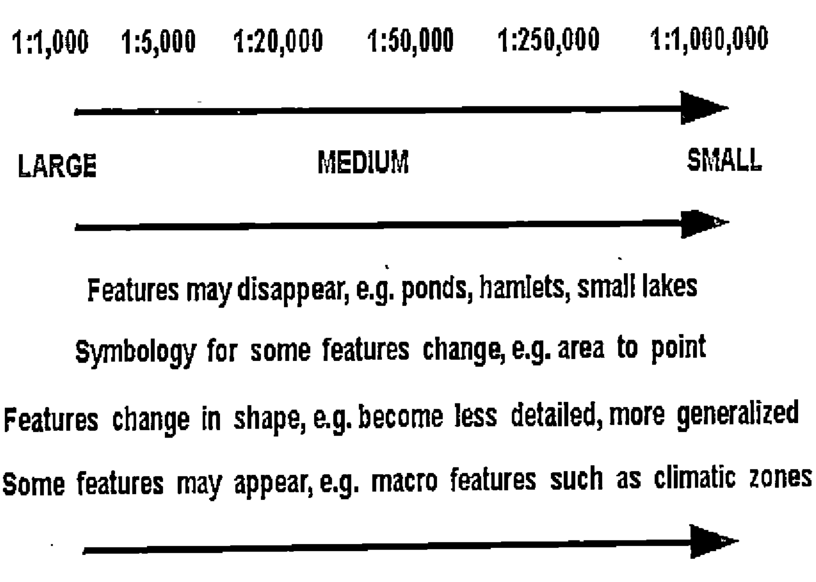
Geographic features and symbols used to represent them is dependant on the scale used to represent the data. Scale is the ratio of a distance on an image/map to its corresponding distance on the scene. Therefore accuracy of a feature's location is lesser at a smaller scale than a larger



scale. Generalisation of feature is an inherent characteristic of the data presented at a smaller scale.

Figure 6. Generalisation of features with scale

The figure above depicts (Fig 6.) the changes that happen on a decreasing scale of maps. As the scale of map decreases from 1:1000 to 1: 1000000 the relative size of the features decrease and following changes may occur.



- Some features may disappear, e.g. features such as ponds, hamlets, and lakes, become indistinguishable as a feature and are eliminated.
- Features change from areas to lines or to points, e.g. a village or town represented by a polygon at 1:15,000 may change to point symbology at a 1:100,000 scale.
- Features change in shape, e.g. boundaries become less detailed and more generalized.
- Some features may appear, e.g. features such as climate zones may be indistinguishable at a large scale (1:15,000) but the full extent of the zone becomes evident at a smaller scale (1:1,000,000).

The table (**Table1**) shows the location accuracy at some common map scales. At 1: 5000 map scale 1cm^2 area on a map represent 0.25 ha in real world. Also any point on the map can locate a feature with an accuracy of ± 1.25 m, but as the scale decreases to 1: 1000,000 the area represented increases to 10000 ha and any point can represent a feature within ± 250m.Scale of map is important as because maps to be stored in a GIS must be similar in scale if they are to be manipulated together *i.e.* maps with large difference in scale cannot be compared and overlaid without serious distortion and error.

Table1: Location accuracy at some common map scales

Map scale	Area covered by 1cm^2/ ha	Maximum location accuracy/m
1:5,000	0.25	1.25
1:10000	1.0	2.5
1:15,000	2.25	3.75
1:20,000	4.00	5.0
1:25,000	6.25	6.25
1:50,000	25.00	12.5
1:1,00,000	100	25.0
1:2,00,000	400	50.0
1:250,000	625	62.5
1:5,00,000	2500	125
1:1,000,000	10000	250

Data input

Once the data collection is over the data is entered into the GIS by:

1. *Digitizing*: digitizing is a simplification process that converts all spatial data to a point, line or polygon. Digitizing allows a user to trace spatial data from a hard copy product, e.g. a map, and have it recorded by the computer software. It can be done either manually or automatically.
2. *Automatic scanning*: This method employs use of scanning devices for capture of spatial data. This has the advantage of capturing spatial data at a greater speed. Still it is not popular in GIS technology as scanners are generally expensive to acquire and operate. Most scanning devices have limitations with respect to the capture of selected features, e.g. text and symbol recognition.
3. *Coordinate Geometry*: Another technique for the input of spatial data involves the calculation and entry of coordinates using coordinate geometry procedures. This involves entering, from survey data, the explicit measurement of features from some

known monument. This input technique is obviously very costly and labour intensive and it is rarely used for natural resource applications in GIS.

4. *Existing digital data*: This is yet another technique of data input where a variety of existing spatial data, including digital maps which are openly available from a wide range of government and private sources are input into the current GIS. The most common digital data to be used in a GIS is data from CAD systems and numerous software exist for conversion of CAD data into GIS. Some of the data formats common to the GIS are:
    - IGDS - Interactive Graphics Design Software (Intergraph / Microstation)
    - DLG - Digital Line Graph (US Geological Survey)
    - DXF - Drawing Exchange Format (Autocad)
    - GENERATE -ARC/INFO Graphic Exchange Format
    - EXPORT - ARC/INFO Export Format

Data Editing and Quality Assurance

The input data may be incorrect due to errors that arose during the encoding of spatial and non-spatial data. Most common errors are

- *Incompleteness of the spatial data*: This includes missing points, line segments, and/or polygons.
- *Locational placement errors of spatial data*: These types of errors usually are the result of careless digitizing or poor quality of the original data source.
- *Distortion of the spatial data*: Base maps that are not scale-correct over the whole image, e.g. aerial photographs, or from material stretch, e.g. paper documents usually cause this kind of error.
- *Incorrect linkages between spatial and attribute data*: This type of error is commonly the result of incorrect unique identifiers (labels) being assigned during manual key in or digitizing. This may involve the assigning of an entirely wrong label to a feature, or more than one label being assigned to a feature.
- *Attribute data is wrong or incomplete*: Often the attribute data does not match exactly with the spatial data. This is because they are frequently from independent sources and often-different time periods. Missing data records or too many data records are the most common problems.

  These errors result in spatial data errors like
- Slivers and gaps in the line work;
- Dead ends e.g. also called dangling arcs, resulting from overshoots and undershoots in the line work;
- Bow ties or weird polygons from inappropriate closing of connecting features.

These errors are to be cleaned by several tools provided by software of GIS. The process is called cleaning up of data.

Organizing Data for Analysis

Once the data is cleaned they have to be organized for analysis. Most GIS software organizes spatial data in a thematic approach that categorizes data in vertical *layers*.

Spatial Data Layers - Vertical Data Organization

In most GIS software spatial data is organized in themes as *data layers*. In this data are input as separate themes and overlaid based on analysis requirements. This can conceptualized as vertical layering the characteristics of the earth's surface. Spatial data layers are commonly input one at a time. Accordingly, attribute data is entered one layer at a time. Depending on the attribute data model used by the data storage subsystem data must be organized in a format that will facilitate the manipulation and analysis tasks that will be required. Themes, coverages, layers, levels, objects, and feature classes are the terms used to define data layers in commercial GIS software. Most GIS projects integrate data layers to create derived themes or layers that represent the result of some calculation or geographic model, e.g. forest merchantability, land use suitability, etc.

Spatial Indexing - Horizontal Data Organization

The organization of data layers in a horizontal fashion within a GIS is known as *spatial indexing*. Spatial indexing is the method utilized by the software to store and retrieve spatial data. This involves the partitioning of the geographic area into manageable subsets or *tiles*. These tiles are then indexed mathematically, e.g. by quadtrees, by R (rectangle) trees, to allow for quick searching and retrieval when querying is initiated by a user.

Data manipulation and analysis

Once the data is input and converted to digital format in a GIS, it is compiled by relating all spatial features to respective attributes, cleaned, edited and errors corrected using specific processes. This prepares the data for the most important procedure in any GIS – the data analysis.

Data analysis

This is the heart of any GIS and differentiates it from all other map-making softwares. Data analysis involves three processes

i. Manipulation and transformation of data
ii. Integration and modeling of spatial data
iii. Integrated analytical functions

These are performed by the toolkits available in the software. Toolkit is a set of generic functions that a GIS user can employ to manipulate and analyse geographic data.

Manipulation and transformation of data

These involves following procedures

- *Co-ordinate thinning*: Coordinate thinning involves the *weeding* or reduction of coordinate pairs, from arcs. This function is often required when data has been captured with too many vertices for the linear features.
- *Geometric Transformations*: This function is concerned with the registering of a data layer to a common coordinate scheme. This usually involves registering selected data layers to a standard data layer already registered.
- *Map Projection Transformations*: This function concerns the transformation of data in geographic coordinates for an existing map projection to another map projection. Most GIS software requires that data layers must be in the same map projection for analysis. Accordingly, if data is acquired in a different projection than the other data layers it must be transformed.
- *Conflation / Sliver Removal*: Conflation is formally defined as the procedure of merging the positions of corresponding features in different data layers. Conflation is concerned with the process for removing slivers and unifiying the common boundary. More commonly this is referred to as *sliver removal*
- *Edge Matching*: Edge matching is simply the procedure to adjust the position of features that extend across typical map sheet boundaries. Theoretically data from adjacent map sheets should meet precisely at map edges.

- *Interactive Graphic Editing*: Interactive graphic editing functions involve the addition, deletion, moving, and changing of the geographic position of features. Many of the editing that is undertaken involves the cleaning up of topological errors identified earlier. The capability to *snap* to existing elements, e.g. nodes and arcs, is critical.

Integration and modeling of spatial data

These are the techniques that allow the GIS to answer complex how much? or where? and what if? questions. This is called spatial modeling. Spatial modeling refers to the use of spatial characteristics and methods in manipulating data.

Integrated Analytical function in a GIS

Most GIS's provide the capability to build complex models by combining primitive analytical functions. Aronoff (1989) identifies four categories of GIS analysis functions. These are:

- *Retrieval, Reclassification, and Generalization*: Reclassification does the selection and presentation of a selected layer of data based on the classes or values of a specific attribute e.g. cover group. It involves looking at an attribute, or a series of attributes, for a single data layer and classifying the data layer based on the range of values of the attribute. Reclassification is an attribute generalization technique. Typically this function makes use of polygon patterning techniques such as crosshatching and/or color shading for graphic representation.
- *Topological Overlay Techniques*: Topological overlay is concerned with stacking polygon data over polygon data, e.g. soils and forest cover. However, there are requirements for overlaying point, linear, and polygon data in selected combinations, e.g. point in polygon, line in polygon, and polygon on polygon are the most common. The following diagram illustrates a typical overlay requirement where several different layers are spatially joined to create a new topological layer. By combining multiple layers in a topological fashion complex queries can be answered concerning attributes of any layer. (**Figure. 6**)

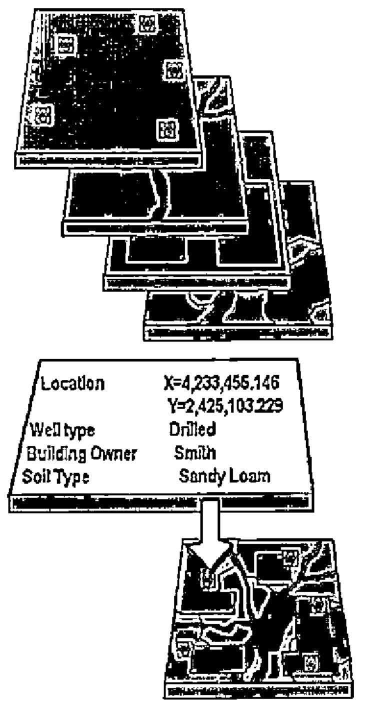


Figure 6. Overlaying functrion of a GIS

- *Neighbourhood Operations*: Neighbourhood operations evaluate the characteristics of an area surrounding a specific location. This involves a variety of *point interpolation* techniques including slope and aspect calculations, contour generation etc. Interpolation is defined as the method of predicting unknown values using known values of neighbouring locations. The most common neighbourhood function is buffering. Buffering involves the ability to create distance buffers around selected features, be it points, lines, or areas. Buffers are created as polygons because they represent an area around a feature. Buffering is also referred to as corridor or zone generation with the raster data model.

- *Connectivity Functions*: Connectivity functions include proximity analysis, network analysis, spread functions, and three-dimensional surface analysis such as visibility and perspective viewing. The most commonly used ones are
    - *Proximity analysis* techniques are primarily concerned with the proximity of one feature to another. *Proximity* is defined as the ability to identify any feature that is near any other feature relative to location, attribute value, or a specific distance.
    - *Network analysis* is a widely used analysis technique. Two example network analysis techniques are the *allocation of values* to selected features within the network to determine capacity zones, and the determination of *shortest path* between connected points or nodes within the network based on attribute values. This is often referred to as *route optimization*. Attribute values may be as simple as minimal distance, or more complex involving a model using several attributes defining rate of flow, impedance, and cost. Thus representation, management and manipulation of the network of linear features are an important operation of a GIS (Rao, 1992).

The figures 7 and 8 below depicts in general the analytic and manipulative technique of any GIS

Output

All the manipulation and data analysis in any GIS end up in certain output or results that are in digital form, which are the final output of GIS. The most common output from a GIS are:

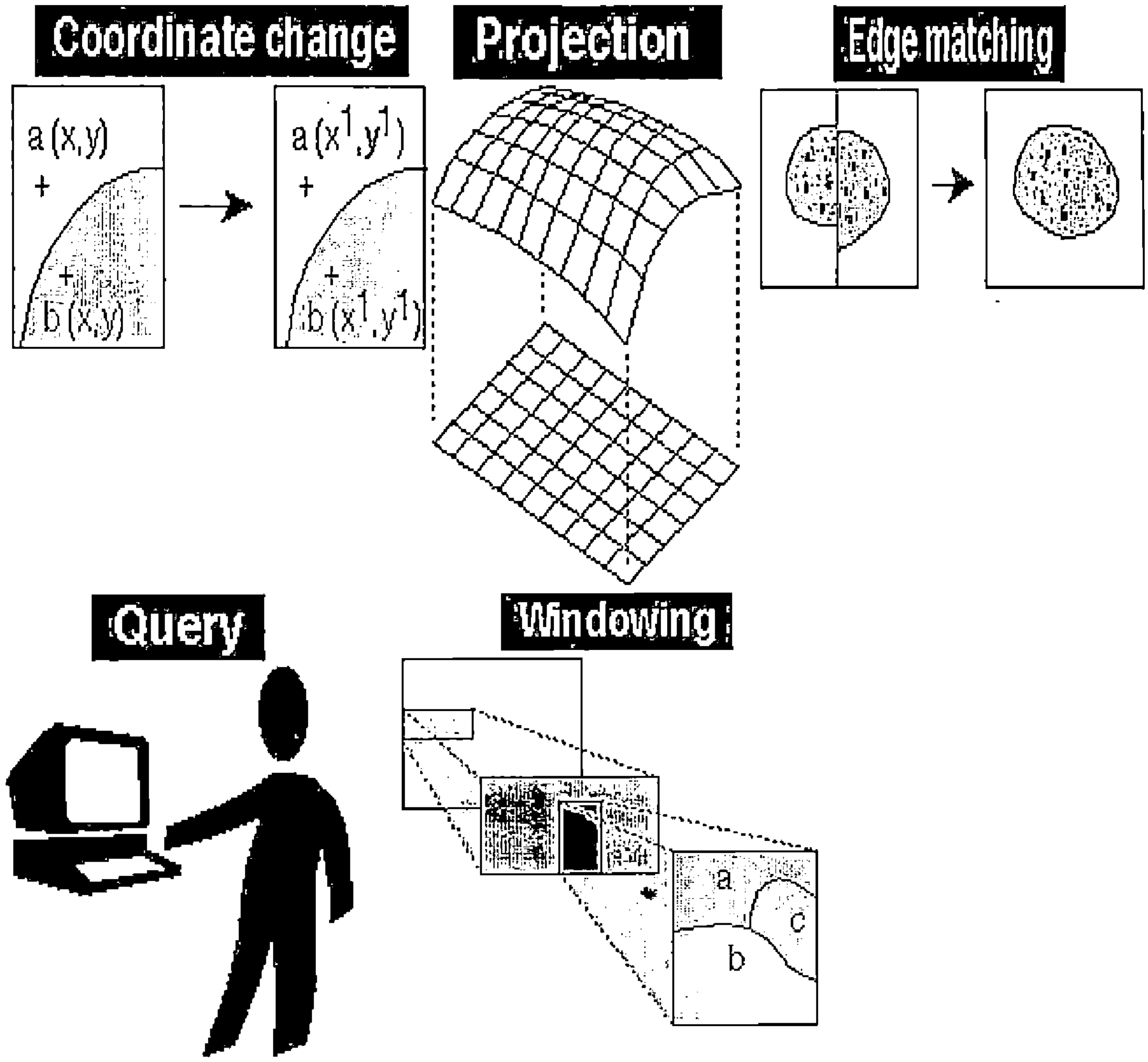
- Maps
- Tables
- Reports
- Graphs
- Textual form
- Digital data

The output generated as digital data has the advantage that it could be input into other digital modeling systems, statistical packages, and tools for further analysis.

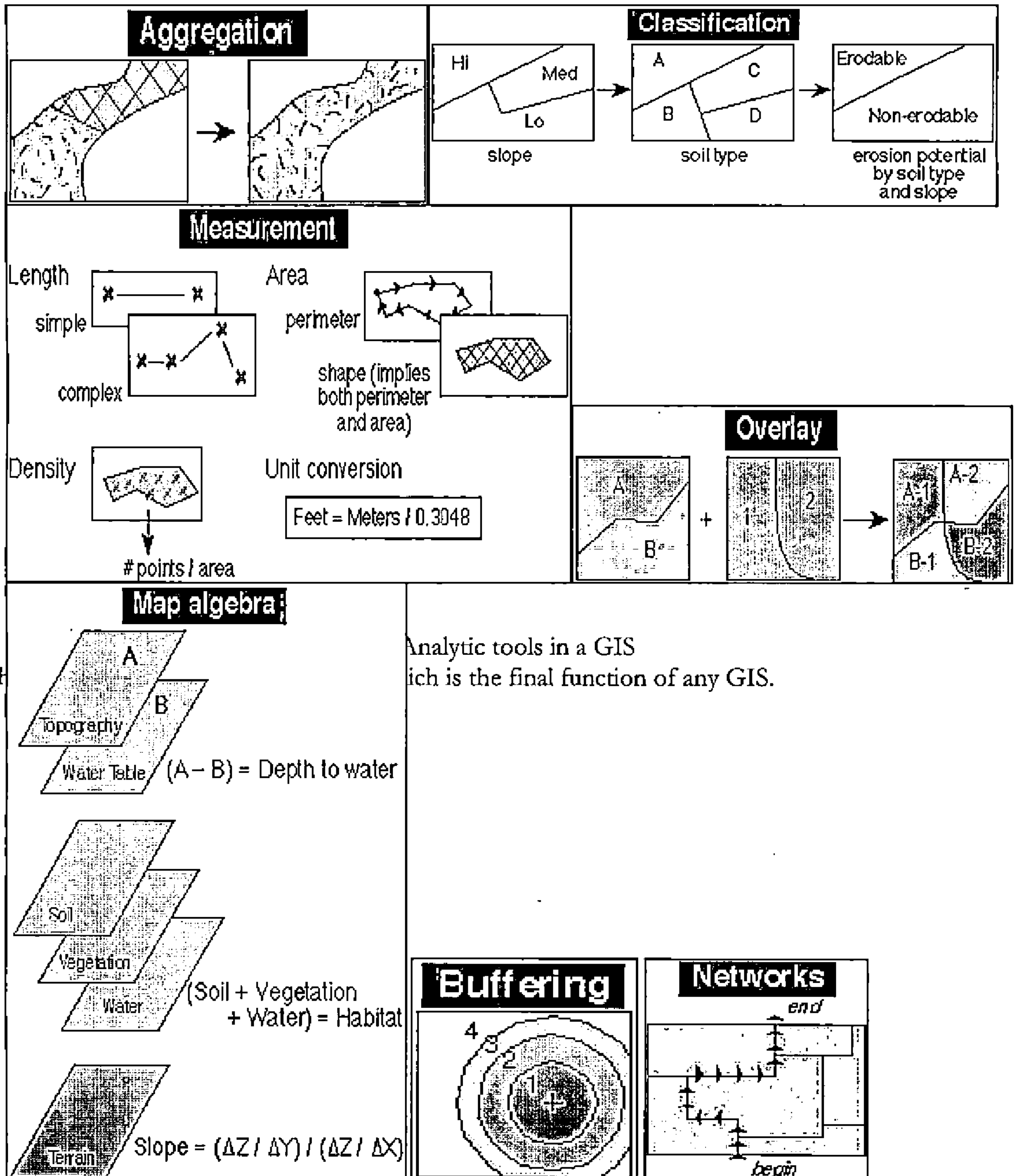
Need for GIS in Agriculture

The technology discussed above is used for planning in several fields. GIS is currently used in solving a variety of problems. Agriculturists more than any other profession, have an intimate relationship with the land. The qualities of their land determine the quality of their crops or the well being of their animals that in turn decide their livelihood. The farmer always has to think about how she or he is going to manage various parts of the farm, because they are all different. That is, there is tremendous *spatial variability* in farmland and farmers need to understand the effects this will have on their crops and livestock. Scientists encounter similar spatial variability with their field experiments and trials. Therefore, these areas envisage the need of GIS as a planning tool.

Fig.7: Manipulation tools of GIS



Data manipulation tools include coordinate change, projection, and edge matching, which allow a GIS to reconcile irregularities between map layers or adjacent map sheets called "tiles." Query and windowing are spatial retrieval tools. Query provides a way to retrieve user-specified data from the database. Windowing allows the user to select a specified area from a map displayed on the monitor to examine it in greater detail.



Th

nalytic tools in a GIS
ich is the final function of any GIS.

Data analysis tools include aggregation, classification, measurement, overlay, buffering, networks, and map algebra. *Aggregation* helps the user in interpreting the data, *classification* allows the user to classify areas within a map, and measurement can be used to determine the size of any area. The *overlay* function allows the user to "stack" map layers on one another. *Buffering* examines an area that surrounds a feature of interest such as a point. *Network functions* examine the movement of objects along an interconnected pathway. *Map algebra* utilities allow the user to specify mathematical relationships between map layers.

Application in Agriculture

Numerous applications exist for GIS in various field of agricultural research. Some important faculties in the field of agriculture using GIS are

Agronomy: Brown and Steckler (1995) developed a method to use digitized colour infrared photographs to classify weeds. The classified data was integrated into a GIS a decision support system was developed to select the appropriate herbicide and amount. Similar application can be developed for predicting disease and pest management.
Association of remote sensing and GIS technologies with physiological growth models tried by Carbone *et al.* (1996) has opened a new vista for agricultural research. Remotely sensed data inputs to growth models provide a means to obtain predictions over large areas, which will increase the application of these models to site-specific agricultural management. Capability of GIS in irrigation management has been demonstrated by Dadhwal, (1994).

Watershed development: Watershed development on a holistic basis requires data o natural resources that cover both physical and socio-economic aspect. These data, as discussed already, are in the form of maps/ tables. Preparation and execution of developmental plans and projects need analysis of these data for which GIS serves as a tool.

For effective planning of watersheds it is essential to integrate various resources information for identifying land areas having analogous characteristics, resource potential and constraints, which need similar treatment. GIS can be utilized in the following aspects of watershed management (Dutta and Sharma, 1997):

1. Watershed characterization
2. Watershed prioritization
3. Integrated land and water sources development planning
4. Agro ecological mapping
5. Run off modeling

Some of the applications where GIS is used in watershed development are:

a. *Soil erosion modeling:* A regular record on erosional soil loss and soil erosion hazard is vital for effective soil conservation plans of a watershed for sustainable development. The potential of remotely sensed imagery and aerial photograph to map and asses land area characteristics that aid erosion has been extensively studied by Pande *et al.,* 1992.
   A number of modeling approaches are used to quantitatively assess erosional soil loss. Some important models for erosional soil loss assessment employing remote sensing and GIS technology are:
   - Universal soil loss equation USLE (Wishmeier and Smith, 1978)
   - Morgan, Morgan and Finney model (1984)
   - Sediment yield predictive equation (Flaxman, 1971)
   - Silt Yield Index (Bali and Karale, 1977)

   Spanner *et al.* (1982) demonstrated the use of GIS for erosional soil loss assessment using USLE. Several studies later showed the potential use of Remote Sensing and GIS for assessing erosional losses (Saha *et al.,* 1991; Saha and Pande, 1993). Kudrat and Saha (1996) showed the feasibility for assessing sediment yield using SYPE.

Watershed prioritization: Prioritization of watersheds help in ranking the soil conservation measures to be employed there. Prioritisation helps in identifying erosion prone areas within a watershed and helps us in planning appropriate soil conservation measures.Watershed prioritisation can be done using RS data integrated into a GIS based on USLE (ASD, 1996), SYPE (Kudrat and Saha, 1996). Generally SYI is commonly used for watershed prioritization (Dohare *et al.,* 1985). Sidhu *et al.* (1998) prioritized upper Machkund watershed of Andhra Pradesh based on SYI approach using GIS and RS.

b. *Run off modeling*: Watershed based runoff modeling using GIS and RS has been demonstrated by Das (1997). In his study he ranked 36 watersheds in the Tilaiya catchment of Bihar based on run off indices.. He ranked the watersheds based on the run-off coefficient obtained by modeling. The watershed with most runoff flow and the least on are indicated in the map. Runoff flow was simulated using SLURP watershed model in conjunction with ILWIS GIS as data input at Bhakra dam outlet of Sutlej Catchments (Jain *et al.*, 1998). They observed that simulated flows compared well with observed flows. A sustainable watershed development plan envisages the assessment of natural resources potential of the watershed and identification of the local problems, which would lead to suggestion of location specific, plans for development. Sharma (1997) suggested a detailed remote sensing and GIS based methodology for this.

Horticulture: GIS has also got numerous applications in the field of horticulture. GIS can be employed in landscape horticulture (Turner and Bowen, 1998). It has potential in identifying storage and post harvest processing units at needful areas as post harvest losses estimated to be in the range of 20-40 per cent in India. Ray *et al.* (*Internet*) identified the need of 57 new cold storage units in Burdawan district of west Bengal using RS and GIS technology. Gupta and Owais [*internet*] demonstrated the capability of GIS in identifying areas with large cardamom cultivation potential in Sikkim. They concluded that the cardamom growing potential is very high at whole watershed level and in non-reserve forest area. They also developed a decision supporting system and suggested measures for improved production and marketing opportunities using the DSS.

Forestry: Remote sensing and GIS has been a monitoring tool for conservation of forest. These were used for formulation of strategies for forest preservation (Malyvanh and Feldkotter, 1999). In the Forest Cover Monitoring Programme in Laos PDR they generated recent reliable information about existing forest cover, forest resource use pattern and socio-economic status leading to forest distribution. Their planning ministries and agencies to formulate strategies and policies to preserve the existing forest cover used this information. Nair and Menon (1998) used IDRISI – a raster based GIS package, IRS (LISS) multi spectral imagery and aerial photograph in conjunction with GIS link for supplementing GIS and Image processing Package to estimate bamboo resources in the Wayanad Region of Kerala. Lakshmi *et al.* (1998) reported the need of RS and GIS for efficient management of forest resources. They illustrated the potential application of GIS in development of Forest Resource Information System for micro-level planning at Divisional level. Lakshmi and Dutt (1998) highlighted the success of Peoples Participatory Forestry Development Programme. They envisaged the need of RS and GIS in projecting the demand of fuel wood and fodder and its supplies to the user communities. The fuel wood and fodder sustainability could be forecasted for the next 25 years and 50 years respectively by this technology.

Bio Diversity Conservation: Potential of GIS in conjunction with remote sensing and other data sources to estimate forest cover, prepare vegetation cover maps, and to chalk out migration path of fauna can aid in bio-diversity conservation. Prasad *et al.* (1998) identified potential areas for bio-diversity conservation in Kerala by integrating several theme maps using GIS. They suggested an action plan for bio-diversity conservation in Western Ghats of Kerala.Prasad (1998) used GIS to analyse forest habitats and transformation over 30 years for Western Ghats of India. He reiterated the need of GIS in habitat change analysis for conservation planning in India. The traditional spatial approach using RS alone could not suffice as long-term ecological studies were non spatial in nature and therefore need a GIS where spatial and non-spatial data could be integrated for analysis. GIS models were used for identification of biospheres to conserve North America's rare orchids (Sperduto and Congalton, 1996). The location of valuable medicinal plants based on phyto-habitat can also identified using GIS models Mustalish *et al.* (1996).

A sustainable approach for biodiversity conservation could be achieved by integration of several spatial and non-spatial characteristic of a location that could easily be undertaken by GIS.

Land Use Planning: RS and GIS can effectively be used in various land use planning schemes. In a soil reclamation project in UP GIS was employed to identify location of specific villages/area of interest that satisfied suitable condition for selection based on specific parameters. Pre and post monsoon fluctuation in water table was also monitored using GIS for defining spring level and flow direction. GIS also had been employed to delineate shallow water table area, zonation based on ground water table, locate suitable boring sites and pump set installation, plan drainage development to enhance existing drainage system and to identify the catchments of the drain. Thus it has been reported by Thakur(*internet*), that environmental monitoring data can be integrated on GIS platform for analysis and evaluation of sustainability of reclamation, selection of project villages, post reclamation monitoring and behavioural changes in ground – water levels and quality. Maji *et al.* (1999) suggested a land use plan in different agro ecological region of Arunachal Pradesh using soil resource database and analysis of different thematic maps, problems and potential in a GIS environment. The capability of GIS in conjunction with remote sensing to develop a digital map has been shown by Nair *et al.*(1996).

Works Undertaken at Centre for Land Resources Research and Management Kerala Agricultural University: Centre for Land Resource Research and Management under Kerala Agricultural University is a pioneer research center undertaking GIS works in Kerala. The center under the guidance of Dr. N. Saifudeen was instrumental in developing soil resource map of Thrissur named '*SRI Thrissur*'. The potential land use in the Thrissur District has been suggested based on the soil resources and suitability for various crops. The center also has guided the students of 1996 RAWE batch to develop the map of the watershed they surveyed. The center developed a map of the main campus of Kerala Agricultural University that was found to be accurate to ± 2 m. This work has been undertaken as a part of M. Sc thesis submitted to the University during the year 1999.

Other Applications of GIS

Some of the fields in which GIS is applied are:

- *Urban Development Planning*: GIS is used in chalking out developmental plans in urban area. It can be used in demarcating different sectors for industry, residential areas, office area *etc.* and also in identifying and allocating land for further developmental plans.
- *Telecommunications:* GIS may be used for establishing and managing cable networks.
- *Tourism:* Selection of best sites to attract tourist can be done using GIS based on the criteria of the tourist.
- *Transport*: GIS is a good tool for management of traffic on roads and rails. It can be a useful tool in suggesting an alternate route in case of roadblocks and traffic jams.
- *Coastal and Marine Applications*
- *Environment*
- *Infrastructure Development Planning and Civil Engineering:* GIS could be used in designing and planning sewage disposal channels, pipelines for drinking water, drainage channels, roads and highways *etc.*
- *Disaster Management*
- *Market analysis, health care, Banking, Insurance etc*: GIS database can be effectively used to identify potential customers in banking, insurance and other consumer market. It can be also used in maintaining area wise details about healthcare details and immunization programme. Such information can be used for further planning in the healthcare sector.
- *Precision Agriculture*: Another major break through in the field of agriculture employing GIS is the Precision Farming technology. In this system each farming area having tremendous spatial variability is demarcated using hi-tech equipments and technologies. Global Positioning System (GPS) in conjunction with images from aeroplane and satellite borne cameras with satellite navigation system delineates the farm area into different input groups in a GIS environment. The intention of this system is to allow the farmer to use the right amount of chemicals at the right time in the right place to achieve best crop growth with minimum pollution of the environment.

Conclusion

A developing and highly populated country like India has tremendous pressure on its various resources. With the increasing demand of the growing population the development and improvement on a sustainable basis needs adequate planning on utilizing the available resources. For an integrated developmental plan various data need to be assessed in relation to others for arriving at a holistic plan. Hence it is necessary to have the information system capable of integrating information from several resources in different fashions and in conjunction with socio-economic and demographic set up of that region in arriving at alternate plans and decisions. The integration can be successfully done by any GIS and therefore has got a great potential in our country. Now it is the time to grab the opportunity and adopt the state of art technology of GIS for effective resource planning for a bright future.

MAPS, MAP SCALES AND DATA RESOLUTION

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1. Map is a graphical representation of information. In other words map is defined as a picture of a portion of earth's surface. But it differs in many respects from a picture. So map has been defined as "A selective, symbolised and generalised picture of earth features / spatial relationship or distribution of a large area on a reduced scale. To this lettering, legends etc. has been added".

A map is different from an image in following respects

No.	Photo Images	Maps
1.	Synoptic view of the area	Limited view
2.	Perspective projection	In any projection suited
3	Show all details	Selection and emphasis
4.	Name and lettering lacking	Name and written information
5	No uniform scale	Uniform scale
6.	No symbols	Symbols
7.	Tilting and no orientation	No tilting good orientation
8.	No generalisation	Generalisation
9.	It is updated	Not updated
10	Readily available at low cost	Not so
11	Stereoscopic view	Two dimension
12	Topographic purpose	Thematic purpose

In a good map following elements should be present

1. *Reference system*: In a form of geographical grid or co-ordinates such as latitude or longitude or rectangular grid. Its position can be defined on the earth surface.
2. *Projections*: In map, we try to depict earth surface, which is spherical into a plain surface. For this various projections has been developed according to suitability either preserving shape or area or direction etc. Small area are shown by arbitory projection
3. *Scale*: Scale is the ratio between map distance and ground distance. In all maps scale is a must and mostly shown in three ways:

    a. Representative Fraction (RF) - 1 :50,000.
    b. Verbal form such as 2 cm = 1 KM.
    c. Graphical form for user 0 1 2 Km

4. *Selection*: Only selected information as per limitation of scale is plotted. We omit all those are unnecessary for the purpose of the map without overcrowding.
5. *Emphasis*: Certain features are emphasized depending upon the purpose of the map. Large symbols, heavy lines, prominent colours, arrows etc. are the various techniques of emphasis in map making.
6. *Generalisation*: Congested detail is generalised and simplified on a map according to scale of map and space available. The smaller the scale, the greater is the degree of generalisation.
7. *Symbolisation*: By conventional sign/symbols we represent the point, line, area and relief symbol in the map. Both qualitative and quantative symbols are used as per need. .
8. *Lettering*: Gives life to the map. It makes the map to speak after title, legend, name & other explanatory footnotes. Form, style, size, colour are the main elements of lettering in the map.

Types of Map

There are two basic types of map.

A. Basic reference map eg. Topographical maps, Hydrological chart, Aeronautic etc. General reference maps and Thematic maps.
B. Other way at classification can be done depending on user or information content such as physical map, political map, population map, statistical map or distribution map, topographical map, geological map, town plan, cadastral map, weather map, navigation map, tourist map, soil maps and various other thematic maps, digitized maps and so on.

One of the easiest ways of classification of map is scale. As per scale, there are three types of maps.

1. Large scale maps - Here small area (relatively) is shown for departmental purpose or special purpose such as
   Guide map, plan, charts - 1: 1 0,000
   Forest map - 1 : 25,000
   Cadastral maps. - 16 : 1 mile (1:3960)
   Detail information can be plotted as the scale becomes larger i.e. R.F decreasing.

2. Medium scale maps: Between 1: 25,000 to 250,000 can be considered as medium scale maps as these are comparative terms. There is no fixed demarcation of scale value in terms of medium.
3. Small-scale maps: Above 1:250,000 and above (million maps) and all other geographical maps, Atlas comes under this category. Here bigger area is represented in form of generalisation and details are not available.

Now our soil map is a thematic map and a thematic map may be defined as a special purpose map showing qualitative and/or quantitative information on specific features or concept or theme in relation to the necessary topographic details. BASE MAP for a thematic map is a map having topographical information on which the thematic information can be plotted. Topographical maps (toposheets) are most commonly used as base map.

Elements of base map: There are several primary elements for a map. The important ones are

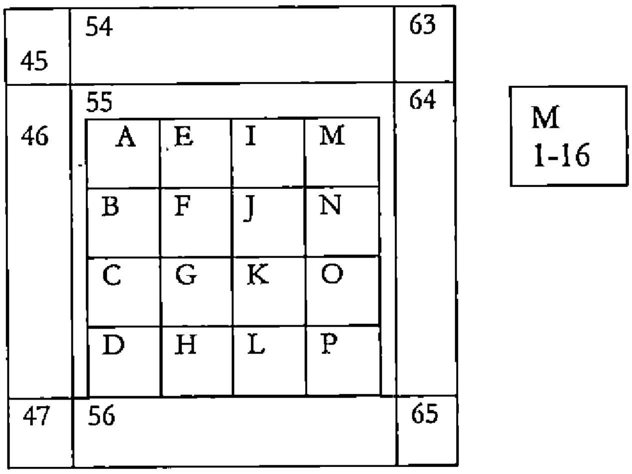
a) Grid
b) Drainage pattern
c) Relief
d) Settlements
e) Communication system
f) Administrative Unit boundary
g) Geographical name

There are mainly three Cartographic bases for soil survey.
a) Topographical sheets at various scales as per purpose of the survey.
b) Air photos of various scales
c) Satellite imageries

Before going in detail of each let us see in brief the kinds of soil map and its appropriate base for plotting. Depending upon the details mapping units plotted in the field and considering the purpose, three general kind of soil maps are recognized

1. *Detailed*: In this kind of maps soil types/series and phases are mapped in detail showing slight variations in map unit. This type of survey is done on large scale maps. Base maps are cadastral maps (1:4000 approx.). Larger scale than the stated can be used such as farm survey, project survey and so

sheets on scale of I :25,000. Each topographical maps of one Inch, half inch & quarter inch has an index to adjoining sheets.



Survey of India topomaps are printed both coloured and uncoloured edition. In coloured hills are shown by brown contours & grey shades water courses are shown in blue, forests & plantations are shown in green cultivated area are shown in yellow, railways names, dry streams in black and road, towns villages are shown in red colours.

By name itself scale is clear as stated following:

55 (million sheet)

55A - 1:250,000 (11500 sq.kms).

55A/NE - 1: 1 00,000 (Now not published)

55A / 16 - 1:5 0,000 (720 sq. kms .)

Study of the Toposheet: The topomap provides a huge mass of information and a reader detects the useful and needed observations from the sheet.

Marginal or Preliminary information: A large number of information is provided on the margin of the sheet. At the top name of the State to which the map area belongs is given and in the top left the districts are given. The season during which the area was surveyed is also appended and the top right the sheet no. is given. The direction of Magnetic north as well as Grid north with reference to True north are given. At the bottom of the map the scale of the map is given in three ways ie. in a statement, in RF and in a constructive form. Contour interval is also mentioned. dministrative index and index to sheets are also provided to the right & left of scale respectively. Further conventional signs must be consulted during different stages of analysis, when doubts arise. Line of latitudes & longitudes are also given in the margin ie. extent of the area.

Relief: Relief & drainage are the main concern of soil survey. For study of relief one must have acquainted with the nature and behaviour of contour lines. Reference to the figure in the margin, indicating value of contour lines will generally, but not always gives the idea of height /elevation above sea level. Firstly examine the general nature of landform whether the area is a plain or plateau or hilly region. For distinguishing these the following generalised rules will be helpful.

- If there is no contour line or less (one or two), the area is a plain. The contour lines crossing a plain will be smooth and not contorted. Further if the stream do not flow in deep valley the relative height of the riverbank will be small and stream will be broader developing meander/ oxbow lakes and flood plain etc. Spot height/Bench mark figures are the indication of elevation.
- A plateau area is comprised of several contour lines of zigzag nature. River flows in deep valley so that a contour line generally encloses a river on both sides. In some plateau there are high and regular ranges surmounted by hills.

- The area will be mountainous if there are a large number of contours and height above the sea level is also quite large. Hills, valley & spurs abounds in all directions, contour lines are generally close spaced indicating steep slopes.

In mountainous area valley should be properly examined. Important hills should be described and height of peaks should be given. Hills may be rounded or conical or flat topped. If contour lines are close together slope is steep. In the young mountains, where erosion is prominent, the valleys are V shaped and have a convex slope and contour of higher value are comparatively farther spaced them contour of lower value and interlocking spurs are generally present in such valleys. In glaciated region landforms are different from humid region.

To determine nature of slope, sections should be drawn and it will clear the observation. In plateau valleys are quite important where the hill & ridges are absent. The nature of ridges should be analysed. Ridge may have varying degrees of slopes. A plateau generally meets a plain area in a steep escarpment. Meeting of that junction should be clearly noticed.

From the point of view of relief a survey sheets can be divided into several parts and each of these parts can be described in detail separately. Sketches and sections should always be drawn to make every thing clear to the eye.

Drainage: While describing drainage emphasis is given on slope rather than height. Firstly general slope of the area is known by means of trunk stream. Courses of the stream can be described. In the plain rivers are generally mature with well-developed meanders and deposits of sands are found . Relative height, along the river, is mentioned or embankment is shown. In plateau rivers are in a youthful or early maturity having narrow valley. In mountain rivers are mostly in youthful stage, V shaped indicating convex slopes. Sketch of drainage pattern should be appended.

If the sketch of rivers alone is drawn the pattern of drainage will at once be clear. It is a dendritic pattern of drainage if the main river has got a large number of tributaries all branching out like the branches of the tree. The drainage is parallel pattern if rivers are flowing sub-parallel courses. In radial pattern rivers go out in all directions from a particular region just as radii go out from centre. In trellis pattern, rivers flowing in parallel valleys separated by anticlines, main river has short tributaries meeting them perpendicularly. This type is found in many of the granitic area. The other patterns are barbed, rectangular and complex type etc. The drainage pattern may partly explain some landform. Radial drainage may suggest igneous intrusions, Inland drainage desert. topography, dentritic - well developed drainage system

Vegetation: Yellow colouration represent agricultural area whereas green shows natural vegetation. Tree, grass & shrubs are vividly represented. Forest areas are clearly demarcated. Factors for vegetation distribution depends on

1. Distance from the equator
2. Distance from the sea
3. Altitude from mean sea level
4. Rocks
5. Soils
6. Slopes & other aspects such as climate etc.

Geology: Some aspects of geological information can be inferred such as pervious & impervious rocks, low of erosion, rock types etc.

Irrigation: Canal, well & tank system of irrigation can be easily brought out by topo sheet.

Occupation: By careful study of settlement pattern and other associated features one can draw his own conclusion regarding occupation eg. cultivated land plantations, quarries, mines, factories etc.

Settlement: Rural & Urban settlement with density can be easily brought out by study of toposheets. Site and pattern of settlement is dependent on various factors. Site should be examined in context of contour & drainage etc. Factors of site viz. problem of water supply, provision of food, nature & character of occupation, nature of relief/land, security etc. are some of the points to be considered. Due to some factor particular town has developed are some of the points to be analysed during study of settlement.

Means of communication & transport: The various aspects of communication roads, footpath, railways, waterways, telegraph or power line etc. line etc. link up the human settlement. The site of bridge embankment, cutting tunnel, etc. which would reveal the nature of topography. The presence of numerous means of communication in the form of metalled road, National highways, airways, railways indicate the country is well developed and their absence or scarcity will show the backwardness of the area.

The interrelation of the environment to man's activities are reflected by the above analysis. The above interpretations of toposheets will offer helpful clues and be a starting point for undertaking resource mapping and becomes a rich source of information to be used in combination with other sources. However, toposheet interpretation cannot be a substitute for well planned field studies. We know that soil maps and other interpretative maps are thematic maps. For these, topographical maps (on various scales) being the base map provides required information facilitating the soil resource mapping for land use planning.

Aerial photographs: Nearly all detailed and reconnaissance mapping are being done on these bases. The survey work can be rapidly enhanced if soil-physiography relationship is established through ground check.. These are also available on various scales and present a true picture of the area. Aerial photos can be easily enlarged or reduced. They provide a vivid detail picture of the area in stereoscopic three-dimensional view due to alternate coverage (more than 60%). The basic elements of photo interpretation are tone, texture, pattern etc. It is easily updated and smooth and precise soil boundary can be delineated on this base. Main demerits are not uniform in scale lack of descriptive reference distortion and tilting. For bigger area, it is difficult to handle, resulting in more matching, joining and accumulation of error. For inaccessible area it is the best base for soil survey (Vertical or oblique photographs).

Satellite imageries: Aerial photographs and imageries come under Remote Sensing base. Remote Sensing is broadly defined as the process of collecting information about a subject without being in physical contact with the subject. The use of imageries in recent years has opened up new vistas in soil survey. The principle of air-photo interpretation is applied for imageries also. The major advantage of imageries are their ready availability without involving clearances. The different types of land sat data available today are
Film negative, film positive, positive in 1:3 million to 1:25,000 scales in different spectral bands.

Computer compatible Tapes (CCTS): Generally band 2 & 4 are used for soil mapping in combination with False Colour Composite (FCC.). Delineation of physical boundary is done through visual interpretation aided by magnifying glass. Further delineation are done based on uniqueness of image characteristics such as colour tone, texture, pattern etc. either single or in appropriate combinations. Transfer of delineated boundaries on topographical base of the same scale is done to correct orientation, titling and scale. The main disadvantages are titled orientation, scale distortion and lack of descriptive references. After establishing landform-soil relationship speedy work is possible through imageries. These are most updated and provides a synoptic view of large area for various purposes. Now a-days Thematic Mapper (TM) base of larger scale are also being used for soil survey. Now geo-coded F.C.C. of various season scale are available with NRSA, Hyderabad both in digital and pictorial data as per requirement of the user.

2. *Reconnaissance*:- In this type of survey, map units are soil series association and guided by observations at some interval. Base for this type of survey is 1 :50,000 topographical maps. Police station maps of 1" = 1 mile and aerial photos ranging from 1 :50,000 to 1: 100,000 are also suitable for reconnaissance soil survey.

3. *Rapid Reconnaissance and/or generalised soil map*: Here association of dominant and sub-dominant or more soil group make a map unit. Base maps are on scale 1: 250,000 or quarter inch toposheet / district maps. The base of generalised soil man is smaller than the above stated scales. For this purpose, satellite imagery are very useful giving the correct boundary delineation.

Thus, different types of map/data base are used for different kind of soil maps, which are mostly guided, by the objective and purpose of the user.

The main characteristics, advantages and disadvantages of principal kind of base map/data used in soil mapping are outlined in the following:

Topographical sheets

For every type of survey, topographical sheets are the most commonly used as base map. This map presents almost all the important features of earth surface i.e. physical and cultural which are the main elements of base map. A general map of large and medium scale showing all important features including relief is topographical maps. According to Survey of India, topographical maps are sufficiently on large scale to enable individual topographic features to be identified on the ground by its shape and position. As per the purpose of survey, various types of topographical sheets can be used as discussed earlier. No doubt, it is the best base so far as orientation, scale, direction and elements of base maps etc. are concerned. Only disadvantage is not showing all the details as in air photos as well as not updated frequently.

The topographical maps present at one place important features of the earth. Physical e.g. river, mountain, escarpment plain lake etc. and cultural eg.. building, road, railways, settlement, both influence the life of man. The characteristics of topomaps are:

a) All features are shown by fixed symbol called conventional signs.
b) Conventional signs showing Physical features, hydrography,vegetation.
c) Conventional signs showing Cultural features - Road, Railway, lettering, marginal information, settlement.
d) Reference, projection, scale always shown.

Study of Survey of India Topomaps

In the catalogue of Survey of India, India, Pakistan and adjacent country are divided by rectangles numbered from 1 to 105. The number denotes the sheets of "India and adjacent countries Series". In the new series of metric system these are on scale of 1:1000,000.

45	54	63
46	55	64
47	56	65

Thus say sheet no.46 or 55 are known as 1/M sheets. The 1/M sheets are further divided into 16 equal parts of 1^0 lat.& 1^0 long. extend and bearing letters A to P. Each of these rectangles has an average of map on scale of one inch to four miles or 1:250,000 in the metric system which is mostly known as "Quarter Inch map" as well as "degree sheet". Each of these sixteen rectangles is divided into four quadrants. North East, South East, North West and South West. These quadrant covers map of one inch to two miles or 1:100,000 in the metric system or Half inch map. Each quarter Inch map is further divided into 16 equal parts covering map of one inch to one mile or 1:50,000 in metric system. Otherwise known as one-inch sheet within which lies an area of 15 minutes of latitude and longitude. Each one inch or 1 :50,000 contains four/six

The following tables explain the various features and characteristics of maps made in different scales for different purposes.

Scale, area of 1 cm² on the map and minimum number of observations per km².

Scale of map	Size of 1 cm² area	Minimum number of observations per km²
1:2,500	0.000 625 km²	8000
1:10,000	0.01 km² (1 ha)	400
1:25,000	0.062 5 km²	64
1:50,000	0.25 km²	16
1:1,00,000	1 km²	4
1:2,50,000	6.25 km²	0.7
1:5,00,000	25 km²	0.15
1:10,00,000	100 km²	0.05

Scale RF	Meter per cm	Ha per sq cm
1:500	5	0.0025
1:1000	10	0.01
1: 1980 32" = 1mile	19.8	0.0392
1:3960 16"=1mile	39.6	0.1562
1: 5000	50	0.25
1:7920 8" =mile	79.2	0.63
1: 10000	100	1
1: 15840 4" = ile	158.4	2.51
1:25,000	250	6.25

Kind	Scale	Area of 1sq cm	Distance between observations	Frequency of observations
Recon	**1: 250,000** 1: 100,000	625 100	2.5 1.0	1 in 625 ha 1 in 100
Semi detailed	1:50,000	25	500m	1 in 25
Detailed Low intensity	1:10.000	1	100m	1 per ha
High intensity	1: 5000	0.25	50 m	4 per ha

CONCEPTUAL MODEL OF NON-SPATIAL INFORMATION

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Non-spatial Information and concept of Database

Non spatial information, also known as attribute data, is the descriptive data that defines spatial data. Data are raw material from which every land information system is built. They are gathered and assembled into records and files. A database is a collection of data that can be shared by different users. It is a group of records and files that are organized, so that there is little or no redundancy. A data base consists of data in many files, in order to be able to access data from one or more files easily, it is necessary to have some kind of structure or organization. There main kinds of data base structure are commonly recognized, termed as: Hierarchical, Network and Relational.

Data Base management Systems

Because the cost of maintaining a database increases with its size, care must be taken when working with large quantities of data to ensure that the same information is not duplicated unnecessarily. Avoiding such data redundancy helps to serve another important database function, which is to achieve *consistency*, whereby data values referring to the same entity are not contradictory, as could happen if a value was updated in one part of the database but not in another.

Consistency may itself be regarded as part of a larger problem of *data integrity*. This concerns the correctness of the database contents. In general, a database cannot 'know' whether its data values are correct, but it can perform certain checks, such as for unrealistic values and for data items that have been corrupted by the computer hardware. Checks on the initial validity of data can be performed when data are entered.

The fact that there will not in general be any automatic mechanism to prove that the contents of the database are correct means that it may be important to impose restrictions upon personnel entitled to make changes to the database contents. This includes the addition of new data and the deletion of existing data. This is one aspect of database *security*. Another aspect of security concerns control over who can retrieve information from the database and from particular parts of the database.

A DBMS can be regarded as a tool for representing, in a computer, a real-world oriented model of a set of data. This relatively high-level representation, or abstraction, is referred to as a *conceptual model* and its specific description in the database is often referred to as a *schema* or a *conceptual schema*. The database tool for defining the conceptual schema is a *data definition language*. The syntax of this language differs somewhat between different database systems.

Most commercial database management systems are implemented by one of three widely recognized data models, also referred to as *logical models and internal models*. These are the hierarchical, the network and the relational model. More recently, object-oriented and logic-based, or deductive, models have been introduced but are not yet widely used, although some of the associated techniques have been introduced in 'post-relational' database management systems. Commercial database management systems are conventionally categorised as either hierarchical, network, relational or object-oriented. The hierarchical data model is currently the least widely represented (IBM's IMS is an example). It can be regarded to some extent as a specialisation of the network model, for which several commercial systems are currently available. The relational model is very much the most widely implemented for commercial applications and it is characterised by quite simple concepts of data organization and related query languages.

Queries to the database are expressed in terms of the data entities and attributes that constitute the conceptual model and its local subsets which are the external models.

Execution of a query results in a request to the database manager software to find the named data items or classes of data items.

Hierarchical Data Base Structure

A hierarchical file is a case of a tree structure. The tree is composed of hierarchy of nodes; the upper-most node is called the root. With the exception of this root, every node is related to a node at a higher level called its parent. No element though it can have more than one lower level element called children. A hierarchical file is one with a tree-structure relationship between the records for example a master detail file with two record types. Such a representation is often very convenient because much data tend to be hierarchical in nature or can easily be cast into this structure.

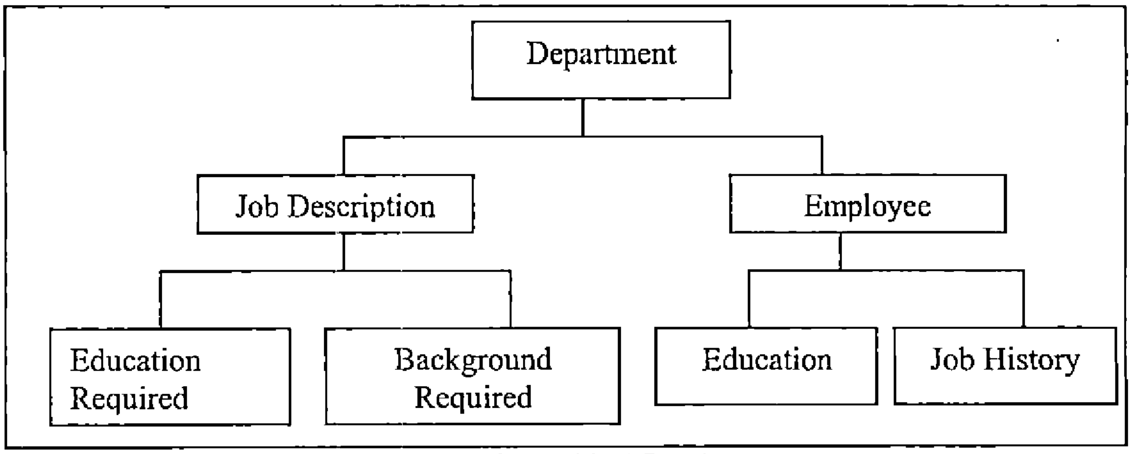

Figure 1. Hierarchical Database

Hierarchical approach is very efficient if all desired access paths follow the parent child linkages. However, it requires a relatively inflexible structure to be placed on the problem at the outset, when the record type consisting the tree structure is setup. The combination of inflexible structure is setups and the overheads of maintaining or changing pointer system makes extensive modification of the structure of hierarchical systems to meet new requirements, a resource intensive operation. These reasons have contributed to the lack of adoption of this type of DBMS for flexible GIS requirements.

Network Structure

A network structure exists when a child in a data relationship has more than one parent. An item in such a structure can be linked to any other item. The physical data to support complex network structures is far more difficult to develop than for simple structures.

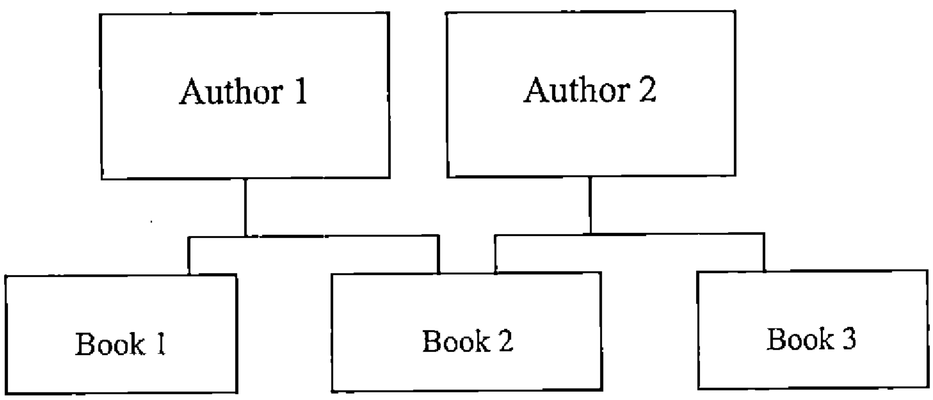

Figure 2.:Network Structure

Each entity set with its attributes is considered to be a node in the network. Relationship sets are represented as linkages in the form of pointers between individual entities in different entity sets. As a result, all the different forms of mapping one-to-many, many-to-many, etc. can be handled directly with large number of pointers.

The network approach is powerful and flexible. For many applications, it is also very fast and efficient in terms of CPU resources. From the implementation point of view, it may be comparatively difficult to set up the database correctly and although the query language is comprehensive, it may also be complex and confusing for less expert users. Major restructuring of the data base may be time consuming because of the extensive pointer structure that have to be rebuilt.

The Relational Model

The main data storage concept in the relational model is a table of records, referred to as a *relation,* or simply a *table.* The records in a table contain a fixed number of fields, which must all be different from each other, and all records are of identical format. There is, therefore, a simple row and column structure. In relational database terminology the rows, or records, are also referred to as *tuples,* while the columns of fields are sometimes referred to as *domains.* Each record of a table stores an entity or a relationship and is uniquely identified by means of a *primary key* which consists of one field, or a combination of two or more fields in the record. The need *for composite keys,* consisting of more than one field, arises if no one field can be guaranteed unique. The fields of an entity table store attributes of the entity to which the table corresponds. Table 1 illustrates an example for Settlement.

Table 1. Example of Relational Database

Settlement name	Settlement status	Settlement population	County name
Gittings	Village	243	Downshire
Bogton	Town	31520	Downshire
Puffings	Village	412	Binglia
Pondside	City	112510	Mereshire
Craddock	Town	21940	Binglia
Bonnet	Town	28266	Binglia
Drain	Village	940	Mereshire

In this type, data are organized in two-dimensional tables, such tables are easy for a user to develop and understand. This structure can be described mathematically, a most difficult task for other types of data structure. These structures are called relational structures because each table represents a relation.

Since different users see different sets of data and different relationships between them, it is necessary to extract sub-sets of the table columns for some users and to join tables together for others to form larger tables. The mathematics provides the basis for extracting some columns from the tables and for joining various columns. This capability to manipulate relations provides flexibility is normally not available in hierarchical or network structure.

For purposes of handling spatial data there is a problem concerning the definition of records in a relational database. The records are intended to store a set of data fields of different type. Several important entities in spatial data consist of sets of data items of the same type, such as the coordinates making up a line or the arcs making up a polygon. in a standard relational database such data items of the same type must be stored in separate records, the consequence of which can be overheads in storage space and poor performance in accessing all the data items, such as coordinates, that constitute a logical entity such as a line. Relational databases are sometimes used in GIS in combination with special purpose file .

Relational systems are characterized by simplicity, in that all the data are represented in tables (relations) of rows and columns.

From the data base design viewpoint, entity relationship modeling fits very closely with relational systems. Each entity set is represented by a table, while each row or 'tube' in the table represents the data for an individual entity. Each column holds data on one of the attributes of the entity set.

Since relationships between entities are directly represented as tables, there is no requirement for pointers or linkages between data records to be set up, as was the case with hierarchical or network systems.

Relational operators

Retrieval from a relational database involves creating, perhaps temporarily, new relations which are subsets or combinations of the permanently stored relations. There are several relational algebra operators that can be used to search and manipulate relations in order to perform such retrievals. Some of these operators are selection, project, union and join. Other standard operators include product, divide and intersection. From the user's point of view, the operators are not named as such but are implemented by means of the standard Structured Query Language (SQL) using a number of commands and key words. For example, the command

```
SELECT settlement-name, county-name
FROM Settlement
```

will create a new table which consists only of the settlement name and county fields of the Settlement table.

The selection (or restrict) operation is concerned with retrieving a subset of the records of a table on the basis of retrieval criteria expressed in terms of the contents of one or more of the fields in each record. For example, to retrieve all settlements in the county of Mereshire with a population greater than 20000, the SQL command would be

```
SELECT
FROM Settlement
WHERE county-name = Mereshire AND settlement-population > 20000
```

Note that the WHERE condition consists of a logical expression. This query could have been combined with a projection operation by specifying field names after the SELECT command.

The join operator is more complicated than projection and selection in that its purpose is to combine fields from two or more tables. The operator depends on the tables being related to each other by means of a common field.

Important features of Relational Data Bases

- Primary and Foreign keys
- Relational joins
- Normal forms

The Primary and Foreign Keys: The Relational approach has important implications for the design of data base tables. Since each table or relation represents a set, it cannot, therefore, have any rows whose entire contents are duplicated. Secondly, as each row must be different to every other, it follows that a value in a single column, or a combination of values in multiple columns, can be used to define a primary key for the table, which allows each row to be uniquely identified.. The uniqueness properly allows the primary key to serve as the sole row level addressing mechanism in the relational data base model.

A field that stores the key of another table is called *a foreign key*. It is important to realize that the primary key of a table and any foreign keys that it may store consist of logical data items which may be attributes such as names or some allocated numerical identifier. They do not consist of physical addresses in the database. They will, however, be used as the basis of indexing mechanisms which the database management system uses to provide efficient query processing.

Relational joins: The mechanism for linking data in different tables is called a relational join. Values in a column or columns in one table are matched to corresponding values in a column or columns in a second table. Matching is frequently based on a primary key in one table linked to a column in the second, which is termed a foreign key. An example of the join mechanism is shown below :

Name	Designation	Emp. Code
MARTIN	PROFESSOR	1107
KEN EASAN	READER	1205

Name	Salary	Experience (years)
MARTIN		12

Join

Figure 3.:Example of the join mechanism

Normal Forms: A certain amount of necessary data redundancy is implicitly in the relational model because the join mechanism matches column values between tables. Without careful design, unnecessary redundancy may be introduced into the database. One of the tasks of a database designer would be to reduce all information to normalised form. Thus a relational database table can be regarded as representing a set of entities, each of which is stored in a record of the table. Alternatively, a table can represent a relationship which links key fields of associated entities. There are several degrees of normalisation. They differ in various respects, including the extent to which data items within a record are dependent upon each other, as opposed to having an independent

All the tables must contain rows and columns and column values must be atomic, that is they do not contain repeating groups of data, such as multiple values of a census variable for different years.

The second requirement of normal form is that every column, which is not part of the primary key, must be fully dependent on the primary key.

The third normal form requires that every non-primary key column must be non-transitively dependent on the primary key.

Nevertheless, the fundamental working rule for most circumstances ensure that each attribute of a table represents a fact about the primary key, the whole primary key and nothing, but the primary key, while this is entirely valid from the design view point, it must also be said that practical implementation requirements may, on occasion, override theoretical considerations and lead to tables being merged and denormalized, usually for performance reasons.

Advantages and disadvantages of relational systems

The **Advantages** can be summarized as follows:

- Rigorous design methodology based on sound theoretical foundations
- All the other data base structures can be reduced to a set of relational tables, so they are the most general form of data representation
- Ease of use and implementation compared to other types of system
- Modifiability, which allows new tables and new rows of data within tables to be added without difficulty

- Flexibility in ad-hoc data retrieval because of the relational joins mechanism and powerful query language facility.

The **Disadvantages** are as follows:

- A greater requirement for processing resources with increasing numbers of users on a given system than with the other types of data base.
- On heavily loaded systems, queries involving multiple relational joins may give slower response times than are desirable. This problem can largely be mitigated by effective use of indexing and other optimization strategies, together with the continued improvements in price performance in computing hardware from mainframes to PC's.

The DBMS provides a wide range of ready-made data manipulation tools, so programming effort can be concentrated on algorithms for spatial analysis and user interface requirements. Though, a data base approach has several advantages over file system approach, GIS system designers prefer the latter approach for storage of digital map coordinates. This had led to the development of two different approaches to implementation, based on either a hybrid or an integrated data model.

Object Oriented Databases

A recent trend in both software engineering and in database design is towards the use of object-oriented techniques. For the purposes of geographical databases these techniques are of great interest since they hold the promise to overcome significant shortcomings, from the point of view of GIS, of the widely used relational database methods.

Normal queries to a GIS require spatial data processing operations which such standard query languages cannot currently handle. Object-oriented techniques provide the tools for building databases which, unlike relational databases, model complex spatial objects. The database representations of objects include, in addition to stored data, specialized procedures for spatial searching and for executing queries which may require geometric and topological data processing. Objects in an object oriented database are intended to correspond to classes of real-world object and are implemented by combining data, which describe the object attributes, with the procedures, or *methods,* which operate on them. Accessing an object involves sending a message to it, which results in the addressed object using its internal methods to respond to the message. A variety of types of message may be sent to an individual object, depending upon its properties and the methods that it has implemented. Examples of the types of message that might be sent to a polygon class of object would be to return its coordinates, to return the result of a measurement, such as area or perimeter calculation, or to display the polygon on a graphics device.

An individual object is an *instantiation,* or a particular example, of a class of objects, and as such it is uniquely identified within the database with an object identifier. An object class may inherit the properties, data attributes and methods of one or more other object classes. Thus having defined typical object classes, new ones may be created which are combinations of or subclasses of existing ones

Considerations in Adopting a Database Approach

The adoption of a data base approach to data management is a major decision that impacts on every facet of CBIS, the decision dictates a virtually irreversible course of system design, and for existing file oriented systems the decision may involve some temporary disruption of services and no small risk to file integrity during the conversion process.

7.1 Advantages of the Data Base Approach

1. Redundancy in data storage is reduces
2. Data maintenance is simplified
3. Processing time is reduces
4. Internal consistency among data is improved
5. Data can be shared by many applications

7.2 Disadvantages of Data Base Approach

1. Costs are high
2. Security is difficult to maintain
3. Consequences of Security breaches may be severe
4. Greater control over data is required.

COORDINATE SYSTEMS AND MAP PROJECTIONS

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Mention map projections, spheroids, geoids, datums, or coordinate systems to the average person and you will probably get a blank stare. Mention them to some GIS specialists and they may roll their eyes and groan as if you'd asked them to loan you money. Simply put, they are mathematical marvels to some of us and mathematical mysteries to others. Although understanding map projections and coordinate systems is a big task, it doesn't have to be confusing.

This note breaks down the components and presents the complexities of map projections and coordinate systems using small introductory concepts and discusses the earth's shape, size, and spherical coordinate system, and presents the basics of map projections.

Discovering the earth's shape and size

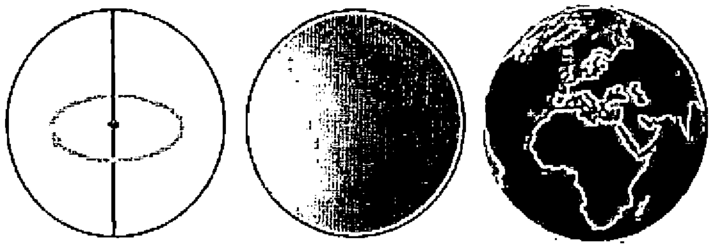
The shape and size of the earth confounded scholars for thousands of years. It is the ancient Greeks to whom we are indebted for finally resolving these issues. Of course, the road to this knowledge was neither straight nor smooth. Today, when you ask anyone to describe the shape of the earth, they immediately tell you it is round. Of course, they mean that it's round like a ball, not round like a circle or a disk. To be more precise, we would say its shape is spherical. While today a discussion about the earth's shape may be a matter of semantics, historically, the shape of the earth has not enjoyed such a wide consensus.

In 3000 BCE (Before Common Era), the Babylonians believed the earth to be shaped like an oyster. Much later, two Greeks, the philosopher Thales (600 BCE) and the poet Homer (800 BCE), thought the earth was a flat disk. As time passed, various other shapes were proposed, such as a cylinder and a cube. As late as the sixteenth century, the earth was described by Christopher Columbus as a roundish pear. By 500 BCE, the Greek mathematician and philosopher Pythagoras declared the earth's shape to be a sphere. He arrived at this determination not through scientific observations but because he believed the sphere to be the perfect geometric shape and the gods would only create a "perfect" world.

The ancient Greeks liked geometric shapes and the mathematical harmony of nature. This preference probably influenced their speculations about the shape of the earth.

Supported by scientific observations, such as that of the silhouette of the earth on the moon during a lunar eclipse, Pythagoras' assumption eventually proved correct.

By the European Middle Ages, most scholars accepted the sphere as the earth's true shape, but many non-scientists still believed the earth was flat. With the coming of the Renaissance and the rediscovery of ancient Greek texts, the flat earth theory reluctantly gave way to that of the sphere.



Using a circle's diameter as an axis and rotating the circle 360 degrees creates a perfect sphere.

Sphere: A three-dimensional shape whose center is equidistant from every point on its surface, created by spinning a circle about one of its axes.

Determining the earth's size

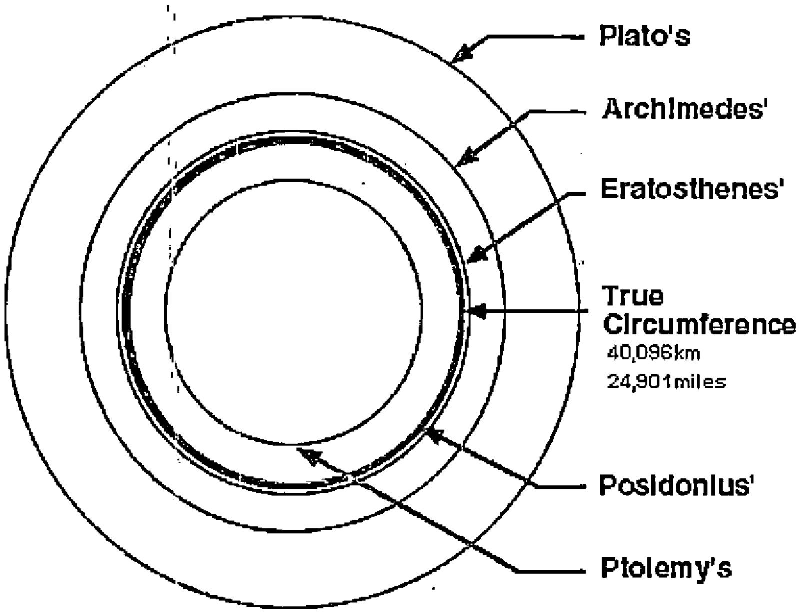
By the fifth century BCE, the Greeks had firmly established that the earth was a sphere. Although they knew it was a sphere, they didn't know how big the sphere was.

The philosopher Plato (400 BCE) declared the earth's circumference to be 64,412 kilometers (40,000 miles). Some 150 years later, the mathematician Archimedes estimated it to be 48,309 kilometers (30,000 miles). It's not known exactly how Plato or Archimedes arrived at their calculations, but Plato's measurement was off by sixty percent and Archimedes' by twenty percent. At least they were making progress. Observations and calculations by two later Greeks, Eratosthenes and Posidonius, finally resulted in accurate estimates of the size of the earth.

In the third century BCE, Eratosthenes, a Greek librarian in Alexandria, Egypt, determined the earth's circumference to be 40,250 to 45,900 kilometers (25,000 to 28,500 miles) by comparing the Sun's relative position at two different locations on the earth's surface. Because of differences in translations or interpretations of his records, and his own methodological errors, the exact figures are in dispute. Today, the earth's circumference is usually accepted to be 40,096 kilometers (24,901 miles). If you take the lowest estimate attributed to Eratosthenes, his error was less than one percent—a phenomenal calculation.

Posidonius used the stars to determine the earth's circumference. He observed that a given star could be seen just on the horizon at Rhodes. He then measured the star's elevation at Alexandria, Egypt, and calculated the angle of difference to be 7.5 degrees or 1/48th of a circle. Multiplying 48 by what he believed to be the correct distance from Rhodes to Alexandria (805 kilometers or 500 miles), Posidonius calculated the earth's circumference to be 38,647 kilometers (24,000 miles)—an error of only three percent. The exact details of his methods are not known, but we do know the distance he used was incorrect and the fact that Rhodes is not due north of Alexandria would result in computational errors. Although his measurements were flawed, he was lucky because the errors canceled themselves out and he arrived at a fairly accurate calculation of the earth's circumference.

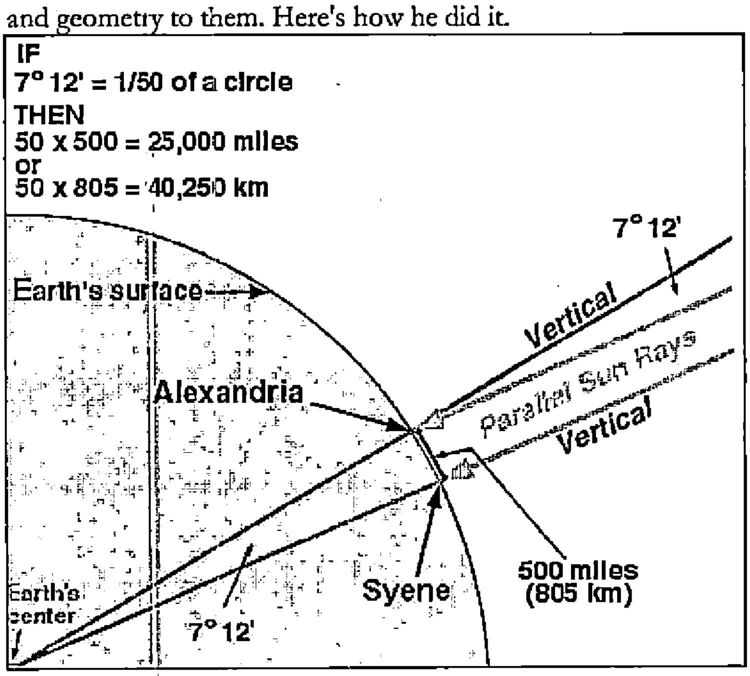
In the second century CE (Common Era) in Alexandria, a philosopher named Claudius Ptolemaeus, or Ptolemy, revised Posidonius' calculations and set the earth's circumference at 28,985 kilometers (18,000 miles)—an error of nearly 28 percent. Because of Ptolemy's contributions to geography and cartography, his circumference was used throughout the Renaissance. It is believed that Christopher Columbus used Ptolemy's number to plan his voyage to the Far East. Everyone knows how that voyage ended—Columbus bumped into a continent that was hiding in the 28 percent error.



With the circumnavigation of the globe and subsequent scientific calculations, the accepted value of the circumference of the earth returned from Ptolemy's calculation back to that of Eratosthenes. After countless millennia, scientists, explorers, clergy, and laymen finally knew the "true shape" and "true size" of the earth. Of course, this geographic euphoria wouldn't last.

Eratosthenes' methods

Eratosthenes determined the earth's size by observing known phenomena and applying basic arithmetic and geometry to them. Here's how he did it.



Eratosthenes' methods were simple but effective. All he needed to know was the distance between two locations and what percentage of a circle this distance constituted.

While in Syene, Egypt (known today as Aswan), he noticed that the sun's rays shone directly down a well, casting no shadow at all. From this, he concluded that the sun was directly overhead at Syene. On the same date in Alexandria, a rod perpendicular to the ground cast a shadow that was 7° 12' from perpendicular.

Eratosthenes then divided 360° by 7° 12' and determined that 7° 12' was 1/50th of a circle. Now all he had to do was find the distance from Syene to Alexandria and multiply it by 50 to get the earth's circumference.

Many scholars believe Eratosthenes measured the distance by measuring a single pace and then counting the number of paces from Syene to Alexandria. While this is possible, it is just as likely that he counted the revolutions of a wheel with a known circumference, since this was a common method of measurement in both Egypt and Greece. Either way, he probably hired someone or enlisted a slave to accomplish the task. The distance figure he used was 805 kilometers or 500 miles.

Next, he multiplied this distance by 50 to get 40,250 kilometers (25,000 miles). Today, most scientists set the earth's circumference at 40,096 kilometers (24,901 miles). This gives Eratosthenes' estimate less than a one percent error—an excellent approximation of the earth's circumference.

Eratosthenes' errors

Syene is not on the Tropic of Cancer, where the sun's rays are directly overhead during the summer solstice. It is actually 37 kilometers (23 miles) north of the Tropic of Cancer.

Alexandria is not due north of Syene and the distance between them is not 805 kilometers. The actual distance corresponds to an angular measurement not of 7° 12', but rather of 7° 30'.

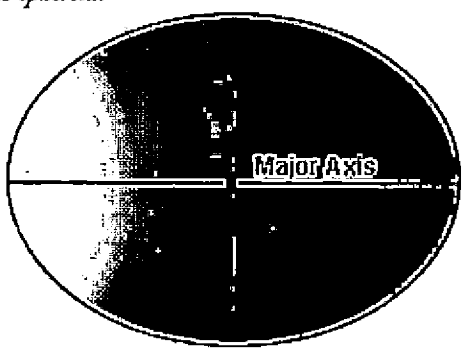
All in all, it's amazing that his calculations came as close as they did to the earth's true circumference.

Refining the earth's shape

It seems that nothing is perfect, and that goes for the earth's shape as well. As explorers and scientists of the past investigated the earth more closely, they realized that it is not a perfect sphere but an ellipsoid—and an imperfect one at that.

ellipsoid

When used to represent the earth, a solid geometric figure formed by rotating an ellipse about its minor axis. Same as *spheroid.*



Rotating an ellipse about its minor axis creates an oblate ellipsoid, while rotating an ellipse about its major axis creates a prolate ellipsoid.

Concept

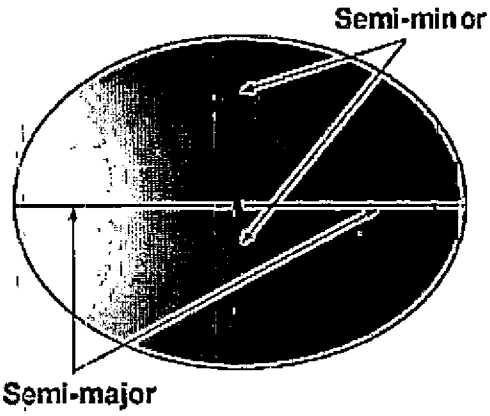
The earth's shape is an ellipsoid

As the centuries passed, scientists and explorers began to realize that the earth was not a perfect sphere. British scientists, led by Isaac Newton, theorized that the centrifugal force from the earth's rotation would force the earth to "spread out" from east to west as it rotated about its axis. The French, using their own local measurements, believed the earth to be squished at the equator and bulging at the poles. In 1753, this debate was resolved when a French survey expedition took measurements at the equator in Peru and at the Arctic circle in Lapland and determined that the earth was indeed bulging at the equator. The earth's shape is not a sphere but an *ellipsoid.*

Just as a sphere is based on a circle, an ellipsoid is based on an ellipse. By rotating an ellipse about one of its axes, an ellipsoid of rotation is created. It is this type of ellipsoid that most closely approximates the earth's shape. To be more precise, the earth rotates about its shortest axis, or minor axis, and is therefore described as an oblate ellipsoid.

The earth is not a perfect sphere but an oblate ellipsoid. If it rotated about its major (longer) axis, it would be described as a prolate ellipsoid.

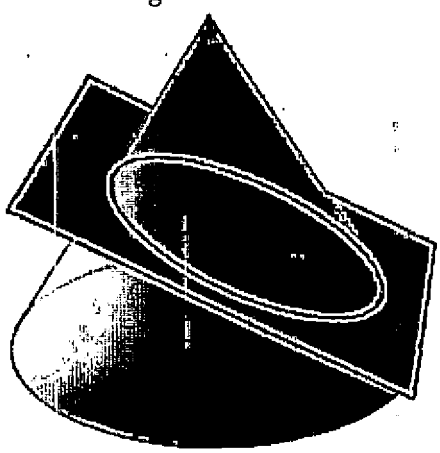
Ellipsoids are not usually measured with major and minor axes but rather with semi-axes. A semi-axis is half of an axis.



When you examine the parameters for any ellipsoid used to describe the earth, its semi-major and semi-minor axes are given.

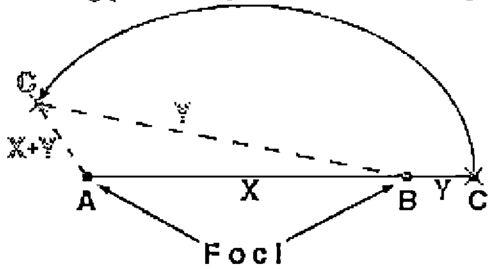
Ellipses and ellipsoids

How to make an ellipse: No one knows for sure when the ellipse was discovered, but in 350 BCE the Ancient Greeks knew about the ellipse as a member of the group of two-dimensional geometric figures called conic sections. An ellipse is created by using the two dimensional plane to slice the three dimensional cone at an angle.



The ellipse is one of the many conic section shapes, such as a line, circle, parabola, or hyperbola.

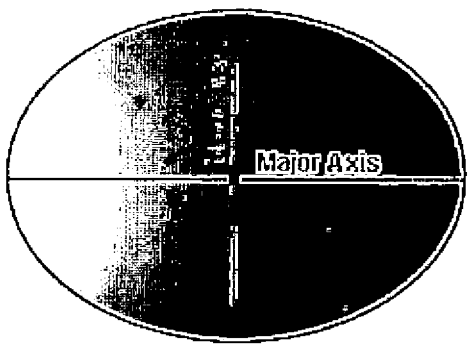
An ellipse is basically a curve with a simple formula. Create a straight line (X in the graphic below) connecting two fixed points (A and B), called foci. Next, create another straight line (Y) that begins at one of the foci and ends at a new point (C) that is not on the first line (X). Move the end point (C) while keeping the summed distance of the two lines (X+Y and Y) the same until you return to the starting point and you will create an ellipse.



Moving point C while keeping the summed length of lines X+Y and Y constant creates an ellipse

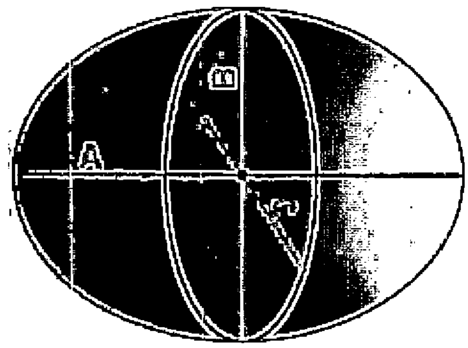
For nearly two thousand years, the ellipse had no known application in nature, a situation most early astronomers and alchemists had difficulty accepting. Early in the seventeenth century, German astronomer and philosopher, Johannes Kepler, seeking an explanation for the unusual orbits of the planets around the sun, discovered that the ellipse described the orbits perfectly. Kepler had his solution and the ellipse had its first known application. Little did Kepler know that the shapes of the planets themselves are best described as ellipsoids—a three-dimensional representation of an ellipse.

Making an ellipsoid: Drawing a line through an ellipse's two foci and then another line perpendicular to and bisecting this line creates two axes, a major axis and a minor axis. Rotating an ellipse about either axis creates a special type of ellipsoid called an ellipsoid of rotation.



Spinning an ellipse about its minor axis creates an oblate ellipsoid while spinning an ellipse about its major axis creates a prolate ellipsoid.

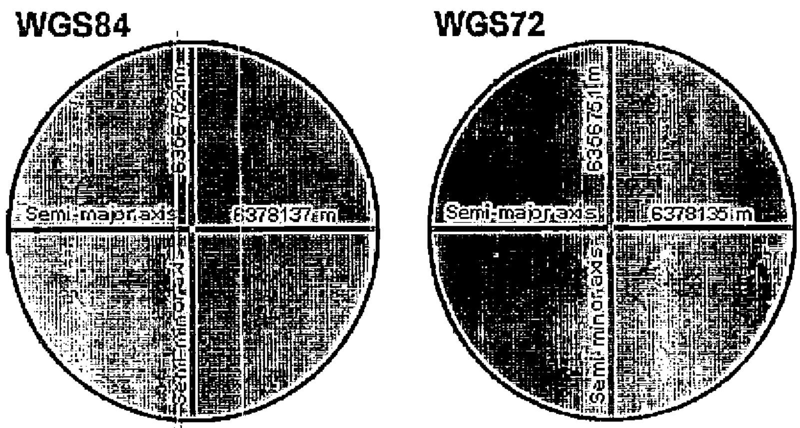
Ellipsoids of rotation are defined using two axes but ellipsoids are actually mathematically defined using three axes. When you rotate the ellipse about one of its axes, as in an ellipsoid of rotation, two of the axes are equal.



Not all ellipsoids are ellipsoids of rotation. Mathematically an ellipsoid is triaxial or defined using three axes (A,B,C).

The earth's shape is a spheroid

Although the earth's shape is technically an ellipsoid, its major and minor axes do not vary greatly. In fact, its shape is so close to a sphere that it is often called a spheroid rather than an ellipsoid.



A spheroid is simply an ellipsoid that approximates a sphere. These examples are two common world spheroids used today with their values rounded to the nearest meter. For each spheroid, the difference between its major axis and its minor axis is less than 0.34 percent.

The terms "spheroid" and "ellipsoid" are often used interchangeably and have caused confusion for many GIS users. Most map projection authorities consider both terms equally correct. Because spheroid is a bit more descriptive than ellipsoid, and because ESRI® software and documentation use spheroid, spheroid is the term that will be used in this course.

Specific definitions for exactly what a spheroid is can vary, but the two most common definitions for a spheroid are:

1. An ellipsoid that approximates the shape of a sphere
2. An ellipsoid created by rotating an ellipse about either its major axis (called a *prolate spheroid*) or its minor axis (called an *oblate spheroid*)

The second definition is generally considered a more precise geometric definition because it doesn't involve any subjectivity. Using this definition, the earth's shape would be described as an oblate spheroid. To most people, however, the first spheroid definition better describes the earth's shape, so that will be the definition used in this course.

Spheroid: An ellipsoid that approximates the shape of a sphere. See also *ellipsoid*.

Defining ellipticity

The degree of ellipticity, or flattening, of an ellipse, ellipsoid, or spheroid can be expressed as a fraction or decimal measuring the difference in the length of the two axes. For example, if you assign two axes to a circle, and measure both of them, the resulting difference will be 0. A circle's ellipticity is therefore 0. As an ellipse becomes more elongated its ellipticity increases. Eventually, it approaches the shape of a line, which has an ellipticity of 1.

A circle has an ellipticity equal to 0 because the length of both axes is the same. The example ellipse above has an ellipticity of .5 because the major axis is twice as long as the minor axis. A line has an ellipticity of 1 because it has length but no height.

Large elliptical values describe narrow ellipses or ellipsoids and small elliptical values represent almost circular ellipses or spheroids. Earth's ellipticity is approximately 0.003353 because it bulges slightly at the equator and is flattened at the poles. While this difference doesn't seem like much, it can greatly affect large-scale maps.

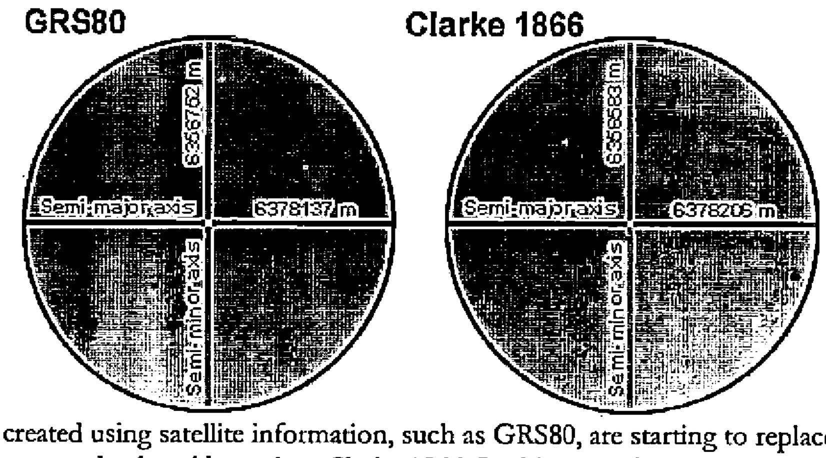
Why do we need different spheroids?

Now you know that the earth is a spheroid (which is another word for ellipsoid). As you may have suspected, however, it is not a perfect spheroid. The earth's surface is not perfectly symmetrical, so the semi-major and semi-minor axes that fit one geographical region do not necessarily fit another one.

Satellite technology has revealed several elliptical deviations. For one thing, the most southerly point on the minor axis (the South Pole) is closer to the major axis (the equator) than is the most northerly point on the minor axis (the North Pole). In addition, the earth's spheroid deviates slightly for different regions of the earth.

Many different spheroids are used throughout the world to account for these deviations. For example, the International 1924 and the Bessel 1841 spheroids are used in Europe while in North America the GRS80 spheroid is the most common. Ignoring deviations and using the same spheroid for all locations on the earth could lead to errors of several meters, or in extreme cases hundreds of meters, in measurements on a regional scale.

Because of improvements in technology, refinements in measurements, or for political reasons, you may see different spheroids used for the same geographic area. For example, until recently, the Clarke 1866 spheroid was the most commonly used spheroid for North America. Today, the GRS80 spheroid is replacing Clarke 1866 in most geographic databases. However, just because a spatial database covers North America, you cannot assume it uses the GRS80 spheroid. Many North American databases have not yet been converted from Clarke 1866.



Spheroids created using satellite information, such as GRS80, are starting to replace traditional ground-measured spheroids, such as Clarke 1866. In this example, measurements for both spheroids have been rounded to the nearest meter.

As technology improves, more spheroids of higher local accuracy will be developed. Remember that changing spheroids changes the location values for the features you are mapping. Because of the complexity of changing spheroids, ground-measured spheroids will remain in use for several years.

World Spheroids

SPHEROID	YEAR	SEMI-MAJOR AXIS	SEMI-MINOR AXIS
WGS72	1972	6378135 m	6356750.519915 m
WGS84	1984	6378137 m	6356752.31424518 m
Authalic sphere		Axis 6370997 m	

India

SPHEROID	YEAR	SEMI-MAJOR AXIS	SEMI-MINOR AXIS
Everest	1830	6377276.3452 m	6356075.4133 m
Everest	1856	6377301.243 m	6356100.22837 m

When to use a sphere

Although a spheroid best represents the earth's shape, the earth is sometimes treated as a sphere to make mathematical calculations easier.

You can use a variety of methods to define a sphere that approximates the earth's shape. For instance, you could base your sphere on either the major axis or the minor axis of the earth (as defined by a particular spheroid). The most commonly accepted method, however, is to create a sphere that has the same surface area as the spheroid. Such a sphere is called an *authalic sphere*. Although there are discrepancies between authalic spheres, the most common authalic sphere diameter used is 12,741.994 kilometers or 7,912.778 miles.

While difference between the semi-major and semi-minor axes must be considered in regional applications, for most world maps the difference can be ignored and the world can be treated as a sphere. In fact, the difference is so small that for this graphic it would be undetectable.

If your mapping scales are smaller than 1:5,000,000 (small-scale maps), you can use an authalic sphere to define the earth's shape. To give you some perspective, a 1:5,000,000 scale map of the coterminous United States would be approximately 122cm (48") wide. At this scale, the difference between a sphere and a spheroid is not significant. If your applications use scales that are larger than this, you may need to choose a spheroid.

Unless you specify a sphere for your application, ESRI products use an authalic sphere with a diameter of 12,741.994 kilometers or 7,912.778 miles.

Establishing location

Early mapmakers recognized the need for a system that could locate features on the earth's surface. From this need, a system of imaginary intersecting lines was created—today we call that system *latitude* and *longitude.*

Creating the graticule

The idea of using a system of intersecting lines to locate features on a map existed almost from the inception of systematic mapmaking. As early as the third century BCE, Chinese mapmakers put reference lines on their maps, but they didn't apply the technique to the entire earth. In fact, there is no evidence that they recognized the earth was a sphere.

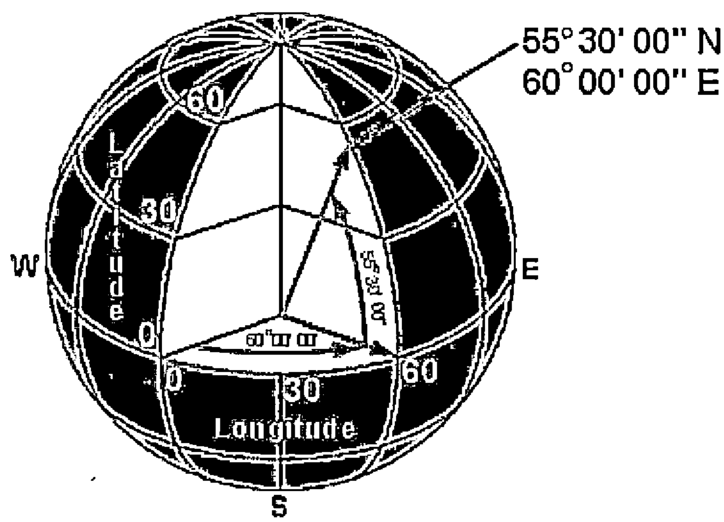
The first person credited with tackling the problem of locating surface features on a spherical earth was our friend, Eratosthenes. Eratosthenes devised a system of north–south and east–west oriented lines encompassing the earth's surface and intersecting each other.

In the second century BCE, a Greek astronomer and geographer named Hipparchus refined and formalized the system. His system is the same one we know today as latitude and longitude. The system of latitude and longitude, also called *parallels* and *meridians*, is based on 360 degrees. Each degree is divided into 60 minutes and each minute into 60 seconds. The 360-degree Babylonian system for dividing a circle or sphere, including the heavens, was already in use by the ancient Greeks. Hipparchus had the foresight to apply the system to the earth's surface.

Latitude lines are parallel, run east and west around the earth's surface, and measure distances north and south of the equator.

Longitude lines run north and south around the earth's surface, intersect at the poles, and measure distances east and west of the prime meridian.

The network of intersecting lines of latitude and longitude is called the *graticule.* It is imaginary on the earth, of course, but is drawn on globes and maps for reference.



The graticule of latitude and longitude lines is an angular measurement system. All features on the earth's surface are located using measurements that are relative to the center of the earth. Latitude lines are parallel to each other while longitude lines converge at the poles.

Prime meridian: Any line of longitude designated as 0 degrees east and west, to which all other meridians are referenced. Nowadays, the prime meridian is usually the one that runs through the Royal Observatory in Greenwich, England.

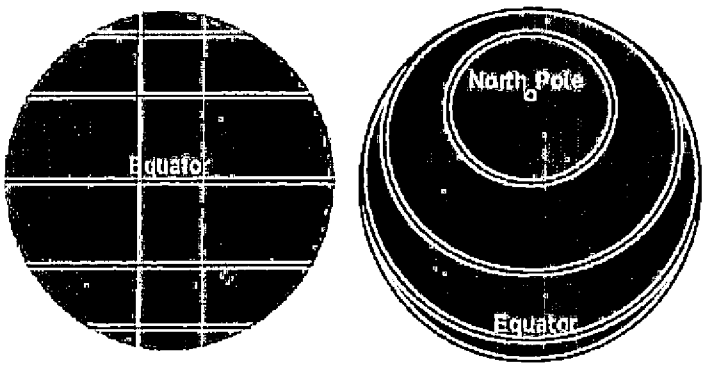
Locating features from north to south

Although the graticule was developed more than two thousand years ago, not everyone agreed where the starting point for the system should be—that is, where was zero?

Where to begin measuring latitude was the first problem to be tackled. The ancient Greeks are known to have used at least two different latitude lines as their origin. One line passed through Rhodes and another passed through Alexandria. Two different origins is manageable if you know how to convert from one system to the other, but one origin is a lot better.

Latitude lines, or parallels, are actually a series of parallel circles intersecting the earth's axis at right angles and decreasing in size as they near the poles. Because only one of the parallels is a *great circle*, a circle that divides the earth into two equal halves, scholars reasoned using that parallel as the starting point for latitude seemed logical. This line is called the *equator.* The resulting southern hemisphere and northern hemisphere surfaces are theoretically equal, but because the earth isn't a perfect sphere or spheroid, the hemispheres are in fact a little different.

Degrees of latitude are measured from 0° to 90° north and 0° to 90° south from the equator. The north pole and the south pole are then 90° north and 90° south respectively.

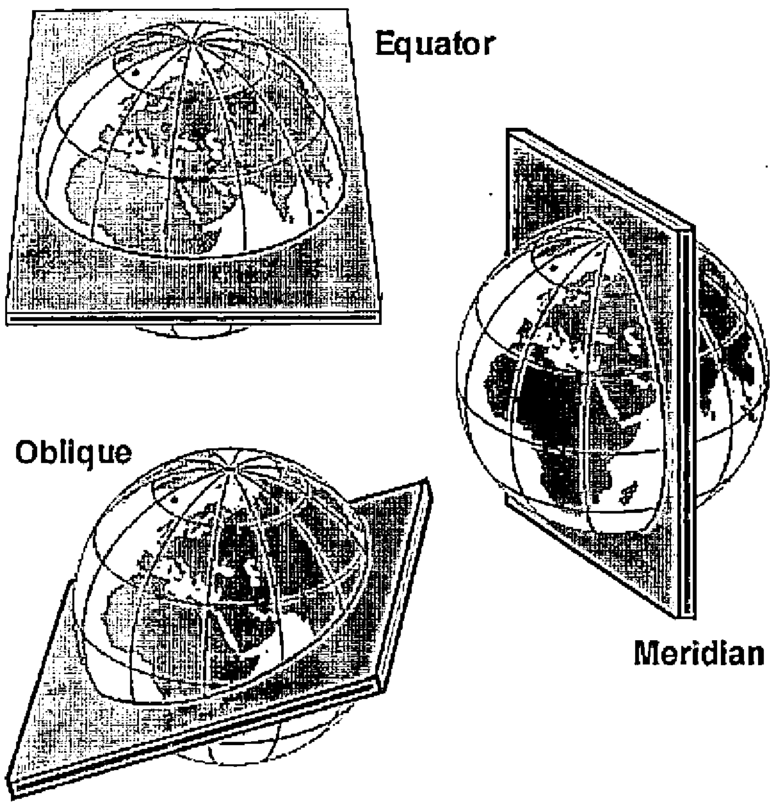


Because latitude lines are parallel, every degree of latitude is theoretically equal. Since the earth is not a perfect sphere, however, the degrees vary slightly (110.572 kilometers or 68.708 miles at the equator and 111.69 kilometers or 69.403 miles at the poles).

The invention of the compass (which points north), combined with the fact that the most influential countries were located in the northern hemisphere, meant that north was placed at the top of most maps and globes.

Great circles

A great circle is any circle that defines the point where an imaginary plane intersects the earth and divides the earth into equal halves or hemispheres. To create a great circle, you spin a sphere's diameter in any direction and trace its path. The resulting circle divides the sphere into two equal halves. Opposite meridians, when combined, create a great circle, as does the equator. All other parallels are called small circles because they fail to divide the earth into equal hemispheres.



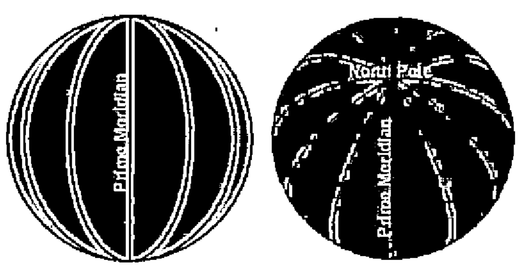
Rotating two connecting meridians or the equator in any direction creates a great circle. When the circle does not intersect the equator at a right angle, its orientation is called oblique.

An arc, or section, of a great circle represents the shortest distance between any two points on the earth. This makes great circles very useful in plotting courses for airplanes, missiles, or, in some situations, ships.

Locating features from east to west

Determining the starting point, or *prime meridian*, for longitude is not an easy task. Longitude lines, or meridians, converge at the poles so every meridian is half of a circle, specifically, half of a great circle.

Since each circle is the same size, choosing one meridian over another is completely arbitrary. To give just a few examples, the Spanish have used a meridian passing through Madrid, the French a meridian passing through Paris, and the Austrians a meridian passing through the island of Ferro in the Canary Islands. Around the time of the American Revolution, colonial maps used either London or Philadelphia as the starting point. Later, the United States adopted Washington, D.C. as the prime meridian. Finally, in 1884, an International Meridian Conference was held in Washington, D.C., and the Observatory of Greenwich in Great Britain was adopted as the official prime meridian.



The distance for a degree of longitude varies. A degree of longitude at the equator is 111.317 kilometers or 69.171 miles, and gradually decreases toward the poles, which have a value of zero.

Degrees of longitude are measured from 0° to 180° east and 0° to 180° west from the prime meridian. The 180° meridian is often called the International Dateline, but the dateline actually deviates from the meridian and is more a political or chronological construct than a locational one.

Not every nation has adopted the Greenwich Meridian as its prime meridian. Today, several prime meridians are used by a variety of countries. When examining the coordinates for a set of features, especially from different data sources, you must be sure they are referenced from a common prime meridian.

Decimal degrees

Decimal degrees (DD) are similar to degrees/minutes/seconds (DMS) except that minutes and seconds are expressed as decimal values. Decimal degrees are generally used to store digital coordinate information because they make digital storage of coordinates easier and computations faster.

The example below shows the location for Moscow in DMS and DD.

How to convert from DMS to DD: [Example coordinate is 37° 36' 30" (DMS)]

1. Divide each value by the number of minutes or seconds in a degree:
   36 minutes = .60 degrees (36/60)
   30 seconds = .00833 degrees (30/3600)
2. Add up the degrees to get the answer:
   37° + .60° + .00833° = 37.60833 DD

ESRI products allow feature coordinates to be stored as degrees/minutes/seconds in text files or database tables. However, decimal degrees must be used for all feature coordinates in geodatasets (shapefiles, coverages, geodatabases, and so on).

Converting degrees on your calculator: You can convert DD to DMS and DMS to DD using your computer's calculator. Click the Start button, point to Programs, point to Accessories, and click Calculator. From the View menu, choose Scientific.

Converting DD to DMS: Enter the decimal degree coordinates and click the dms button. The result is given in degrees, minutes, and seconds (although it is formatted as a decimal).

For example, enter 51.487911, the latitude of London, England. Click dms. The result is 51.29164796. This means 51 deg., 29 min., 16 sec. (north).

Try 104.177116, the longitude of Singapore. The result is 104.10376176. This means 104 deg., 10 min., 38 sec. (east).

Negative numbers work fine. Enter 37.852959 and click the +/- button. That gives–37.852959, the latitude of Melbourne, Australia. Click dms. The result is -37.51106524. This means 37 deg., 51 min., 11 sec. (south).

Converting DMS to DD: Enter the degrees, minutes, seconds coordinates (formatted as a decimal), check the Inv box and click the dms button. The result is given in decimal degrees.

For example, enter **45.3228**, the latitude of Montreal, Canada (45 deg., 32 min., 28 sec.). Check Inv and click dms. The result is 45.541111, the value in DD.

Try **18.0503**, the longitude of Stockholm, Sweden (18 deg., 5 min., 3 sec). Check Inv and click dms. The result is 18.084167, the value in DD.

Lesson summary

- The ancient Greeks conjectured that the earth was round based on observations such as the way ships disappear on the horizon. Pythagoras was the first to advance this proposition.
- Eratosthenes estimated the circumference of the earth by measuring the angles of shadows cast in Syene and Alexandria and finding the distance between the two cities.
- In the eighteenth century, it was determined that the earth is not a perfect sphere but an ellipsoid that bulges slightly at the equator. Because this bulge is very slight, the earth's shape is often called a spheroid—an ellipsoid that approximates a sphere.

- Because of surface irregularities, the earth cannot be adequately modeled by a single spheroid. Instead, different spheroids are applied to different parts of the world to achieve local accuracy.
- For scales smaller than 1:5,000,000, it can be assumed that the earth is a sphere. An authalic sphere is a perfect sphere that has the same area as a given spheroid.
- Locations on the earth's surface are measured with lines of latitude and longitude. Because these lines do not always intersect at right angles, they form a graticule rather than a grid. Latitude and longitude are measured in degrees, minutes, and seconds.
- Latitude lines (parallels) are parallel circles that intersect the earth's axis at right angles. They measure distance 90° north and 90° south of the equator, which has a latitude of 0°.
- Longitude lines (meridians) are half circles that converge at the poles. They measure distance 180° east and 180° west of the prime meridian, which has a longitude of 0°.
- Decimal degrees are decimal equivalents of measurements in degrees, minutes, and seconds. Decimal degrees make computer calculations faster.

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GLOBAL POSITIONING SYSTEMS AND ITS USES IN DATA COLLECTION FOR GIS

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What is GPS ?

The Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites and 5 graond stations. GPS was originally intended for military applications, but in the 1980s, the government made the system available for civilian use. GPS works in any weather conditions, anywhere in the world, 24 hours a day. There are no subscription fees or setup charges to use GPS.

Origin of GPS

In the 1970s the Department of Defense (DoD) conceived the idea of GPS. It was born from a need to accurately determine the position of ballistic missile submarines prior to launching missiles. All the old methods of determining position had their flaws. Those methods were affected by atmospheric conditions, limited in range, subject to enemy jamming, or degraded by interference.

Segments of GPS

Space Segment: The space segment of GPS consists of 24 satellites fielded in nearly circular orbits with a radius of 26,560 km, period of nearly 12 hours and stationary ground tracks. The satellites are arranged in sis orbital planes inclined at ˉ550 relative to the equatorial plane, with four satellites distributed in each orbit. With this constellation, almost all users with a clear view of the sky have a minimum of four satellites in view. Each satellite receives and stores information from the control segment; maintain very accurate time through on board precise atomic clocks
Control Segment: The control segment of GPS consists of five tracking stations distributed around the earth of which one, located in Colorado Springs, is a Master Control Station. The control segment tracks all satellites, ensures they are operating properly and computes their position in space. The computed positions of the satellites are used to predict where the satellite will be later in time. These parameters are uploaded from the control segment to the satellites and referred to as broadcast ephemeredes.
User Segment: The GPS user segment consists of the GPS receivers and the user community. Almost all GPS tracking equipment have the same basic components: an antenna, an RF (Radio Frequency) sections a microprocessor, a control and display unit (CDU), recording device and a power supply. Usually all component, with the exception of the antenna, are grouped together and referred to as a receiver. GPS receivers convert SV signals into position, velocity, and time estimates. Four satellites are required to compute the four dimensions of X, Y, Z (position) and time. GPS receivers are used for navigation, positioning, time dissemination, and other research. The 24 satellites that make up the GPS space segment are orbiting the earth about 12,000 miles above us. They are constantly moving, making two complete orbits in less than 24 hours

Basic principle of GPS

A GPS unit uses the combination of radio signals and clocks to determine a position relative to the surface of the earth. Specifically, each satellite continuously transmits, among other things, a **radio signal** and a **navigation message**. The navigation message contains the current **satellite almanac**. The almanac contains information telling the receiver exactly where the satellite is located in space, and the clock correction, which aligns the receiver clock to the satellite clock. In effect, the navigation message tells the receiver exactly where the satellite is located in space. The next step determines the distance between the satellite and the receiver using the radio signal.

It is known that radio signals travel at the speed of light. Once the navigation message is processed, the receiver knows how long it takes for the radio signal to reach it. The distance between the two can then be calculated using simple arithmetic:

Rate x Time = Range

Where rate = speed of light

This formula gives one range from one satellite. To determine the position of the receiver, the coordinates of the satellites and a minimum of four ranges from four different satellites must be known.

Types of GPS

Autonomous (Hand Held, Spot track)-15 - 100 meters Accuracy
Differential GPS (DGPS)- 0.5 - 5 meters
Real-Time Kinematic (RTK) - 20cm - 1 meter

Error correction

As would be expected, a variety of different errors can occur within the system, some of which are natural, whilst others are artificial. First of all, a basic assumption, the speed of light, is not constant as this value changes as the satellite signals travel through the atmosphere. As a GPS signal passes through the charged particles of the ionosphere and then through the water vapour of the troposphere it gets slowed down, and this creates the same kind of error as bad clocks. This problem is tackled by attempting to use modelling of the atmospheric conditions of the day, and using dual-frequency measurement, i.e. comparing the relative speeds of two different signals. Another problem is multipath error , this is when the signal may bounce off various local obstructions before it gets to our receiver. Sophisticated signal rejection techniques are used to minimize this problem.

There are also potential problems at the satellites. Minute time differences can occur within the on-board atomic clocks, and sometimes position (*ephemeris*) errors can occur. These other errors can be magnified by a high GDOP "*Geometric Dilution of Precision*" This is where a receiver picks satellites that are close together in the sky, meaning the intersecting circles that define a position will cross at very shallow angles. That increases the grey area or error margin around a position. If the receiver picks satellites that are widely separated the circles intersect at almost right angles and that minimises the error region. Obviously good receivers determine which satellites will give the lowest GDOP.

Finally up to recently there was another , man-made source of errors. The U.S. was very mindful of the fact that terrorists and unfriendly governments could use the accurate positioning provided by GPS and so intentionally degraded GPS's accuracy. This policy is called *Selective Availability* or SA. This involves the DOD introducing some "noise" into the satellite's clock data which, in turn, adds noise (or inaccuracy) into position calculations. The DOD may also has been sending slightly erroneous orbital data to the satellites which they transmit back to receivers on the ground as part of a status message. Together these factors made SA the biggest single source of inaccuracy in the system. Military receivers used a decryption key to remove the SA errors and so they were considerably more accurate.However, effective May 2, 2000 selective availability has been eliminated. The recent terrorist attacks on America have not changed this position. This is due to the fact that civilian uses of GPS have become critical across the world, and because the United States Department of Defence now has the technology to localise the control system to deny GPS signals to selected areas.

Limitations of GPS: Heavy tree cover and cliffs, steep hills, or tall buildings can interfere the signals.

GPS for GIS Data collection

There are three types of Feature, which can be mapped: Points, Lines and Areas. A Point Feature is a single GPS coordinate position, which is identified with a specific Object. A Line Feature is a collection of GPS positions, which are identified with the same Object and linked together to form a line. An Area Feature is very similar to a Line Feature, except that the ends of the line are tied to each other to form a closed area.

Use of GPS in Agriculture

- GPS is used to delineate field boundaries, Water shed boundaries etc:
- In large fields pest or disease infestation can be demarcated using GPS co-ordinate for appropriate control measures
- GPS Co-ordinates are used to rectify satellite imagery
- Used to collect GCP's (geographic control points) registering cadastral maps etc.

INTRODUCTION TO AERIAL PHOTOGRAPHY AND SATELLITE REMOTE SENSING

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Aerial Photography

Aerial photographs are the pictures taken by camera fitted in an aircraft and flying over the terrain at a predetermined height. The flying height is decided by the scale of aerial photography and focal length of camera. They have two principal uses in soil surveys

1. As a base maps for soil surveys
2. For interpretation where they act as a source of primary information

Advantages of aerial photographs

- More amount of ground information is available. On aerial photographs physical and cultural features that are present on the ground are clearly seen
- Aerial photographs increase the speed and accuracy of soil surveys, because it serve as a base map in soil survey. It tells us about inaccessible terrains like marshes, swamps.
- Large areas can be covered in less time
- Possibility of stereoscopic vision. (Stereoscopic vision is the ability to perceive the features on 3-demension)

Disadvantages of aerial photographs

- Elevation information is not available
- They lack uniform scale throughout the area due to variation in ground elevation and altitude of aircraft
- The distances and elevation cannot be measured in aerial photographs
- Skill is required for interpreting them.

However the advantages of aerial photographs generally outweigh the limitation and make them a valuable tool in soil mapping.

Remote sensing

Remote sensing is the art and science of obtaining information about an object, area or phenomena through the analysis of data obtained by a device that is not in contact with the object, area or phenomena under consideration. Simply it means getting information by being remotely.

Human eye, aerial photographs, camera, video etc are some forms of remote sensing. But the term remote sensing is largely used for the collection of information by sensors placed on platforms of satellites. The sensors of the satellites collect information regarding the earth surface by recording the electromagnetic energy (mainly solar energy) reflected by various earth features. These information are recorded in terms of brightness values and are delivered to ground stations. The ground stations process this data and supply them to users in photographic form or in digital form.

Remote sensing is broadly deemed as the process of collecting information about a subject without being in physical contact with the subject. Aerial photography is also a form of remote sensing and was widely used for land resource mapping and even today in the age of the satellite and electronic scanner, it is also used as remotely sensed data. In the 1960s technological developments enabled imagery to be acquired in visible and IR spectrum and it is now mostly used for natural resource inventories.

In soil watershed planning these satellite imageries are used as **base maps**. These imageries will be interpreted either visually or using computer aided image processing techniques for identifying various physiographic units.

Principles of Remote Sensing

Remote sensing, a technique for making measurements of an object at a distance, to a great extent relies on the interaction of EMR with matter. Different stages in remote sensing can be broadly enlisted as (1) a source of electromagnetic energy (Sun/Self emission), (2) transmission of energy from the source (Sun) to the surface of the earth wherein it also undergoes absorption and scattering during passage through the atmosphere, (3) interaction of EMR with the earth's surface (reflection, scattering, absorption and reemission), (4) transmission of reflected/scattered/emitted energy from the objects/features of earth's surface to the remote sensors and (5) sensor data output.

Electromagnetic spectrum

Information from an object to the sensor is carried by the electromagnetic energy and could be encoded in the form of frequency, intensity of polarization of the electromagnetic wave. Electromagnetic spectrum is divided into a numbers of spectral regions of varying wavelength

Region	Wave length	Remarks
Gamma Ray	< 0.03 nm	Incoming radiation is completely absorbed by the upper atmosphere and is not available for remote sensing
X-ray	0.03 to 3.0 nm	Completely absorbed by atmosphere. Not. employed in remote sensing.
Ultra violet	0.03to 0.4 μm	Incom ing wavelengths less than 0.3 μm are completely absorbed by ozone in the upper atmosphere
Photographic UV band	0.3 to 0.4 μm	Transmitted through atmosphere, detectable with film and photodetecctors, but atmosphoric scattering is severe.
Visible	0.4 to 0.7 μm	Imaged with film and photodetecctors includes reflected energy peak of earth at 0.5 μm .
Infra red	0.7 to 100 μm	Interaction with matter varies with wavelength. Atmospheric transmission windows are separated by absorption bands.
Reflected IR band	0.7 to 3.0 μm	Reflected solar radiation that contents no information about thermal properties of materials. The band from 0.7 to 0.9 μm is detectable with film and is called the photographic IR band.
Thermal IR band	3 to 5 μm 8 to 14 μm	Principal atmospheric windows in the thermal region. Images at these wavelengths are acquired by optical and mechanical scanners and special vidicon systems but not film.
Micro wave	0.1 to 30 cm	Longer wavelengths can penetrate clouds, fog and rain. Images may be acquired in the active or passive mode
Radar	>30cm	Active form of microwave remote sensing. Radar images are acquired at various wavelength bands
Radio	>30cm	Longest wavelength portion of electromagnetic spectrum. Some classified radars with very long wavelength operate in this region

The commonly used parts of the spectrum that are used for soil resource mapping are: Visible (VIS), Near Infra red (NIR), Mid Infrared (MIR) and Thermal infrared (TIR).

Passive and Active Remote Sensing Systems

There are two basic type of remote sensing systems: Passive and Active. A passive remote sensing system uses the Sun as the source of electromagnetic radiation. Radiation from the Sun interacts with the surface (for example by reflection) and the detectors measure the amount of energy that is reflected.

Camera system: Multispectral scanners (MSS) record the same energy as cameras over a much wider range of wavelengths. Thermal Infared (TIR) scanners detect the heat given off by targets

An active remote sensing system carries onboard its own electromagnetic radiation source. The electromagnetic radiation is directed at the surface and the energy that is scattered back from the surface is recorded.

Examples of active remote sensing system are SONAR, RADAR, X-ray and Laser are all active remote sensing systems. The commonest active remote sensing system is radar that, produces electromagnetic radiation in the microwave band of the spectrum

Scanner and camera system: Photographs are taken by cameras using film which is sensitive to different wavelengths of radiation. The whole scene is photographed in a single exposure.

Images are recorded by scanners in digital format (ie as numbers representing brightness values). Photographic film is not used. Depending on which part of the spectrum is being studied, one or more sensors will be appropriate.

Multispectral scanners simultaneously record multiple segments of spectrum from UV to thermal infrared (TIR). RADAR instruments record microwave wavelength.

Types of remote sensing image: The main type of remote sensing photographs are: 1) Panchromatic, 2) Photographic infrared, 3) Multispectral, 4) Natural colour, 5) False colour.

The different spectral bands used in remote sensing

Band	Spectral range (microns)	Application
1.	0.45 - 0.52 (Blue)	Coastal environment studies, chlorophyll absorption region
2.	0.52 - 0.59 (Green)	Green vegetation, useful for discrimination of rocks and soil for their iron content
3.	0.62 - 0.68 (Red)	Strong correlation with chlorophyll absorption in vegetation, discrimination of soil and geological boundaries.
4.	0.77-0.86 (Near Infra-red)	Sensitive to green biomass, opaque to water resulting in high contrast with vegetation.

False colour composite

In case, the images generated by remote sensing measurements in blue, green and red bands are combined by superimposing the transmission through blue, green and red filter respectively, the resultant print/transparency is known as true colour composite. When the reflectance of an object is different from other object in all wave lengths except for the infrared, the normal colour image will best display the differences between them. However, when the reflectance for two different objects are more or less similar e.g. water and wet black soil, then the normal colour image is not the best option. In that case, it makes much more sense to produce an image by using the green, red and infrared ranges where the two substances have different reflectance. However, projecting the green range in blue, the red range in green and the infrared range in red light can produce a false colour image. A false colour composite (FCC), which is formed by projecting green data in blue, red in green and infrared in red, is known as a standard false colour composite. The vegetation normally reflects predominantly in near-IR region as compared to green or red spectral bands. Hence vegetation appears red in standard

FCC due to assignment of infrared based to red colour. In case of clear deep water, very little signal would be received by satellite in green and red bands (green band provides little more details than red band) and practically nil in near IR band, as a result water body appears sky blue depending on its depth and concentration of sediments. Thus, the deep clear water would appear as dark blue while shallow and turbid water would appear as mixture of blue and green giving sky blue appearance. Snow, ice and cloud would reflect most of the energy in the similar manner for the bands and thus would appear white in the FCC.

Interaction of earth surface features with EMR

Two types of reflections are commonly observed during the interaction of EMR on earth surfaces. When the surface is smooth (equal angle of incidence and reflection) the reflection is called spectral reflection. A rough surface reflects the incident EMR in all directions independent of angle of incidence. This short of reflection is called diffuse reflection. Earth surface materials vary widely in their nature and composition; consequently so in their reflective properties at various regions of the electromagnetic spectrum. The variations in total reflectance of the Earth's surface is the combined effect of wavelength, angle of incidence, physical, chemical and biological properties of the earth cover.

Broadly the reflected radiance, recorded by the remote sensor, is governed by a group of four components viz. i) Surface composition, ii) Physical aspects of surface (smooth, roughness etc.), iii) Angle of incidence and observation, iv) Frequency or wavelength of incident radiation.

Spectral reflectance is the ratio of reflected energy to incident radiation as a function of wavelength. Many surface materials of the earth have different spectral reflectance characteristics when illuminated by different regions of the electromagnetic spectrum. For example, vegetation may reflect only 10 to 15 percent in the green portion of the spectrum, and as such as 40 to 60 percent in the near infrared. Similarly, water and soil may have different reflection characteristics.

The values of spectral reflectance of objects averaged over different well defined wavelength intervals comprise the spectral signature of the objects. These are the features by which the objects can be uniquely distinguished. Measurement of spectral reflectance are made by spectro-photometers and spectro-radiometers. Spectro-photometers measure the absolute reflectance characteristics of samples in the laboratory. Spectra-radiometers are field instruments which measure the radiance. The multispectral scanner (MSS), Thematic mapper (TM) and Linear Imaging Self Scanning Sensors (LISS) used in satellites for measuring the radiances of the earth surface at distinct spectral band widths.

Spectral characteristics of vegetation

Each of the three features - pigmentation, physiological structure and water content have effect on the reflectance, absorption and transmittance properties of a green leaf. In the visible wavelength, pigmentation dominates in spectral response of plants wherein chlorophyll is important. Absorption by chlorophyll gives very low reflectance in red and blue bands. The green colour of the leaf is responsible for peak reflectance at 0.54 µm. The middle infrared (MIR) has strong water vapour absorption at 1.6 and 2.2 µm The peak reflectance in MIR occur at 1.6 and 2.2 µm . Thus remote sensing measurements in 1.55 1.75 and 2.08 - 2.35 µm can give information about moisture content of the plant canopy. Low pigment content results in higher reflectance in red region. Stress in vegetation due to disease, insect infestation and nutrient deficiency can also affect the reflectance characteristics. A healthy plant gives less reflectance in red region and high reflectance in near infrared as compared to moderately and severely affected plant

Role of Remote Sensing in Soil Resource Mapping

Soil, resource mapping is a 3tier approach, comprising image interpretation, field survey, laboratory investigations and cartography and printing. Before going for soil survey work, the satellite imageries are to be procured depending on the type and purpose of the survey.

Type of survey and sensor data used

Type of survey	Scale of survey	Mapping unit	Sensor data used
Reconnaissance	1:250,000	Sub-group associations	Landsat, MSS, LISS-I, IRS LISS-I
Semi detailed reconnaissance	1 :50,000	Families/Series association	Landsat TM - 2,3,4 IRS-IA, ID-LISS-II IRS-IC - LISS-III, Spot
Detailed	1:25,000 & below	Phases of soil series	IRS-IC, LiSS-III, PAN fused data

After procuring the imageries, the first step is the interpretation of the imagery. The interpretation of satellite imagery can be done by the following methods: Visual interpretation and Digital analysis

Visual interpretation

Visual interpretation of satellite imagery is done on the basis of some photo elements or image characteristics seen on the image. These are tone/colour, size, shape, texture, pattern, site and association.

Generally, bands 2 and 4 are used for soil mapping in combination with false colour composites (FCC) produced by a combination of band 1,2 and 4 with primary colour filters of blue, green and red respectively.

Using available thematic maps, such as dealing with geology and geomorphology and Survey of India toposheet, the physiographic boundaries are delineated on the satellite imagery of I :250,000 scale depending on photo elements. Further, subdivisions of boundaries are delineated based on uniqueness of such image characteristics. The delineated boundaries are then placed on the topographic base of the same scale to prepare the basemap. Such maps will be used during field pedological activities for its ultimate conversion into a soil map. Based on ground truth data, the final delineation of boundaries is done for the preparation of soil map.

Digital Image Processing

The tasks of computer assisted image interpretation are detection, identification, measurement and problem solving. The digital data is stored in the form of Computer Compatible Tapes (CCT's) generated on data processing system. This is analyzed on PC based and large mainframe/super mini computer systems for processing and analyzing using image-processing algorithms.

Digital image consists of discrete picture elements, called pixels. Associated with each pixel is a number (digital number/gray level) which is the average radiance of a relatively small area within a scene called ground resolution element (GRE). The GRE affects the production of details within the scene. Smaller the pixel are more scene details are preserved. Digital image processing techniques can be divided broadly into four groups image rectification and restoration, enhancement, classification and merging.

Major specifications of IRS Systems

Satellite	Sensor	Resolution (m)	Swath (km)	Repetivity (days)	Spectral Bands µm	Highest possible scale
IRS-IA11B	LISS-I	72.5	148.5	22	0.45-0.52 0.52-0.59 0.62-0.68 0.77-0.86	1 :250,000
	LISS-II	36.5	45.5	22	0.45-0.52 0.52-0.59 0.62-0.68 0.77-0.86	1 :50,000
IRS-IC/ID	PAN	6	70.5(nadir) 91 (off nadir)	24	0.54-0. 75	1 :10,000
	LISS-Ill visible	23.5	141.8	24	0.52-0.59 0.62-0.68 0.77-0.86 1.55-1.70	

Application of Remote Sensing in studies of Soils and Agriculture are Mapping of land degradation

- Monitoring of soil and land resources
- Erosion assessment
- Watershed management
- Crop acreage estimation
- Land use/Land cover
- Crop condition/Stress assessment
- Crop yield prediction.

SATELLITES, SENSORS, IMAGERIES AND THEIR INTERPRETATIONS

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Introduction

Remote sensing is defined as the science which deals with obtaining information about objects on earth surface by analysis of data, received from a remote platform. In the present context, information flows from an object to a receiver (sensor) in the form of radiation transmitted through the atmosphere. The interaction between the radiation and the object of interest conveys information required on the nature of the object. In order for a sensor to collect and record energy reflected or emitted from a target or surface, it must reside on a stable platform away from the target or surface being observed.

Platforms

Platform is a stage to mount the camera or sensor to acquire the information about a target under investigation. Based on its altitude above earth surface, platforms may be classified as (1) Ground borne (2) Air borne (3) Space borne

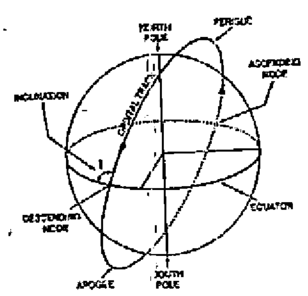
Ground-based platforms: The ground based remote sensing system for earth resources studies are mainly used for collecting the ground truth or for laboratory simulation studies.
Air-borne platforms: Aircraft's are generally used to acquire aerial photographs for photo-interpretation and photogrammetric purposes. Scanners are tested against their utility and performance from these platforms before these are flown onboard satellite missions.
Space-borne platforms: Platforms in space are not affected by the earth's atmosphere. These platforms are freely moving in their orbits around the earth, and entire earth or any part of the earth can be covered at specified intervals. The coverage mainly depends on the orbit of the satellite. It is through these space borne platforms, we get the enormous amount of remote sensing data and as such the remote sensing has gained international popularity. Depending on their altitude and orbit these platforms may be divided in two categories; (1) Geostationary (2) Polar orbiting or Sun-synchronous

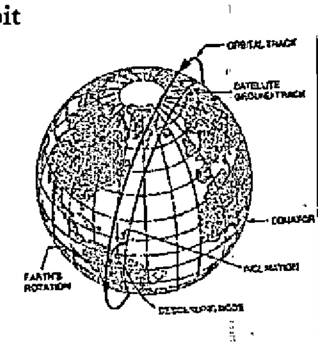
Geostationary satellites

An equatorial west to east satellite orbiting the earth at an altitude of around 36000 km., the altitude at which it makes one revolution in 24 hours, synchronous with the earth's rotation. These platforms are covering the same place and give continuous near hemispheric coverage over the same area day and night. Its coverage is limited to 70^{o}N to 70^{o}S latitudes and one satellite can view one-third globe. These are mainly used for communication and meteorological applications viz. GOES METEOSAT, INTELSAT, and INSAT satellites.

Sun-synchronous satellites

An earth satellite orbit in which the orbital plane is near polar and the altitude is such that the satellite passes over all places on earth having the same latitude twice in each orbit at the same local sun-time. **Fig 1. Sun-synchronous orbit**





Through these satellites the entire globe is covered on regular basis and gives repetitive coverage on periodic basis. All the remote sensing resource satellites may be grouped in this category. Few of these satellites are LANDSAT series, SPOT series, IRS series, NOAA, SEASAT, TIROS, HCMM, SKYLAB, SPACE SHUTTLE etc.

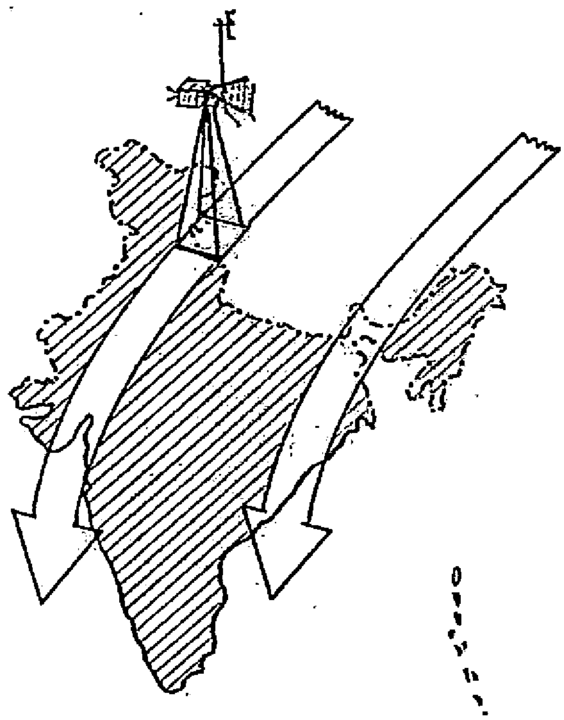


Fig Area Coverage on each Consecutive pass

Remote Sensing Sensors

Sensor is a device that gathers energy (EMR or other), converts it into a signal and presents it in a form suitable for obtaining information about the target under investigation. These may be active or passive depending on the source of energy.

Sensors used for remote sensing can be broadly classified as those operating in Optical Infrared (OIR) region and those operating in the microwave region. OIR and microwave sensors can further be subdivided into passive and active.

Active sensors use their own source of energy. Earth surface is illuminated through energy emitted by its own source, a part of it is reflected by the surface in the direction of the sensor which is received to gather the information. Passive sensors receive solar electromagnetic energy reflected from the surface or energy emitted by the surface itself. These sensors do not have their own source of energy and can not be used at night-time, except thermal sensors. Again, sensors (active or passive) could either be imaging, like camera or sensor which acquire images of the area and non-imaging types like non-scanning radiometer or atmospheric sounders.

Instantaneous field of view (IFOV)

It is defined as angular subtence at a given instant of the limiting detector aperture at the second principal point of the system. IFOV is both a linear and angular quantity.

IFOV = D/F radian

GRE = (D/F) x H meter

where,

D=detector dimension, F=focal length, and H=flying height

Resolution

Resolution is defined as the ability of the system to render the information at the smallest discretely separable quantity in terms of distance (spatial), wavelength band of EMR (spectral), time (temporal) and/or radiation quantity (radiometric).

Spatial Resolution: Spatial resolution is the projection of a detector element or a slit onto the ground. In other words, scanner's spatial resolution is the ground segment sensed at any instant. It is also called ground resolution element (GRE).

Ground Resolution = H x IFOV

The spatial resolution at which data are acquired has two effects –the ability to identify various features and quantify their extent. The former one relates to the classification accuracy and the later to the ability to accurately make mensuration. One important aspect in classification accuracy is the contribution of boundary pixels. As the resolution improves, pure center pixels of a feature increase in comparison to boundary pixels. Thus the boundary error gets reduced with improved resolution. The accuracy of measurement of an area will depend upon the accuracy of locating the boundary. Since it is not possible to locate with accuracy better than a fraction of a pixel, the larger the pixel size, the more error will be the error in the area estimation.

Images where only large features are visible are said to have coarse or low resolution. In fine resolution images, small objects can be detected.

Spectral Resolution: Spectral emissivity curves which characterize the reflectance and/or emittance of a feature or target over a variety of wavelengths. Different classes of features and details in an image can be distinguished by comparing their responses over distinct wavelength ranges. Broad classes such as water and vegetation can be separated using broad wavelength ranges (VIS, NIR), whereas specific classes like rock types would require a comparison of fine wavelength ranges to separate them. Hence spectral resolution describes the ability of the sensor to define fine wavelength intervals i.e. sampling the spatially segmented image in different spectral intervals, thereby allowing the spectral irradiance of the image to be determined. ***The selection of spectral band location primarily depends on the feature characteristics and atmospheric absorption.***

Radiometric Resolution: This is a measure of the sensor to differentiate the smallest change in the spectral reflectance/emittance between various targets. It is normally defined as the noise equivalent reflectance change NE$\Delta\rho$ or noise equivalent temperature NEΔT. The radiometric resolution depends on the saturation radiance and the number of quantisation levels. Thus, a sensor whose saturation is set at 100% reflectance with an 8 bit resolution will have a poor radiometric sensitivity compared to a sensor whose saturation radiance is set at 20% reflectance and 7 bit digitization.

Temporal Resolution: Obtaining spatial and spectral data at certain time intervals. Temporal resolution is also called as the repetivity of the satellite, it is the capability of the satellite to image the exact same area at the same viewing angle at different periods of time. The temporal resolution of a sensor depends on a variety of factors, including the satellite/sensor capabilities, the swath overlap and latitude. It is an important aspect in remote sensing when persistent cloud offers limited clear views of the earth's surface short lived phenomenon need to be imaged (flood, oil slicks etc.) multi temporal comparisons are required (agriculture application) the changing appearance of a feature over time can be used to distinguish it from near similar features (wheat/maize)

Across-Track Multispectral Scanning

Sensor system builds up two-dimensional images of the terrain for a swath beneath the aircraft. There are two different ways in which this can be done - using across-track (whiskbroom) scanning or along-track (push broom) scanning. Fig. 2a illustrates the operation of an across-track, or whiskbroom scanner. Using a rotating or oscillating mirror, such systems scan the terrain along scan lines that are right angles to the flight line. This allows the scanner to repeatedly measure the energy from one side of the platform to the other. Data are collected within an arc below the system typically of some 90° to 120°. Successive scan lines are covered as the flight moves forward, yielding a series of contiguous, or just touching, narrow strips of observation composing a two-dimensional image (very similar to the individual lines used to produce a picture on a television screen). The incoming energy is separated into several spectral components that are sensed independently. The non-thermal wavelength component is directed from the grating through a prism (or diffraction grating) that splits the energy into a continuum of UV, visible, and near-IR wavelength. At the same time, the dichroic grating disperses the thermal component of the oncoming signal into its constituent wavelengths. By placing an array of electro-optical detectors at the proper geometric positions behind the grating and the prism, the incoming beam is "pulled apart" into multiple narrow bands, or channels, each of which is measured independently. Each detector is designed to have its peak spectral sensitivity in a specific wavelength band. Figure illustrates a five-channel scanner.

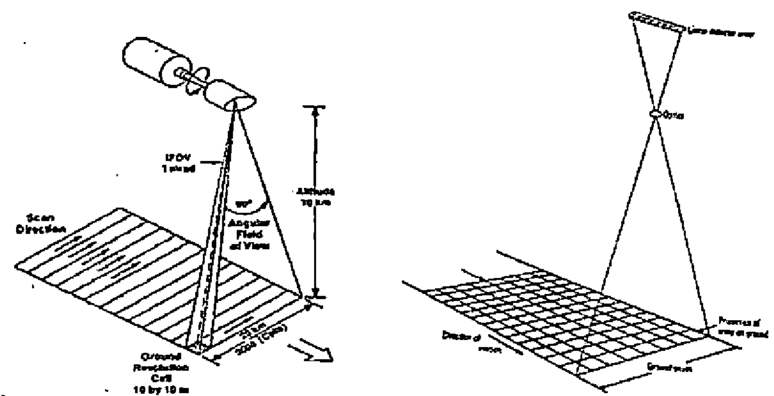


Figure 2a) Principle of Across Track Scanner b) Along Track Scanner

The electrical signals generated by each of the detectors of the MSS are amplified by the system electronics and recorded by a multi-channel tap recorder. Usually, on board signal conversion is used to record the data digitally for subsequent computer processing on the ground. Subsets of the data can also be viewed in-flight on a monitor to verify flight line coverage and to provide a real time interpretation capability of the scene being recorded.

Along-Track Multispectral Scanning

As with across-track systems, along track or push broom scanners record multispectral image data along a swath beneath an aircraft. Also similar is the use of the forward motion of the aircraft to build up a two-dimensional image by recording successive scan lines that are oriented at right angles to the flight direction. However, there is a distinct difference between along-track and across-track systems in the manner in which each scan line is recorded. In an along-track system there is no scanning mirror. Instead, a linear array of detectors is used to "scan" in the direction parallel to the flight line (Figure 2b). Linear arrays normally consist of numerous charge-coupled devices (CCDs) positioned end to end. As illustrated in Figure 1b, each detector element is dedicated to sensing the energy in a single ground resolution cell along any given scan line. The data for each scan line are electronically compiled by sampling each element along the array (eliminating the need for a scanning mirror).

The size of the detectors comprising a linear array determines the size of each ground resolution cell. Hence, CCDs are designed to be very small and a single array may contain over 10,000 individual detectors. Each spectral band, or channel, of sensing requires its own linear array. Normally, the arrays are located in the focal plane of the scanner such that all scan lines are viewed by all arrays simultaneously.

Linear array systems afford a number of advantages over mirror scanning systems. First, linear arrays provide the opportunity for each detector to have a longer dwell time, or residence time, to measure the energy from each ground resolution cell. This enables a much stronger signal to be recorded and a greater range in the levels of signal that can be sensed. This leads to better spatial and radiometric resolution. In addition, the geometric integrity of linear array systems is greater because of the fixed relationship among detector elements recording each scan line. The geometry along each scan line is similar to that characterizing an aerial mapping camera. Because CCDs are solid-state microelectronics devices, they are generally smaller in size and weight and require less power for their operation. Having no moving parts, a linear array system has higher reliability and longer life expectancy. (Due to such advantages, CCDs are used extensively in satellite remote sensing systems.)

One disadvantage to push broom systems is the need to calibrate many more detectors. Another current limitation to commercially available CCDs is their relatively limited range of spectral sensitivity. Charge-coupled detectors are not really available that are sensitive to wavelengths longer than the near-IR. However, detectors capable of operating at longer wavelengths are under development.

Optical Sensors

Data products obtained by various scanner/detector/recorder combinations in analogue or digital form fall in this class. Scanner systems working beyond the visible and near infrared range of the electromagnetic spectrum, in thermal and microwave region (RADAR) are all non-photographic systems. Such data is collected by sensor system in satellite and transmitted to earth, where it is received and recorded at Ground Station. Some of the non-photographic data acquisition systems available for resource survey, sensitive in Visible & Near IR region are mentioned below.

(i) *Multispectral Scanner (MSS)* used in Landsat series satellites: Multispectral scanner (Optical Mechanical Scanner) onboard Landsat series of satellites of U.S.A. (L1, L2, L3, L4 & L5) gives line scan type imagery using an oscillating mirror to continuously scan the earth surface perpendicular to the spacecraft velocity. Six lines are scanned simultaneously in each of the four spectral bands for each mirror sweep. Spacecraft motion provides the along-track progression of the scan lines. Radiation is sensed simultaneously by an array of six detectors each of four spectral bands from 0.5 to 1.1 μm. The detectors' outputs are sampled, encoded and formatted into continuous digital data stream.

(ii) *Return Beam Vidicon (RBV)* used in Landsat series satellites: Return Beam Vidicon onboard Landsat 1, 2 & 3 is a camera system which operates by shuttering 3 independent cameras (2 in case of L3) simultaneously, each sensing a different spectral band in the range of 0.48 to 0.83 μm. The ground scene viewed (185 km x 185 km) is stored on the photosensitive surface of the camera tube and after shuttering, the image is scanned by an electron beam to produce a video signal output. In order to produce overlapping images along the direction of spacecraft motion, the cameras are re-shuttered after every 25 seconds.

(iii) *Thematic Mapper (TM)* used in Landsat series satellites: Landsat 4 & 5 have onboard a new payload called "Thematic Mapper" with 7 spectral bands & ground resolution of 30 meters. This is in addition to the MSS payload which is identical to those carried onboard Landsat 1 & 2 and replaces RBV payload. TM is also an Optical Mechanical Scanner, similar to MSS; however, being a 2nd generation line scanning sensor, it ensures better performance characteristics in terms of (i) improved pointing accuracy and stability, (ii) high resolution, (iii) new and more number of spectral bands, (iv) 16 days repetitive coverage (v) high scanning efficiency using bi-directional scanning and (vi) increased quantization levels. For achieving the bi-directional scanning, a scanline corrector (SLC) is introduced between the telescope and focal plane. The SLC ensures parallel lines of scanning in the forward and reverse direction.

(iv) *High Resolution Visible (HRV)* Imager used in SPOT Satellite: The French SPOT-1 spacecraft carrie two nominally identical High Resolution Visible (HRV) imagers, which can be operated independently or in various coupled modes. In contrast to the oscillating mirror design used in the Landsat imaging system, HRV cameras use Charge Coupled Devices (CCD) array as the sensing element for the first time in space environment. Each of the two cameras can be operated in either multispectral (20 m resolution) mode or panchromatic (10 m resolution) mode. The swath covered is 60 Km; and the cameras can be tilted off-set upto 27° on either side of Nadir. Thus any point within a width of 950 km., centred on the satellite track can be observed by programmed camera control. SPOT-1 has stereo coverage capability in orbit with tiltable cameras, which again provides stereo image pair almost similar to metric camera air photos, for the first time in space environment.

(v) *Linear Imaging Self Scanning (LISS)* Camera used in IRS-1A & B: Indian Remote Sensing Satellite (IRS-1A) fully designed and fabricated by the Indian Space Research Organization (ISRO) was launched on 17th March, 1988 by Russian launcher. It has four spectral bands in the range of 0.45 to 0.86 μm (0.45 to 0.53 μm to 0.59 μm, 0.62 to 0.68 μm and 0.77 to 0.86 μm) in the visible and near infrared range with two different spatial resolution of 72.5 m. and 36.25 m. from one no. of open LISS-1 and two nos. of LISS-2 cameras respectively. It provides repetitive coverage after every 22 days. Like all other LANDSAT/SPOT missions which are designed for global coverage IRS is also in sun synchronous, polar orbit at about 900 km altitude and cover a width of 148 km. on ground. It uses linear array detectors (CCD) like SPOT.

(vi) *Linear Imaging Self Scanning-3 Camera (LISS-3):* This camera is configured to provide imageries in three visible bands as well as in shortwave infrared band. The resolution and swath for visible bands are 23.5 m and 142 km, respectively. The detector has a 6000 element CCD based linear array with a pixel dimension of 10μm by 7 μm. The detector is placed at the focus of a refractive type optical system consisting of eight lens elements which provides a focal length of 360 mm. The processing of the analogue output video signal is similar to that of PAN. For this camera, a 7-bit digitization is used which gives an intensity variation of 128 levels. Table 1 gives the characteristics of LISS-3.

Table 1. Characteristics of LISS-3

Band 2	0.52-0.59 μm
Band 3	0.62-0.68 μm
Band 4	0.77-0.86 μm
Band 5	1.55-1.70 μm
Geometric resolution	23.5 m for bands 2,3,5 70.5 m for band 5
Equivalent focal length(bands2,3,4/band 5)	347.5 mm/301.2 mm
Swath	141 km for bands 2,3,4 148 km for band 5
Radiometric resolution	7 bits
Band-to-band registration	±0.25 pixel

(vii) *Panchromatic camera (PAN)*: The PAN camera is configured to provide the imageries of the earth in visible spectrum, in a panchromatic band (0.5-0.75 μm) with a geometric resolution of greater than 10 m and a swath of 70 km. The camera uses an off-axis reflective type optics system consisting of three mirrors for providing the required focal length. A 7 μm pixel sized CCD is being used as the detector element. The total swath of 70 km. is covered by using three linear array charge-coupled detectors and each of these detectors covers a swath of about 24 km. The central detector is offset from the other two detectors by a distance in focal plane which corresponds to 8.6 km on the ground. The other two detectors cover swath of 24 km each adjacent to the central CCD. These two detectors are aligned with an accuracy of 30 arc sec^{-1}. The overlap of the central swath with the side swaths is 600 m on the ground. Each of the detectors provides four analogue outputs, which are independently processed by video chains, converted to digital and provided a data handling system for formatting. For a PAN data compatible with the expected signal to noise ratio, a 6-bit digitization is used which gives 64 radiometric gray levels.

The PAN payload with its capability to tilt ±26°, can view (revisit) any particular scene once in 5 days, if required. Additionally this provision can be used for getting stereo pairs or imageries. The tilting capability is achieved by steering the camera as a whole by the required angle using a steering mechanism to which PAN camera lugs are fixed. Table-2 gives the characteristics of PAN camera.

Table 2. Characteristics of PAN camera

Geometric resolution from altitude of 817 km	5.8 m
Effective focal length for optics	980 mm
Swath	70 km
Field-of-view for optics	±2.5° (across track) ±0.3° (along track)
Spectral band	0.5-0.75 μm

(viii) *Wide Field Sensor (WiFS):* This camera operates in two bands B3:0.62 μm to 0.68 μm (Red) and B4:0.77 μm to 0.86 μm (NIR). Each band uses a 2048 element CCD with an element size of 13 μm by 13 μm. A wide angle refractive optics system with 8-lens elements is used with a focal length of about 56 mm. This payload covers a ground swath of 770 km with a resolution of 188 m. This ground swath with the selected 817 km orbit can provide the required repetivity for the intended application. To cover the 770 km, swath two separate band assemblies are used for each band. Thus the entire swath in each band is covered by two detectors. Each of the detectors covers half of the swath. The signal processing chain in similar to LISS-3 wherein the analogue video signal is converted to 7 bits and given to data handling system for formatting. Table 3 gives the characteristics of WiFS camera.

Table 3. Characteristics of WiFS

Band 3	0.62-0.68 μm
Band 4	0.77-0.86 μm
Resolution	188.3 m
Swath	810 km
Radiometric resolution	7 bits
Band-to-band registration	±0.25 pixel

Thermal Scanners

In a thermal image, the tone of an object is a function of its surface temperature and its emissivity. Of these parameters, the surface temperature is the dominant factor for producing tonal variations in the scene. All objects emit infra-red radiation and the amount of emitted radiation is a function of surface temperature. Hot bodies appear in lighter tone in a thermal image and cooler bodies appear darker. The emitted radiation are collected by thermal scanner, which works on the principle of Optical Mechanical Scanner, and cryogenically cooled detectors are employed to sense the radiation in the wavelength of 8 to 14 μm wavelength. Temperature variations of upto one degree centigrade can be estimated from the thermal imagery.

Table 4. Thermal sensors

	HCMM	TM
Operational period	1978-1980	1982 to present
Orbital altitude	620 Km	705 Km
Image coverage	700 by 700 Km	185 by 170 Km
Acquisition time, day	1:30 p.m.	10:30 a.m.
Acquisition time, night	2:30 a.m.	9:30 p.m.
Visible and reflected IR detectors		
Number of bands	1	6
spectral range	0.5 0 - 1.1μm	0.4 - 2.35 μm
Ground resolution cell	500 by 500 m	30 by 30 m
Thermal IR detector		
Spectral range	10.5 - 12.5 μm	10.5 - 12.5μm
Ground resolution cell	600 by 600 m	120 by 120m

Microwave sensing radar

Microwave data can be obtained by both active and passive systems. Passive system monitor natural radiation at a particular frequency or range of frequency. Data may be presented numerically as line trace data or as imagery. Active systems (like SLAR and SAR) transmit their own energy and monitor the returned signal.

Characteristics of such radar imagery both in SAR and SLAR and their resolution depends on various parameters like frequency of the signal, look direction, slant range, dielectric constant of the objects, phase, antenna length etc. Spatial resolution in range and azimuth direction varies in different manners.

RADAR (SAR) imageries have been obtained from satellite SEASAT, ERS and space shuttle missions SIR-A, SIR-B and SIR-C using synthatic aperture radar which has all weather capability. Such data products are useful for studies in cloud covered region of the earth and in oceanography.

Table 5: Microwave Sensors

	Seasat SAR	SIR-C/X-SAR	ERA SAR	RADSAT SAR	JERS-1
Orbit	108°, @ 14				Sunsynchrous
Frequency	L band 1.275 GHz	X band 3cm C band 6cm L band 23 cm	5.3 GHz	5.3 GHz	
Wave length	23 cm		C band	C band	L Band (23cm)
Swath Width	100 Km, centered 20° off nadir	15 to 90 Km Depend on orientation is antenna	100 Km	45-510 Km Varies	75 km
Ground Resolution	25 x 25 m	10 to 200m	30 m	100x100 m to 9x9m varies	30 m
Altitude			785 Km	793-821 Km	568

Satellite Missions

Landsat Series of Satellites

NASA, with the co-operation of the U.S. Department of Interior, began a conceptual study of the feasibility of a series of Earth Resources Technology Satellites (ERTS). ERTS-1 was launched in July 23, 1972, and it operated until January 6, 1978. It represented the first unmanned satellite specifically designed to acquire data about earth resources on a systematic, repetitive, medium resolution, multispectral basis. It was primarily designed as an experimental system to test the feasibility of collecting earth resources data from unmanned satellites. About 300 individual ERTS-1 experiments were conducted in 43 US states and 36 nations. Just prior to the launch of ERTS-B on January 22nd 1975, NASA officially renamed the ERTS programme as the "LANDSAT" programme. All subsequent satellites in the series carried the Landsat designation. So far six Landsat satellites have been launched successfully, while Landsat-6 suffered launch failure. There have been four different types of sensors included in various combinations on these missions. These are Return Beam Vidicon camera (RBV) systems, Multispectral Scanner (MSS) systems, Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM).

SPOT Series of Satellite

French Government in joint programme with Sweden and Belgium undertook the development of Systeme Pour l'Observation de la Terre (SPOT) program. Conceived and designed by the French Centre National d'Etudes Spatiales (CNES), SPOT has developed into a large scale international programme with ground receiving stations and data distribution outlets located in more than 30 countries. It is also the first system to have pointable optics. This enables side-to-side off-nadir viewing capabilities, and it affords full scene stereoscopic imaging from two different satellite tracks permitting coverage of the same area. SPOT-1 was retired from full-time services on December 31, 1990. The SPOT-2 satellite was launched on January 21, 1990, and SPOT-3 was launched on September 25, 1993 Spot 4 was launched on 26 March 1998.. SPOT-1, -2 and -3 have identical orbits and sensor systems which are described in the Table 6.

SPOT-4 includes the additional 20m resolution band in the mid-infrared portion of the spectrum (between 1.58 and 1.75 μm). This band is intended to improve vegetation monitoring and mineral discriminating capabilities of the data. Furthermore, mixed 20m and 10m data sets will be co-registered on-board instead of during ground processing. This will be accomplished by replacing the panchromatic band of SPOT-1, -2 and -3 (0.49 to 0.73 μm) with red band from these systems (0.61 to 0.68 μm). This band will be used to produce both 10m black and white images and 20m multispectral data. Another change in SPOT-4 is the addition of a separate wide-field-of-view, sensor called the Vegetation Monitoring Instrument (VMI).

IRS Satellite Series

The Indian Space programme has the goal of harnessing space technology for application in the areas of communications, broadcasting, meteorology and remote sensing. The important milestones crossed so far are Bhaskara-1 and 2 (1979) the experimental satellites which carried TV Cameras and Microwave Radiometers. The Indian Remote Sensing Satellite was the next logical step towards the National operational satellites which directly generates resources information in a variety of application areas such as forestry, geology, agriculture and hydrology. IRS -1A/1B, carried Linear Imaging Self Scanning sensors LISS-I & LISS-II. IRS-P2, was launched in October 1994 on PSLV-D2, an indigenous launch vehicle. IRS-1C, was launched on December 28, 1995, which carried improved sensors like LISS-III, WiFS, PAN Camera, etc. Details of IRS series platforms are given in the following section. IRS-P3 was launched into the sun synchronous orbit by another indigenous launch vehicle PSLV - D3 on 21.3.1996 from Indian launching station Sriharikota (SHAR). IRS-1D was launched on 29 September, 1997 and IRS-P4 was launched on 26 – 5 1999 onboard PSLV from Shriharikota.

Table 9. Orbital characteristics of IRS series satellites

Features	IRS-1A/1B	IRS-P2
Altitude	904km	817km
Orbital period	103.2(min)	101.35(min)
Temporal resolution	22 days	24 days
Equatorial crossing time (local sun time)	10.00 AM	10.00 AM
Sensors	LISS-I - LISS-II* (LISS II has two cameras A and B)	LISS-II*
Swath (Km)	2 x 74 148	2 x 74 148
Resolution (m)	72.5	36.25

Table 10. Orbital characteristics of IRS-1C / IRS-1D

Features	IRS-1C	IRS-1D
Orbit type	Polar Sun synchronous	Polar Sun synchronous
Altitude	817 km	780 km (mean)
Inclination	98.69°	98.53°
Distance between adjacent traces	117.5 km	111.94
Repetivity for LISS-3	24 days	25 days
Repetivity for WIFS	5 days	3 days
Revisit for PAN	5 days	3 days
Off-nadir coverage ± 26° for PAN	398 km.	407 km
Stereo viewing capability	5 days	3 days

IRS-P4 (Oceansat-1): IRS-P4 carrying an Ocean Colour Monitor (OCM) and a Multi-frequency Scanning Microwave Radiometer (MSMR) launched on May 26 1999. OCM has 8 narrow spectral bands operating in visible and near-infrared bands (402-885 nm) with a spatial resolution of 350 m and swath of 1500 kms. IRS P4 OCM thus provides highest spatial resolution compared to any other contemporary satellites in the international arena during this time frame. The MSMR with its all weather capability is configured to have measurements at 4 frequencies (6.6, 10.6, 18 & 26 GHZ) with an overall swath of 1500 km. The spatial resolution is 120, 80, 40 and 40 kms for the frequency bands of 6.6., 10.6, 18 and 26 GHz. MSMR will also be in a way a unique sensor as no other passive microwave radiometer is operational in the civilian domain today and will be useful for study of both physical oceanographic and meteorological parameters.
CARTOSAT-1: It has a cutting-edge technology in terms of sensor systems and provides state-of-art capabilities for cartographic applications. The satellite has only a PAN camera with 2.5 m resolution and 30 km swath and Fore-Aft stereo capability. The 2.5 m resolution data will cater to the specific needs of cartography and terrain modeling applications.
RESOURCESAT-1: It is state-of-art satellite mainly for resources applications and has a 3-band multi-spectral LISS-4 camera with a spatial resolution better than 6m and a swath of around 25 km with across – track steerability for selected area monitoring. An improved version of LISS-III, with 4 bands (green, red, near—IR and SWIR), all at 23 meters resolution and 140 km swath will also provide the much essential continuity to LISS-III. These payloads will provide enhanced data for vegetation applications and will allow multiple crop discrimination, species level discrimination and so on. Together with an advanced wide-field sensor, WiFS with ~ 70 m

resolution and ~ 800 km swath, the payloads will aid greatly for crop and vegetation applications and integrated land and water applications. The data will also be useful for high accuracy resources management applications, where the emphasis is on multi crop studies for type mapping, vegetation species identification and utilities mapping. The Resourcesat-1 is slated for launch by PSLV towards the end of 2000.

***CLIMATSAT/OCEANSAT-2*:** In order to meet the information requirements to study the Planet Earth as an integrated system, satellite missions are planned which would enable global observations of climate, ocean and the atmosphere, particularly covering the tropical region, where sufficient data sets are not available. The instruments like radiometers, sounders, spectrometers etc. for studying the land, ocean and atmospheric interactions are being planned for these missions.

***IKONOS*:** The IKONOS-2 satellite was launched in September 1999 and has been delivering commercial data since early 2000. IKONOS is the first of the next generation of high spatial resolution satellites. IKONOS data records 4 channels of multispectral data at 4 m resolution and one panchromatic channel with 1 m resolution. This means that IKONOS is first commercial satellite to deliver near photographic quality imagery of anywhere in the world from space.

Bands:	Panchromatic	0.45 - 0.90 μm.
Band 1	(Blue)	0.45 - 0.53 μm.
Band 2	(Green)	0.52 - 0.61 μm.
Band 3	(Red)	0.64 - 0.72 μm.
Band 4	(Near Infrared)	0.77 - 0.88 μm.

Radiometric Resolution: Data is collected as 11 bits per pixel (2048 gray tones).

Timings of collecting / receiving IKONOS data and satellite orbit characteristics vary considerably depending on accuracy of product, extent and area.

Meteorological Satellites: Designed specifically to assist in weather prediction and monitoring, meteorological satellites, or meteosats, generally incorporate sensors that have very coarse spatial resolution compared to land oriented systems. On the other hand, meteosats afford the advantages of global coverage at very high temporal resolution. Accordingly, meteosat data have been shown to be useful in natural resource applications where frequent, large area mapping is required and fine detail is not. Apart from the advantage of depicting large areas at high temporal resolution, the coarse spatial resolution of meteosats also greatly reduces the volume of data to be processed for a particular application.

Numerous countries have launched various types of meteosats with a range of orbit and sensing system designs eg. NOAA series (operated by U.S. named after the National Oceanic and Atmospheric Administration). These have near-polar, sun-synchronous orbits. In contrast GOES and INSAT series satellites are in geo-stationary orbits. India has launched INSAT series satellites which are telecommunication and meteorological satellites.

INSAT Series: INSAT satellites are basically communication satellites used for telecommunication and broadcasting which carried meteorological sensor for weather monitoring. These satellites are used in day to day weather forecasting, cyclone monitoring etc. The sensor is Very High Resolution Radiometer (VHRR). Among this series, the most powerful satellite is INSAT-1C, launched from French Guyana on December 1995 weighing 2070 kg in a geo-stationary orbit. This satellite has heralded a new era in telecommunication by introducing mobile phones. The details are given below.

Table 11. Orbital characteristics of INSAT series satellites

Altitude	36000 km
Nature	Geostationary
Repetitive coverage	3 hr.
Sensor	VHRR
Resolution	2.75 km
Spectral bands	0.55 - 0.75 μm 10.5 - 12.5 μm.

REMOTE SENSING AND ITS APPLICATIONS IN FORESTRY

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Indian space programme

The primary objective of the Indian space programme is to use space technology for the socia-economic development of the country. In this direction, over the years, India has The primary objective of the Indian space programme is to use space technology for the socia-economic development of the country. In this direction, over the years, India has established two operational space systems, the Indian National Satellite system (INSAT), providing .services for telecommunications, television broadcasting and meteorology including disaster warning and the Indian Remote Sensing Satellite (IRS) system for resources inventorying, monitoring and management for sustainable development. The Indian Remote Sensing Programme is directed towards realisation of operational capabilities in space and ground segment of the technology for regular inventorying and monitoring of the earth resources and the environment. India made significant progress towards this. Important among them are conducting of aerial flights using different types , of sensors like cameras, multispectral scanners and airborne radars; development of a variety of satellite sensors; building and launching of state-of-the-art remote sensing satellites, setting up of ground-based data processing and interpretation systems; reception and processing of data from various remote sensing satellites; cai-rying out several applications projects covering a wide spectrum of disciplines using aerial and satellite based systems in close association with the users; and evolution of a National Natural Resources Management System (NNRMS) for utilising remote sensing methods in conjunction with the conventional techniques. India has developed technological capabilities to plan, design and build satellites for earth observations. India has emerged as one of the few countries in the world having its own remote sensing satellites with launch capability to use satellite based remote sensing data for various resources monitoring on operational basis.

Remote Sensing is a multidisciplinary activity, which deals with the inventory, monitoring and assessment of natural resources through the analysis of data obtained by observations from a remote sensing platform. In other words, remote sensing is the science of deriving information about an object from measurements made at a distance from the object without actually coming in contact with it. The observations are synoptic, provide repetitive coverages of large areas and the data is quantifiable. With the development of remote sensing techniques, a new era has started in the field of resource survey, management and monitoring the changes. It is a multidisciplinary activity dealing with (i) Inventory, (ii) Assessment of Resource and (iii) Monitoring.

The characteristic features of Remote Sensing are: (i) Synoptic nature, (ii) Repetitive coverage of large area and (iii) Quantitative data procurement.

The Basic Elements of Remote Sensing are: (i) Energy source (ii) The atmosphere (iii) The objects (iv) Platforms (v) Sensor systems and (vi) Recording systems.

The major regions of Electromagnetic spectrum used in Remote Sensing are: (i) Visible Spectrum (ii) Near Infrared (NIR) (iii) Middle Infrared (MIR) (iv) Thermal Infrared (TIR) and (v) Microwave (for Radar imaging).

Based on the position of sensors RS can be divided into: (i) Ground based R.S (ii) Air based RS and (iii) Space based Rerl10te Sensing.

Three types of platforms used for Remote Sensing are: (i) Balloon (ii) Aeroplane and (iii) Satellite.

The different types of Sensors used in R.S include: (i) Photographic Cameras (ii) T V Cameras (iii) Optical Mechanical Scanner (iv) Microwave Scanning Radars

Four major types of resolutions in RS are: (i) Spatial resolution (ii) Spectral resolution (iii) Radiometric resolution and (iv) Temporal resolution.

The major types of satellites are: (i) Geostationary satellite, (ii) Sun synchronised or Polar satellites (iii) GPS satellites

Principles of remote sensing

Remote sensing is generally defined as the science of collecting and interpreting information about a target without being in physical contact with the object under study. In the present context, the term remote sensing is restricted to methods, which employ electro-magnetic energy as the means of collection of information about the object. Depending on its physical features and. chemical properties, different objects on earth's surface reflect, reradiate or emit different amount of electro-magnetic energy in various wavelengths. The measurement of reflected or reradiated or emitted electro-magnetic radiation forms the basis for understanding the characteristic of earth's surface features. These typical responses are used to distinguish the objects from one another. Only selected portions of the electro-magnetic spectrum that can pass through the earth's atmosphere with relatively little attenuation are used for remote sensing purposes. The selected region of the electro-magnetic spectrum which are employed in remote sensing include: 0.4 to 0.7 μm 0.7 to 3.0 μm (IR band), 3 to 5 μm and 8 to 14 μm (TIR) and 0.1 to 30 m (microwave). Depending on the source of energy which illuminates the object under study, the remote sensing techniques are classified into two types, namely (i) passive remote sensing and (ii) active remote sensing. In passive remote sensing system, the naturally radiated or reflected energy from the earth's surface features is measured by the sensors operating in different selected. spectral bands, on board the air-borne/space borne platforms (similar to photography in day time without flash). An active remote sensing system supplies its own source of energy to illuminate the objects and measures the reflected energy returned to the system (similar to photography in night with flash).

Visible Near Infrared Remote Sensing (VNIR)

Unlike geostationary satellites, these remote sensing satellites are sun-synchronous (crossing the equator/latitude at the same local time every day with the descending node enabling the study of natural resources at various regions under the same illumination condition), and polar orbiting type with a repetitive cycle of 16 to 26 days enabling repeated collection of data at the same place at the same local time for continuous monitoring of the earth's resources. The imaging payloads of these satellites operate in different spectral bands, spatial resolutions (the smallest area on the ground being sensed. by the sensors), and radiometric resolutions (number of grey levels which are distinguishable). Currently the remote sensing satellites such as IRS-1C/1D, IRS-P4 (India), Landsat-7 (USA), SPOT-4, France and ERS-2 (Europe) provide data services. In addition to these, data from NOAA satellite (USA) and INSAT-3 (India) are being used for meteorological purposes including studies on cloud cover, sea surface temperature, humidity, etc. Earth Resources Technology Satellite (ERTS-1) later renamed as Landsat-1 was the first remote sensing satellite to be launched by NASA, USA for surveying, mapping and monitoring of earth resources. Releasing the potentials of this emerging technology, many other countries like France (SPOT Programme), India (IRS Programme), Japan (JERS Programme) have entered into this venture. So far, five satellites in the series of Landsat have been launched, of which first three were of first generation and carried Return Beam Vidicon (RBV) and Multispectral Scanner (MSS) imaging sensors while the second generation satellites carry apart form MSS and advanced imaging sensor called Thematic Mapper (TM). Three satellites in the series of SPOT launched by France provided data in multispectral and panchromatic spectra bands with normal and/or stereoscopic mode. Indian remote sensing satellites, IRS- 1A and IRS-1B, the indigenously developed satellites have been put into orbit in 1988 and 1991 respectively with two different sensors called Linear Imaging Self Scanning Sensors - 1 (LISS -1) and LISS - 2 operating in four spectral bands covering visible and Near Infra Red (NIR) regions of electromagnetic spectrum.

Microwave Remote Sensing

The major problems faced in the use of optical remote sensing data available from IRS, Landsat, SPOT, etc., are the persistent cloud cover. In this context remote sensing data collected in microwave region is found to have the following advantages:

- All weather capability, specifically it can collect data even in cloudy condition which is not possible using optical remote sensing
- Day and night observing capability
- Soil depth penetration in ideal conditions is possible to certain extent

The first microwave satellite to carry microwave sensor was the Seasat launched in 1978. The Shuttle Image Radar flights (SIR -A & SIR-B) in 1981 and 1984, respectively, provided the additional data.

Regular data available from ERS-1 Satellite (ESA) launched in 1991 and JERS-1 . launched in 1992 have led to the initiation of several Research & Development studies which include the use of SAR data for the study of soil moisture, delineating areas affected by canal seepage, mapping of agricultural irrigated, un irrigated areas etc. Further, multi date SAR imageries were also used for mapping of forest areas, built up areas, near shore bathymetry, study of internal waves, monitoring of surface water bodies, flood mapping, etc. It can be noted that as part of microwave application programme, India has successfully developed and test flown a C-band air-borne radar. With the expertise gained in this area, it is also planned to have microwave payload (s) in the future series of IRS Satellites.

Indian Remote Sensing Satellites

India's first indigenously developed operational Remote Sensing Satellite; IRS-IA was successfully launched on March 17, 1988. IRS-1A has been placed in the sunsynchronous orbit of 904 km with equatorial crossing time of the descending mode being at 10.25 AM, which enables the study of natural resources at various regions under the same illumination condition. The repetitivity cycle of IRS-1A is 22 days.

The payloads of IRS-IA are of two types of imaging sensors operating in push broom scanning mode using Linear Imaging Self Scanning Sensor (LISS). In this mode of operation each line of the image is electronically scanned by a linear array of detectors called Charged Coupled Devices (CCD) consisting of 2048 elements.

Application Potentials of IRS-IA Imaging

Band Spectral Range (in microns)	Application Areas
0.45 - 0.52	Coastal environmental studies (Coastal morphology and sedimentation studies) SoilN egetation differentiation Coniferous/Deciduous vegetation discrimination
0.52 - 0.59	Vegetation vigour Rock/soil discrimination Turbidity and bathymetry ins hallow waters Strong chlorophyll absorption leading to discrimination of plant species
0.62 - 0.68 0.77 - 0.86	Delineation of water features Landfonn/geomorphic studies

Applications of Remote Sensing

Remote sensing applications in India cover diverse and national issues such as agricultural crop acreage and yield estimation, wasteland management, water resource management, ocean/marine resources survey and management, mineral, ground water potential zone mapping, forest cover mapping and monitoring, disaster management of forest fires, earthquakes, drought monitoring and assessment, flood control and damage assessment, land use/ land cover mapping for agro-climatic planning and integrated resources management for formulation of developmental action plans. Realising the potential applications of remote sensing, Govt. of India has established National Natural Resources Management System (NNRMS) which is an inter departmental resource management system which plans strategy for optimal utilisation of country's natural resources through a systematic inventory using modem tools including remote sensing. It aims at providing complete natural resource database, reduce regional imbalance by effective planning and help in maintaining ecological balance by evolving implementing environmental management models. The leading institutions involved in this effort are National Remote Sensing Agency (NRSA), an autonomous organisation of Dept. of Space, Space Applications Centre (SAC) of Indian Space Research Organisation (ISRO) and Regional Remote Sensing Service Centres (RRSSCs) at five locations (Jodhpur, Kharagpur, Nagpur, Dehra Dun and Bangalore). The States have also established remote sensing centres for achieving the objective of NNRMS. The leading natural resources survey institutions have also been equipped to use satellite remote sensing and related mapping technology. The activities of NNRMS are coordinated at the national level by the Planning Committee-National Natural Resources Management System (PC-NNRMS) and the standing committees set up with user ministries and departments. The impact is assured through active involvement of different departments of the user ministries, thus, enabling the effective harnessing of this powerful technology in solving problems of relevance to the national development. Some of the important application areas where significant progress has been made are

- Land use/land cover mapping
- Wasteland mapping
- Mapping of saline and alkaline soils
- Crop acerage and production estimation of selected crops
- Monitoring of Drought
- Food studies
- Cyclone Monitoring
- Wetland Mapping
- Forest Cover mapping
- Environmental Impact Assessment (EIA) and monitoring studies
- Ground water targeting under drinking water technology mission
- Coal Mine Fire Mapping
- Monitoring and Assessment of V olcanic Eruption
- Sea Surface Temperature/Potential Fishing Zone Forecasting
- Coastal Regulation Zone (CRZ) Programme
- Snowmelt studies
- Urban sprawl and urban land use mapping
- Pipeline alignment studies etc.

The present situation of over exploitation of forest resources have brought about irrevocable deleterious effects, like change in climatic condition, flash floods, soil erosion, desertification and loss of genetic resources. The national forest policy approved by Government of India in 1952 recommended that 33% of the total geographical area of the country should be under forest permanently for proper ecological conservation and economy of our country. Official estimates reveal that about 22% of the total geographical area of the country is under forests. However, actual wooded area is much less than the reported area.

Evolution of the strategy to hold this process of devastation needs basic information about the existing forest cover. The importance of having nationwide forest monitoring system is due to the fact that the conventional data gathering system have not been able to keep pace with the deforestation process and also take remedial measure on priority basis.

The experience gained in the satellite remote sensing survey of the forest and other vegetation in India and abroad has shown that it can be a promising tool to estimate the forest resources of the country, using a uniform data collection system and in the real time basis. The remote sensing techniques-small-scale aerial photography or satellite image is one of the most valuable data source for forest cover monitoring system. The aerial photographs are the best source to prepare forest cover map which will give more reliable information about density classes and stand height, but up till now they have been providing practically unused tool for monitoring at regular interval due to cost and time involved in the interpretation of aerial photographs of the entire country.

The satellite remote sensing technology, which has developed so much that, similar resolution, is achieved by imageries of Landsat TM (Thematic Mapper) and IRS (Liss II & III). In addition, satellite data has added advantage of being able to provide repetitive coverage. Some of the studies carried out by Forest Survey of India and National Remote Sensing Agency, at national level confirms the possibility of mapping forest cover at national level. Such mapping, however, should have certain criteria at the time of execution with respect of following aspects:

- Data selection and Screening
- Mapping scale
- Ground truthing
- Ground checking
- Time of imagery/photographs.
- Interpretation! Analysis techniques
- Evaluation

Data Selection and Screening

The multispectral satellite data is available either in individual bands or in the form of false colour composite transparency or paper print. The individual bands show the vegetation characteristics differently based on the greenness, vigour and type. The false colour composite combines all the information and can. be the best used for preparing forest cover map by visual interpretation. The selection and screening of the data is the first stage, which should be taken into consideration at the time of taking up forest mapping exercise. For visual interpretation, quality of the print should be of good contrast. The cloud, snow and the fog should be screened at the time of data selection by viewing quick look..

Mapping scale

Mapping scale should be determined before taking up the task based on the magnitude of work, availability of resources, manpower available and details required. For the vast country like India, first level of mapping should be done on 1: 1 million scale. However, when such mapping is to be extended to State, region or district level, the scale should be larger. The mapping scale is directly related to the identification, delineation accuracy, mapping accuracy and application. Normally, for visual interpretation on satellite imagery, 1 mm x 1 mm can be the minimum identifiable area, which relates to 1 sq. km area on ground. The patches of less than 0.5 mm x 0.5 mm on map are just shown and can not be of proper geometric shape due to cartographic limitation. The mapping scale determines the generalization of the unit also. Thus, while estimating forest of entire country or large area omission and generalization should not have significant bearing if it is done in optimum way.

Ground truth: Remote-sensing technique is found most appropriate by thematic scientist as the data source provides signature for mapping. The calibration of the thematic units is done by establishing ground correlation between signature and ground information. The collection of this information and calibration is called 'ground truthing'. The amount of ground truth required is scene dependant and classification envisaged. In high contrast areas the ground truth requirement is less and is only required to calibrate the tonal variation. But scenes were tonal and textural variations are more, like in dry deciduous or low density forests, the amount of 'ground truth' requirement is more, since the response from the vegetation is poor and for high accuracy, detailed information is required to determinate the boundary.

Ground check: The term ground check is referred to the ground data collection exercise carried out after completing the preliminary interpretation. The impact of ground check on the accuracy of mapping will vary in different phytogeographical region. The checks can also be carried out using ancillary data like aerial photographs and other maps. Normally the ground check should be carried out in the areas where extrapolation is done using ground truth information.

Time of imagery/photograph: The identification of forest cover is best when spectral response of other land cover classes is poor. Since vegetation's phenological condition is season dependant and follows a cycle, the repetitive coverage should be used to select best data for interpretation. It has been found that unless the right season data is selected, the delineations may have gross inaccuracies. It is observed that in different phytogeographical regions the suitability of the season of the data varies. The forests of eastern and western ghats and also areas under moist deciduous forests can be better interpreted using data selected during January to March. Fortunately the cloud free condition also coincides with the right season of the data needed for interpretation, i.e. January to March. For mangrove forest areas, the mapping should be carried out using low tide images of Feb-March period. Preferably two season data should be selected for accurate delineation in case of dry deciduous forests.

Interpretation technique: The identification of forest cover can be done using visual and computer aided techniques. The broad classification can be achieved by visual interpretation itself. However, there will be certain amount of subjectivity while doing the interpretation and therefore depend on the interpreter. By the advancement of computer technology and software technology, different digital image processing techniques and soft wares are available for all sorts of data manipulation and analysis. ILWIS, ERDAS, Intergraph, ER Mapper, Envi etc are some of the image processing softwares widely used.

Integrated Mission for Sustainable Development (IMSD)

Sustainable development means development of natural resources to meet the immediate needs of the present population and also the requirements of the future generations without endangering the ecology and environment. In other words, such development should take into account the local as well as global effects to achieve an optimum solution for meeting the basic aspirations of the society. The Integrated Mission for Sustainable Development (IMSD), launched in 1992, aims at integrating the remote sensing data obtained from satellites with the data obtained through conventional means and the collateral socio-economic information. The satellite data is being used to prepare various resource maps like land use/land cover, types of waste lands, forest cover/types, surface water resources, drainage pattern, potential ground water zones, geomorphology, geology, soil types, etc., which are integrated with meteorological and socio-economic data in a Geographic Information System (GIS) environment to generate locality-specific prescriptions for an integrated land and water resources development. The action plans generated under the IMSD project are being implemented by the district-level functionaries and non-governmental organisations with the participation of the local people. . Funds available under various developmental schemes of the Central and State governments are utili sed for implementation of the action plans. Under IMSD programmes the information of above-mentioned themes are available for four districts of Kerala viz. Kasaragode, Palakkad, Thrissur and Pathanamthitta.

The implementation of the action plan under 15t Phase of IMSD has started yielding positive results. After construction of the recommended rainwater harvesting structures in some of the districts, the ground water table in downstream has increased considerably after the monsoon, thus enabling cultivation of crops. The condition of the vegetation covers due to the construction of check dams and farm ponds has improved considerably as revealed by the multi date IRS data.

IMPORT ANT MILESTONES

1963	First Satellite Launch from Thumba	21-11-1963
1967	Launch of first Indian Rocket (RH-75)	21-11-1967
1968	TERLS dedicated to United Nations	2- 2-1968
1969	Formation of Indian Space Research Organisation	15- 8-1969
1972	Formation of Dept. of space (DOS) and Space Commission	1-6-1972
1972	First Launch of sounding Rocket RH- 300 MK-l	9- 7-1972
1973	First launch of RH-560 MK-l	-
1975	Launch of India's' First Satellite - 'Aryabhatta'	19-4-1975
1975	Satellite Instructional Television Experiment (SITE)	1-8-1975
1977	Satellite Telecommunication Experiment Project (STEP)	1-8-1977
1978	First launch ofRH-200	10-1-1978
1979	Launch of first Indian Satellite Vehicle (SLV-3)	10-8-1979
1979	Launch of Bhaskara - 1 Satellite	7-9-1979
1980	Second launch of SL V -3	18-7-1980
1981	First developmental flight of SL V -3 (D I)	31-5-1981
1981	Launch of India' s First experimental communication	-
	Satellite 'APPLE'	19-6-1981
1981	Launch of Bhaskara-2 satellite	20-11-1981
1982	Launch of India's Multipurpose communication	10-4-1982
1983	Second developmental flight of SL V-3 (D2)	17-4-1983
1983	Launch of INSA T - 1 B	30-8-1983
1987	First developmental flight of ASL V (D 1)	24-3-1987
1987	First launch of RH - 300 MK-11	8-7- 1987
1988	India's first Application Remote Sensing Satellite	17-3-1988
1988	IRS - 1 A launched	
1988	Second developmental flight of ASL V (D2)	13-7-1988
1988	Launch of INSA T - 1 C satellite	21-7 -1988
1990	Launch of INSA T - 1 D satellite	12-6-1990
1991	Launch of IRS - 1B satellite	29-8-1991
1992	Third developmental flight of ASL V (D3)	20-5-1992
1992	Launch of first indigenously built communication Satellite INSA T 2	9-7-1992
1993	"Launch ofINSAT-2B satellite	23-7-1993
1993	First developmental flight of PSLV (D1)	20-9-1993
1994	Fourth developmental flight ofPSLV-D2	4-5-1994
1994	Second developmental flight ofPSLV-D2	15-10-1994
1995	INSAT -2C satellite-the third in the INSAT - 2 series launched Satellite	7-12-1995
1995	IRS - 1 C the third satellite in the IRS 1 series launched	28-12-1995
1995	First launch ofRH-560 MK II	16-8-1995
1996	Third development flight of PSLV (D3)	21-3-1996
1997	INSAT- 2D, the fourth satellite in INSAT - 2 series launched	4-6-1997
1998	IRS 1D launched through PSLV-C1	29-9-1997
1999	INSAT-2E (5th satellite in INSAT -2 series) launched	3-4-1999
1999	PSL V - C2 launched IRS-P4 along with Korean KITSAT - 3 and German DLR-TUBSAT	26-5-1999
2000	Launch of INSAT - 3B (first launch ofINSAT-3 series)	22-3-2000
2001	First developmental flight of GSLV-D 1 launched (GSAT-1 Satellite)	18-4-2001

2001	PSL V - C3 launched TES along with German Satellite BIRD and Belgium satellite PROBA	22-10-2001
2002	INSAT - 3C launched successfully from Sath's Dhavan Space Center SHAR - putting METSA T in GTO	12-9-2002
2003	INSA T - 3A launched on Ariane - 5	10-4-2003
2003	Second developmental flight of GSL V launched	8-5-2003
2003	INSA T 3 E launched on Ariane-5	28-9-2003

INDIA SATELLITES

Name	Date of launch	Weight (Kg)	Launch vehicle
Aryabhatta	19/4/1975	358	C-1, Intercosmos, USSR
Bhaskara 1	7/6/1979	444	C-1, Intercosmos, USSR
RTP	10/8/1979	35	SLV-3, India
RS 1	*1817/1980*	35	SLV-3, India
RS-D1	31/5/1981	38	SL V -3, India
APPLE	19/6/1981	670	Ariane, Europe
Bhaskara-2	20/11/1981	436	C-1, Intercosmos, USSR
INSAT lA	10/4/1982	1150	Delta, USA
RS-D2	17/4/1983	415	SLV-3, India
INSAT 1 B	30/8/1983	1194	Space Shuttle, USA
SRUSS - 1	24/3/1984	150	ASLV, India
IRS - lA	17/3/1988	980	VOSTOK, USSR
SROSS - 2	13/7/1988	150	ASL V, India
INSAT- lC	22/7/1988	1190	Ariane, Europe
INSAT- lD	12/6/1990	1293	Delta, USA
IRS- lB	29/8/1991	990	Vostok, USSR
SROSS-C	20/5/1992	106	ASLV, India
INSAT- 2A	10/7/1992	1906	Ariane, Europe
INSAT- 2B	23/7/1993	1932	Ariane, Europe
IRS -lE	20/9/1993	845	PSLV, India
SROSS-C2	4/5/1994	113	ASL V, India
IRS -P2	15/10/1994	904	PSLV, India
INSAT- 2C	7/12/1995	2050	ARIANE, Europe
IRS- 1 C	28/12/1995	1250	MOLNIA, Russia
IRS-P3	21/03/1996	920	PSLV, India
INSAT-2D	4/06/1997	2070	Ariane, Europe
IRS-1D	29/09/1997	1200	PSLV-C1, India
INSA T -2DT	(Procured in Orbit from ARABSA T in Jan. 1988)		
INSAT-2E	3/04/1999	2550	Ariane, Europe
IRS - P4	26/05/1999	1050	PSL V -C2, India
INSAT-3B	*22/0312000*	2070	Ariane, Europe

SLV-Satellite Launch Vehicle; AS LV-Augmented Satellite Launch Vehicle; PSLV-Polar Satellite Launch Vehicle; GSL V -Geosynchronous Satellite Launch Vehicle; RS-Rohini Series; RTP-Rohini Technology Payload; APPLE-Ariane Passenger Payload Experiment; SROSS-Stretched Rohini Satellite Series; INSAT-Indian National Satellite; IRS-Indian Remote Sensing Satellite; TES-Technology Experiment Satellite; METSAT Meteorological Satellite

Principles and Techniques of Digital Analysis for Resources Inventory

A variety of non-photographic image-forming systems have been developed to detect radiation reflected or emitted (or both) from a remote scene. Technological development in above areas was aimed at overcoming problems inherent in the use of common optical devices, the camera. Non-photographic sensors operate the microwave to the ultraviolet region. Infrared, passive microwave and radar sensors operate under both day and night conditions, and radar sensors are not seriously hindered by clouds in electrical form. They can be transmitted to any location. Maximum importance lies in its amenability in processing with electronic devices. However, non-photographic sensors are complicated, larger, and have lower spectral resolution than comparable photographic systems.

Digital image

The image or picture, which. is produced by a camera or non-photographic imaging sensor, is a 'flat scene' representation that varies in visual properties from point to point. The varying visual properties include brightness, colour or reflectance. This variation can be described mathematically by a function of two variables. When colour is involves involved, the function should be regarded as vector valued or several functions should be used. Each of these functions or the single function for a monochromatic (black or white) picture is real valued, non-negative, bounded and analytically well behaved. The value at a point of this function is termed the grey level. The elements of digital picture/image array are called 'pixels'.

Within the confines of remote- sensing the term image refers to a continuous or discrete record of a two dimensional view (land cover). An aerial photograph is an example of continuous image where detail is displayed by means of a continuous signal that we can see and interpret. A Landsat multispectral scanning system is an example of a discrete image where detail is held in discrete digital units that we cannot see but can be handled quantitatively. Ability to transfer images between the continuous and discrete states is a basic requirement of many image procedures. For example, an enyironmental scientist may wish to convert a continuous thermal infrared line scanner image into a discrete image or digital analysis and then convert it back to a continuous image for visual interpretation.

The remotely sensed images are very 'poor representation' of thematic information required by resource managers, both continuous image processing (through optical means) and discrete image processing (through electronic processing) in being used for maximizing image information extraction procedures for particular application.

Multispectral scanning

The multi-spectral scanner provides valuable data about various resources in reflective and emittive part of electromagnetic spectrum. These systems derive electronic energy detectors and designed to sense energy in a number of narrow spectral bands simultaneously. These hardly may range from ultraviolet wavelengths through the visible, reflected infrared and thermal portion of the spectrum. The MSS data are expression of the spectral response patterns of the objects in a scene. These patterns in turn relate to the particular form of the energy matter interactions that characterize each object type in each band of sensing. If these interactions are significantly distinctive for the various objects of interest the spectral patterns can be used to interpret/extract resource information without regard for spatial patterns.

Digital analysis techniques for resource information extraction

While a wealth of information can be extracted from the analog form of data (photographic format), the overwhelming volume of digital data recorded by various platforms are more amenable to computer-assisted analysis. Multiple of procedures have been evolved to deal this digital data in the computer compatible tapes (CCT) format. It is this format that provides the most faithful rendering of each scene as sensed electro magnetically and recorded digitally. The CCTs contain the image data in digital format without significant loss of radiometric detail associated with the photographic processing of these data. Computer based procedure for analysing resource data can be categorized as follows:

a. ***Image restoration***: The operations act to 'restore' distorted image data to a more true representation of the original scene. This involves correcting a variety of radiometric and geometric distortions that may be present in the original image data. Radiometric corrections take care of anomalies incorporated by multiple detectors array, intermediary atmosphere (between the sensing platform and the object) and 'sixth line striping' effect. This 'cosmetic' improvement of the data makes the image of better quality for image processing.

Geometric correction is brought about due to sensing platforms, attitude and velocity. These distortions may be systematic or random systematic distortions are corrected by applying formulas derived by mathematically modelling the sources of the distortions. Random distortions are complex systematic distortions and are corrected by analysing Ground Control Points (GCPs). However, this requires the availability of an accurate map of the image area and image identifiable ground control points. Features that make good control points include highway intersection, small water bodies, river/drainage bends etc. In such correction process GCPs are located in terms of both their image coordinates (column, row) and ground coordinates. These values are then submitted to a least square regression analysis to determine coefficients for two transform equations that interrelate the geographic and image coordinates.

b. ***Digital Image Enhancement***: Prior to displaying image data for visual analysis, digital enhancement techniques can be applied to accentuate the apparent contrast between features in the scene. In many applications, this greatly increases the amount of information that can be visually interpreted from the image data. Enhancement operation transforms the image values into a form more appropriate for interpretation; but do not involve interpretation of the data. Following are the important methods for accomplishing this:

c. ***Gray scale adjustments:*** The gray scale adjustment process accepts a digital image as an input and produces an output image in which each of the pixel gray values has been changed according to some rule. For example although Landsat MSS on CCTs allow 8 bits of encoding the gray levels of the pixels, the gray levels for bands 4,5 and 6 range only between 0 and 127. The grey levels for band 7 ranges from 0 to 63, to display this data effectively on an image display device with a 0 - 255 dynamic range.

1. *Contrast stretching:* The actual distortion of original data may not utilize 0 - 255 gray levels. In stretching process the Digital Numbers (DN) values are distributed in such away that it utilizes full dynamic range of the display device. The uniform expansion of histogram is referred to as a 'linear stretching'. The linear stretched images allow mapping of thematic units more accurately by allowing more confidence in drawing the boundaries. Histogram equalized stretch assigns image values to the display values as output gray levels on the basis of their frequency of occurrence; such stretching allows to enhance all the features equally.
2. *Edge enhancement:* The technique used to emphasize subtle gray scale variations where the values of adjacent pixel vary by more than a predetermined threshold value; the interface is marked on the image display with a contour, a step in the gray scale or a colour change. This technique can be used to determine the paths of roads, rivers, railroads, geological faults and lineaments.
3. *Smoothing:* Some digital image has an unacceptable amount of noise. This shows up as stripes scattered pixels commonly known as 'salt and pepper' haze or any number of other effects. This can change image content and diminish the utility of an image through smoothening extreme fluctuations in gray level from point to point in the image can be minimized. Mostly in this process the data is scanned through the image pixel by pixel adjusting gray level values to assure that the change in gray level value from on pixel to the next pixel never exceeds some maximum allowable amount.
4. *Band to band ratio and subtraction:* The ratio and difference of image of different bands will

suppress details common to the two images and will enhance detail that is different between the two images. For example, when working with Landsat MSS images ratios of MSS 4 (green) to MSS 5 (red) used for locating red soils and iron ore deposits and MSS 6 (near infra red) to MSS 7 (near infra red) to minimize the influence of vegetation cover. The most useful ratio has been MSS 5 (red) to MSS 7 (near infra red) as this ratio is positively related to vegetation amount. A difference image derived from two images of two dates/times can be used for monitoring changes. This process is more complicated than the just image data of same date, since in this process geometric corrections by resembling need to be done. This technique has proved to be of particular value in the monitoring of short term events like flood, fire cloud movement and crop growth or long term changes like urban development deforestation or desertification.

5. *Data compression:* Resource scientists some time face the task of trying to comprehend many multispectral images of a scene at the same time. These problems are common while handling data set having 4 to 10 bands or while analysing multi date data. This problem can be eased of the information which is particular to each image if combined into a new image by means of a statistical transformation. The most popular techniques for the transformation of multi-spectral images are the statistical techniques of Principal component analysis (PCA) and Canonical analyses. Both of these techniques aim to replace the original wave bands, which describe the data with new orthogonal axes that better describe the particular scene under study. The statistical variance (information) of Landsat multispectral data in PCA is divided between all four wave bands. As for example, two correlated bands will have some redundant information. To overcome this problem PCA creates new axes called band axes along the lines of 'maximum variance' within the data. Therefore, once the pixels have been located by their new coordinates system first band axis image would contain more information than any other band axis image (Meizerink and Donker, 1978). Canonical analysis, like PCA, compresses the information component of several images into one image and this maximizes the difference in DN between the major scene component.

d. Multispectral digital classification: One of the most widely accepted applications of pattern recognition technique to image processing has been the assignment of pixels to land use categories through multispectral classification. The process employs multiple images of the same scene obtained from several spectral regions as input and produces as output both displays or amps of scene content in tabular fonn. Multispectral classification has found a great deal of usage in agricultural assessment, forest management, urban planning, ecological monitoring and water resources infonnation collection. Dozens of processing algorithms have been developed to perfonn this classification. Main classifications are minimum distance classifier, parallelopiped classifier and maximum likelihood classifier. Perhaps the last one is most accepted algorithm employed in processing of multispectral data. The classification is achieved through dedicate image processing system which provides a machine interaction environment. During digital classification one must train the classifier to execute this algorithm by ascertaining values for the population means and covariance matrix elements. This training is either 'supervised' or 'unsupervised'. In Supervised training, the user presents the computer with spectral signatures from a relatively small set of pixels or identifies common from each of the categories under consideration. The user does this on the basis of either manual interpretation or ground truth. Typically this set of training pixels which constitute less than 1 % of the full scene, where upon the computer can classify rapidly and automatically the remaining 99% of scene. In improvement training the user allows the computer to select the population means and covariance matrix elements by performing a clustering process on the input data. In both approaches can encounter situations in which two classes cannot be separated spectrally. Because of this limit on discriminability an introductive approach involving both supervised and unsupervised training is often employed. One aspect of this is that, under supervised training it is difficult to know how many classes are separable using spectral signatum. With interactive analysis, a variety of supervised clustering can be 'tried'. On
the other hand many classes of high interest to the user are differentiation only by subtle spectral differences, where some classes that are closely separable spectrally are of low user interest. Supervised training can prevent the needless discrimination of low interest categories.

Consequently a relatively high level of non-machine interface is indicated for assessment of this type. These procedures have made available detailed levels of land cover status information determination.

Problems in digital classification

1. The spectral characteristics of various types of vegetation change drastically on a function of time. These changes occur both in the course of a growing season and from the year to the next. This applies to changes in the spectral signature of vegetation and while discrimination phenological state determines the discrimination.
2. Changes in background soil, climate, elevation and other physical factors can cause vegetation to exhibit spectral signature differences even in relatively nearly geographical areas. These sources of variation are compounded by the effects of atmosphere attenuation, which vary unpredictably in both space and time.
3. Tropical variations interfere with the digital classification. These anomalies are getting complex with the increase in spatial resolution. If textual classification is combined with spectral classification thematic classification can be improved. The textual classification is performed on the basis of the spatial variations in the vicinity of each pixel. Then spatial variations in spectral characteristics are termed as 'textures'.

Applications of Remote Sensing Techniques and Geographical Information System in Forestry (Kerala): An overview

The techniques of remote sensing has ushered in studying, surveying and monitoring forest features. With the development of remote sensing techniques, a new era has started in the field of resource survey, management and change detection studies. Stratification of vegetation cover with respect to structural features, is highly essential for resource evaluation. The satellite remote sensing techniques coupled with aerial photographs have been found very useful in forestry studies. The forest resource evaluation using remote sensing data was proved to be invaluable tool (Harding and Scott, 1976; Porwal and Pant, 1989). The development of computer technology and various software packages were yet another boost in the field of satellite data processing.

One of the greatest advantages in using remote sensing data is its ability to generate information in spatial and temporal domain, which is very crucial for successful model analysis, prediction and validation. The use of remote sensing technology involves large amount of spatial data management. The GIS technology provides suitable alternate for efficient management of computer database. The key to all GIS is the fundamental map base, to which all data eventually relates. Remote sensing is now being widely regarded as a layer in GIS. Remote sensing, although a specialized technique, is now accepted as a basic survey methodology, means of providing data for a resource scientist, whereas the GIS is the method by which data layers can be interrelated in order to arrive at more logic conclusion.

The information on forest type classification prepared by Champion and Seth (1968) shows various forest types and vegetation formations in the country. This can neither provide spatial maps nor facilitate spatial integration of collateral data. The present paper deals with the attempts done at Kerala Forest Research Institute on these lines, especially in the field of forest resource mapping and evaluation in Kerala.

1. Remote sensing in Forestry Sector - Kerala Scenario

The remote sensing techniques were very rarely used in the forestry sector of Kerala prior to 1985. With the exemption of some scattered studies of Kerala State Land Use Board, practically no work was done prior to 1985. Kerala Forest Research Institute has started using remote sensing data in 1987, a preliminary study of data standardization for forestry purpose. The study was conducted at Attappadi-Silent Valley region in 1987, using different types of remote using data viz. aerial photographs in 1: 15,000 scale, Landsat imageries (both MSS and TM) and digital data of IRS-IA. The main objective of the study was to evaluate the potentiality of different remote sensing data products in the field of forestry sector (Saxena, et ai, 1992). This was a break-through in remote sensing activities of KFRI; ever since KFRI is doing forestry studies using remote sensing techniques. The major activities in this field are higlighted below:

2. Vegetation mapping

2.1. *Vegetation mapping of sanctuaries and National Parks:* The detailed vegetation/land cover maps are essential for the efficient management of Sanctuaries and National Parks. With this aim, sanctuary mapping programmes were started at KFRI in 1987, using large scale aerial photographs (1:15,000 scale) and satellite imageries (1 :50,000 scale). Along with the aerial photographs, geocoded satellite imageries of 1:50,000 scale of IRS IA, IB, IC and ID of LISS 1 to 3 sensors were used, as the basic remote sensing data input. An interpretation key was prepared for visual interpretation of the forests of Kerala (Varghese and Menon, 1997). The output maps of land cover classes were prepared in 1 :25,000 scale with density slicing parameters '(3 density levels) for selected Sanctuaries and National Parks viz. Peppara WLS (Varghese, 1997), Chimmony WLS (Menon, 1998a), Eravikulam National Park (Menon, 1998b), Aralam WLS (Menon, 1999), Agasthyavanam Biological Park (Varghese and Menon, 1999a), Idukki WLS (Menon, 2000), Neyyar WLS (Menon, 2001). This, being pioneer work of this type in Kerala Forests attracted much attention, and similar studies for other Wildlife Sanctuaries and National Parks in the State are to be conducted for efficient management of natural reserves.

2.2. *Working plan map preparation:* The working plan maps of Nemmara Forest Division in Kerala, was updated using 1:15,000 B & W aerial photographs and geo-coded IRS 1B LISS 2 imagery. Here again, the visual interpretation techniques using the photo element characteristics were adopted for the generation of land cover map of the area. Similar techniques can be adopted for the revision of maps of other forest division and it is high time to revise the working plan map of all the other forest division of Kerala using the modern technology and data products.

2.3. *Density mapping of forest types:* Yet another important work attempted at Kerala Forest Research Institute during the past few years is the preparation of density sliced maps of the major forest types in selected locations, using remote sensing data products (Varghese and Menon, 1999b). Based on the canopy density variation in the imagery/aerial photographs, the major cover types were sliced into three major sub units viz. high density area, medium density area, and low density area, for selected localities (Peppara WLS, Pooyamkutty and Idukki). The output maps of this study will give an idea regarding the distribution status of various cover types (forest types) with respect to canopy density viz. <40%, 40-60% and >60% cover density. Such maps are very much essential for management decision-making, especially for prioritization of area for implementing afforestation programme.

2.4. *Land Cover mapping of natural reserves:* Land cover maps of natural reserves in. selected forest region viz. Thrissoor, Palghat, Idukki, Parambikulam, Nemmara, Wynad, Sholayar, Agastyamala, Kutiadi, Pamba, and Pooyamkutty were prepared in 1 :50,000 scale using geocoded satellite imageries of IRS lA, 1B and 1C of LISS 1,2 & 3 sensor data. Similar, general vegetation maps were prepared for more than 30 sites with an accuracy levelj: 60%. The maps thus generated are available at KFRI for user reference.

2.5. *Forest Atlas of Kerala:* As a long-term programme, works on the preparation of forest atlas was started to prepare "Range Atlas" in 1:25,000 scale. In addition to the general features.

2.6. Digital mapping of Kerala Forests: Digital mapping of Kerala Forests were done using IRS data. The digital mapping facility of Regional Remote Sensing Service Center (RRSSC, Bangalore) and Dehra Dun were availed initially for this purpose. Now, the image processing facilities are available at KFRI, ever since the installation of PC based system and the procurement of necessary image processing software like ERDAS and IL WIS. All the major cover classes were delineated with more than 70% classification accuracy by using maximum likelihood algorithm (Varghese and Menon, 2001). Supervised classification techniques were adopted for processing satellite data. The digital maps are generated for different forest regions viz. Wynad, Nelliampathy, Nil ambur, Silent Valley, Parambikulam, Thrissur, Chimmony WLS, Peppara WLS, Neyyar WLS, Aralam WLS, Peechi-Vazhani WLS, Eravikulam National Park, Sultan Battery and surroundings, Kakki Pamba region, Malayattoor region and New Amarambalam area.

3. Digital Elevation Models

The application of GIS and Remote Sensing technology, particularly the Digital Election Model (DEM) has become an important tool for data management. DEM is an ordered array of number that represents the spatial distribution of elevations above some arbitrary datum in the landscape. It can be used to derive a wealth of information about the morphology and land surface. The DEM/DTM (Digital Terrain Model) represent the topography and landforms whereas remote sensing records the spectral characteristics of the land cover; combining these two types of information by draping over the other is a powerful way to examine the relationship between the two. The DEM of selected locations viz. Thrissur, Peppara etc. were generated using appropriate software and contour information from Survey of India toposheets. The DEM thus generated are available at KFRI for further GIS structuring and evaluation.

4. Change detection studies

The forest vegetation developed generally experience changes over a period of time. Biotic pressure, coupled with developmental activities are the major cause of forest cover depletion and degradation. Hence, a detailed knowledge of the forest resources along with major landuse/landcover classes within the ecosystem is considered to be very important for any developmental planning. With this view in mind, a change detection study was conducted at Idukki and surrounding region of central Kerala using remote sensing data of different time series (Menon and Pillai, 1985). A comparative assessment of major land cover classes viz. dense forest, sparse forests, agricultural land and barren area for the period 1973, 1975 and 1983 (i.e. before the construction of Idukki dam, during construction and after the construction respectively) were done using Landsat – 5 TM FCC of March 1973, 1975 and 1983 periods respectively. The overall vegetation changes with respect to vegetation density were evaluated and the degradation of vegetation/continuity breakage of the area are studied.

5. Forest degradation assessment

Forest degradation mapping project was undertaken in 1995 to delineate degraded forests of Kerala, as a part of World Bank sponsored project (Nandakumar and Menon, 1996). The major goal of the work was to establish parameters for forest degradation and quick assessment of forest degradation status. With these objectives, IRS IB geocoded FCC of 1: 50,000 scales were visually interpreted for the period 1995-96. About 40 imageries were used for the study. In addition to the major forest type classification, density slicing was also done in three class level viz., less than 40% crown density, 40-60% and more than 60% crown density. Correlation parameters were worked out with crown density and site qualities, thus to evaluate the degradation status. Existing supplementary information from Survey of India topomaps, Forest Survey of India records, and Forest Department records were also incorporated while updating the maps. The degradation maps thus prepared are available for reference at KFRI. In addition to this, very detailed degradation mapping of some protected areas were also done using 1:15,000 aerial photographs (Varghese and Menon, 2000).

6. Forest Resources Evaluation and Survey

6.1. *Reed resources of Kerala:* As a part of checking reed resources of Kerala Forests, a reed resources map in 1 :25,000 scale was prepared using 1:15,000 B &W aerial photographs.

6.2 *Rattan (cane) resource survey:* The use of remote sensing in identifying probable rattan (cane) habitats in the natural forests of Kerala has been successfully demonstrated by our study conducted in 1993 (Nandakumar and Menon, 1993). Rattans occur as climbing palms in scattered, isolated pockets in different forest types. The heterogeneous nature of the overstorey vegetation as well as the lack of information on their tonal differentiability characteristics are the major problems in detlineating cane area from the rest of the forests. A new approach has to be adopted to overcome this difficulty. Ground truth information was collected from as many locations as possible to include all habitat variations. A few of these data were statistically selected as training sets for map preparation through digital image processing. The rest were used to cross check the map and method involving deductive and inductive analysis based on the colour signature of the over storey vegetation. The digital image processing was carried out on VAX 11/780 using the software at Regional Remote Sensing Service Center (RRSSC), Bangalore. IRS 1A LISS 1 data of 1989 was used for this experiment. More detailed experimental analysis in this regard is necessary using recent high resolution satellite data like IRS 1D LISS 3 and PAN data, so that forest resource evaluation can be done more precisely and efficiently with less effort.

6.3 *Bamboo resource estimation in Kerala forests*: As the pioneer study in India for bamboo resource estimation using remote sensing data; KFRI has successfully completed a project on bamboo resource estimation in Kerala Forests. The standardization of methodology in this regard was done as part of our earlier IDRC sponsored bamboo project Phase II, during 1990-1995 period (Varghese et al. 1996). Since the bamboos in natural forests of Kerala are sympodial in nature, the use of remote sensing data can be effectively carried out, due to tonal variation of photo elements. The method thus standardized was effectively used for bamboo resource evaluation. IRS 1 C LISS 3 data was the major input in this study, along with the supplementary information gathered through field visits (Nair and Menon 2001). The survey of India toposheets were used as the base map for generating the bamboo distribution map of different stocking groups. Supervised classification technique using 'maximum likelihood algorithms' was adopted for digital image processing of satellite data. The density sliced map thus generated was used as the base line information for further sampling procedure. Based on the bamboo distribution map generated appropriate sample locations were identified statistically for estimation of bamboo stocking. The bamboo distribution map thus generated was used for further growing stock estimation.

7. Biodiversity assessment and mapping:

In landscape ecology, biodiversity is considered as an integral part for management and conservation. Therefore, to characterize the landscape, diversity plays an important role. Hence it is essential to study the landscape elements of either to be conserved or already conserved areas for their status and interactions. Under the biodiversity assessment project of KFRI, as a part of National Biodiversity Assessment Programme of NRSA, the forest type distribution and continuity assessment was made using IRS ID LISS 3 digital data. Based on the overall distribution status of different forest types, sample locations were selected from the vegetation mosaics and the selected sites were identified in the field using Global Position System (GPS) for structural data collection of vegetation. These data, along with other supplementary information like patch characteristics (size, shape, porosityetc); community characters (species diversity, structural peculiarity) etc. were used for biodiversity mapping and prioritization of area for further landscape elevation. Identification and documentation of the ecological niches and amplitudes of rare, threatened and endemic species are considered as a priority exercise in conservation of biodiversity. These species usually have specific ecological niches, edaphic gradients, and vulnerable habitats. As a pioneer study in India KFRI has successfully standardized and mapped ecological niches of rare, threatened and endemic tree species of Peppara Wildlife Sanctuary using remote sensing and GPS (Varghese and Menon, 1999c).

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DIGITAL CARTOGRAPHY

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Some topics are particularly suited for computerization. Cartography is one such subject. Traditional and modern techniques contribute to this in a complementary way. Map of one kind or other is required in many situations. Most maps are derived from existing ones with addition or removal of features. There can be situations where one has to make a map altogether new. The techniques required in either case are slightly different. The size and accuracy of the map also would vary with the end use. In this note we examine the history, features and potential of digital cartography.

Printed topo sheets

Topo sheets are made by professionals with due regard for cartographic composition, accuracy and graphic quality. They are printed in large numbers, are durable and can be used for tracing or scanning. Topos usually have lat-long marks, scale bar and North arrow. Contour features are specially useful for height information. But up dating is once in 10-20 years. Can be carried to field. With a combination of GPS, it is a good tool for exploration. Many sheets are restricted.

Tracing

Tracing on translucent film or paper used to be made for making maps manually. In these cases, ink is applied over the pencil drawing. This facilitated duplication by the prevalent method of last decade, ammonia printing. Inked sheets can be reproduced through photographic/printing technology. Some amount of layering was possible.

Mechanical scaling

Map scaling has always been an uphill task in mechanical map preparation. Combining features from two scales would need instruments such as mechanical or optical pentagraph. Planimeters were also used in this combination for estimating area of features. Some amount of accuracy can be retained during down ward scaling, but upward scaling gives very poor results.

Vector GIS programs

Autocad showed how a PC can be used as an effective drawing program. Two vector GIS programs are popular, Arc info and Mapinfo. Unfortunately there are not any free ware in this category. These programs permit

- Registering scanned maps
- Tracing features into layers
- Editing at node and object level
- Support of attribute data base
- Data driven charts from database
- Showing topography in 3d
- Layout of professional maps
- Printing, image/pdf outputs
- Maps can be exported to a wide variety of formats

Scanning

Large format scanner is a recent addition. It saves much time in converting documents to image. Often colour and tilt correction in image processing programs such Adobe Photoshop is essential. Scanning is usually done at 200 dpi, 24 bits.

Vector maps

Main feature of vector maps is their small size. Can be scaled and printed to any size. Length and area can b e measured from the map. Graphic attributes such as colour, thickness, shading and letter size pf individual features can be changed. Map can be composed in layers. Node editing, splitting and joining of features. Common boundary for adjacent objects.

Autocad

Autocad is the first widely used drawing program. It has vector features. Facility for geographic coordinates limited.Exporting to GIS programs involve more steps.

New maps

Creating a map from scratch is a task that requires proper planning. A combination of GPS and can be used. Images from Google map can be panned, captured and combined as a background layer.

GPS

GPS has many uses. Readings in locations can be used for registering scanned maps and satellite images. This may yield better results if GPS data is to be projected over map. In the case of large areas, GPS reading along boundary/nodes can be directly plotted over map. Under canopy map can be generated with the help of magnetic compass and measuring tape. Several points to be borne in mind while using GPS. A) Do not truncate decimals. B) Record xd, xm, xs and yd, ym, ys in columns. Convert to decimal degrees before use.

GPS-compass combination

This technique is useful for mapping large areas such as forest or large farms. When there is difficulty in getting GPS reading due to canopy, one can switch to compass bearing and distance measurement.

Updating maps

A digitized map can be updated by adding features collected through GPS or copied from other maps.

Map projections

A map can be prepared using polar coordinates or rectangle coordinates. Base map and GPS projections should match for accurate overlays. Even with all precautions, maps rarely align 100%. Techniques of geo-registration is used for aligning the maps.

Map-GPS combination in the field

A combination of topo sheet and GPS is a valuable tool in exploring remote areas. One's position with in a map grid can be known from GPS. Advanced GPS or laptop linked to GPS can show one's position over map.

SRTM

Till recently the only source of altitude information of a location was contour lines in a map. An exclusive shuttle mission mapped entire globe digitally and the data is available in the public domain. Three d views can be generated from this data. This was more than any cartographer ever dreamed.

Satellite images

Quite a few satellite images are available in the public domain up to resolution of about 30m. At this resolution they are hardly useful as mapping tool, but higher resolutions are useful.

Aerial photographs

Aerial photographs are useful, but scale variations and availability make its use difficult

Plotting technology

Flex and vinyl printing is bringing map preparation with in the reach of average computer user. GIS programs allow printing large maps in pieces. A3 laser prints are now cost effective. Mounting over light weight boards, cold or hot lamination are also feasible now.

Google maps

Google provide maps of major city limits with very high clarity. These are good mapping tools. One has to fix scale, pan and capture images and stich them together to use them.

LANDSCAPE ATTRIBUTES VERSUS SOILS: USE OF DIGITAL ELEVATION MODELS (DEM)

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Prologue

Management is dependant on facts but not the whims and fancies of the manager. Knowledge of soil genesis is basic to soil management. Man's influence on the factors of soil formation can better be controlled and planned in the future in the light of discoveries by soil geneticists. One of the first lessons in soil science describes the soil as a three dimensional natural body with a specific volume with components likes solid matter, porosity and liquid phases within its volume. According to Jenny (1941) there are five soil forming factors viz., parent material (geological or organic precursors to the soil), climate (primarily precipitation and temperature), biota (living especially native, vegetation, microbes, soil animals and human beings), topography (slope, aspect and landscape position) and time (the period of time since the parent materials became exposed to soil formation). With reference to these factors of soil formation, soils are often defined as "dynamic natural bodies having properties derived from combined effects of climate and biotic activities as modified by topography, acting on parent materials over periods of time".

Soil horizons, properties etc. at a given point in the landscape occur due to the action and interaction of soil-forming processes over the period of soil formation (Simonson, 1959). Spatial differences in the type and intensity of the soil-forming processes over the period of soil formation lead to a distinctive, repeated suite of soil taxonomic units in the landscape – the basis of the soil catena concept (Milne, 1935, 1939). One of these factors of soil formation, topography decides the nature of soils when the other factors of soil formation are kept constant. This is the reality every one observes in undulated terrain, the very origin of a watershed. In the present lecture much of effort is put forth in describing topography in relation to soils and use of digital elevation models in understanding the retain.

Topography

Topography relates to the configuration of the land surface and is described in terms of differences in elevation, slope and landscape position – in other words the lay of the land.

Topography can hasten or delay the work of climatic forces. Steep slopes generally encourage erosion of the surface layer and allow less rainfall to enter the soil before running off, thus preventing soil formation from getting very far ahead of soil destruction. In semi-arid regions, less effective soil moisture on the steeper slopes also results in a more sparse, less diverse plant cover. Therefore, soils on steep terrains have relatively shallow, poorly differentiated soil profiles, compared to nearby soils on more level terrain. Fig.1 illustrates the influence of topography on the development of soil profiles.

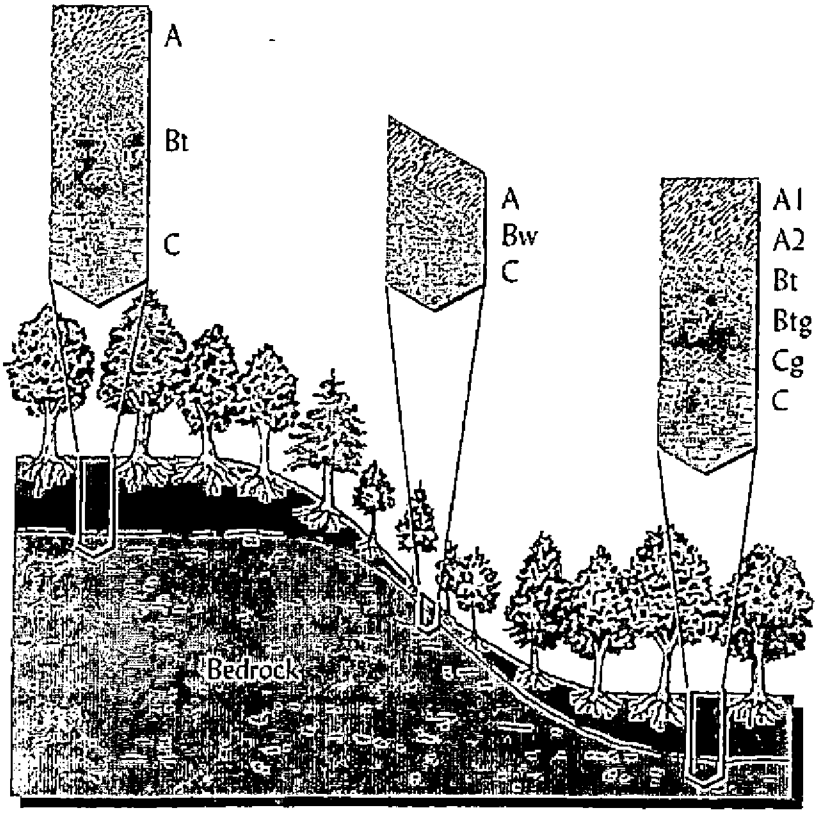

Fig.1. Soil profile development as modified by topography

Further, the interaction of topography with parent material is illustrated in Fig. 2, which greatly influence the nature of soils even in a small transects of an undulated land.

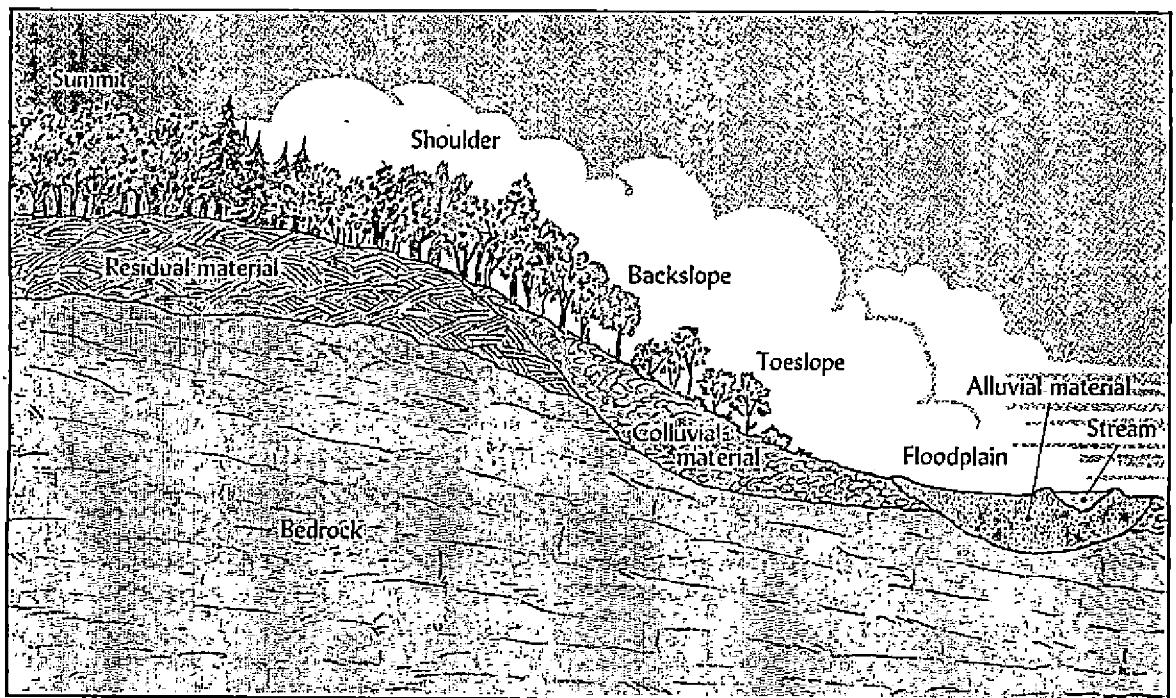

Fig.2. An interaction of topography and parent material as factors of soil formation

Troeh (1964) found strong correlation between the surface morphological variates and soil distribution, which he attributed to the influence of surface configuration on the drainage status of the soil. Hall (1983) had indicated that water movement and distribution on slopes was the principal reason for differences in soils on the landscape. Pennock *et al.* (1987) suggested that the higher moisture contents in the convergent landscape elements should lead to more pronounced profile development at these points.

The illustration (Fig. 3) showed the surface water flow patterns on an inclined surface. The size of arrows indicates the depth of water flow at that point on the surface, which determines the nature of soil formed at that point.

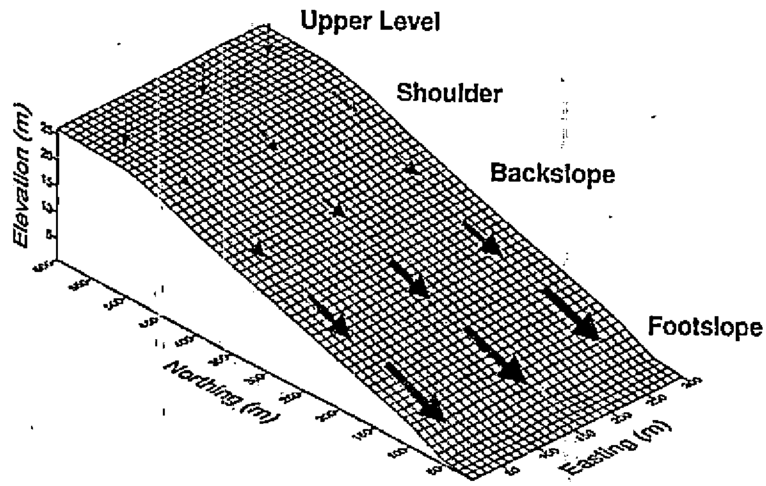

Fig.3. Schematic diagram pf surface water flow patterns on in inclined surface

The surface water flow on a surface with significant plan curvature leading to convergence and divergence of flow paths. The size of arrows indicates the depth of water flow at that point on the surface (Fig.4).

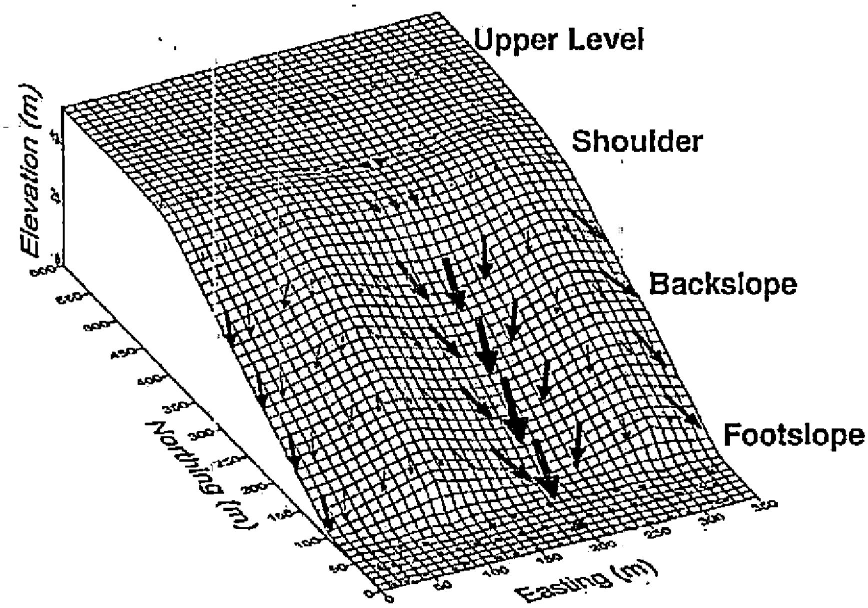

Fig.4. Schematic diagram of surface water flow on a surface with plan curvature

Hummocky surface represent yet another kind of topography and Fig. 5 indicates the flow pattern of surface water.

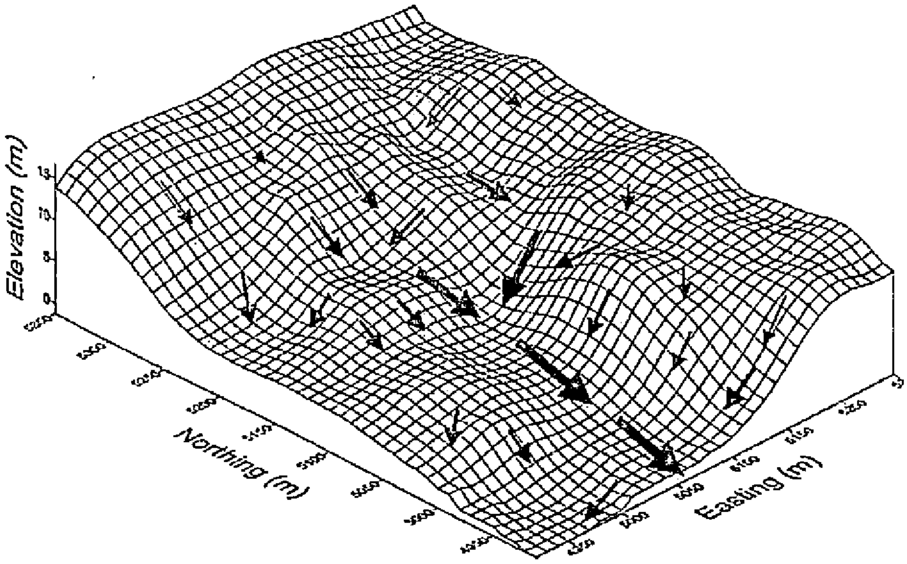

Fig.5. Schematic diagram of pattern of water flow on a hummocky terrain surface

All this highlight the necessity to consider the topography during decision making process while managing a given area.

Digital Elevation Model (DEM)

A digital elevation model (DEM) is a digital representation of the relief of the earth's surface. It can be derived from a pair of stereoscopic aerial photographs, SPOT data or radar images or simply from digitized contour lines, elevation data collected from GPS receivers and laser scanning technology etc. Typically it consists of arrays and values that represent topographical elevations measured at equal intervals on the earth's surface. Fig.6 shows a digital elevation model with representation of surface of earth's surface with different elevations like peaks and valleys etc. DEMs are most commonly used to extract terrain parameters, model water flow or mass movement or for pure visualization purposes (3D draping).

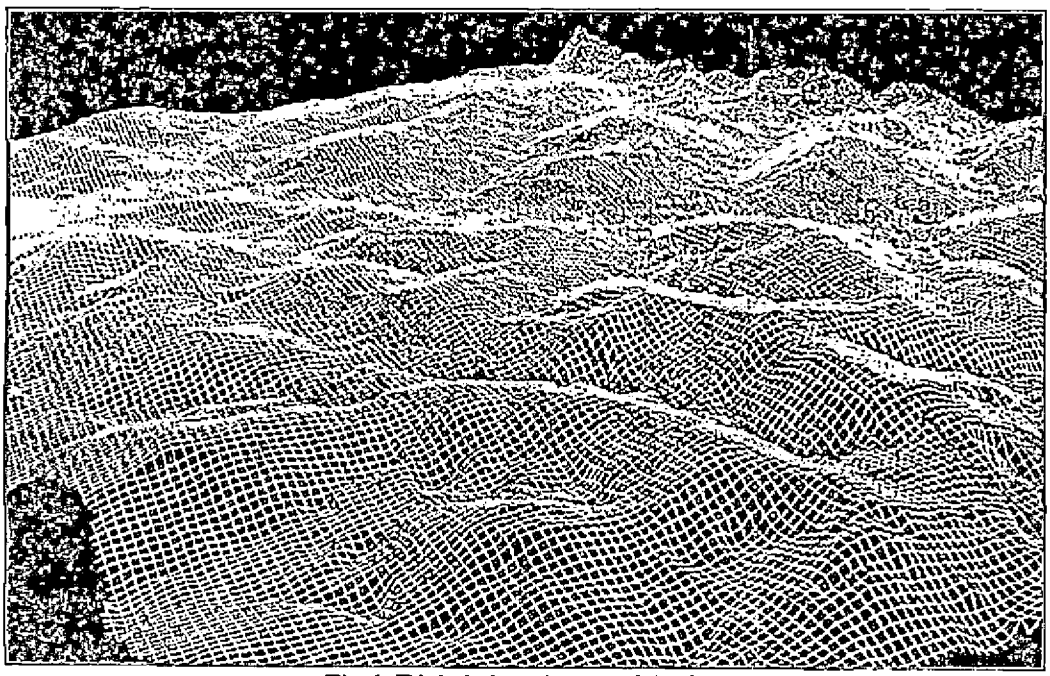

Fig.6. Digital elevation model of an estate

The quality of a DEM is a measure of how accurate elevation is at each pixel (absolute accuracy) and how accurately is the morphology presented (relative accuracy). Several factors play an important role for quality of DEM-derived products: terrain roughness; sampling density (elevation data collection method); grid resolution or pixel size; interpolation algorithm; vertical resolution; terrain analysis algorithm;

Many national mapping agencies produce their own DEMs, often of a higher resolution and quality, but frequently these have to be purchased, and the cost is usually prohibitive to all except public authorities and large corporations. However, a much higher quality DEM from the Shuttle Radar Topography Mission (SRTM) is freely available for most of the globe and represents elevation at a 3 arc-second resolution (around 90 m). This covers entire Indian subcontinent and is freely downloadable from Intenet. These DEMs can be beneficially used in terrain analysis while studying the landscape attributes and resultant a soil properties.

Terrain Attributes

The most commonly used terrain attributes can be divided into three groups: morphological; positional; compound. The relevance of any particular terrain attribute for soil redistribution depends on both the overall landform shape and the specific redistribution processes operating in the landscape (Table 1).

Table 1. Description of terrain attributes

Attribute	Description
Elevation	Elevation above sea level or a local datum (m)
Relief	The elevation difference between the highest elevation in the site and the elevation of a given cell or the lowest point in the site overall (m)
Gradient	Slope between the land surface and a horizontal plane at a given point (m m^{-1}, degrees or per cent)
Aspect	The compass direction that the slope segment is facing (degrees)
Profile curvature	DS curvature of a slope segment; by convention convex curvatures are assigned positive values and concave curvatures negative values (degrees m^{-1})
Plan curvature	Across-slope or contour curvature of the slope segment; by convention convex curvatures are assigned positive values and concave curvatures negative values (degrees m^{-1}).
Slope length	The distance from the point of flow origin (typically a drainage divide) to the specific landform segment (m)
SCA	The area upslope of a contour segment that contributes flow to that segment divided by the length of the segment (m^2 m^{-1})
SDA	The area down slope of a contour segment that can receive flow from that segment divided by the length of the segment (m^2 m^{-1})

Soils and DEM – A Case Study

Recent research on the relationship between soil redistribution and topography has been greatly aided by the ease with which terrain attributes can be derived from any digital elevation model (Pennock, 2003). Land elements have been used as basic landform descriptors in many science disciplines, including soil mapping, vegetation mapping and landscape ecology (Schmidt and Hewitt, 2004). Odeh *et al.* (1995) mentioned that DEMs provide a cheap and reliable way of predicting land properties which have strong correlations with attributes derived from elevation data. Odeh *et al.* (1991) stated that DEM could be used to derive landform attributes important to soil development and distribution in the landscape. Odeh *et al.* (1994) suggested that digital elevation models provide a good way of deriving landform attributes that may be used for soil prediction.

Terrain attributes have also been shown to be important in delineating soil properties important to crop production (Kravchenko *et al.* 2000). Jaynes *et al.* (2003) indicated that with a DEM, primary terrain attributes such as slope (SL), aspect (AS), plan curvature (PL) and profile curvature (PR) can be calculated, which are influencing crop yield in a given terrain. In a study, they observed that the clusters were roughly equivalent to landscape position. There was considerable research on the influence of terrain attributes on the plant performance also. For instance, the work done by Kaspar *et al.* (2003) showed that the yield of corn was negatively correlated with relative elevation, slope and curvature during the years of subnormal rainfall while it was positive during the years of rainfall greater than normal ones. The relationships between soil physical properties and landscape attributes indicate that landscape attributes including slope, aspect, and elevation affect plant growth through indirect influences involving soil physical properties (Rezaei and Gilkes, 2005). All this leads to the invariable necessity to understand the terrain for an efficient management and monitoring of natural resources.

Literature is available with reference to characterisation of soils under rubber in Kerala State of India, in both discrete as well as comprehensive fashion. Krishnakumar (1989) reported some of the characteristics of some soils under rubber in traditional region. Rao (2000) documented the taxonomical variations among soil profiles studied at the top, middle and bottom of the slopes in different physiographic units that support rubber cultivation. Rubber Research Institute of India went ahead with the idea to get the soils under rubber in 1: 50,000 scale surveyed and mapped (NBSS & LUP, 1999), where crop based soil survey was conducted for the first time in India. However, the two-dimensional maps do not reveal the terrain of rubber growing areas, which in general are hills and valleys. Rao *et al* (2006) showed the utility of a modern information technology tools in rubber cultivation in which the use of DEM was shown. Use of DEM is a better option in understanding the landscape and soil interrelationship for better and profitable management of natural resources.

Terrain attributes

DEM can be used was used for extraction of important terrain attributes like elevation, slope, aspect which are of significance in management of agriculture. Freely available software and DEM (SRTM) enable us easy understanding of a given terrain all over globe (with some exceptions). Fig. 7 indicated the pseudocoloured DEM obtained during SRTM while Fig. 8 showed the contour map of the study area, which was extracted with ease from the DEM with much ease.

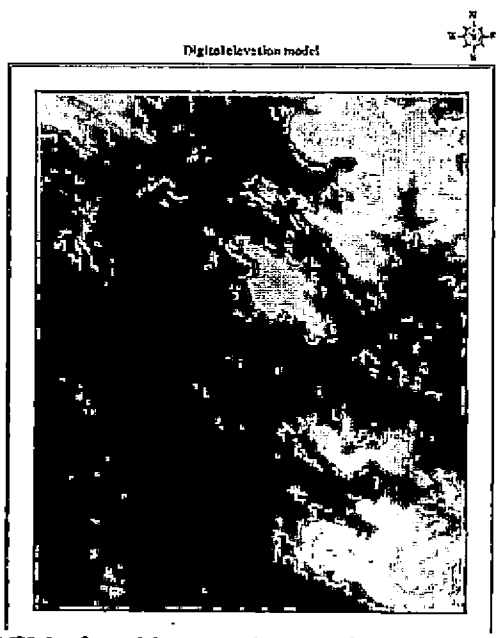

Fig 7. DEM of a rubber growing area in Tamil Nadu

Manual digitization of contours to derive DEM is a tedious exercise, which also depends on the availability of toposheet and is not possible for all to do so due to restriction policy. The contour map could be used to plan the operations that are required to be taken up in undulating terrain like planning terraces for planting rubber, soils conservation practices etc.

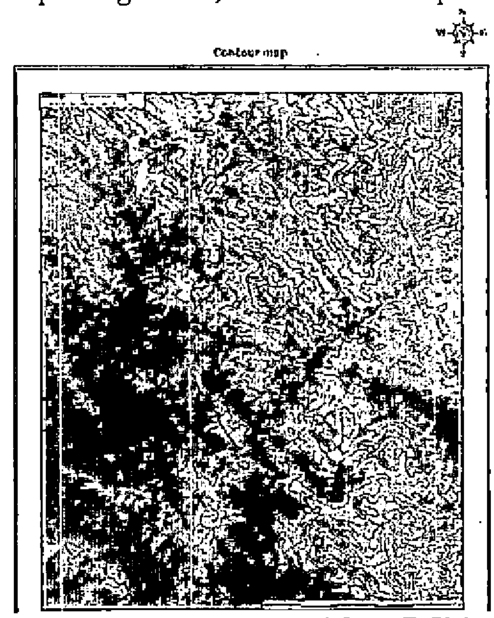

Fig. 8. Contour map generated from DEM

Similarly, the aspect analysis of the terrain was possible with relative ease, which otherwise would be difficult to generate aspect map (Fig. 9). Literature is available with reference to the effect of aspect on growth of different crops and in case of rubber also there were reports on this subject (Saseendran, 1993). Aspect analysis provides an idea to assess the possible performance of rubber plantations in different aspects.

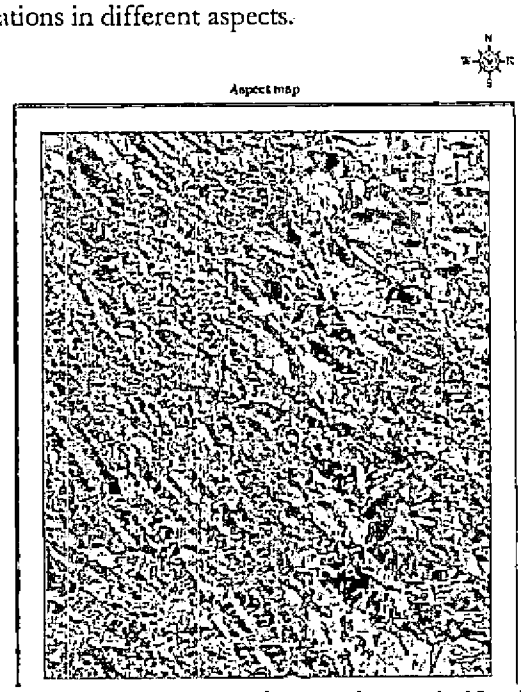

Fig.9 Aspect derived from DEM of the study area in Tamil Nadu

Terrain visualization

Terrain visualization is an important idea to analyse the terrain in 3D perspective for all practical purposes. There are software packages available with rendering capability to show an area in 3D perspective and to extract the elevation, slope, aspect and profile curvature etc. Rao *et al* (2006) showed the image of a terrain by 3D rendering in an exercise to use modern tools of IT in rubber cultivation. The DEM with 90 meter resolution obtained during SRTM pertaining to the study area was used for visualization. The 3D perspective generated from the DEM was given in Figure 10, which showed the hills, slopes, valleys etc that support rubber in this region. Similarly, the false color composite (FCC) of the satellite image draped on this undulated surface showed the distribution of rubber over undulations and surface features as was shown in Fig. 11. This kind of visualization essentially gave an idea about the landscape of area of interest,

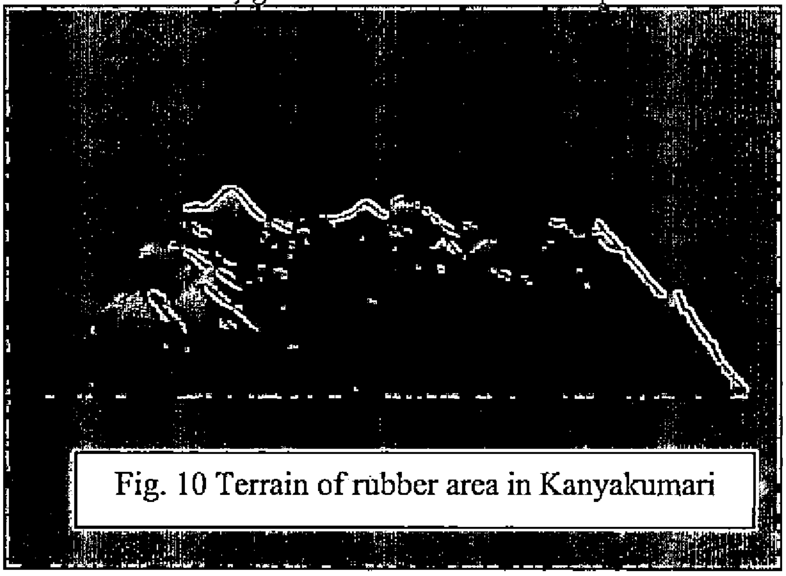

Fig. 10 Terrain of rubber area in Kanyakumari

which is not possible from 2D maps. The 3D perspective gave an overview of the area as to how rubber was distributed in the undulated terrain so that appropriate measures in controlling soil and water erosion, efficient use of fertilizer material etc. can be planned. Normally, fertilizer materials are calculated based on the soil test values and the stage of the crop. However, the fertilizer application method does not really regard the undulated terrain ultimately leading to loss of fertilizer material in addition to possible deficiency on the top slope because of loss of fertilizer in runoff.

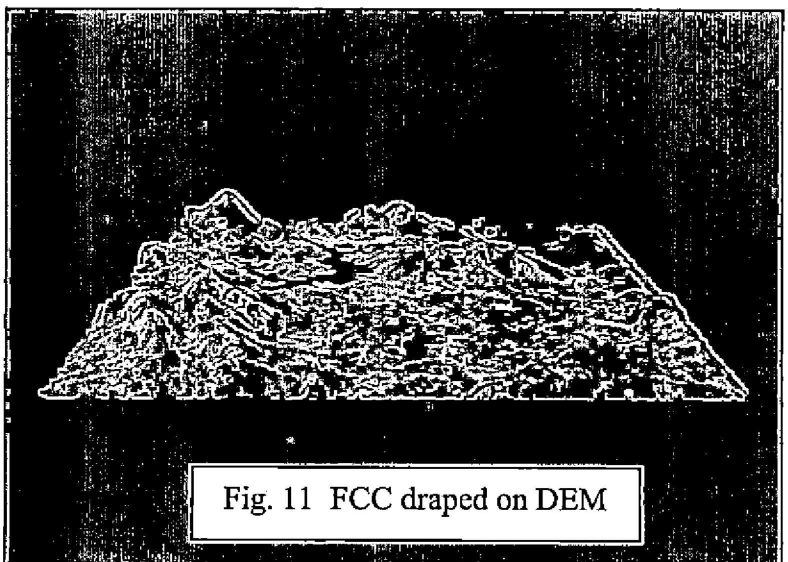

Fig. 11 FCC draped on DEM

Tey *et* al. (2000) described the utility of DEM in plantation management in undulating terrain. Suitable contour maps and slope maps could be generated directly from DEM for use in planning of terraces and roads on hilly areas in a traditional way. With current available technology, it was possible to generate digital contour maps at desired intervals for draping on orthophotos of area of interest to simulate planting terraces that could be assessed visually. Efficient road network cold be planned and hills subdivided or grouped by an experienced planner for terrace cutting in ways not possible previously.

Slope and length are known to have significant effects on runoff and soil erosion. Tey *et al.* (2000) unambiguously showed that the primary advantage of DEM in soil erosion control was in the production of LS (length x slope) map for soil loss computation using USLE (universal soil loss equation) as given below:

$$A = R \times K \times L \times S \times C \times P$$

Where A is the soil loss in tones per ha, R is the rainfall (erosivity) factor, K is the soil (erodibility) factor, expressed in terms of amount of soil loss in (t ha^{-1}) per unit area or erosivity index, L and S are the length and steepness (slope) factors, C is the crop cover factor and P is the land management factor.

The erosivity and erodibility factors could be easily derived from the available rainfall data and soil maps given by the NBSS & LUP (1999) while the crop is rubber along with some cover crops and certain intercrops and land management factors can also be assessed. Based on this, a comprehensive runoff and erosion risk map could then be produced for use in site specific practices. For instance fertilizer may be accurately estimated for site specific fertilizer inputs, construction of soil conservation terraces and implementation of other erosion control measures at the right places to effectively reduce erosion and minimize runoff losses.

Tey *et al.* (2000) stated that the information about the soils under oil palm and their properties played a key role in yield improvement in plantations and detailed and semi detailed soil surveys were carried out in several plantations so that productivity could be maximized on different soil types. However, in traditional rubber growing region in India, soil survey maps are available 1:50,000 scale (NBSS & LUP, 1999). Though there could be scale limitations, the resource maps can be used in the initial approximations. However, it is essential to have detailed soil survey maps in digital format and use of GPS certainly proves beneficial.

Table 2 presented slope, elevation details along with the soil map units (NBSS & LUP, 1999) found out at the GPS points. The map unit 9 is the association of soil series, Kunnathur, Chandanikunnu and rock land and the other unit 48 is the association of soil series; Kadambanad, Chandanikunnu and Thrikkannamangal. Kunnathur soils series is designated as clayey-skeletal, kaolinitic, isohyperthermic Ustic Kanhaplohumults with 130 cm depth. The other series, Chandanikunnu is taxonomically clayey-skeletal, kaolinitic, isohyperthermic Ustoxic Dystropepts with a depth of 57 cm. The soil series Kadambanad was described as clayey-skeletal, kaolinitic, isohyperthermic, Ustic Kanhaplohumults with 100 cm depth. Thrikkannamangal soil series was classified taxonomically as clayey-skeletal, kaolinitic, isohyperthermic Ustic Kandihumults with 152 cm depth. Though it is very difficult to know identity of the soil series in the given soil map unit at the GPS points, Table 2 indicated that unit 48 was associated with gently sloped and low elevated areas.

Table 2. Slope & elevation at GPS points and map units

Field	Slope (%)	Elevation (m)	Soil map unit
1	18.5	88.9	9
2	42.9	171.1	9
3	17.7	143.2	9
4	22.7	174.4	9
5	4.0	73.6	48
6	4.4	76.8	48
7	3.0	68.5	48

More accurate and complete estimation of slope can be achieved with the use of good DEM. Moore *et al.* (1993) demonstrated that terrain attributes (elevation, slope, aspect and wetness index etc.) derived from DEM at an appropriate scale could be used to enhance soil survey as a source of soil attribute data that are essential for soil specific crop management. Slope is one of the main factors affecting the costs of development, field operations, maintenance and upkeep, crop recovery and realized yield in any plantation agriculture. Conventional ground survey is tedious, limited in coverage and hence usually does not satisfactorily represent the actual conditions ob the grounds. Depending on the requirements, digital slope gradient data derived from DEM can be resampled into desired pixel sizes, classified and grouped for use in the prediction of site yield potentials, estimation of area that could be mechanized and identification of areas that require planting terraces. Rubber growing areas in traditional region had got all the reasons to go for modern information technology tools for a better management of resources in a profitable manner. Another potential use of DEM is in the prediction of water catchment and stream flow while studying watershed areas (Tey *et al.*, 2000).

In the present study, freely available DEM at 90 m resolution acquired during STRM (Shuttle Radar Topographic Mission) were used to demonstrate the utility of the available technology in rubber cultivation. This research article indicated the advantages of using modem tools of information technology in understanding the terrain and reviewed the landscape and soil associations. With advent of technological development in the sensor construction, possible high resolution DEM could be made available to public at less or nominal costs. Though not discussed in the present paper, application of GIS tools bringing several themes into one environment for multilayer analysis and decision making is very well known and being used effectively in several ways.

Epilogue

The utility of the digital elevation models in many spheres of earth science is shown by several workers in understanding the terrain for all kinds of management. The same is true in the case of scientists working in the field of soil science. Hence the capability to derive DEM using space based platforms is introduced in some satellites making the availability of DEMs easy when compared to conventional sources. More over the availability of precise DEM helped in modeling earth surface for all reasons. In addition to that the tedious job of digitisation of contour lines given in a map is avoided thus saving a lot of man hours. The use of DEM is widely known in estate management or watershed studies. The freely available SRTM is sufficiently precise in understanding the landscape to initiate appropriate measures of management. Similarly, freely downloadable software from Internet enables us to handle the DEM for terrain analysis or for visualization in more understandable 3D form. Hence it is appropriate to use these tools and inputs to understand the terrain of interest be it a rubber plantation or hill agriculture or watershed management.

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WEB ENABLING OF GIS DATA

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The latest advances in GIS have come most notably in the form of the Internet. Access to spatial data over the internet is growing rapidly. Through the web, now users can access a GIS, view a smart intelligent active Vector map, perform relevant queries without even having a GIS software installed in the client's machine. Now GIS data is being published on the web all over the world and GIS on Internet is no more just a concept.

In the typical GIS computing scenario, the spatial databases and attribute data integrated into the maps reside in a stand-alone computer that has the GIS software in it. The tailor made GIS data base serves only a few users who have access privileges to that machine. The costs involved in providing the data to multiple users through a LAN are prohibitive, considering software costs. In the present era of information revolution where internet and mobile computing technology is jumping leaps and bounds, GIS might have taken a back seat had it not undergone a revamping to fit into a network environment; making GIS data accessible to a large cliental at no extra costs.

Using these technologies, intelligent, smart, vector-based map can be published in an open Active-CGM format. This permits the publication of both vector and raster data. The amount of vector data sent over web could be three to four times less than the amount of raster data needed for equivalent resolution. thus resulting in faster response time and greater productivity. This "Dynamic Map Creation" ensures fewer data downloads and more efficient use of server resources. To do all these, the user at the client site does not need any GIS software to be installed in the computer, nor any expertise is required to view the GIS over web. The user can browse through the GIS data using any popular Internet browser available in the market today, such as Internet Explorer or Netscape. This whole technology make a simplified GIS access with almost no cost at client site, thus a cheaper solution.

Internet is also a perfect means of GIS data transmission. The World Wide Web and FTP (file transfer protocol) programs make it convenient to transfer data files across the Internet. They provide GIS users easy access to acquire GIS data from different sources of data providers. GIS users can download data almost instantly from the Web over the Internet without the hassles of calling or writing around to find who has what data, making a formal request, and then waiting for days or weeks for the data disks to be arrived. Distributed search engines have facilitated the findings of GIS data among all sources of data providers (Peng and Nebert, 1997).

What is Internet GIS?

Internet is a global network of computers connected through communication devices to one another. It is a means for GIS users to exchange GIS data, conduct GIS analysis and present GIS output. Therefore, Internet GIS is a special GIS tool that uses Internet as a means to access and transmit remote data, conduct analysis and make GIS presentation. Internet GIS should have all or almost all functionalities the traditional GIS software have. In addition, Internet GIS should have additional functions that take advantage of the Internet and its associated protocols such as World Wide Web (WWW) and File Transfer Protocol (FTP). These additional functions include exchanging remote data and application programs, conducting GIS analysis on the Internet without owning GIS software on the local machine, and presenting interactive maps and data on the Internet. The key features of the Internet GIS are object-oriented, distributed and interoperable. Each GIS data and functionality is an object. These objects are resided on different servers on the Internet and are assembled and integrated when needed. These data and analysis functionalities can be exchanged or interoperable by any other systems on the Internet.

Internet GIS is an integrated client/server network system

The concept of client/server involves splitting an application into tasks between the server and client. A client/server application has three components: a client, a server, and a network (Hall, 1994). Each of them is supported by specific software and hardware. The client sends a request to the server, which processes the request and returns the result to the client, the client then manipulates the data and/or results and presents to the user. The connections between the client and server are established according to a communication protocol such as a TCP/IP.

Internet GIS applies the client/server concept in performing GIS analysis tasks. It breaks down the task into server side and client side. The client can request for data, analysis tools or modules from the server. The server either performs the job itself and sends the results back to the client through the network, or sends the data and analysis tools to the client for use on the client side.

Internet GIS is an Interactive System

World Wide Web provides a natural interactivity to the Internet through its hypertext linkage. The user can browser the Web page by page through the hypertext linkage. However, each Web page is a static image that is organized by the Web developer. Similarly, many map pages that was published on the Web are also static map images. Typically, static maps are portrayed at many sites to provide some geographic context to a site's information such as where the regional representatives of a company are located or where the major regional attractions are in a given state or county. Most of them are static image file like JPEG or gif (Graphics Interchange Format) file. The user cannot manipulate the map and perform even a simple analysis function such as zoom, pan and query on the map.

Internet GIS, on the other hand, enables users to manipulate GIS data and maps on the Internet interactively. Users can perform basic GIS functions such as zoom, pan, query, and labeling using Web browser. It can perform spatial queries like where is the closest restaurant and hotel is. It should be able to perform more advanced analyses such as spatial analysis and network analysis. Use Internet GIS on the Web should just like use desktop GIS software at the local machine.

Internet GIS is a Distributed System

One advantage of the Internet is that it can access distributed database and perform distributed processing (Hall, 1994). Information and applications can be resided on different computers across the network. Internet GIS takes advantage of this distributed system so that the GIS data and analysis tools can be resided in different computers on the network.

GIS data and analysis tools are individual components or modules. Users can access those data and application programs on-demand from anywhere on the network. The user does not have to install the data and application programs in his/her local computer. Whenever it sends requests to the server, the server would deliver the data and analysis tool modules for just-in-time performance.

Internet GIS is a Dynamic System

Because Internet GIS is a distributed system, database and application programs reside on computers that publish them. Those data and application programs are updated by those who manage them. Once the data and application programs are updated, they are available to every user on the Internet. In other words, Internet GIS is dynamically linked with the sources. The GIS is updated as soon as the sources are updated. This dynamic linkage with the sources always keeps the data and software current. The Internet GIS can also link with real time information, such as satellite images, traffic movements and accident information by real time connection with the relevant information sources.

Internet GIS is Cross-Platform

Internet GIS can be accessible cross platforms. It doesn't matter what operating system the user is running. The Internet GIS is not limited to any one kind of machine or operate system. As long as one has access to the Internet, he/she can access and use Internet GIS, giving that the Internet GIS providers provide platform neutral or cross-platform GIS tools.

Internet GIS can access many forms of GIS data and functions in the heterogeneous environment on the Internet

This is the direction of future Internet GIS. Access and share GIS data, functions and application programs among a group of GIS users in the heterogeneous environment needs high interoperability (Bishr, et al. 1996). The Open Geodata Interoperability Specification (OGIS) is attempting to lay the ground rules for GIS interoperability (http://www.ogis.org/). There are a series of issues needed to be resolved, such as standards for data formats, data exchange and data access, standard specification of GIS analysis components. But the fully interoperable Internet GIS becomes promising as the Internet standards and technologies rapidly improve.

Internet GIS is a graphical hypertext information system

With the help of the hypermedia system in the Web, Internet GIS can link different map pages through a hypermedia hot link. For example, one can browser a national map to the state map, to the city map by clicking on the hot link that links the national map to the state maps and further to the city maps (Peng and Nebert, 1997). Furthermore, the World Wide Web provides Internet GIS a capability of integrating multimedia systems such as video, audio, maps, text, and broadcasting into the same Web page, which enriches the contents and the presentations of GIS. In summary, Internet GIS is a special type of GIS tools that uses Internet as a major means to access and transmit distributed data and analysis tool modules, to conduct analysis and make GIS presentation. The end use does not necessarily need to have GIS data and software installed in his/her local computer, all data and analysis modules can be installed on the network servers that can be requested by and delivered to the end user on-demand. The GIS analysis tools are componentized or modularized objects that can be shipped to the Web browser just in time.

Internet GIS: State of the Art

The Internet GIS has emerged and is rapidly evolving. At the current stage, there are two major Internet GIS applications: server-side applications and client-side applications. Server-side applications rely on GIS server (usually reside on a remote server) to perform all GIS analysis, while client-side applications perform GIS analysis and processing on the Web browser on the user's local machine.

Server-Side Internet-GIS

Server-side Internet GIS depends on the GIS server to perform analysis and generate output. The user at Web browser client initiates the request that is sent across the Internet to the server. The server processes the request and sent back the results to the user client. The server-side Internet GIS applications include the simple HTML to Common Gateway Interfaces (CGI) approach and application-sharing approach using Internet communications software such as Microsoft NetMeeting.

The initial development of linking GIS with Internet is by linking the GIS programs with the Internet server through a Common Gateway Interface (CGI). The GIS server runs on the background at the GIS server and is linked with the Web server. The Internet browser acts as a friendly user interface for the end user to request GIS data and service. The GIS performs the requested analysis and provides the graphics and text output to the Web server, which in turn presents the results to Internet users or clients. The CGI script handles the information exchange between the Web server and the GIS server. This approach is mainly for simple map display and does not facilitate much direct interaction between the Internet user and GIS analysis.

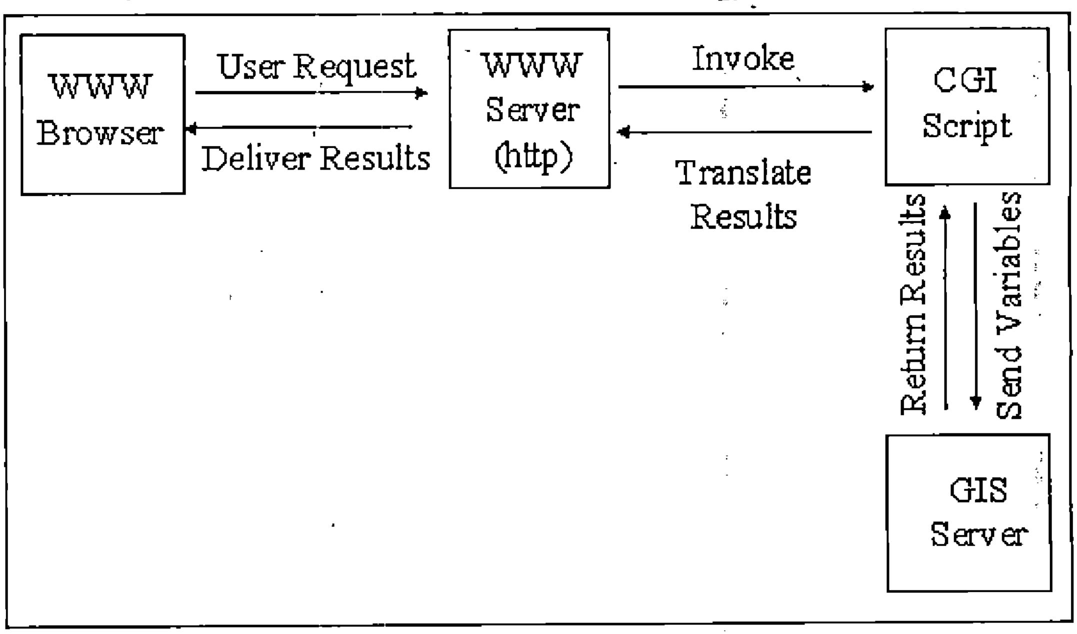
Web Browser to GIS Server through Common Gateway Interface (CGI)

Web browsers and Web servers communicate by using the Hypertext Transfer Protocol (HTTP). Web browsers cannot directly communicate with GIS programs, which have to connect with Web servers. The linkage between GIS programs and Web servers is established by the Common Gateway Interface (CGI) or gateway script. The CGI script allows Web servers execute GIS programs and interpret their output information to Web browsers. The server and the CGI program work together to enhance and customize the World Wide Web's capabilities to link with GIS data and functions.

How Do CGI-based Internet GIS Work?

CGI-Base Internet GIS is an extension of the HTML. It needs a GIS server running on the background. The GIS server is linked with the Web server via a CGI script as shown in Figure 1. Here is the simple version of how do CGI-based Internet GIS really work:

Figure 1. Work process of CGI-based Internet GIS



1. The Web user requests the document file by clicking on a Universal Resource Locator (URL) on a Web page.
2. The Web browser decodes the URL and contacts the Web server.
3. The Web server receives the request and translates the URL into a path and file name.
4. The server realizes that the URL points to a program (CGI) instead of a static file.
5. The server launches the CGI script and the script executes.
6. The CGI script calls the GIS server and translates the user input from the browser to a format or variable that the GIS server can recognize and use.
7. The GIS server performs the analysis based on the user's request. Fore example, the GIS server may generate a thematic map and transfer the map into an image file (via other programs) such as JPEG and gif file.
8. The CGI script returns to the server the GIS output and information about the output, i.e., MIME (Multimedia Internet Mail Extension) type of the output.
9. The Web server receives the result from the CGI script and passes it to the browser.
10. The browser displays the output to the user.

In a nutshell, CGI scripts are called by the Web server based on the user requests from the browser. The scripts launch the GIS server and translate the request to a format or variables that GIS server can understand. GIS server then performs the analysis and sends the output back to the CGI script. The CGI script sends the output and the information about the output (e.g. MIME type) to the Web server and browser for display.

Advantages and Drawbacks of CGI-based Internet GIS

CGI-based Internet GIS focuses solely on the server-side operation. The GIS server does all the work, and the Web browser is a user-friendly front-end interface. The CGI scripts act as an intermediate translator between the browser client and the GIS server.

The advantage of the CGI-based Internet GIS is that all analyses are conducted by the GIS server. So the workload on the client side is small. It is a thin client. Since all work are conducted by the GIS server, the CGI-based Internet GIS can take advantage of the functionalities of existing GIS server software such as ArcInfo. The analysis tools and software developed in the last two decades can be fully utilized. Anybody who has Internet access can access and use the CGI-based Internet GIS, regardless of what operate systems and platforms are used.

The CGI-based Internet GIS, however, is also limited by the limitations inherent in the Web browser and its static HTML. First of all, CGI and the current HTTP are stateless. It means that an HTTP Web server doesn't remember callers between requests. If a user requested a map and he/she wants to zoom in to the same map, the whole routine from browser to the Web server, to invoke CGI script, and to initialize GIS server has to be gone through again. Every single user inputs has to be sent to the GIS server via CGI script, and every result has to be interpreted by the CGI script and transmitted to the Web client. Therefore, it generates a lot of traffic on the Internet.

Secondly, because every operation has to be conducted by the GIS server, the information transmission between the Web browser user and the backend operation by the CGI script and GIS server is rather slow.

Third, since the CGI script handles all input from the Web browser and interpret all output for the GIS server, it becomes very difficult for the CGI script to handle a large amount of requests from users, especially those simultaneous requests. For any frequently used site, this incurs a considerable load on the server. The CGI script could become a failing point. That is, when the CGI script or the GIS server fails to work properly, the whole system will fail to function.

Finally, the final result of all the GIS server's work is more static images. These static map images are passively displayed by the Web browser to the user. The user cannot interact with HTML documents other than by pressing hyperlinks. The limitations inherent in the HTML prohibit the direct manipulations of maps on the Web browser. For example, the user cannot drag a rectangular, a circle or an irregular polygon on a map image to select an area feature. The user cannot select a linear or a point feature on the map either.

There are many examples of CGI-based Internet GIS on the Web, such as VISA International's ATM (automated teller machines) locator (http://www.visa.com/), Yahoo Maps (http://www.proximus.com/yahoo/), MapQuest (http://www.mapquest.com/), and West Virginia Division of Environmental Protection (http://www.dep.state.wv.us/).

Application Sharing

Another approach of server-side Internet GIS is to share GIS applications among a group of users. Microsoft has created a freeware software tool that supports collaboration of GIS users over the Internet, called Microsoft NetMeeting. NetMeeting consists of a suite of technologies that enable real-time, multiparty, multimedia communication over the Internet. The most important feature of NetMeeting for GIS users is its capability of sharing applications with many users over the Internet in an online meeting. "Sharing" an application means all participants can view and use the applications simultaneously with others. For instance, while one participant in a NetMeeting conference launches ArcView or MapInfo to work on a project, other participants in the conference can take control of the application and edit it while each of the others watch what is being done. Many people in conference can simultaneously work in the same application. However, only the participant who has initiated the GIS application can save or print files from that application (Matuschak, 1996). Application sharing using Internet communication software such as NetMeeting is not a true server-side application, because the GIS application can reside in any participant's machine, not necessarily on the "server".

In addition to program sharing, NetMeeting includes features of Whiteboard, Chat, Clipboard and File Transfer. The Whiteboard feature allows online meeting participants to draw pictures and write text simultaneously and see what other people are drawing. The Chat feature allows online meeting participants to send typed messages to each other. The File Transfer feature allows the user to send a file to one or all the participants in a meeting. NetMeeting allows all the participants in a meeting to share a common Clipboard. When one person in a meeting copies data to the Clipboard, all participants can then paste the data into documents on their computer.

Client-Side Internet-GIS

Client-side Internet GIS allows GIS analysis and data processing execute on the Web browser in the user's local machine. GIS data and analysis tools initially reside in a server. Users usually request for data and process tools from the server, which sends the data and analysis modules to the client for local processing. Client-side applications include three major technical approaches: GIS plug-ins and helper programs, GIS ActiveX Controls, and GIS Java applets.

GIS plug-ins or helper programs are created to work inside the Internet Web browser such as Netscape and Internet Explorer to handle GIS data and maps. The GIS plug-in is downloaded from the Web server and operated in the front end at the user's local machine. It acts as a helper application to handle GIS data type that the current HTML (HyperText Markup Language) cannot recognize. Microsoft ActiveX Document is a special helper program.

The second client-side application is to use Microsoft ActiveX Controls to create GIS Controls. GIS Controls are similar to GIS Plug-ins in that they are created to extend the capabilities of the HTML to handle spatial maps and data. GIS Controls are downloaded and executed in the user's local machine.

The most recent development is to use Internet programming language Java to create GIS Java applets, which are executable small Java applications. GIS Java applets are downloaded from the Internet servers and are executed inside the Web browser immediately. All the GIS functionalities and data are encapsulated in the package and shipped to the client on demand. No plug-in or helper program is needed to be installed at the client's Web browser. Because the GIS applications are executed at the user's local machine, no unnecessary information exchanges between the Internet users and servers.

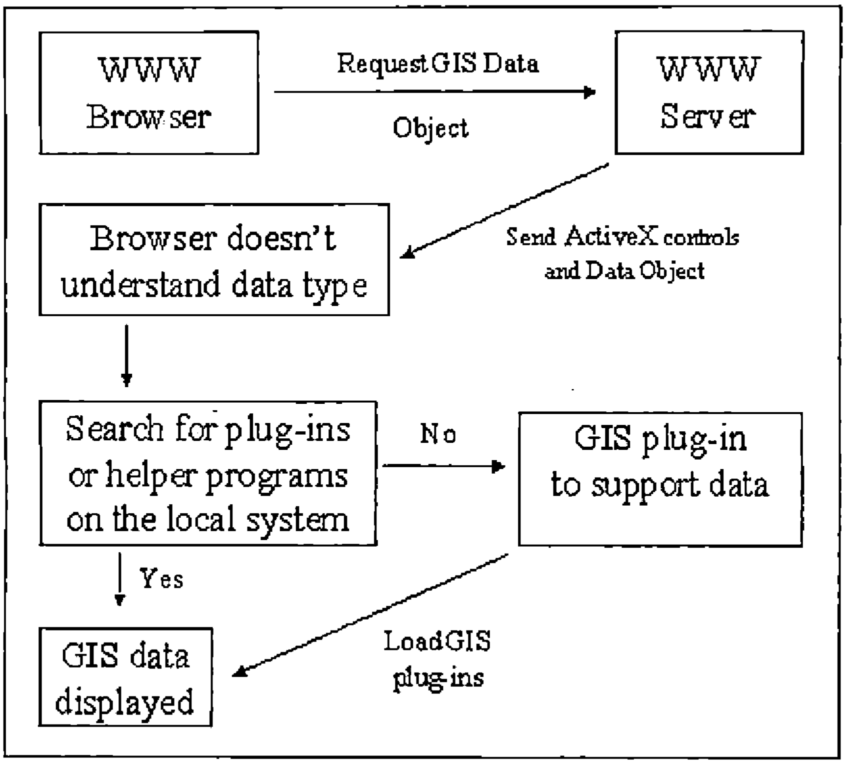
GIS Plug-Ins and Helper Programs

To overcome the limitations of the HTML, a client side GIS application called plug-in and helper program can be created. GIS plug-ins are small applications installed at the client side to extend the capabilities of Web browsers. The role of plug-ins is to provide seamless new GIS data supports for Web browsers and to facilitate the Web browser to communicate with GIS data.

How Do GIS Plug-Ins and Helper Programs Work?

Plug-ins are dynamic code modules. They are associated with a data type that the Web client has no native support for. When the Web browser starts, it enumerates the available plug-ins in a platform-specific manner and registers them according to their MIME type. When Web browser encounters an unknown data type (most GIS data types are unknown to Web browsers) in a Web page from a server it will look for a plug-in that is associated with that data type and load it. The work process of the client side GIS plug-ins is shown in Figure 2 and can be simply described as follows. The GIS helper program works the same way, and thus will not repeat here.

Figure 2. Work process of GIS plug-ins or helper programs



1. A Web browser user sends a request to the Web server by clicking on a URL via hypertext link.
2. The Web server receives the request, identifies the MIME types (e.g., shape file, or CGM file) of the requested data or document, and tells the browser what type of document is being sent.
3. The Web browser interprets the document according to its MIME types.
4. Since the browser does not support the GIS MIME types directly, it will look for a GIS plug-in or helper program that is associated with that MIME type to open the document.
5. If a GIS plug-in or helper program is not available in the local machine, they have to be installed and/or downloaded from the server over the network.
6. Once the GIS plug-in or helper program is installed, it is used to interpret and manipulate the GIS data. The plug-ins and helper programs communicate directly with the GIS data stream.

A typical example of GIS Plug-Ins is Softdesk's MapGuide (http://www.mapguide.com/).

ActiveX Compatible GIS Documents

A special helper program is Microsoft ActiveX Documents, which are documents created in Microsoft Office applications and other compatible applications that can be viewed inline in a Web browser. When an URL points to such a document, and the Web server serving it is configured with the correct MIME types, the application program that support that document can automatically be launched from directly within a Web browser.

A Web browser is an ActiveX container. When it comes across a file format, such as ArcInfo coverage or ArcView shape file, the file's native program (ArcInfo or ArcView) can launch within the browser's windows, combining the browser's toolbar with the viewing program's own, and combining the browser's menus with the viewing program's own. The result is a file that opens without conversion in the same, single-window as used to view Web pages, but with the functionality required to manipulate the new file. A user can now use the browser to access HTML pages on the Web and applications specific file on the local hard drive.

For example, ArcView shape files can be seen on the Internet as ActiveX documents. When shape files are encountered, they are considered by the browser to be OLE objects, and launch ArcView within the browser, combining commands and interfaces in a way that most people find much simpler and intuitive than either helper applications or plug-in modules. At the current stage, the native programs such as ArcView have to be preinstalled in the user's local machine. In the future, this requirement may not be necessary. When a Web browser client click on an ActiveX document file format that requires another program, the browser will instruct the viewing program located on the server to ship along with the data over the Internet.

To make use of ActiveX Documents, the local applications have to also be ActiveX Document compatible. This means that local GIS software needs to be reconstructed to fit the needs of ActiveX Documents. At the current stage, there is no GIS software being ActiveX Document compatible. A GIS viewer can be created to facilitate those who do not have their GIS applications available in their desktop and to provide capacity to view GIS documents without launching the full GIS application.

GIS ActiveX Controls

Another approach in the development of Internet GIS is the use of ActiveX controls to create GIS Controls. ActiveX is developed by Microsoft to "activate the Internet." It builds on the Object Linking and Embedding (OLE) standard to provide a common framework for extending the capability of Microsoft's Web browser, Internet Explorer (Chappell, 1996).

An ActiveX is a modular piece of software that performs tasks and communicates information. It communicates to other programs, modules, and Internet via OLE. It can also be used and reused by any program or computer language that is able to contain ActiveX controls, such as Web browsers like the Internet Explorer 3.0 and Netscape Navigator (with certain plug-ins installed) or languages like Visual Basic, Visual C++, and FoxPro (Chappell, 1996). GIS controls have computational power, communications power, and their own small graphic interface, and can be used like plug-ins and Java applets within Web pages. There are many different types of ActiveX controls, each with different capabilities and functionalities. GIS controls are created to handle GIS data and perform GIS analyses.

ActiveX controls are similar to plug-ins. Both of them are dynamic modules to extend the functionality of Web browsers. But ActiveX controls can also be used by any programming languages or applications that support the OLE standard. ActiveX controls are general componentware that can plug into any application. Therefore, one can access an existing library of commercially available controls. Plug-ins, on the other hand, are specific to the browser. They can only be used in Web browsers.

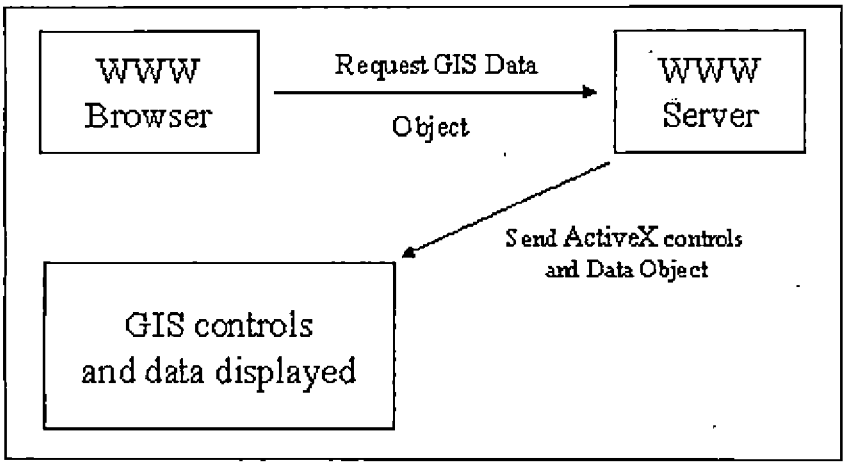
How Do GIS ActiveX Controls Work?

As mentioned before, current Web browses cannot directly support GIS data type. When an HTML page contains GIS data it requires loading a specialized GIS plug-in, helper program, or GIS ActiveX Control into the client's browser to view it. GIS controls are referenced inside an HTML document and executed by a Web browser. They initially reside on the server side. These controls are downloaded when a user connects to the Web site and invokes the HTML document containing a reference (<OBJECT> tag) to the GIS control. The GIS control is downloaded from a web server when it's needed, or it might already be presented on the client machine if it was previously downloaded.

ActiveX controls integrate with Web browser client very flexibly and seamlessly. The GIS control can access an URL and retrieve MIME data just as a standard Web browser client does. GIS data are streamed asynchronously to the GIS control as it arrives from the network, making it possible to implement viewers and other interfaces that can progressively display information. If the GIS control needs more data than can be supplied through a single data stream, multiple and simultaneous data streams can be requested by the GIS Control.

ActiveX Controls are generally embedded within HTML code and accessed through the reference <OBJECT> tag. GIS controls are loaded as needed and executed on the browser's machine. Figure 3 illustrates some of the following steps that take place when loading a GIS Control:

Figure 3. Work process of ActiveX Controls



1. A Web browser user sends a request to the Web server by clicking on an URL via hypertext link.
2. The Web server receives the request and loads the HTML file.
3. The Web browser interprets the HTML file and detects the GIS Control reference <OBJECT> tag.
4. The GIS control is downloaded from the server.
5. Other Control files and data files referenced by the GIS Control are detected and downloaded as well.
6. The GIS control is displayed inside or outside the Web browser, as embedded controls, full-screen controls or hidden controls.
7. The GIS controls, with their built-in GIS functions, interpret and manipulate GIS data that streamed asynchronously from the server.

The MapObject Internet Map Server (http://www.esri.com/) created by the Environmental Systems Research Institute (ESRI), Inc. adopts the GIS ActiveX Control approach. So does the GeoMedia Web Map server developed by Intergraph Corporation (http://www.intergraph.com/software/).

Another interesting implementation of the ActiveX Controls is the Citrix's WinFrame Web Client ActiveX Control (http://www.citrix.com/). The WinFrame Web Client ActiveX Control can allow users access GIS data and applications remotely. WinFrame Web Client uses the techniques of Application Launching and Embedding (ALE) to run applications remotely from a Web page. Users can launch an application from a Web page by clicking on a hyper-link. The server will launch a GIS application in a window on the user's local desktop. The launched application can run on its own window or within the Web page (embedding). The user can then use this application as if it were installed and running locally on his/her own machine.

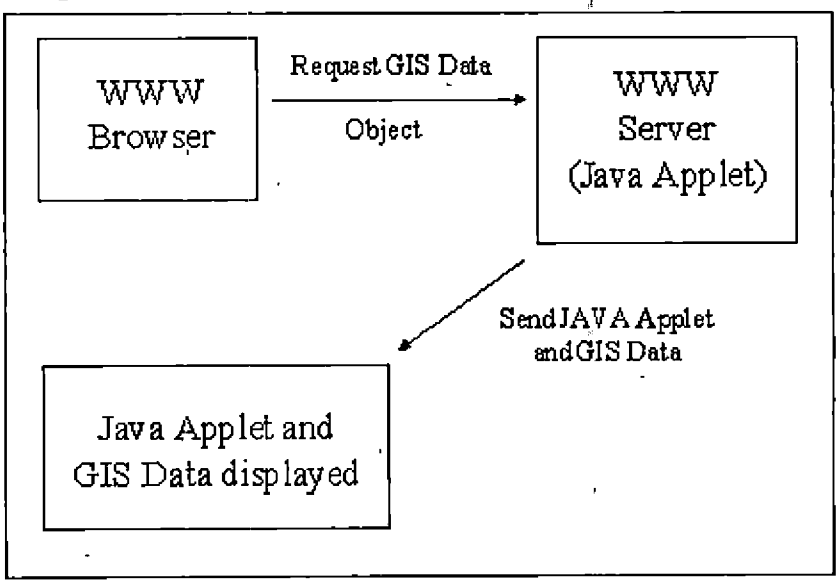
Java-Based Internet GIS

The most recent Internet-GIS is to use Internet programming language Java. Java is an object-oriented programming language. Java applets are mini applications that run inside a Java-enabled Web browser. Java applet is seamlessly integrated inside the Web browser, and is downloaded and executed on a client computer on demand. Java provides a wide range of tools for creating and displaying graphics. It is the most appropriate to manipulate GIS data on the Web.

How Do Java-Based Internet GIS Work?

GIS Java applets are written in Java. They are created to interpret GIS data and perform GIS analysis. Each GIS function such as zoom in, zoom out, zoom area, query, label and the report of query output could be one applet. GIS applet is executable code resides on a machine that is accessible to a Web server at a Web site. GIS applets are referenced inside an HTML document and executed by a Web browser at the client side. They initially reside on the server side, just as HTML documents, GIS plug-ins and GIS controls do. These applet class files are downloaded and executed when a user connects to the Web site and invokes the HTML document containing a reference (<APPLET> tag) to the GIS applet. There is a specific sequence of events that takes place when a Java-enabled browser loads an HTML document and GIS applets. Figure 4 illustrates some of the following steps that take place when loading a GIS applet:

Figure 4. Work process of Java applets



1. A Web browser client sends a request to the Web server by clicking on a URL via hypertext link.
2. The Web server receives the request and loads the HTML file.
3. The Web browser interprets the HTML file and detects the <APPLET> tag.
4. The Applet class file is downloaded from the server.
5. Other Java class files and data files referenced by the applet class are detected and downloaded as well.
6. The GIS applet is displayed inside the Web browser or outside, if it uses its own frame.
7. The GIS applet interpret and manipulate GIS data.

Several programs are using Java applications on the Web, such as the ArcView Internet Map Server being developed by the Environmental Systems Research Institute, Inc. (http://www.esri.com/) and ActiveMaps by Internet.com (http://www.internetgis.com/).

Performance of Internet GIS

A major drawback of current Internet GIS is its slow performance. It takes a long time to initially download the vector and image data, GIS plug-ins, controls and Java applets. This will become especially a problem when more analysis functions are added to plug-ins, controls and Java applets. A progressive data stream helps in a way that it will not make the user feel boring when looking at the screen. However, the user cannot do anything until all the data arrive. It is not uncommon to have data with 100k in size. It will take about anywhere from 30 seconds to 10 minutes to load. It will take much longer if you are using slower speed modem. This is a significant amount of time just waiting for data.

The issue of slow performance can be tackled in two ways: increasing the speed of Internet connection and developing more efficient Internet GIS programs. The speed of Internet connection is improving with faster modem and faster communication connections. At the higher education institutions, the next generation of Internet, Internet 2, will increase the Internet speed dramatically (Shapley, 1997). This fast Internet connection will make the current GIS data movement on the Internet a trivial task.

Security

Security is less an issue for server-side applications, because there is no program codes that are executed in the user's local machine. It is, however, a concern for client-side applications, which are downloaded from the network, often from machines over which the user have no control. Such application codes could contain fatal flaws or viruses that could damage the user's local machine.

Plug-ins, helper programs and ActiveX Controls are binary codes executing directly on the machine's hardware. Therefore, all of the dangers of running unknown software from the Internet apply to them. Unknown plug-ins and ActiveX Controls downloaded from the Internet can do anything on the client computer. How do you know that a downloaded ActiveX Control won't erase your hard drive (Chappell, 1996).

To address this concern, Microsoft's Internet Explorer Web browser supports Authenticated code-signing technology and Netscape uses Object Signing protocol. This enables vendors of ActiveX Controls and developers of plug-ins and other software components to digitally sign these components. When they are downloaded and the digital signature is recognized, a code signature certificate is displayed on the screen. This certificate ensures that the software component is coming from the trust source and hasn't been tampered with (Chappell, 1996). The user then decides whether to install the applications on his/her local machine.

The download and execution of Java applets are relatively more secure. All applets loaded over the network are assumed to be potentially hostile and are treated with appropriate caution. Java has established the Java security framework to establish an intelligent, fail-safe stance for the execution of Java programs (Weber, et al. 1996). The Java security framework consists of three major layers that create the Java execution environment, from the Java language, to the Java compiler and verifier, to security managers in the runtime. When Java bytecode is loaded, it has to be verified by the Java verifier. If the verifier cannot confirm that the code being loaded was produced by the Java compiler, the code will not be loaded and executed. On the browser side, a specific policy has been identified for the loading of untrusted applets. For example, Java applets are not allowed to create, modify, or delete files or directories on the local system. They are not allowed even to read file on the local system. Internet security is not unique to Internet GIS. It applies to all Internet applications. As the overall Internet security improves, Internet GIS will become more secure and more flexible.

Conclusions

Internet GIS has emerged and is rapidly evolving. Integrating GIS with Internet is an inevitable trend of the future. It is important for the GIS community to monitor and define the course of its development. Hopefully, the discussion in this paper will generate some systematical discussion among GIS users and developers. Internet GIS is a network-centric GIS tool that uses Internet as a major means to access and transmit distributed data and analysis tool modules, to conduct analysis and visualization. Internet GIS allows the end user to download all componentized data and analysis modules directly from the network servers on demand. The end user does not necessarily need to have desktop GIS software installed in his/her local system.

The current server-side Internet GIS based on stateless http and CGI script offers little flexibility and interactivity to the end user. The user cannot directly work with spatial object as one does with the vector-based stand-alone GIS software. The limitations of the stateless HTTP prohibit the construction of more advanced analysis tools in the development of interactive GIS on the Web. It can merely be used for static spatial query and display.

The client-side Internet GIS offers more flexibility and interactivity than the server-side applications. GIS plug-ins, helper program and ActiveX Controls extend the capability of HTTP to directly handle GIS data. The end users can view GIS data and perform simple analysis on the Web just like they work on local GIS software. However, the platform-dependent specifications of plug-ins and ActiveX Controls impose information management problems for both users and developers.

Java offers its unique contribution to Internet GIS with its object-oriented and platform-independent characteristics. It is an Internet programming language that is well suited for graphic presentation on the Internet, an essential part of Internet GIS. Java applets are more secure to be loaded from the network and executed in the user's local system. Although the Java programming language seems offer the most promising for the future development of Internet GIS, several issues need to be addressed, particularly access to local system and access to other remote computers. It is essential for Internet GIS to be able to take advantage of the distributed processing to access analysis models and distributed data on the network in order to achieve high interoperability. It is also desirable for end users to be able to save data and results to the user's local system. For Java to be the programming language of Internet GIS, these issues have to be resolved.

Interactive mapping is only the first step in the development of Internet GIS. Future developments will inevitably focus on interactive GIS analysis. The trend is toward small-componentized GIS analysis modules, just-in-time delivery and network-centric architecture.

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DIGITISATION AND STRUCTURING OF MAP DATA

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Introduction

The process of digitising existing maps may be regarded as one of secondary data acquisition, in the sense that it is a transformation from one (analogue) form of information storage to another (digital). This may be distinguished from primary data acquisition whereby new data are obtained by surveying. Ground-based and remote-sensing surveying methods are now heavily dependent upon computing technology, with the consequence that the survey results are readily available in digital formats.

Data input is the operation of encoding the data and writing them to the database. The creation of a clean, digital database is a most important and complex task upon which the usefulness of the GIS depends. Two aspects of the data need to be considered separately for geographical information systems, these are first the positional or geographical data necessary to define where the graphic or cartographic features occur, and second, the associated attributes that record what the cartographic features represent.

Entering the spatial data

There is no single method of entering the spatial data to a GIS rather, there are several, mutually compatible methods that can be used singly or in combination The choice of method is governed largely by application, the available budget, and the type of data being input. The types of data encountered are existing maps, including field sheets and hand-drawn documents, aerial photographs, remotely-sensed data from satellite or airborne scanners, point-sample data (e.g. soil profiles), and data from censuses or other surveys in which the spatial nature of the data is more implicit than explicit. The actual method of data input is also dependent on the structure of the database of the geographical system.

Manual input to a vector system

The source data are envisaged as points, lines, or areas. The coordinates of the data are obtained from the reference grid already on the map, or from reference to a graticule or overlaid grid or point data using GPS. They can then be simply typed into a file or input to a program.

Digitising

A digitizer is an electronic or electromagnetic device consisting of a tablet upon which the map or document can be placed. The most common typed currently used for mapping and high quality graphics are either the electrical orthogonal fine wire grid or the electrical wave phase type. Different sizes of digitizers are as follows:

Active Area	Digitizers
12" x 18"	A3 Size
24" x 36"	A1 Size
36" x 48"	A0 Size
42" x 60"	A00 Size

Digitizer accuracy is limited by the resolution of the digitizer itself and by the skill of the operator. The co-ordinates of a point on the surface of the digitizer are sent to the computer by a hand-held magnetic pen, a simple device called a 'mouse' or a 'puck'. For mapping, where considerable accuracy is required, a puck consisting of a coil embedded in plastic with an accurately located point are digitized by placing the cross -hairs over it and pressing a control button on the puck. The principal aim of the digitizer is to input quickly and accurately the coordinates of point and bounding lines.

Manual Digitising

Manually operated digitisers probably provide the most widely used means of converting pre-existing maps into digital form. Spatial data are recorded in the form of single coordinate pairs representing points, and series of coordinates representing lines and area boundaries. The main components of a *manual digitiser* (Fig. 6.1)are a flat surface, ranging in size between small tablets about 30x30 cm to large tables 120x80 cm or more in dimension; a hand-held puck or cursor, used by the operator to indicate positions to be recorded; and a keyboard for entering alphanumeric data and possibly commands. It is the larger devices that are generally of most use in cartography. Exact positioning of the puck is made possible by a cross hair mounted within a flat glass panel, which may sometimes include a magnifying lens. Also mounted on the puck are buttons that may be used for controlling data entry.

The most commonly used technology for the digitising tables is electromagnetic, in which a table inlaid with a fine grid of wires is associated with the puck which contains a metal coil. The grid of wires in the table and the coil in the puck act either as transmitter and receiver, or receiver and transmitter, respectively. If the puck is the transmitter, the position of the cross hair is found by scanning the x- and y-coordinate grid wires to identify those nearest the puck. The exact position is then found by interpolating between the adjacent wires on the basis of the nature of the signals received. Small-format, lower resolution digitising tablets may sometimes use a stylus with a small coil in its tip, rather than a puck, as the locating device.

Automated scanning

Scanners that scan entire documents are designed to create a digital representation of the source in the form of a 2D array of pixel values. For the majority of cartographic and GIS applications, this array or raster must then be analysed to derive a vector representation of the geographical features and of the annotation as indicated above for the VTRAK system. In respect of their primary function, commercial scanners have usually been very effective in generating high-resolution rasters of either binary, or grey scale or colour values. It is only recently, however, that raster to vector conversion software has become sufficiently sophisticated to be able to identify and correctly digitise (in vector format) a significant proportion of the graphical and textual information found on topographic maps. Even so, considerable effort must often be expended in validation, feature coding and interactive graphical editing of the vectorised data.

Early application of scanner systems was confined to digitising simple high-quality line work, such as the colour separates of contours of published maps. Current systems use pattern recognition techniques to distinguish between, and hence provide feature identification codes for, a variety of point, line and area symbols. They can also interpret, to a high degree of success, both printed and hand-written text. It maybe appreciated that the latest scanning systems have enormous potential for dealing with the backlog of traditional 'analogue' maps which must be digitised by many of the organisations wishing to take advantage of GIS technology. With the recent improvements in processing of scanned data it can be expected that these systems will continue to become more widely used.

Raster scanners (Fig 2) are usually based on either drum or flat-bed design (Petrie, 1990a). Drum scanners, such as those manufactured by Optronics, Scitex and Tektronix, wrap the document on a drum that is rotated adjacent to a photo detector head which moves incrementally along the length of the drum. The documents may be monochromatic requiring a single detector, or full colour, in which case several photodetectors may be used simultaneously, each with their own colour filter. As an alternative to the relatively large and expensive scanners, there are available small-format devices which use movable linear or area arrays of charged couple devices (ccd). The ccds can be combined with a lens to form a camera which, in the case of the linear arrays, moves the length of the document in a single scan.

Spatial data already in digital raster form

All satellite sensors and multispectral sensing devices used in aeroplanes for low-altitude surveys use scanners to form an electronic image of the terrain. These electronic images can be transmitted by radio to ground receiving stations or stored on magnetic media before being converted to visual image by a computer system.

The scanned data are retained in the form of pixels. Each pixel has a value representing the amount of radiation within a given bandwidth received by the scanner from the area of the earth's surface covered by the pixel. This value can be represented visually by a grey scale or colour. Because each cell can only contain a single value, many scanners are equipped with sensors that are tuned to a range of carefully chosen wavelengths. For example, the scanners on the original LANDSAT 1 were tuned to four wavebands (Band 1, 0.5-0.6μm; band 2, 0.6-07μm; band 0.7-08μm; band 4, 0.8-1.1μm) in order to be able to record differences in water, vegetation, and rock.

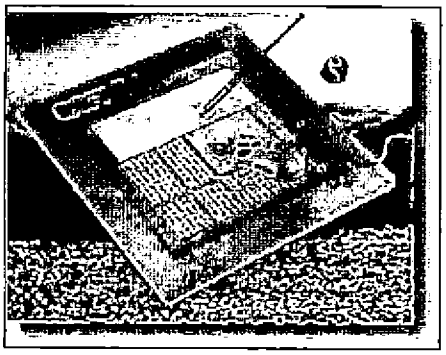

Fig.1 Digitiser

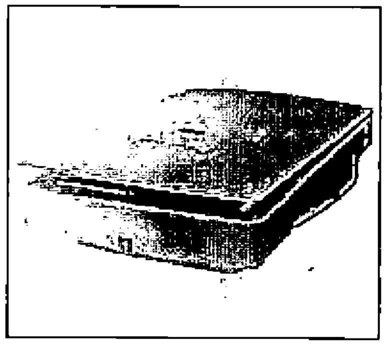

Fig.2 Scanner

Editing : Error Detection & Correction

All digital map data can be assumed to include errors of some sort. They arise from a combination of inaccuracy in the source data and from limitations of the digitiser operator and the computer system in use. Certain types of error, such as that due to inaccuracy of the original surveyed data, are implicit in the map source and cannot be rectified without obtaining another source of data. Other errors arise due to the operator failing to position the cursor accurately over the graphic object to be digitised or, more blatantly, missing objects from the map or wrongly entering the identity of an object. As a general rule, if an error can be detected at the time of data acquisition it will be easier to correct it then than if it is detected later, when someone is attempting to use the data. It is also the case that errors will usually be much easier to detect at the time of acquisition. Undoubtedly many digital data sets contain errors that may never be detected. In particular, locational errors often do not become apparent until similar data from different sources are combined

ARC/INFO marks potential node errors with special symbols. The two types of nodes and the potential errors they represent. Pseudo Node drawn with a diamond symbol occurs where a single line connects with itself an (island) or where only two arcs intersect. Pseudo Node does not necessarily indicate an error or a problem. Acceptable Pseudo nodes may represent an island (a spatial pseudo node) or the point where a road changes from pavement to gravel (an attribute pseudo node). A dangling node, represented by a square symbol refers to the unconnected node of a dangling arc (Fig.3).

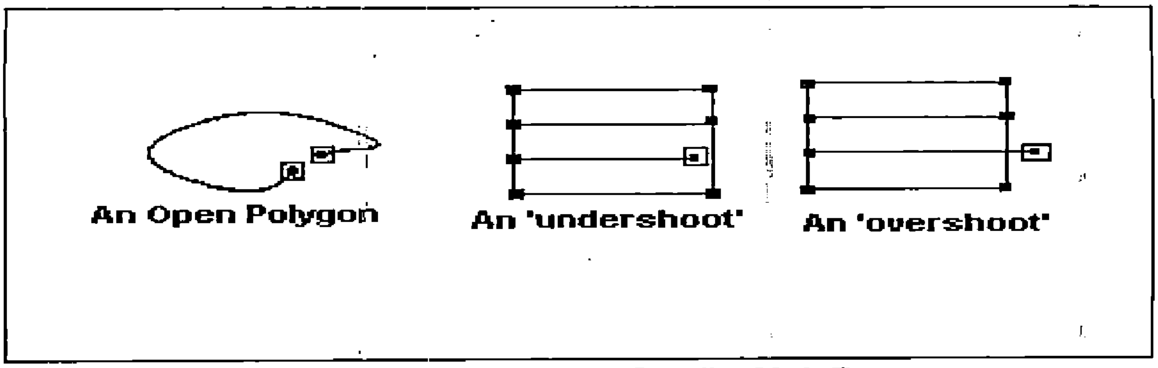

Fig.3 PseudoNode Error & Dangling Node Error

Correcting the errors

Correcting the errors is one of the most important steps in constructing your database. Unless errors are connected, your area calculations, any analysis and subsequent maps will not be valid.

Topology creation-Structuring Map data

In a GIS, Topology is used to represent the spatial relationships that exist between geographic data. Spatial relationships are the associations between geographic data based on their relative locations to one another. People intuitively understand the spatial relationships that exist between objects. If you look at a road map, you know that road 'X' intersects road 'Y' because you can see that the two roads cross. The problem for a GIS is to take these intuitive relationships and make the GIS understand them. The intuitive relationships must be converted into physical relationships in order to describe the relationships in terms of finite definitions, such as contiguity, containment or area definition and connectivity. This is what topology does: it defines data, so that the intuitive relationships are physical relationships, thus the system understands the spatial relationships that exist between objects on a map. Finally we can say that Topology is the mathematical representation of the physical relationships that exists between the geographical elements.

The ability to create and store topological relationships has a number of advantages. Topology stores data more efficiently. This allows processing of larger data sets and faster processing. When topological relationships exist, you can perform analyses such as modeling the flow through connecting lines in a network, combining adjacent polygons that have similar characteristics and overlaying geographic features.

The three major topological concepts of a GIS are:

- Arcs connect to each other at nodes (Connectivity)
- Arcs that connect to surround an area define a polygon (Containment or area definition)
- Arcs have direction and left and right sides (Contiguity)

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TUNING YOURSELF FOR BETTER OUTCOMES

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Humans are social animals; we need connection with other humans in order to function well. All of us have an innate drive towards being as psychologically healthy as we can be. We therefore strive to attain as much autonomy as possible, so that we can fulfill our potential and have good relationship with other people. Regrettably, sometimes we do not understand what is holding us back. The more we can understand about ourselves and others, the more we can increase our range of options and become open to real connection and meaningful and enjoyable relations.

> *As per Old Testament Christians believe that Adam and Eve lived blissfully in the paradise. They felt complete and remained in absolute close relationship even with birds, bees and beasts. Osho Rajneesh says, the story of paradise is the most powerful story woven by man. This story, according to him, has layers of meaning. One analysis is that God provided everything; Adam and Eve had no need to think. Devil made them think This made them proud and 'ego' or the feeling of 'I' was born. 'I' and God cannot exist together and man lost paradise and his relationship with God and blissfulness. Paradise is a story of broken relationship.*

The ways in which we join and co-operate in teams are influenced by our mental images or imagoes. An imago is a picture we create in our heads of a group of people. We are not usually consciously aware of the imago but it influences our actions. Thus, before we enter a room to join a group, we already have in our minds an imago of them and us. This is likely to be based on a mixture of past events, preconceptions, rumour and fantasy. The imago will be personal to each of us, so that we enter a group with different expectations, leading in turn to different perceptions.

Simply knowing that we start our involvement in a team with a pre-existing imago can be useful. Recognizing this phenomenon means we can unpack our mental baggage and decide how much of it is relevant, how much is assumption, how much we should discard if we are to meet people with an open mind. However the concept has additional advantages when we realize that our imago stays with us and is updated as we spend time in the group. Constant monitoring of its content will enable us to relate more effectively to others in the team.

As we become involved in a group, we collect more information about our fellow group members. Dr. Eric Berne (1965) describes four phases through which an individual moves, in fantasizing his or her relationship to a group. These phases will determine both how the individual will structure time with the group and the degree of relatedness the individual experiences with regard to the group. Each phase will involve a different imago representing the degree to which the individual has differentiated the members of the group.

Provisional Group Imago

Upon entering a new group, the individual will have a 'provisional imago' with very little differentiation and in addition to the activity for which the group is formally structured, the individual will probably not feel psychologically secure in structuring time in any way other than rituals. During this phase, the individual's sense of relatedness to the group will be simply that of 'participation'.

Adapted Group Imago

After the individual has been in the group for a brief period and has differentiated a few of the members and has also become aware of their imagoes, the individual will develop an 'adapted imago' and feel comfortable in engaging in pastimes as well. During this phase, the person will develop a sense of 'involvement' with the group.

Operative Group Imago

In the third phase, the individual develops an 'operative group imago' which concerns his relationship with the leader and how the other group members are further differentiated based on this. A person needs to sort out this relationship with the leader before he can decide how to behave towards other members of the group. In addition to engaging in pastimes people may resort to ***'psychological games'*** also at this phase. This phase will produce a sense of ***'engagement'*** with the group.

Adjusted Group Imago

Finally when the group is fully differentiated the individual may develop an adjusted group imago resulting in a new synthesis allowing for intimacy. The final phase will produce a sense of 'belonging' with the group. His image will now contain sufficient data to guide his interactions with every other members of the group, apart from having shared expectations about the functioning of the group.

Identity ?

Ego
Self Image
Mind
Brain
Soul or spirit
"I think, therefore I am"

- Descartes.

"Cogito Ergosum" - I think, therefore I exist

- Sartre.

True?

Identity = Thinking
Thinking = Being
You = Your mind
Watch the thinker and experience a higher level of consciousness
becoming activated.
Thought is only a tiny aspect of consciousness.
Learn to disidentify from your mind

- Eckhart Tolle

Beliefs

Open the door to excellence.
"Man is what he believes"

- Anton Chekkov.

Even at the level of physiology, beliefs control reality.
Beliefs are internal representations that control behaviour.
The birth of excellence begins with our awareness that out beliefs are a conscious choice.
"They can, because they think they can"

-Virgil

"One person with a belief is equal to a force of ninety-nine who have only interests"

- John Stuart Mill.

Beliefs are

Preformed preorganized approaches to perception that filter our communication to ourselves in a consistent manner,
an internal representation that governs behaviour.
"Our doubts are traitors and make us lose the good we often might win, by fearing to attempt"

- William Shakespeare

"People don't usually lack resources; they lack control over their resources"
"The more you relive an experience, the more likely you are to use it again"
"People are not lazy. They simply have impotent goals - i.e. goals that do not inspire them".

- Anthony Robbins

COMPARISON OF SOFTWARE APPLICATIONS IN GIS

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S. No.	System name	Computing environment	System type	First instal.	Data stru.	DBMS interface
1.	AGIS	PC - DOS	GIS	1986	VECTOR/RASTER	Not available
2.	ARC/INFO (ESRI)	DEC, PRIME,DG, IBM PC - DOS	GIS	1981	VECTOR, TIN	INFO, ORACLE, INGRES, DBASE
3.	Axis Mapping	PCs/DOS, Sun VAX/IBM/UNIX	GIS	1978	Vector/Raster	Not available
4.	CRIES - GIS	PCs/DOS	GIS	1978	Raster	Dbase III
5.	Deltamap	HP9000, SUN APPOLLO, SGI/UNIX	GIS	1986	Vector/Raster TIN	Oracle, Ingres, Informix
6.	Earth One	PCs/DOS	GIS	1987	Vector/Raster	Not available
7.	EPPL 7	PCs/DOS	GIS	1987	Raster	Rbase, Dbase III
8.	ERDAS	PCs/DOS; SUN/UNIX; VAX/VMS	GIS, IP	1979	Raster	Infor
9.	Geo Spread Sheet	PCs/DOS	GIS	1989	Vector	Not available
10.	Geo/ SQL Mum Map	PCs/DOS; SUN/UNIX	GIS	1987	Vector	Rbase, Oracle, Ingres
11.	Geovision WOW	PCs/DOS	GIS	1985	Vector	Not available
12.	GFIS	IBM S/370 architecture	GIS	1977	Vector	IMS/DLI,SQL/DB2
13.	GDS	VAX/VMS,DEC station/Ultrix	GIS,AM	1980	Object (vector)	Oracle etc.
14.	GRASS	Sun,MASSCOMP etc./UNIX	GIS	1985	Vector, Raster	Not available
15.	IDRISI	PCs/DOS	GIS	1987	Raster	Lotus, Quattro etc.
16.	IMAGE	PCs/DOS	GIS,IP	1989	Vector	Lotus, Dbase etc.
17.	Infocam	VAX/VMS	GIS	-	Raster, quadtree	Oracle
18.	Informap	VAX/VMS	GIS	1975	Vector	SQL Based
19.	Land Trak	PCs/DOS	GIS	1983		Not available
20.	Laser scan	DEC VAX/VMS	GIS	1985	Vector,Raster	RDB
21.	MacAtlas	Macintoash PCs/DOS	GIS	1985	Vector, Raster	Not available
22.	Mac GIS (U.Oregon)	Macintoash	GIS	1987	Raster	Hypercard etc.
23.	Manatron GIS	Unisys/DOS, UNIX	GIS	1983	Vector,Raster	Oracle,Fasport,Adept,Request etc.

S. No.	System name	Computing environment	System type	First instal.	Data stru.	DBMS interface
24.	Map II	Macintoash	GIS	1989	Raster	NO
25.	PAMAP	VAX, PC - DOS, SUN	GIS	1983	Vector,Raster	Any relational DBMS
26.	SPANS	PC-DOS,UNIX	GIS	1986	Region Quadtree	Internal
27.	Topologic	PCs/DOS; OS -2; VAX/VMS	GIS	1987	Raster, Vector Quadtree	Dbase, RDB
28.	UltiMap	Apollo,AEGIS	GIS, AM	1974	Vector,Raster	Oracle,Informix,Ingres, IMS etc.
29.	VANGO	VAX/VAM	GIS	1981	Vector	Userbase
30.	ISROGIS	PC/UNIX	GIS	1992	PM - Quadtree	Any SQL
31.	GEOSPACE	PC - Xenix	GIS	1993	Raster	-
32.	GRAM	PC - DOS	GIS	1992	Raster	Dbase
33.	GISNIC	PC-Xenix/Unix	GIS	1993	Vector	Foxbase interface
34.	THEMAPS	PC-DOS	GIS	1991	Vector	Dbase

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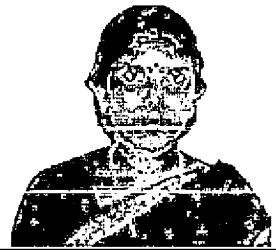
1	Dr. S. Anitha, Assistant Professor, (Agronomy)	Campus Development K.A.U., Thrissur – 680 656. e-mail: anitha_sarala@yahoo.co.in Phone: 09446433292	Type IV/5 Quarters Kerala Agrl. University Vellanikkara, Trissur Phone: 0487 2374292	
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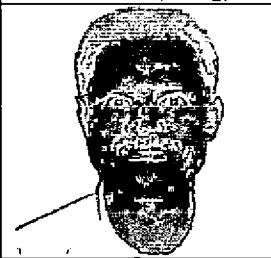
10	Dr. Kuligod Vittal, B. Asst. Professor (SS&AC)	College of Agriculture B'Gudi – 585 287 Tg: Shahapur, Dt:Gulbarga Karnataka.	e-mail: vbkuligod@yahoo.co.in Phone: 09343839553	

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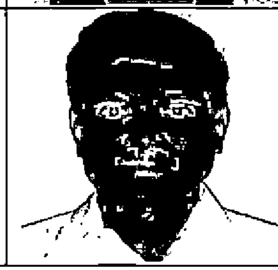
14	Mr. A. Srinivas Scientist (Soil Science & Agril. Chem.),	Rice Research Institute, Maruteru, Acharya N.G.Ranga Agrl. University Andra Pradesh – 534 122. e-mail: alpp_sri@yahoo.co.in Phone: 09849628648, 09441488927.	1-74, C/o Ch Satyamara Yana, Shivalayam Street Neggippudi Maruteru W.Godawari dist AP – 534 122.	

Sl. No.	Name & Designation	Address with e-mail & Telephone No.	Residential Address	Image
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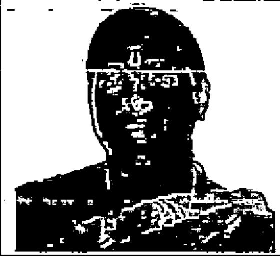
23	Dr. P. K. Sushama, Assoc. Professor (SS&AC)	College of Horticulture Velianikkara Thrissur –680 656 e-mail: prakirithi2000@yahoo.co.in	Prakirithi Gandhi Nagar Mannuthy P O Thrissur, Kerala-680 651 Ph: 0487 2370602	
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