A GEOGRAPHIC INFORMATION SYSTEM FOR MICRO-LEVEL DECISION MAKING IN THE AGRICULTURAL SECTOR OF CENTRAL MIDLANDS OF KERALA

By

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THESIS

submitted in partial fulfillment of the requirement for the degree of

Doctor of Philosophy in Agriculture

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DECLARATION

I hereby declare that the thesis entitled **"A geographic information system for micro-level decision making in the agricultural sector of Central Midlands of Kerala"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that the thesis entitled **"A geographic information system for micro-level decision making in the agricultural sector of Central Midlands of Kerala"** is a record of research work done independently by **Mr. Anup Balakrishnan,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to him.

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Dedicated to my

Friends and Family

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Introduction

1. INTRODUCTION

Sustainable development of the farming communities demand scientific exploitation and optimum utilisation of the production potentials of the natural, material and human resources and calls for investments for building infrastructure that would foster the utilisation of the resource potential (Nair and Saifudeen, 2004). Kerala state is blessed with all the factors that are considered in the development literature as very conducive to a dynamic and sustainable agriculture. They include the basically sustainable integrated farming system (homestead farming), progressive land reforms, easy access to credits and markets as well as the advantages of well-endowed natural resources for biomass production. Consequently, Kerala's performance in the agriculture front has been commendable, especially in sub-sectors such as rubber, milk and marine products. However, the state has been relegated to lower status in the productivity of major crops such as paddy, coconut etc. Kerala has also been overtaken by other states in income per unit of cultivated land.

Lack of appreciation of the biophysical and socio-economic features unique to Kerala has been primarily responsible for this situation. Ecological and economic sustainability are enhanced when available soil, water, energy and human resources are used in a mutually reinforcing manner. Location specific, resource-based planning would lead to the optimised use of specific resource endowments in sustainable manner and help to improve the livelihood security of the people.

Totality of resource management rather than specific commodity production activities (food grains, oilseeds *etc.*) must be the primary consideration. Development programmes must be evolved as per the needs of local community in consonance with local resource endowments. This can be achieved by delineating the state into homogeneous resource endowment areas and by identifying potential opportunities to optimise the use of resources, biophysical as well as human, for sustainable generation of income and employment.

Contemporary planning and management of agricultural resources are facilitated by the application of spatial technology, using 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. Currently, the making and utility of map is in a state of major revolution. 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. In India, 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.

Although many maps and reports are already published and available with many institutions, they are unlikely to contribute significantly to the solution of agricultural and environmental problems. Because, the data presented in many maps and survey reports are often irretrievable or even incomprehensible for planners and decision makes as well as scientists. These maps 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 like District Rural Development Agency, Lead Bank, Departments of Agriculture, Pollution Control Board, Ground Water and so on, 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. These departments do not have facilities for preparation of maps of their own with updated information.

Spatial technologies such as Geographic Information System (GIS) and Remote Sensing (RS) would enable integration of spatial data (maps) from different sources for easy resource analysis. A GIS comprises an automated set of functions that provides professionals including planners with advanced capabilities for the storage, retrieval, manipulation and display of geographically located data that are usually found on maps (Ozemoy *et. al.*, 1981). Data integration in a GIS would enable conceptualised decision making in contrast to specialised sector-based project formulation (Rao, 2000). Moreover, compatibility of IRS-1C data with cadastral maps (revenue village maps at 1:4000) had been studied by Rao *et al.* (1996). They have found that there was good geometric fidelity of the satellite data when overlaid on cadastral maps. The same possibility can be extended for land resource analysis in the decentralised mode in Kerala state by updating information on the resource base.

Informatics and digital analytical tools have potential to create major transformations in the agricultural sector of Kerala, especially in the context of encouragement of "Precision Farming" during the 10th five-year plan. Such an approach will pave way for effective prioritisation of problems and their effective tackling through quantitative approach to evolve eco-friendly techniques and technologies to improve agricultural production at a faster rate on sustainable basis. This was the rationale for the investigation under report. The study under report was intended to make use of Remote Sensing and GIS for better visualisation of the development needs of Madakkathara Panchayat.

The biophysical resources of Madakkathara Panchayat has been inventoried and mapped by several agencies such as Centre for Earth Science Studies, Thiruvananthapuram and Integrated Rural Technology Centre, Mundur. Bindu (2000) compiled socio-economic data on the Panchayath. Comprehensive information on the biophysical and human resources of the Panchayat is available in the development reports published by the Grama Panchayat itself (Lissy, 1996). However, the data are dispersed and are in different formats (textual, tabular, spatial etc.). In such forms these data cannot be used for multi-sectoral, problem - oriented analysis.

Therefore, the thesis programme that is reported in the ensuing chapters was implemented with the objective to integrate available data on the soil-related agricultural resources of Madakkathara Panchayat into a Geographic Information System (GIS) and to demonstrate the capability of GIS as a decision support system to design projects for integrated resource use and management, in a pilot watershed within the Panchayat.

Review of Literature

2. REVIEW OF LITERATURE

Geographic Information System (GIS) is a computerised spatial information system capable of supplying data or information for different levels of planning. In GIS, the maps can be prepared quickly at a lower cost than the conventional manual mapping and updating is easier. It also permits the users to enter different types of data *viz.*, satellite images, tabular data and descriptive text, in a single coordinate system, *i.e.*, map. The Panchayat Raj system of administration in India calls for mapping facilities which are capable of preparing maps at different levels of planning on different themes and as per the requirements of the users quickly and at low cost. This need can be addressed by designing a GIS at different levels of planning.

Research on the application of Remote Sensing (RS) and GIS for civilian applications is relatively new, since these tools were opened up for public use only in the recent past. But, within the last four to five decades, these technologies, together with the information technology revolution, have reached the common man and eased life on the planet substantially. Thus there are voluminous research outputs in these areas pertaining to all walks of life. Relevant literature on the fundamentals of RS and GIS and their applications in agricultural development, in particular and rural development, are collected and collated hereunder.

2.1 GEOGRAPHIC INFORMATION SYSTEMS

Several workers, according to the kind of GIS and its applications, have coined several definitions for this tool. According to Carter (1994), GIS is a system for capturing, storing, checking, integrating, manipulating, analyzing and displaying data, which are spatially referenced to the earth. Bernhardsen (1999) viewed GIS as a system of hardware, software and procedures designed to support the capture, management, manipulation, analysis, modeling and display of spatially referenced data for solving complex planning and management problems. Aronoff (1989) defined GIS as any computer-based procedure to capture and manipulate geographically referenced data (spatial data). Dueker and Kjerne (1989) defined GIS as a system of hardware, software, data, people, organization and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth. Clarke (2001) described GIS as an automated system for the capture, storage, retrieval, analysis and display of spatial data. Star and Estes (1990) suggested that GIS is both a database system with specific capabilities for spatially referenced data, as well as a set of operations for working with the data. Geographic Information System has been defined by Laurini and Thompson (1992) as a computer assisted system for the acquisition, storage, analysis and display of geographic data according to the user defined specification.

Geographic Information Systems (GIS) manage geographically-referenced information by integrating a database and mapping software and providing the tools to analyze spatial relationships between events or phenomena. So, GIS can be described 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, 1995). According to Dunn *et al.* (1997), GIS is a means of evaluating geographical relationships through spatial analyses, database management and geographical display. Chang (2002) defined Geographic Information System as a computer system for capturing, storing, querying, analyzing and displaying geographic data. GIS has four components namely computer system (hardware), GIS software, brain-ware and infrastructure.

Geographic Information System (GIS) has a digital data base management system designed to accept large volumes of spatial data from a variety of sources (Jensen and Christensen, 1986). GIS requires a spatial database representing the terrain situations. Such a database is the result of four levels of data abstraction namely reality, data model, data structure and file structure (Peuquet and Marble, 1990). A GIS has four features - a data input system, a data storage and retrieval system, a data processing and analyzing system and a data reporting system (Marble, 1990).

2.1.1 Data Sources for GIS

The information derived from various sources can be stored as a database in a GIS and enables future use of stored data for an effective and efficient manipulation of spatial and non-spatial data (Aravind and Rakesh, 2004). Lawas and Luning (1996) employed different data acquisition techniques like Rapid Rural Appraisal, farmer based interview schedule, field visit and observation, checklist of questions, analog maps, aerial photographs, published and unpublished reports and documents for primary as well as secondary data collection for integrating into a GIS for further analysis.

Rao (2000) had suggested geographic data base requirement for GIS applications at different scales. He opined that geographical data play a key role in deriving information on natural resources and environment and in the interpretation of spatial and attribute data in a GIS environment for decision-making.

Though topographical maps provide some spatial information about natural and cultural features of the terrain, it is not enough for developmental planning (Rao, 2000). Timely and reliable information on natural resources with respect to their potentials and limitations is a pre-requisite for sustainable development. The reconnaissance soil survey produce maps at 1:50000 scale which are useful for planning at taluk or district level. The detailed soil survey generates soil maps of 1:8000 or 1:4000 scale can be used for planning at village or block level (Natarajan and Arunkumar, 2001). Data sources for creating new data include remotely sensed data, GPS data and paper maps (Chang, 2002).

2.1.1.1 Remotely Sensed Data

Remote sensing is a science of deriving information about an object from measurements made at a distance from the object by a sensor without being in physical contact. The observation is made on the reflected, scattered or self emitted electro magnetic energy from the earth surface in different wavelength bands. The reflectance or emittance patterns under different spectral, polarization or temporal conditions provide signatures specific to a land cover class, which forms the basis for data interpretation (Deekshatulu and Joseph, 1991). Remote sensing applications cover diverse fields such as agricultural crop acerage and yield estimation, drought warning and assessment, land use or land cover mapping for agroclimatic planning, wasteland management, water resource management, ocean or marine resource survey and management, urban development, mineral prospecting, forest resources survey and management and so on, thus touching almost all facets of national development (Rao, 1991).

Rao, D. V. K. N. (2000) studied the reflectance of rubber along with teak and mixed forest in individual bands, false colour composite and Normalised Difference Vegetation Index (NDVI) images. A supervised classification was performed in the images and he found out that using the spectral signatures, rubber could be easily segregated from other vegetation types especially teak and mixed forests.

Integration of GIS and remotely sensed data has a long history and is well documented by Ehlers *et al.* (1989); Ehlers *et al.* (1991); Wilkinson (1996); Hinton (1996) and Chang (2002). GIS users can process satellite images and extract data for a variety of maps in vector format such as land use and land cover, hydrography, water quality and areas of eroded soils (Chang, 2002). Mesev *et al.* (1995) and Hinton (1996) reported the possibilities of creating maps on themes such as land cover, vegetation, urbanization, snow accumulation and environmental degradation by processing satellite images.

2.2 APPLICATIONS OF GIS

GIS is a problem-solving tool (Wright *et al.*, 1997). Any quantifiable social, economic or environmental impacts due to altering some of the conditions or uses may be monitored for a specific site using GIS (Walker and Miller, 1990). This tool is applicable in long term planning as well as in day-to-day management (Hassouna, 1997).

2.2.1 Agricultural Applications of GIS

The integration of hydrology and water quality (H/WQ) models with GIS is well documented in the literature particularly with respect to land use planning, water quality protection and natural resource management. Integrating models with a GIS overcomes the limitations of stand-alone or disjointed approaches to decision making. Also, increasingly powerful computer hardware coupled with lower processing costs and more sophisticated GIS software permit analyses of complex environmental issues in a more timely fashion. (Tim and Jolly, 1994). Pandey *et al.* (2003) integrated GIS with Soil Conservation Service (SCS) model for the estimation of runoff from the Karso watershed of Damodar Barakar catchment in Hazaribagh district of Jharkhand State. The method-involved integration of various types of information related to hydrologic soil group, vegetation and antecedent moisture condition of the watershed in ARC/INFO GIS to generate the vector layers. These layers were used as input to derive modified Soil Conservation Service (SCS) Curve Number for study area. The SCS model was then applied to estimate the runoff for daily storm and was validated comparing it with the measured runoff of few selected events of monsoon period for the year 1993.

Singh *et al.* (2003) developed a suitable methodology for estimating crop area by integrating remote sensing and GIS based spatial sampling approach. The methodology was developed on their study to estimate the area under wheat crop for the district of Rohtak, Haryana for the year 1995-96 using IRS-1B and LISS-II data. The results of the study show that inclusion of remote sensing parameter in GIS assisted spatial sampling techniques considerably enhance the performance of the estimators.

Hegazy *et al.* (2003) described a methodology in using remotely sensed data and Geographic Information System for monitoring the land use of Gabal Elba area, South Eastern Desert, Egypt. Using satellite data, different thematic maps have been produced by visual and digital interpretation of satellite. Topographic contour maps have been used for building Triangulation Integrated Network maps (TIN) for the area and for creating the slope map. These maps, in digital format, have been used as different layers at different levels for building a GIS model. Different interrelated maps have been used as layers affecting the suitability of the different parts of the area for agriculture development. The chosen layer maps were drainage network density, structure lineament density, soil type, terrain slope, and availability of ground water supply. The layers of these maps were combined together to yield an output. The model output provides the most suitable sites for the desired type of land use for agricultural development.

Sundaram *et al.* (2003) employed GIS and remote sensing technology for the identification of the lands that have reached low productivity of Therkar basin situated in the center parts of Madurai, Tamil Nadu. The thematic maps such as land use and soil map were generated from the geocoded image of IRS 1C and they were subjected to visual interpretation with reference to the SOI topographic map sheets (1: 50,000) to arrive at the productivity of land.

Garg and Seth (2003) integrated the information on land use and cropping pattern that was extracted with the help of multi-date satellite imageries as well as existing records and stored as different layers in GIS in the form of spatial and non-spatial data. Crop water requirement for different crops was appended as an information layer along with different data layers of water availability during the entire year, crop calendar, irrigation efficiency, land use efficiency, soil characteristics, proximity of market places, use of agro-chemicals and fertilizers, socio-economic parameters, climatic and weather conditions, ground water to assess possibility of conjunctive uses etc. Integrating above data layers along with analytical models they developed a framework for developing a Decision Support Systems (DSS) to solve complex irrigation problems.

Results of a GIS study gave clues to the reasons behind the high incidence of stunted disease in black pepper in some of the important districts of Kerala where the incidence is surveyed and data plotted. Environmental factors like altitude, temperature and rainfall were also included to corroborate the occurrence of vectors and the disease and it was found that the incidence of the disease is high in Wayanad and Idukki districts (Parthasarathy *et al.*, 2005).

2.2.2 Applications of GIS in Forestry

The population growth, industrial development, bio-climate changes and scarcity of land resources are the main reasons and causes of forest degradation in developing countries. To control and decrease forest degradation, the governments need to know where, when, how fast, and why (with what causes) such degradations happen. On the basis of such knowledge, a general and sustainable management of these resources will be possible.

Spatial information was used by public managers to estimate the forest type and forest distribution in US (Graetz, 1990; Lannom, 1995). It was also used to create thematic map data (Evans, 1994). Zhu (1994) mapped forest density using GIS tools. GIS was used heavily for tropical forest assessment (Kushwaha, 1990; Singh and Roy, 1990; Roy *et al.*, 1991; Benchalli and Prajapati, 1998; Singh *et al.*, 2003) and its relation to global warming (Gillespie, 1994). Other forestry application of remote sensing and GIS include planning in national parks, wild land protection, management and planning (Wilcox, 1984; Spear and Cottrill, 1993; Murphy and Smith, 1995; Niemann and Niemann, 1996), biodiversity conservation, extent of deforestation, gaps in conservation and habitat selection (Chang *et al.*, 1995; Menon and Bawa, 1997).

Geographic Information System was used in data collection about habitats and aided in forming a habitat data bank by McGarile (1994) and Thompson (1996). Jayakumar *et al.* (2002), in a case study to monitor the extent of degradation of forest in Kolli hills of Eastern Ghats using remote sensing and GIS obtained vital information for conservation and planning of the resources.

Saadi and Abolfazl (2003) used Remote sensing and GIS technology for analysis and estimation of deforestation in the forest area of Arasbaran in north-west of Iran in the period of 1987 and 2001.

2.2.3 Applications of GIS in Environmental Monitoring

The healthy living of citizens depends upon the successful and optimal exploitation of the natural resources, however a slight imbalance in any equilibrium is bound to manifest itself in the form of what we call as environmental hazard. GIS based software applications serve as powerful tools for effective environmental risk assessment and management. Raheja (2003) discussed an approach for the use of GIS-based software application framework for environmental risk management due to the need for displaying and analyzing a huge volume of the spatial as well as non-spatial environmental hazards, and exposure data, in a fast and accurate manner.

Integrated development is one of the important dimensions of economic aspects in our country. Mapping communities is therefore an integral component of planning and it is important that they include not only the physical or surface geography but also the social geography (Banarjee *et al.*, 2003). They used GIS technology to integrate and compile the data that were collected from the Surface Water Investigation Department, Health Department, Census data, District Rural Development Cell and District Statistical Hand Book as complete and accurate data were essential in building an information system that evaluated environmental hazard of tea garden belt in Jalpaiguri District, West Bengal.

Geographical Information System and Satellite Image Processing was used to identify, locate, map and analyze the existing data on the district for modeling the Arsenic hazard zones North 24-Pargana District of West Bengal (Basu and Sil, 2003).

Geographic Information System has been included as an analytical tool in a variety of natural resource management practices (Ji *et al.*, 1992; Schreier and Brown, 1992; Perumal, 2002; Nam *et al.*, 2003; Aravind and Rakesh, 2004; Srivastava *et al.*, 2004). Environmental monitoring requires analysis of database on natural resources and understanding the mutual interdependences of various resources (Rao, 1991). Remote sensing in tandem with GIS has been widely used in environmental monitoring (Johnston and Ji, 1994; Ramsey *et al.*, 1994). It served as an analytical tool in monitoring land degradation and soil loss (Wade and Wickham, 1995).

2.2.4 Applications of GIS in Disaster Management

Geographic Information System was used in evaluating damage from natural disaster (Tsuji *et al.*, 1996) and in monitoring pollution contamination of various types (Runyon *et al.* 1994; Pickus and Hewitt, 1992).

Sharma and Dubey (2003) attempted to develop an analytical object oriented model in GIS for flood plain zoning. Inputs to the model were extracted from synergistic use of remote sensing data and conventional data. The model may be used for utilization of flood plains in such a manner so as to reduce the flood damage and disaster.

Pandey *et al.* (2003) prepared a map using GIS technology showing the recorded earthquake data and other derived parameters generated for a part of Delhi city, thus producing the preliminary seismic microzonation map for Delhi. GIS technology was used for impact reduction of water network in urban areas and to provide decision supported disaster management during earthquake in Iran (Mehrizi, 2003).

Emam *et al.* (2003) evaluated risk of desertification of Varamin plain, Iran using GIS. They evaluated three indicators namely soil, ground water and land use using a Geographic Information System to arrive at the rate of desertification process.

2.2.5 Applications of GIS in Business

Business applications of GIS at regional, national and international levels have been demonstrated by Corbley (1995); Chalmers (1996) and Chisholm and Brown (1996). Planning of some business using GIS application is reported by Beniot (1995); Thompson (1996); Thrall (1996) and Stone (1996).

Ammana and Raina (2003) demonstrated the capability of GIS in planning strategy for business. They demonstrated the capability of GIS to integrate strategic business information such as sales, customers, inventory, demographic profiles, addresses and to relate these information geographically to spatially visualize data revealing relationship, pattern and trends in rural marketing. Implementation of GIS resulted in easier identification of markets on the targeted population strata. Number of route plans with desired options also could be worked automatically as well as manually with this application within a few minutes. This resulted into radical cutback in the time between data processing, planning and implementation.

2.2.6 Applications of GIS in Socio-economy

The system was used to identify and map areas of different social groups (Anderson *et al.*, 1993; Madsen, 1994; Lee and Culhane, 1995). It was also used to monitor and solve some urban problems of overpopulation (De Wit, 1992; Baha *et al.*, 1994; Rao *et al.*, 1999; Usha and Suresh, 2002).

GIS was used in medical and public health sectors to trace wide spread medical problems (Glass *et al.*, 1992; Beck *et al.*, 1995; Rushton *et al.*, 1995; Lam *et al.*, 1996) and coordinating planners and public health personnel (Werner and Hedland, 1995).

The use of GIS in routing traffic and traffic control has been demonstrated in various parts of the world (Akinyede, 1990; Genrich and Cooper, 1993; Schnicker, 1993; Cippolloni, 1994; Nyerges, 1995; Krakiwsky, 1996; Waters, 1999; CESS, 2001; Chattopadhyay *et al.*, 2002).

Urban planning, regional planning, studying regional growth and landscape architecture were some of the fields that have efficiently used GIS (Ehlers *et al.*, 1990; Bousaab and Steingraber, 1992; Treitz *et al.*, 1992; Genrich and Cooper, 1993; Azar *et al.*, 1994; Bocco and Sanchez, 1995).

The US military has intensively used GIS (Kish, 1995; Shank, 1996). Sherman (1995) reported that GIS was useful in identifying other uses of military lands. Lopata *et al.* (1992); Murphy and Smith (1995) demonstrated the capability of GIS in archeological studies especially for reveling hidden cultural and historical sites.

To better understand the patterns of administrative boundaries, location of administrative units, parliamentary and assembly constituencies, each of them should be brought on a common platform. Ashwani *et al.* (2003) tried an automated GIS application that uses ARC/INFO to precisely map all the information desired by the Election Commission of U.P., through the process of dasymetric mapping and brought out a base map containing district boundary, taluk boundary, drainage network, transport network and major settlement location to give general information of the study area. Further, using spatial overlay capability of GIS, assembly and parliamentary constituency boundaries were overlaid with district, taluk & transport network layers to get a single map containing all these information to prioritize the development activities to be carried out in future.

2.3 WATERSHED MANAGEMENT AND GIS

GIS has been used in various aspects of watershed management. The use of GIS in watershed related studies and decision support systems for management has been documented by Angermeier and Bailey (1992); James and Hewitt (1992); Pickus and Hewitt (1992) and Frye and Denning (1995). In India, integration of remote sensing and GIS for prioritizing watershed has been done by Navalgund (1995); Saini *et al.* (1995); Thakur *et al.* (1995); CEE (2001); Khan (2002) and Gosain and Rao (2004).

According to Mohrana (2002), GIS provides tools to delineate watersheds and in tandem with remote sensing data, delineation of watershed had become easier. Other operations of GIS in watershed management are its use in resource appraisal (Ram, 2002), evaluation of ground water potential (Sarkar *et al.*, 2001) and land use change detection (Dhinwa *et al.*, 1992; Luong, 1993; Bisht and Kothyari, 2001; Chakraborty *et al.*, 2001). 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 hydrogeo morphological 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.

2.4 DEVELOPMENT PLANNING

Planning is often seen as a state apparatus attempting to coordinate, rationalize and or reorganize human activity and distribution of resources (Simon, 1990). Planning process is a process of decision making about rational choices with the limited resources available to achieve the prioritized developmental objectives (Clayton and Dent, 2001). Planning is about preparing for the future (Clayton *et al.*, 2002).

Rural planning is concerned with the allocation and management of resources in the rural and rural–urban interface (Clayton *et al.*, 2002). Rural planning comprises of three crucial elements; the context – includes the objectives strategies and policies underlying the rural planning; the institutional framework within which the rural planning operates and the approach – top-down, bottom-up or blueprint approach (Plan Afric, 2000).

2.4.1 Commodity Based Planning

Agricultural development planning pursued hitherto in our country and in our state, has been focused on enhancing the production and availability of marketable commodities (for food or industrial raw materials or for export) such as rice, rubber, black pepper, tea, coffee, etc. Evolving policies, designing projects, building infrastructure, research, delivery systems and investment are all attuned to promote the production of these identified commodities. Such a paradigm of agricultural development did enable the state as well as our country in achieving appreciable production advances in selected commodities and attaining overall agricultural growth. However, there are quite a few facts, which are inherent in the development paradigm centered on commodities.

When development is focused on selected commodities only those areas endowed with resources congenial to the production are benefited while poorly endowed are left out naturally (say, the northern districts of Kerala). Thus the rainfed areas, the hilly areas and such other poorly endowed areas are out of the mainstream of development. Evidences are now emerging increasingly that the commodity based development approach has resulted in exclusion of substantial and significant proportion of regions and populations from the main stream of agricultural development (Saifudeen, 2001; Nair and Saifudeen, 2004). Macro economic and commodity-based planning has colluded with a continued plunder of natural resources while failing to secure rural livelihood (Clayton *et al.,* 2002). A shift from commodity-based approach towards resource-based approach is therefore inevitable.

2.4.2 Resource Based Planning

In resource-based planning approach, all the developmental processes would be focused in such a way that ensures sustainable development of total resources and help improve the livelihood security of the people subsisting on the limited and specific resources (Nair and Saifudeen, 2004). Ecological and economic sustainability are enhanced when available land, water, energy and human resources are used in a mutually reinforcing manner. A systems approach involving integrated attention to crop and livestock farming and to agroforestry and aquaculture will be helpful in generating more jobs and maximising income through value addition and in protecting the resource-health. Resource-based planning would lead to the optimised use of specific resource endowments in sustainable manner and help to improve the livelihood security of the people who subsist on them. Full utilisation of the production potentials, through intensification and diversification of the land and water resources themselves offer tremendous opportunities for income enhancement and generation of employment in the agriculture sector of the state.

The aim of the small farm-family households who constitute the bulk of the rural resource-poor in Kerala is not maximising returns from specific activity or product. The farmers' objective is maximising income and employment in a sustainable manner from the total resources, both biophysical and human, at the command of the households or to which they have access, through product conversion and thereby by value addition. Rural families put together a living, through multifarious activities. The urban concept of employment will have little meaning under such conditions. Every effort has to be made to optimise this strength of diversity of sources of occupation and income in daily life, through the integrated use and management of resources. Technology and support services should facilitate the realisation of this objective and thereby improve the livelihood security of the rural households.

2.4.3 Top-down and Bottom-up Approach

The strategy of planned development in the independent India evolved into a policy of centralized planning with a top–down approach. In the centralized top-down planning system, the Planning Commission of India became the powerful agency for disbursement of development fund and states started looking to the Planning Commission for direction and support (Gopalkrishna, 1997).

In the centralized vertical approach the State acted as the sole master in defining the needs of the local communities and determining the measures required to satisfy them and therefore made the local community dependant on outside agencies for solution to local problems (Gueye, 1999). Zazueta (1995) observed that more than 50 per cent of World Bank funded projects had been abandoned after few years on ceasure of external funding. The failure was accorded to top-down approach adopted, which resulted in lack of participation by local communities. Clayton and Sadler (2003) observed that the top-down approach was vulnerable to corruption, takes responsibility away from the people and were inefficient. In the top-down approach the developmental plans drawn up by outsiders with little or no reference to the priorities of the local people were often inappropriate or incompatible to the local community needs and cultural norms. (Zazueta, 1995; Clayton *et al.*, 2002). Though rural development initiatives had been initiated in many countries during the 1950's, the growth impulses did not trickle down as expected. The reasons were the top-down approach adopted in these countries. The centralized planning did not produce major impact despite considerable resources invested in development (Clayton *et al.,* 2002). This triggered attitudinal change from a top-down to bottom-up approach. The centralized standard blueprint of plans had gradually given way to the decentralized mode of planning and to utilization of local wisdom in plan preparation (Chattopadhyay *et al.,* 1999). Thus, planning philosophy started shifting towards participation and decentralization, *i.e.,* the bottom-up approach.

The reality of the most rural people is local, complex, diverse, dynamic, and uncontrolled (Chambers, 1994). He proposed to differentiate local conditions by following different policies in different places according to the different priorities, rather than drawing a universal panacea for solving all local problems. The basic principle underlying the participatory approach is the greater involvement of local people in defining the local problems, identifying solutions and implementing them to ensure more effectiveness and sustainability of the resulting programmes (Chambers, 1994; Gueye, 1999).

Participatory development is defined as a process through which the stakeholder influence and share control over the development initiatives, the decisions and the resources, which affect them. (World Bank, 1994). Blaikie (1985) proposed a bottom-up approach for understanding of decision making, the focus being placed on land, land users and the process starting with the actual people making decisions on how to use the land. Land use evaluation based on top-down approach does not take into account the aspiration, capabilities and constraints of local land users. (Bronsveld *et al.*, 1994)

FAO (1990) developed methodologies such as farming system analysis and participatory approaches to take into account the preference of local people in a bottom-up approach. Burrough (1996) stated that top-down approach was inadequate for land evaluation in resource scarce and market constrained areas.

2.4.4 Decentralization

The centralized planning adopted in India guide the states to seek Planning Commission's assistance for direction and support. The gap between expectations from and achievement of Indian planning started widening and a thinking ethos in favour of decentralization and deregulation of market took place. As a result economic as well as political decentralization was promoted. Economic decentralization aimed to deregulate market and political decentralization entrusted greater power to local bodies (Gopalkrishna, 1997).

The enactment of the 73^{rd} and the 74^{th} Constitutional Amendments in 1996 created 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, the decision-making in the area of rural development has been decentralised.

Kerala was one among the first states to enact political decentralization. It aimed to ensure transfer of administrative power from the state government to the Panchayat and peoples' participation in development (Issac and Harilal, 1997). During the late fifties and early sixties Grama Panchayats were formed in Kerala. Their activities consisted mostly of public works such as roads and buildings (Government of Kerala, 2000). In 1970's district planning offices were set up

(Sharma, 2003). In 1979, Kerala District Administration bill was passed. In mid 1980's the special component programme and Tribal Sub Plan were decentralized to be prepared at district level. In 1990 elected districts councils came into being.

The Kerala Panchayat Raj Act of 1994 endowed the Grama Panchayat with substantial powers and functions. The first election for the three-tier Panchayat was held in September 1995 and Grama Panchayats came into being on October 2nd 1995. Now Kerala State has 1001 Grama Panchayats, 53 Municipalities, 5 Corporations, 152 Block Panchayats and 14 District Panchayats.

The decentralised planning in Kerala primarily focuses on a development process based on the local resources and gives the opportunity to develop the resource base in a given area and to optimise it in a sustainable manner. Between 35-40 per cent of the total developmental expenditure is being implemented by Panchayath Raj institutions. The government of Kerala was very firm in its conviction that without involving people in the process of planning, no genuine democratic decentralisation can be brought about.

Nair and Saifudeen. (2004) suggested that the definition of people's participation in planning meant 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. Enabling the Panchayath Raj institutions means developing concurrently, the skills in plan formulation and implementation on one hand and on the other accessing them the controls of managing public resources, *viz.* human (government staff) and financial (plan and non plan investments).

Panchayath is the basic unit for planning because it is not only the resources entity but is also an institutional entity as the supporting institutions are organised and infrastructure is developed. At Panchayath level both physical resources and the supporting structures and institutions converge.

Economic observers were concerned about the poor economic growth and problems of low productivity and unemployment in the state (Dreze and Sen, 1996). The economic crisis was the major driving force for the intensive involvement of people as a bid to move out of the poor economic growth and low productivity syndrome. Several peoples' organizations in Kerala started experimenting with small developmental projects and many micro-level development initiatives in the state, especially in vegetable cultivation, water conservation and animal husbandry (Sharma, 2003). Industrialization and infrastructure development required state level intervention and a decentralized development strategy is suited for petty production centers and for basic services in Kerala.

2.5 PLANNING AND MANAGEMENT OF NATURAL RESOURCE

Managing natural resources keep those resources intact or modify to a state, which is optimal for the land use type selected. Management of natural resources is always achieved in view of an objective to improve the productivity and or living conditions of the local population on sustainable basis (Verheye, 1993). Strategic rural planning has to integrate elements of soil and water resource conservation, irrigation and drainage, water resource allocation, total catchments management, development of sustainable production system and their supporting infrastructure and the development of human capital of rural areas, for which knowledge of the land, capacity to change and the motivation to change is necessary (Clayton *et al.*, 2002).

CESS (1991) stated that development strategies hardly consider the micro level variations in terrain, climate, geology and socio economic factors apart from land holding. Developmental approaches that consider variations must be built at grass root level and should be based on evaluation and response of local areas and resources. Lack of information at local level especially in terms of socio economic issues and decision-making marks both the development and application of a government policy difficult (Bronsveld *et al.*, 1994; Rossiter, 1996).

Bronsveld *et al.* (1994) demonstrated the use of existing data and integration of remote sensing data and field data for improving land evaluation and making better land use plans. Wessels *et al.* (2001) pointed out that special data on the conservation status of natural resources are required at district, provincial and national scales to enable effective natural resources auditing and monitoring.

Blaikie and Brookefield (1987) proposed that a number of social-environmental data form the initial desired database for land use management practice. The data consists of socio economic characteristics of the decision makers and their access to resources. Singh (1995) said that there was still a considerable potential for development of agriculture in India, which could only be achieved through micro level planning starting from district and sub district levels. In his opinion the basic inputs for such a planning exercises were, database in terms of socio economic characteristics on status of development from micro level to district and state wise level, identification of underdeveloped micro level units, data on existing resources-natural and infrastructures, present pattern of utilization of resources and identification of potential development area.

A comprehensive information system encompassing data base on above identified characteristics would be of immense value for drawing up micro level plans and to integrate these data to evolve plans at district zone, state and nation as a whole. Decision making at all levels should be based on a knowledge system incorporating both biophysical and socio economic factors as they influence land use system (Bronsveld *et al.*, 1994; Rossiter, 1996). Menon and Bawa (1997) reiterated the need to integrate socio economic data and spatial data on land use change to understand the dynamics of land use change.

Ghosh (1995a) emphasized the need for generating database for Panchayat bodies at each tier of the three-tier system. Such a database should consist of socio-economic information of each and every individual member and information of Panchayat bodies' own resources, funds and assets. Ghosh (1995b) emphasized the need for generating a strong database in respect of resources available in the district and sub district level for strengthening decentralization in planning process. Detailed information on the natural resources, demography, agro climate, socio economic status, infrastructure and sectoral details were required for proper formulation of decentralized plan.

Information is vital for successful planning and development of a region. Any development plan requires the basic understanding of resources potential capability, utilization, conservation and management for its future sustainability and use. Integration of natural resource and socio-economic information allows arriving at possible solutions for sustainable development, which can be performed using Geographic Information System (Raghavswamy *et al.*, 1995; Rao *et al.*, 1995). Lawas and Luning (1996) in their quest to identify and analyze user knowledge and a procedure for quantifying and storing that knowledge in a system which allows quick analyses and processing, ended up in GIS.

The bridging of the resource gaps among various sections of the society can be done only with the help of sound planning and with computerized data base management. The collection, storing and manipulation of geographic data are essential at a regional or national level for planners. This can be easily done using advanced tools such as GIS (Palanisami, 2001). He further stated that computerizing of voluminous cartographic data and demographic data that are available in the Panchayat offices, village offices and town offices (micro level institutions), in the traditional methods of record keeping, will ease the development activity. In developing countries the data about natural resources and their use are incomplete and unreliable and much that was gathered has been lost (Clayton and Sadler, 2003).

The capacity of local institutions to manage natural resources depends on the quality of information they receive. The information on the formal roles of stakeholder as well as the formal information about the resources to be managed is lacking or inadequate (Clayton and Dent, 2001). The need for good quality information on a wide range of subjects is required for rural planning (Clayton and Sadler, 2003).

Collection of scientific information generated through modeling with other required information such as demographic, socio-economic, hydrological etc. is required for taking local-level decisions in micro-watersheds (Gosain and Rao, 2004). Chattopadhyay *et al.* (1999) described the scope and potential of Panchayat Resource Mapping (PRM) data by the panchayat for planning. In their study they had demonstrated how PRM data could be used in planning in education, health and watershed management and in social sectors citing Mezhuveli panchayat in Kerala state as an example.

2.6 RESOURCE MAPPING IN KERALA

Decentralization and micro-level planning with peoples' initiative and participation in the process of development was given emphasis during the Eighth Five Year Plan. The Panchayats became the center for developmental activities unlike in top-down approach and they were empowered for preparation and implementation of plans for economic development and social justice schemes. So, information related to resource availability, resource use and information gaps and potentials had to be generated or gathered at Panchayat level for preparing viable plans (Chattopadhyay *et al.*, 1999).

Map as a medium of communication was a felt need even at the grass-root level. An initiative in resource information generation at Panchayat level was started in 1990, and a programme entitled Panchayat level Participatory Resource Mapping was introduced by Centre for Earth Science Studies (CESS) in collaboration with Kerala Sastra Sahitya Parishad (KSSP). Twenty five Panchayats were included in the pilot scheme. The resource maps were prepared in 1:4000 scale. A sketch map showing the water resources of Vazhayoor Panchayat in Malappuram district prepared, by a team lead by A.P. Chandran - a primary school teacher, in 1989 was the first endeavour in this line (Chattopadhyay *et al.*, 1999).

Centre for Earth Science Studies had earlier brought out a Resource Atlas of Kerala in 1984 at 1:1,000,000 and 1:2,000,000 scales. In 1989, CESS with the help of Kerala State Planning Board prepared a series of maps for district planning of Kasaragod in the scale of 1:250,000. CESS (1991) reports that micro level resource survey in 1:12,500 scale for Ulloor Panchayat was completed with collateral plotting in 1: 3960 scale cadastral map. Now various governmental and Non-Governmental Organisations are working in this line.

The study under report made use of published maps and reports from Survey of India, Kerala State Land Use Board, Centre for Earth Science Studies, Socio Economic Unit Foundation and Panchayat Office. Technologies developed by researchers, as reported were also made use of, in the process of GIS preparation and resource analysis.

Materials and Methods

3. MATERIALS AND METHODS

The materials used and the methods adopted during the course of investigation are presented in this chapter.

3.1 LOCATION

The study was conducted in *Madakkathara* Grama Panchayat, *Ollukkara* block, *Thrissur* district, Kerala during the period 2001 to 2004 using the facilities of the Centre for Land Resources Research and Management, Kerala Agricultural University.

3.1.1 The Panchayat

The *Madakkathara* Panchayat is situated 8 kms away in the Northeastern direction from *Thrissur* town. Location map of the panchayat is presented in Fig.1. This panchayat came into existence from October 2nd 1969. The panchayat spans over 25.04 sq. km in area between 76° 14' 44" E and 76° 18' 54" E longitudes and 10° 32' 20" N and 10° 36' 08" N latitudes. The panchayat consist of three villages namely *Madakkathara, Vellanikkara* and *Kurichikkara*. There are 12 wards in the panchayat and is included in the *Ollukkara* assembly constituency. The panchayat is bordered by *Thekkumkara* Panchayat in the North, *Thrissur* Corporation in the South, *Panancheri* Panchayat in the East and *Thrissur* Corporation and *Mulangunnathukavu* Panchayat in the West.

Madakkathara Panchayat consists of 6 watersheds. They are *Mannuthi-Vettikal* watershed, *Chirakkekode* watershed, *Kachithode-Kothara* watershed, *Kadamkuzhi* watershed, *Pullamkandom* watershed and *Ponganamkodu* watershed. Among the six watersheds *Kachithode-Kothara* watershed spanning over 421 ha in the panchayat was selected for the study.

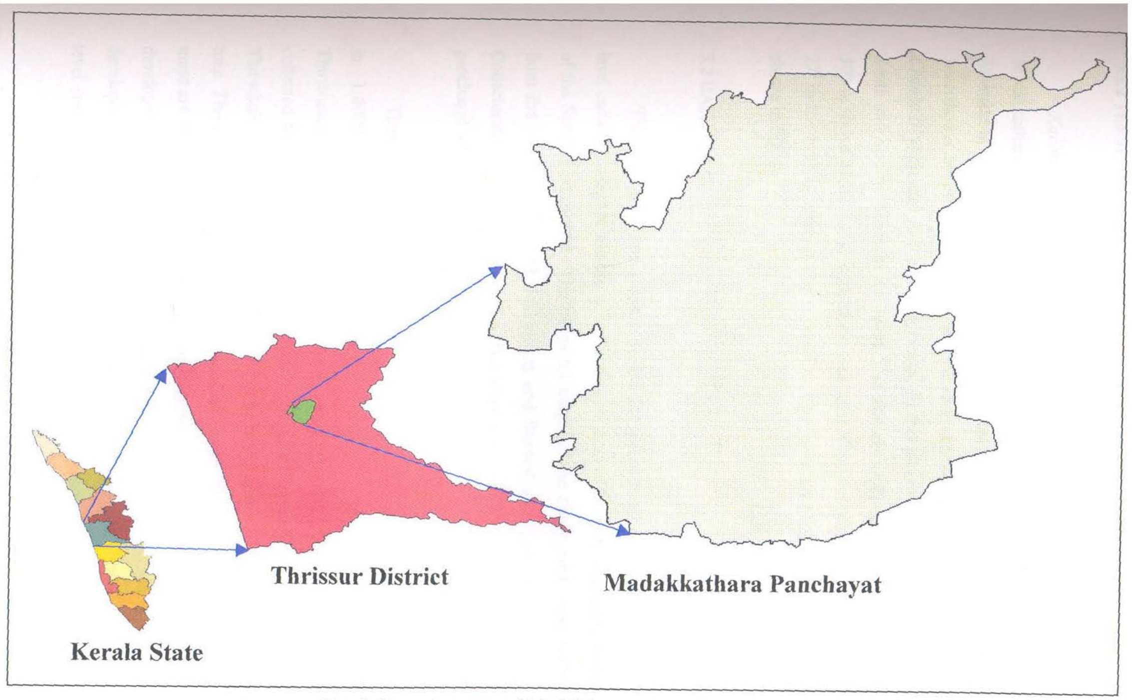


Fig. 1. Location map of Madakkathara Panchayat

3.1.2 The Watershed

Kachithode-Kothara watershed lies in the northeastern part of the Madakkathara Panchayat. *Kachithode-Kothara* watershed comprises of *Ninnukuzhi, Kachithode,* some parts of *Akkarapuram* and *Kallayi* area. The watershed is bordered by *Panancheri* panchayat in the East, Parts of *Vellanimala, Chenkallikunnu* and *Kallyi* in the North, *Kotharakunnu* and *Akkarapuram* in the South and *Kallayi thodu* in the West. The altitude of the area ranges from 20 m – 300 m above MSL. Land with slope less than 5° in the plains to slope more than 27° in the hills is seen in the watershed. The location of the study watershed is shown in Fig. 2.

3.2 BASE MAPS

The source of base maps required for micro level planning is the village level cadastral maps available with the departments of Land Records and Revenue of the State Government. The cadastral maps of the study area were collected from the village office, Madakkathara and Survey and Land Records Office, Collectorate, Ayyanthole, Thrissur. The maps were available at 1:3960 scale. The panchayat was covered in 8 sheets of A_0 size.

Thematic maps collected include the Land Use and Assets map prepared in 1:4000 scale by the Center for Earth Science Studies (CESS), Thiruvananthapuram and Madakkathara Panchayat in 1996. The maps were collected from the office of Kerala State Land Use Board, Aiyyanthole, Thrissur. The whole panchayat was depicted in 4 sheets in the case of Land Use and Assets map. The maps were photocopied in A_0 sized paper. Thematic or special purpose maps are maps that depict the distribution pattern of a theme (Chang, 2002). Area development planning requires thematic maps on appropriate scales to prepare development plans for both rural as well as urban sector at different heirarchial level (regional, district, taluk or village level) depending on the need. So any

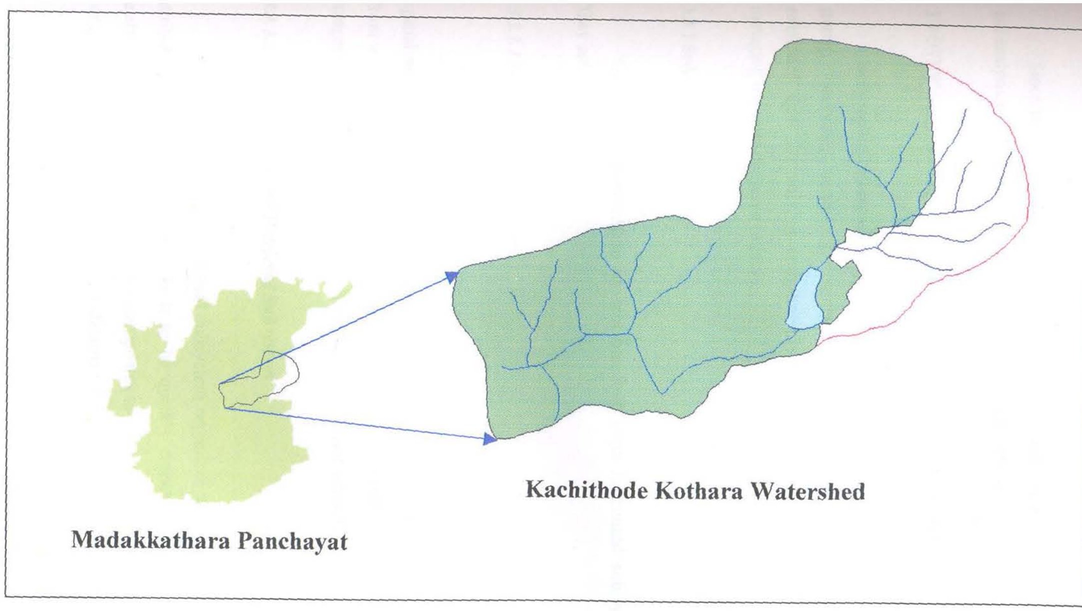


Fig. 2. Location of Kachithode-Kothara Watershed in Madakkathara Panchayat

development plan preparation require generation of thematic maps at the desired scale.

Since the GIS tools were used in the project under report, for preparation and analysis of the data, an overview of the techniques are presented hereunder.

3.3 OVERVIEW OF GEOGRAPHIC INFORMATION SYSTEMS

Geographic Information System (GIS) is a computer system for capturing, storing, querying, analyzing, manipulating and displaying geographically referenced data for solving complex problems in a more effective way by managing the information available.

3.3.1 Sub-systems of a GIS

Geographic Information System has four main functional sub-systems. They are:

3.3.1.1 Data Input Sub-system

A data input sub-system 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 and those from similar sources.

3.3.1.2 Data Storage and Retrieval Subsystem

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. Spatial data is usually encoded and maintained in a proprietary file format.

3.3.1.3 Data Manipulation and Analysis Subsystem

The data manipulation and analysis subsystem allows the user to define and execute spatial and attribute procedures to generate derived information. This subsystem is the heart of a GIS, and usually distinguishes it from other database information systems and computer-aided drafting (CAD) systems.

3.3.1.4 Data Output and Display Subsystem

The data output subsystem allows the user to generate graphic displays, normally maps, and tabular reports representing derived information products.

3.3.2 Components of a GIS

Any working GIS integrates five key components for effective functioning and analysis. They are discussed below.

3.3.2.1 Hardware

Hardware is the computer system on which a GIS operates. GIS software runs on a wide range of hardware types, from centralized computer servers, desktop computers used in stand-alone or networked configurations to mobile palm top computers.

3.3.2.2 Software

GIS software provides the functions and tools needed to store, analyze, and display geographic information. Some of the important GIS software are

Mapinfo, ArcView, Arc/Info, ArcGIS, SPANS, IDRISI, GRAM ++ and Geomatica.

3.3.2.3 Data

Data is the most important component of any GIS. Geographic data and related tabular data can be collected and compiled to custom specifications and requirements. A GIS can integrate spatial data with other existing data resources that are stored in a corporate DBMS. The integration of spatial data (often proprietary to the GIS software), and tabular data stored in a DBMS is the key functionality afforded by GIS.

3.3.2.4 People

The vital component of any GIS is the people. The GIS technology is of limited use without the people who manage the system and users who develop plans for applying it to real world problems.

3.3.2.5 Methods

A successful GIS operates according to a well-designed implementation plan and rules that are the models and operating practices unique to each organization using this technology.

3.3.3 The GIS Technology

A functional GIS requires integration of data with the geography of a place. The datum used in GIS is the most important component and an erratic datum will render any GIS useless. Therefore data component of GIS needs a thorough discussion.

3.3.3.1 Data Types in GIS

GIS technology utilizes two basic types of data. These are *spatial data* that describes the absolute and relative location of geographic features on the surface of earth and *attribute data* that describes the characteristics of the spatial features. These characteristics can be quantitative and/or qualitative in nature.

3.3.3.2 Data Models in GIS

Data model refer to the approaches for storing the data digitally in a GIS. There are two types of data models.

3.3.3.2.1 Spatial Data Models

All spatial data models are approaches for storing the spatial location of geographic features in a database. There are two basic types of spatial data models for storing geographic data digitally, namely, vector and raster models. The two primary spatial data encoding techniques are depicted in Fig.3. Images (pictures or photographs of the landscape) are also utilised in GIS with techniques very similar to raster data.

Vector storage implies the use of vectors (directional lines) to represent a geographic feature (Fig.4). Vector data is characterized by the use of sequential points or *vertices* to define a linear segment. Each vertex consists of an X cordinate and a Y cordinate. 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. Point features are defined by one coordinate pair - a vertex. Polygonal features are defined by a set of closed coordinate pairs.

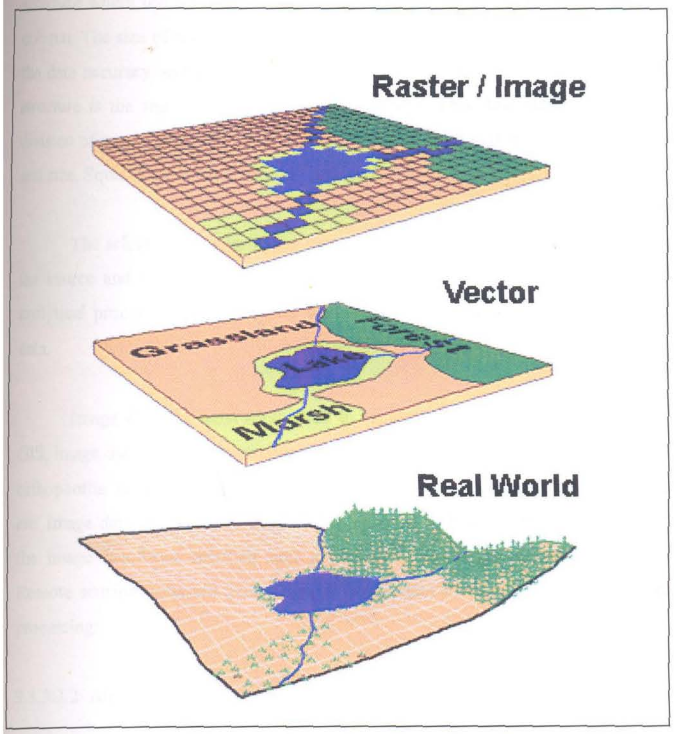


Fig. 3. Primary spatial data storing approach showing vector and raster models (Source: Berry, 1993)

Raster data models (Fig. 5.) incorporate the use of a *grid-cell* data structure where the geographic area is divided into cells identified by row and column. The size of cells in a raster data structure will be selected on the basis of the data accuracy and the resolution needed by the user. The most popular cell structure is the regularly spaced matrix structure. This data structure involves division of spatial data into regularly spaced cells. Each cell is of the same shape and size. Squares are most commonly utilized.

The selection of a particular data model, vector or raster, is dependent on the source and type of data, as well as the intended use of the data. Certain analytical procedures require raster data while others are better suited to vector data.

Image data are most often used to represent graphic or pictorial data. In GIS, image data are used to store remotely sensed imagery, *e.g.* satellite scenes or orthophotos, or ancillary graphics such as photographs, scanned plan documents, *etc.* Image data are typically used in GIS systems as background display data (if the image has been rectified and geo-referenced); or as a graphic attribute. Remote sensing software makes use of image data for image classification and processing.

3.3.3.2.2 Attribute Data Models

A separate data model is used to store and maintain attribute data for GIS software. These data models may exist internally within the GIS software, or may be done in external commercial database management software (DBMS). A variety of different data models exist for the storage and management of attribute data. The most common are Tabular model, Heirarchical model, Network model, Relational model and Object Oriented model. Of these, the Relational model and Object Oriented model are common.

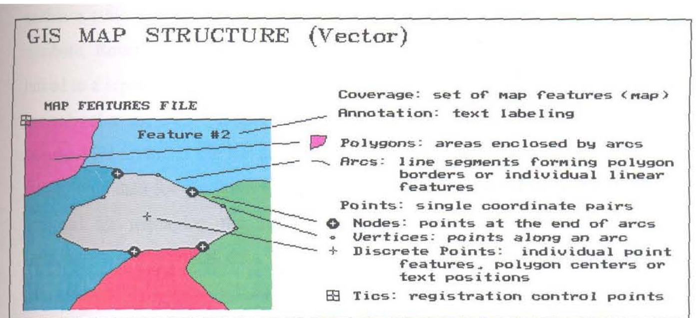


Fig. 4. Spatial data model showing vector data model (Source: Berry, 1993)

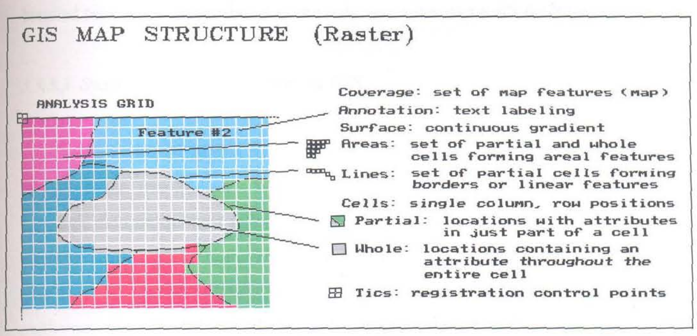


Fig. 5. Spatial data model showing raster data model (Source: Berry, 1993)

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. The basic linkage between a vector spatial data (topologic model) and attributes maintained in a relational database file are illustrated in Fig.6.

The object-oriented database model manages data through *objects*. An object is a collection of data elements and operations that altogether 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.

3.3.3.3 Spatial Data Relationships in GIS

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. 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 is a mathematical approach that allows us to structure data, based on the principles of feature adjacency and feature connectivity.

The most common topological data structure is the *arc/node* data model. This model contains two basic entities, the *arc* and the *node*. The arc is a series of points, joined by straight line segments that start and end at a node. The node is an

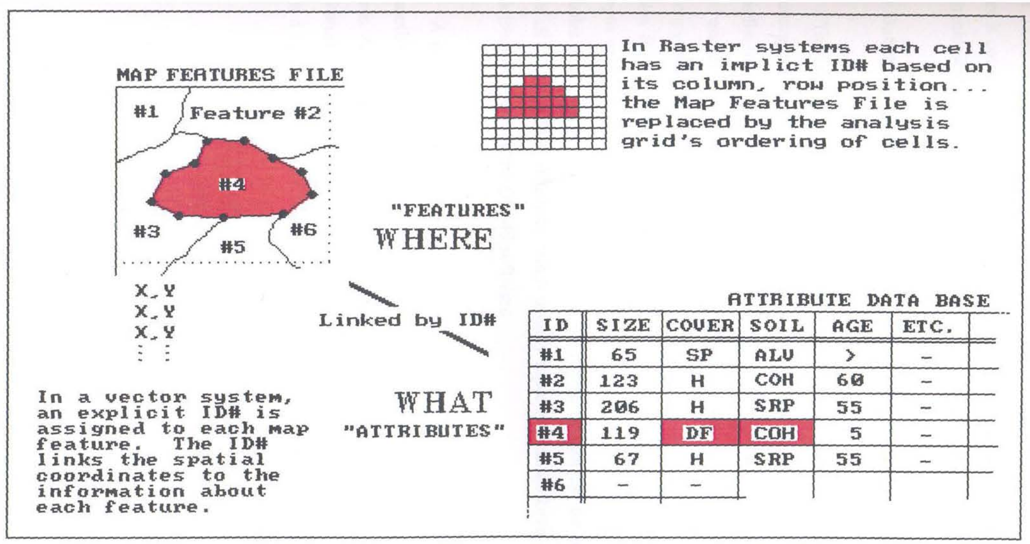


Fig. 6. Attribute data model showing relational database model (Berry, 1993).

intersection point where two or more arcs meet. Nodes also occur at the end of a *dangling* arc, *e.g.* an arc that does not connect to another arc such as a dead end street. Isolated nodes, not connected to arcs represent point features. A polygon feature is comprised of a closed chain of arcs. Since most input data does not exist in a topological data structure, topology must be *built* with the GIS software.

3.3.4 Data Sources for a GIS

The creation of a clean digital database is the most important and time-consuming task upon which the usefulness of the GIS depends. Therefore digital data is the most expensive part of the GIS. There are several data sources for both spatial and attribute data. The most common general sources for spatial data are hard copy maps, aerial photographs, remotely sensed satellite imagery, point data samples from surveys and existing digital files. Existing hard copy maps or *analogue maps*, provide the most popular source for any GIS project. Any textual or tabular data than can be referenced to a geographic feature can be input into a GIS as its attribute data. Attribute data is usually input by manual keying in or via a bulk loading utility of the DBMS software.

A map is a graphic representation of locations, explicitly and relative to one another. The map legend is the key linking the attributes to the geographic features. A map portrays the location and extent of the feature and relationship of one feature to other feature. The identification of relationships between features, within a common theme or across different themes, is the primary function of a GIS.

3.3.4.1 Characterizing Geographic Features

A map is composed of different geographic features represented as points, lines, and/or areas. Each feature is defined both by its location in space (with reference to a coordinate system), and by its characteristics. All geographic features on the earth's surface can be characterized and defined as one of three basic feature types. These are points, lines, and areas. Geographic features and the symbology used to represent them, e.g. point, line, or polygon, are dependant on the *map scale.* Therefore the use and comparison of geographic data from vastly different source scales is totally inappropriate and can lead to significant error in geographic data processing.

3.3.5 Data Input Techniques in GIS

There is no single method of entering the spatial data into a GIS. There are at least four basic procedures for inputting spatial data into a GIS. These are digitizing, automatic scanning, coordinate geometry and conversion of existing digital data.

Digitizing is the process of converting data from analog to digital format (Chang, 2002). Manual digitizing does majority of GIS spatial data entry. In manual digitizing, the user traces the spatial features with a hand-held magnetic pen, often called a *mouse* or cursor. While tracing the features the coordinates of selected points, e.g. vertices, are sent to the computer and stored. All points that are recorded are registered against positional control points, usually the map corners, which are keyed in by the user at the beginning of the digitizing session. Of late onscreen digitizing from scanned maps is possible with software like AutoCAD, R2V, Ace and so on.

Scanning is a digitizing method that converts an analog map into a scanned file, which is then converted to vector format through tracing (Verbyla and Chang, 1997). A variety of scanning devices exist for the automatic capture of spatial data.

A third technique for the input of spatial data involves the calculation and entry of coordinates using coordinate geometry (COGO) procedures. This involves entering, from survey data, the explicit measurement of features from some known monument.

Fourth technique for data input is the conversion of existing digital data. A variety of spatial data, including digital maps, are openly available from a wide range of government and private sources.

3.3.6 Data Editing and Quality Assurance

Data editing and verification is performed to reduce the errors that arise during the encoding of spatial and non-spatial data. Several kinds of errors can occur during data input. They are incompleteness of the spatial data, locational placement errors of spatial data, distortion of the spatial data, incorrect linkages between spatial and attribute data and incomplete or wrong attribute data.

3.3.6.1 Manipulation and Transformation of Spatial Data

The maintenance and transformation of spatial data concerns the ability to update, manipulate, and transform data once it has been created. There are many manipulation and transformation procedures for spatial data. Examples include Coordinate Thinning, *i.e.*, the *weeding* or reduction of coordinate pairs, e.g. X and Y, from arcs. This function is often required when data has been captured with too many vertices for the linear features.

Geometric transformations are 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. Warping, under geometric transformations involves warping a data layer stored in one data model, either raster or vector, to another data layer stored in the opposite data model. Map Projection transformations mean 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 are acquired in a different projection than the other data layers it must be transformed.

Conflation is formally defined as the procedure of reconciling the positions of corresponding features in different data layers. Conflation is concerned with the process for removing slivers and reconciling the common boundary. More commonly this is referred to as sliver removal.

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 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.

3.3.7 Organizing Data for Analysis in GIS

Most GIS software organizes spatial data in a thematic approach that categorizes data in vertical and horizontal *layers*. This approach allows data to be input as separate themes and overlaid based on analysis requirements. Spatial data layers are commonly input one at a time and accordingly, attribute data are entered as one layer at a time. A variety of terms are used to define data layers in commercial GIS softwares. These include themes, coverages, layers, levels, objects, and feature classes. In any GIS project a variety of data layers will be required. Most GIS projects integrate data layers to create derived themes or layers that represent the result of some calculation.

The organization of data layers in a horizontal fashion within a GIS is known as *spatial indexing,* which involve the partitioning of the geographic area into manageable subsets or *tiles*. These tiles are then indexed mathematically for quick searching and retrieval when querying is initiated by a user.

3.3.8 Editing and Updating of Data in GIS

Perhaps the primary function in the data storage and retrieval subsystem involves the editing and updating of data. Data editing capabilities required in a GIS software are interactive editing of spatial data; interactive editing of attribute data; the ability to add, manipulate, modify, and delete both spatial features and attributes (independently or simultaneously) and the ability to edit selected features in a batch processing mode.

The updating function is of great importance for any GIS project. Updating of data implies the resurvey and processing of new information. This process increases the accuracy and/or detail of the data layer.

3.3.9 Data Retrieval and Querying in a GIS

Data retrieval involves the capability to easily select data for graphic or attribute editing, updating, querying, analysis and/or display. The ability to retrieve data is based on the unique structure of the DBMS and command interfaces are commonly provided with the software. Querying is the capability to retrieve data, usually a data subset, based on some user-defined formula. Querying is generally performed by the use of a Structured Query Language (SQL).

The integration of data provides the ability to ask complex spatial or locational questions such as *how much? where?* and *what if?*, that could not be answered otherwise. Answers to locational and quantitative questions require the combination of several different data layers to be able to provide a more complete and realistic answer. The ability to combine and integrate data is the backbone of GIS. The technique used to solve these questions is called *spatial modelling.*

Spatial modelling infers the use of spatial characteristics and methods in manipulating data. Methods exist to create an almost unlimited range of capabilities for data analysis by stringing together sets of primitive analysis functions.

3.3.10 Data Analysis in GIS

The capability of GIS software for transforming the original spatial data in order to be able to answer particular queries differentiates GIS software from CAD mapping software. The chief advantage of using GIS software is that the analytical functions are totally integrated with the DBMS component which is the basis for all analysis techniques. Most GIS's provide the capability to build complex models by combining primitive analytical functions. Aronoff (1989) identified four categories of GIS analysis functions. The range of analysis techniques in these categories is very large.

3.3.10.1 Retrieval, Reclassification and Generalization

Reclassification is an attribute generalization technique. 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. Accordingly, features adjacent to one another that have a common value but differ in other characteristics will be treated and appear as one class. In a raster based GIS, this function makes use of polygon patterning techniques such as crosshatching and/or color shading for graphic representation. In a vector based GIS, boundaries between polygons of common reclassed values are *dissolved* to create a cleaner map of homogeneous continuity. The ability and process for displaying the results of reclassification, a map or report, will vary depending on the GIS software.

3.3.10.2 Topological Overlay

The capability to overlay multiple data layers in a vertical fashion is the most common technique in geographic data processing. Topological overlay is predominantly concerned with overlaying point data in polygon, line data in polygon, and polygon on polygon. By combining multiple layers in a topological fashion complex queries can be answered concerning attributes of any layer.

3.3.10.3 Neighbourhood Operations

Neighbourhood operations evaluate the characteristics of an area surrounding a specific location. Neighbourhood operations include interpolation and buffering.

Interpolation is the method of predicting unknown values using known values of neighbouring locations. A variety of *point interpolation* techniques including slope and aspect calculations, contour generation etc are available in common GIS softwares. Interpolation is generally used with irregularly or regularly spaced point-based elevation data. Irregularly spaced-points are stored in a Triangular Irregular Network (TIN). A TIN is a vector topological network of triangular facets generated by joining the irregular points with straight-line segments. The TIN structure is preferred when data available is irregular.

Triangular Irregular Network (TIN) is a vector data model for 3-D data. An alternative in storing elevation data is the regular point Digital Terrain Model

(DTM). The term DTM usually refers to a grid of regularly spaced elevation points. These points are usually stored with a raster data model.

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.

3.3.10.4 Connectivity Analysis

Connectivity operations do the analysis of surfaces and networks. Proximity analysis, network analysis, spread functions and three dimensional surface analysis such as visibility and perspective viewing are some of the analytical procedure included in this operation.

Proximity analysis is the ability to identify any feature that is near any other feature based on location, attribute value or a specific distance. These functions are primarily concerned with the proximity of one feature to another. The identification of *adjacency* is another proximity analysis function. Adjacency is defined as the ability to identify any feature having certain attributes that exhibit adjacency with other selected features having certain attributes.

A network is a topology-based line having the appropriate attributes for the flow of objects. Network analysis techniques commonly used 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.

Three-dimensional analysis involves a range of different capabilities. The functions that can be performed using three-dimensional analysis are identification of *viewsheds*, the *draping* of features *viz.*, point, lines, and shaded polygons onto the perspective surface, generation of shaded relief models simulating illumination and presentation of symbology on the 3-D surface.

3.4 TRACING, SCANNING AND DIGITISING OF MAPS

3.4.1 Tracing

The whole panchayat was available in 8 sheets of different size but width confirming to that of A_0 sheet. These sheets were manually joined to reduce the errors while performing on screen digitizing and map joining function. The maps were joined appropriately to include the whole area of panchayat into the width of A_0 size tracing paper. The details in the cadastral maps were then traced on to the tracing paper to be scanned using A_0 drum scanner. As the land use and asset maps were available in identically sized A_0 sheets tracing was not required.

3.4.2 Scanning

The maps were scanned using a rotary drum scanner that can scan data from opaque paper or tracing paper or films with width upto 48''. The scanning was performed at the GIS division of Information Kerala Mission, Thiruvananthapuram. The scanned file was saved in *. tiff format.

3.4.3 Digitising

To complete the digitizing process the scanned file must be vectorised. The scanned files were appropriately joined using the map join function in the AutoCAD environment for which AutoCAD 2000 software was used.

Vectorisation was performed using Able Software Corporation's R2V software available at the Center for Land Resources Research and Management, Kerala Agricultural University, Thrissur. The scanned files were digitised on-screen using the R2V software. The digitised maps were saved in *.prj format to be further exported to DXF format. The vectorised file was then imported into PC Arc/Info to make Arc/Info coverage and they were further transformed into Arcview shape files for further analysis.

3.4.5 Contour tracing and digitizing

Contours of the panchayat were traced from Survey of India topographical sheet numbered 58B/6/SW and 58B/2/SE. The contours at 10 m interval was traced manually on a tracing film, scanned using A_0 scanner available at M/s Bahavana Photostats, Thrissur and digitized using Able Soft Corp. R2V to carry out terrain analysis of the study area. The analysis was carried out using ArcView 3.1 software of Environmental System Research Institute (ESRI).

3.5 PROJECTION OF DIGITISED SPATIAL DATA

The transformation from the geographic grid to a co-ordinate system is referred to as Map Projection (Chang, 2002; Kumar, 2004). The digitized map was projected using ground control points with known co-ordinates by the projection utility available with ESRI's PC ARC/INFO. The ground control points used for projection of spatial data were Thanikudam temple (76° 15' 36" E Longitude and 10° 34' 12" N Latitude), Kerala Agricultural University Head Quarters (76° 17' 24" E Longitude and 10° 33' 00" N Latitude), Subhramania temple, Padinjare Vellanikkara (76° 15' 36" E Longitude and 10° 33' 00" N Latitude) and VHSS, Katilapoovam (76° 17' 24" E Longitude and 10° 36' 00" N Latitude). Ground control points were obtained from Survey of India topographical sheet numbered 58B/6/SW and 58B/2/SE at 1:25000 scale.

The "project" utility available with ArcView allowed projecting shape file from one co-ordinate system to other to the other. The digitized contours were projected using the reference grid traced from the Topographical sheet of Survey of India. Albers equal-area projection system was followed as the projection for the current study.

3.6 PRIMARY DATA COLLECTION

Primary data collection for getting socio-economic data about the homesteads and farmsteads in the watershed was done by conventional survey method using a structured, pre-tested schedule of enquiry. Common assets and infrastructure details of the panchayat were collected by transect walk conducted through the watershed and confirmed with the details in reports and other published data.

3.7 SECONDARY DATA COLLECTION

Secondary data collected about the panchayat included data on biophysical and socio-economic resources of the panchayat. Important sources for secondary data regarding the Panchayat were "*Samagra Vikasana Rekha – 1996*" which was the developmental report for the 9th five year plan, *Varshika Padhithi Rekha 2001-2002* which is the annual plan report for the year 2001-02, IRS –1C's LISSIII+ PAN data. at 1:12500 scale acquired on 12th January 2002 for assessing the current land use, details from the land use and asset map prepared by CESS on Madakkathara Panchayat and other relevant data received from the Panchayat. Soil related details were collected from the Soil Survey Organization, Government of Kerala. Population details were collected from Primary Census Abstract for the year 2001 from the Directorate of Census Operation, Kerala.

3.8 SATELLITE IMAGERY ANALYSIS

A satellite imagery of Madakkathara Panchayat was purchased from National Remote Sensing Agency, Hyderabad for assessing the current land use.

The imagery was IRS –1C's LISSIII+ PAN data at 1:12500 scale acquired on 12th January 2002. The LISS III + PAN imagery of IRS –1C was analyzed using the ERDAS Imagine 8.4 software available at Invis solutions, Thiruvananthapuram.

3.9 TABULAR DATABASE GENERATION

Quantitative data generated through primary data collection and secondary data collection from various sources was tabulated using the tabular facility available with ArcView software. The tabular data was linked to the spatial data in ESRI's ArcView 3.1 for effective spatial data analysis.

3.10 DATA ANALYSIS IN GIS

Once the spatial data and tabular data were generated, then various GIS analyses were performed using the capabilities of ArcView 3.1 software to overlay, clip, merge, and to create Triangulated Irregular Network of the panchayat for making thematic maps relevant for the optimized resource use of the panchayat.

Application of GIS techniques have yielded integrated database on the biophysical and socio-economic features of the Madakkathara Grama Panchayat and the Kachithode-Kothara watershed.

Results

4. RESULTS

Madakkathara Panchayat of Thrissur district was inventoried under this project, in which research materials were secondary data generated by different organisations as well as primary data generated through traditional survey and transect walks. The methodology adopted was systematic development of layers in a GIS platform, using tools available in different GIS softwares. The results, evidently, are spatial data on various themes relevant to the agricultural development of the panchayat and the *Kachithode-Kothara* watershed as well as attribute tabular data pertaining to every geographical entity in the study area. Salient results of the current study are presented in this chapter.

4.1 ADMINISTRATIVE DIVISIONS OF MADAKKATHARA PANCHAYAT

The administrative boundary of Madakkathara Panchayat has been digitized and projected using, Albers equal-area projection system, for integrating data in a Geographic Information System (GIS). The digitized spatial data on Madakkathara Grama Panchayat boundaries and constituent village boundaries are depicted in Fig. 7. The panchayat extends over 25.04 sq. km and lies between 76° 14' 44" E and 76° 18' 54"E longitudes and 10° 32' 20"N and 10° 36' 08" N latitudes. Panchayat consist of three villages namely *Madakkathara, Vellanikkara* and *Kurichikkara*.

4.1.1 Administrative Wards

Madakkathara Panchayat comprised 12 administrative wards during the *study* period. The panchayat with its 12 wards are depicted in Fig. 8. Details of Census 2001 are attached to the spatial database of individual wards of the panchayat. An excerpt of the Primary Census Abstract – 2001, of individual wards of the panchayat is presented in Table 1.

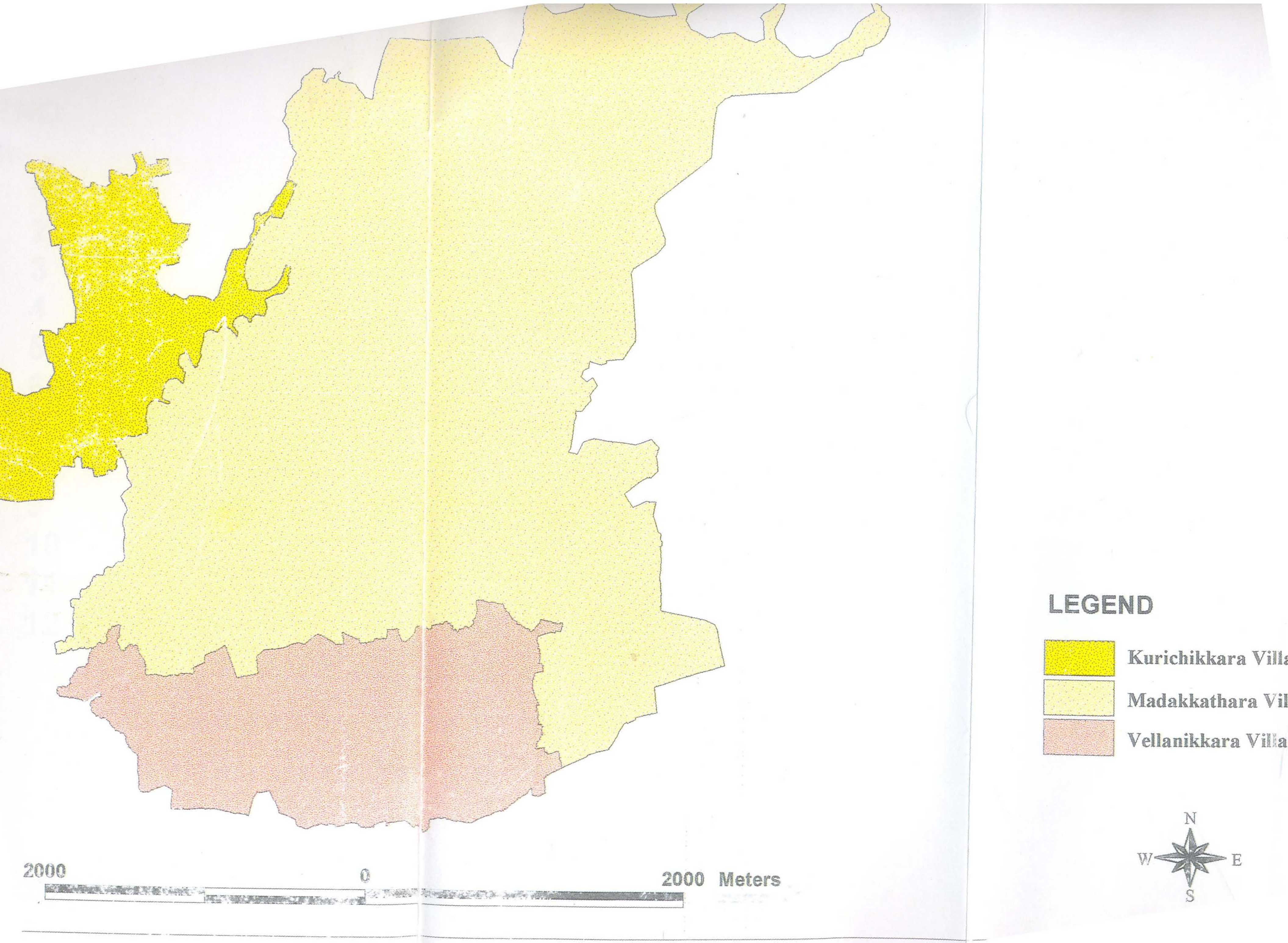


Fig. 7. Administrative villages comprising Madakkathara Panchayat (GIS

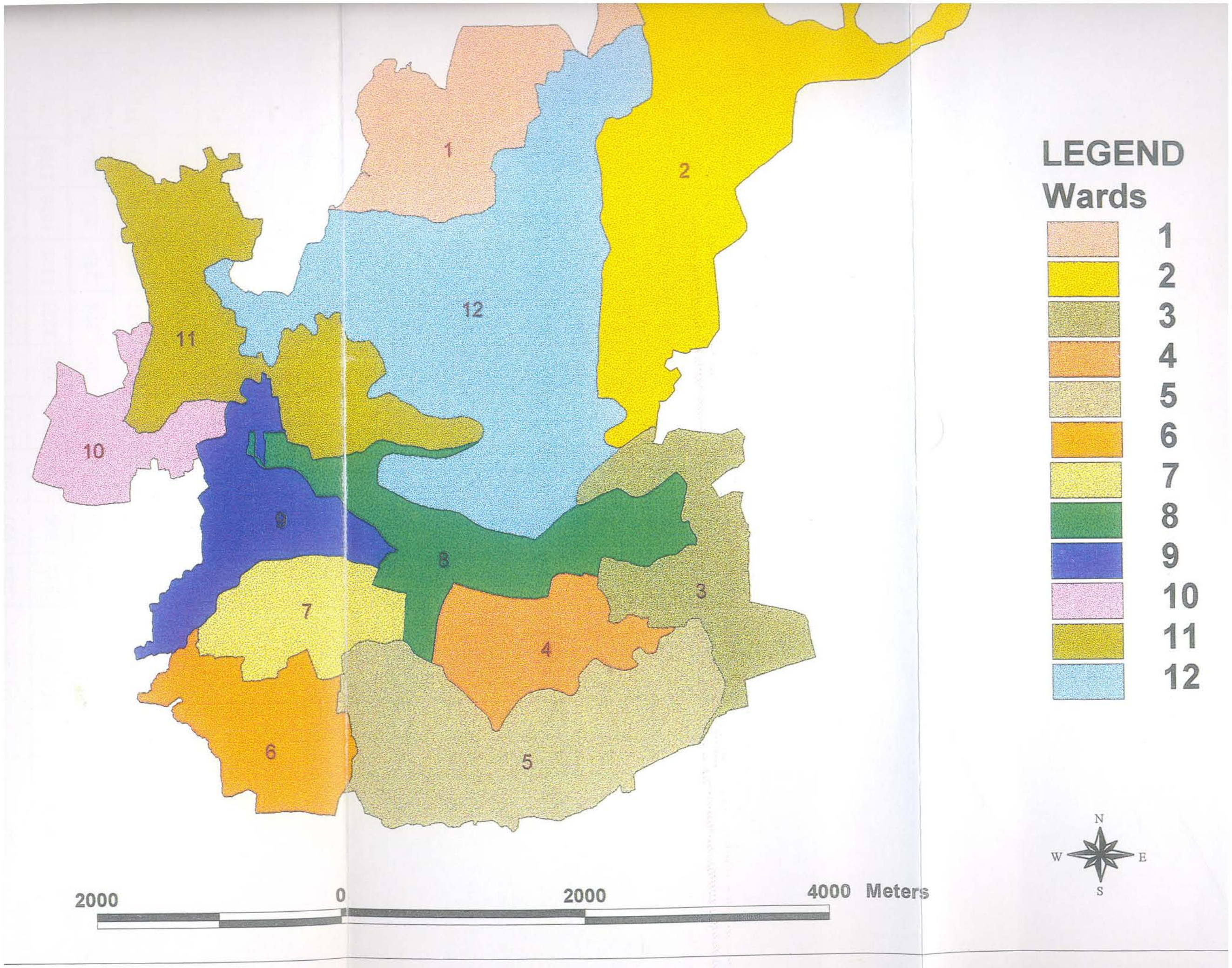


Fig. 8. Administrative wards of Madakkathara Panchayat (GIS output)

Table 1. Primary census abstract of individual wards of Madakkathara Panchayat

Particulars		GIS Database Field	Ward Numbers												Total
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
No. of Households		No_HH	440	443	467	462	426	516	527	491	439	531	483	440	5665
Total Population	Person	TOT_P	1866	1923	2045	2089	1814	2373	2285	2059	2104	2310	2141	1925	24934
	Male	TOT_M	934	957	982	1101	881	1152	1107	1029	996	1112	1043	932	12226
	Female	TOT_F	932	966	1063	988	933	1221	1178	1030	1108	1198	1098	993	12708
Total Population in the age group 0 - 6 years	Person	P_06	173	225	211	201	236	278	275	223	249	263	218	212	2764
	Male	M_06	85	106	111	98	134	137	138	109	117	132	105	98	1370
	Female	F_06	88	119	100	103	102	141	137	114	132	131	113	114	1394
Scheduled Castes	Person	P_SC	273	85	30	95	224	171	211	145	256	107	312	134	2043
	Male	M_SC	121	40	17	56	107	81	108	70	111	51	146	56	964
	Female	F_SC	152	45	13	39	117	90	103	75	145	56	166	78	1079

(Continued)

Table 1. Primary census abstract of individual wards of Madakkathara Panchayat (Continued)

Particulars		GIS Database Field	Ward Numbers												Total
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Scheduled Tribes	Person	P_ST	0	0	0	2	0	0	0	0	0	0	0	0	2
	Male	M_ST	0	0	0	2	0	0	0	0	0	0	0	0	2
	Female	F_ST	0	0	0	0	0	0	0	0	0	0	0	0	0
Literates	Person	P_LIT	1553	1559	1642	1711	1457	1961	1803	1673	1653	1969	1718	1535	20234
	Male	M_LIT	804	805	827	966	713	981	905	867	824	962	869	770	10293
	Female	F_LIT	749	754	815	745	744	980	898	806	829	1007	849	765	9941
Illiterates	Person	P_ILL	313	364	403	378	357	412	482	386	451	341	423	390	4700
	Male	M_ILL	130	152	155	135	168	171	202	162	172	150	174	162	1933
	Female	F_ILL	183	212	248	243	189	241	280	224	279	191	249	228	2767

(Continued)

Table 1. Primary census abstract of individual wards of Madakkathara Panchayat (Continued)

Particulars		GIS Database Field	Ward Numbers												Total
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Total Workers	Person	TOT_WORK_P	738	651	743	729	646	832	875	559	845	741	811	724	8894
	Male	TOT_WORK_M	543	520	555	497	451	624	623	388	585	567	562	567	6482
	Female	TOT_WORK_F	195	131	188	232	195	208	252	171	260	174	249	157	2412
Main Workers	Person	MAINWORK_P	724	497	703	662	435	692	783	515	607	709	517	665	7509
	Male	MAINWORK_M	533	426	535	459	316	540	586	366	471	549	377	535	5693
	Female	MAINWORK_F	191	71	168	203	119	152	197	149	136	160	140	130	1816
Main Cultivators	Person	MAIN_CL_P	73	133	45	22	27	42	52	46	36	22	46	95	639
	Male	MAIN_CL_M	65	124	43	13	22	40	50	42	34	21	41	82	577
	Female	MAIN_CL_F	8	9	2	9	5	2	2	4	2	1	5	13	62

(Continued)

Table 1. Primary census abstract of individual wards of Madakkathara Panchayat (Continued)

Particulars		GIS Database Field	Ward Numbers												Total
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Main Agricultural Labourers	Person	MAIN_AL_P	20	48	45	107	26	34	90	90	83	46	42	48	679
	Male	MAIN_AL_M	11	43	30	63	19	17	53	42	41	27	26	41	413
	Female	MAIN_AL_F	9	5	15	44	7	17	37	48	42	19	16	7	266
Main Household Industry	Person	MAIN_HH_P	13	40	42	20	17	50	32	11	37	26	30	11	329
	Male	MAIN_HH_M	5	33	30	15	13	41	24	6	34	18	22	9	250
	Female	MAIN_HH_F	8	7	12	5	4	9	8	5	3	8	8	2	79
Main Other Workers	Person	MAIN_OT_P	618	276	571	513	365	566	609	368	451	615	399	511	5862
	Male	MAIN_OT_M	452	226	432	368	262	442	459	276	362	483	288	403	4453
	Female	MAIN_OT_F	166	50	139	145	103	124	150	92	89	132	111	108	1409

(Continued)

Table 1. Primary census abstract of individual wards of Madakkathara Panchayat (Continued)

Particulars		GIS Database Field	Ward Numbers												Total
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Marginal Workers	Person	MARGWORK_P	14	154	40	67	211	140	92	44	238	32	294	59	1385
	Male	MARGWORK_M	10	94	20	38	135	84	37	22	114	18	185	32	789
	Female	MARGWORK_F	4	60	20	29	76	56	55	22	124	14	109	27	596
Marginal Cultivators	Person	MARG_CL_P	1	10	0	1	6	5	14	1	3	0	6	3	50
	Male	MARG_CL_M	1	8	0	1	5	5	9	1	3	0	5	2	40
	Female	MARG_CL_F	0	2	0	0	1	0	5	0	0	0	1	1	10
Marginal Agricultural Labourers	Person	MARG_AL_P	1	46	10	15	108	17	35	3	109	10	206	8	5647 8
	Male	MARG_AL_M	1	31	6	8	71	5	4	1	29	4	123	4	287
	Female	MARG_AL_F	0	15	4	7	37	12	31	2	80	6	83	4	281

(Continued)

Table 1. Primary census abstract of individual wards of Madakkathara Panchayat (Continued)

Particulars		GIS Database Field	Ward Numbers												Total
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Marginal Household Industry	Person	MARG_HH_P	0	19	4	1	3	6	4	0	7	0	9	3	56
	Male	MARG_HH_M	0	7	3	0	2	5	1	0	1	0	5	3	27
	Female	MARG_HH_F	0	12	1	1	1	1	3	0	6	0	4	0	29
Marginal Otherworkers	Person	MARG_OT_P	12	79	26	50	94	112	39	40	119	22	73	45	711
	Male	MARG_OT_M	8	48	11	29	57	69	23	20	81	14	52	23	435
	Female	MARG_OT_F	4	31	15	21	37	43	16	20	38	8	21	22	276
Non Workers	Person	NON_WORK_P	1128	1272	1302	1360	1168	1541	1410	1500	1259	1569	1330	1201	16040
	Male	NON_WORK_M	391	437	427	604	430	528	484	641	411	545	481	365	5744
	Female	NON_WORK_F	737	835	875	756	738	1013	926	859	848	1024	849	836	10296

(Continued)

Table 1. Primary census abstract of individual wards of Madakkathara Panchayat (Continued)

Particulars		GIS Database Field	Ward Numbers												Total
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Institutional Population	Person	INST_P	0	0	7	71	76	0	7	0	16	13	0	6	196
	Male	INST_M	0	0	4	71	20	0	4	0	6	0	0	2	107
	Female	INST_F	0	0	3	0	56	0	3	0	10	13	0	4	89
Houseless Population	Person	HLESS_P	0	1	0	0	0	0	0	0	0	0	0	0	1
	Male	HLESS_M	0	1	0	0	0	0	0	0	0	0	0	0	1
	Female	HLESS_F	0	0	0	0	0	0	0	0	0	0	0	0	0

4.1.2 Cadastral Details

The digitized cadastral map showing the survey numbers is presented as a separate theme in the GIS for the panchayat. GIS out put of cadastral map with the survey numbers is in Fig. 9. The cadastral maps in 1:4000 scale is the basic revenue record available in the village offices in the panchayat. The data regarding land ownership and area of each survey number could not be gathered due to official restrictions. Resurvey was not conducted in the three villages of the panchayat. Settlements are observed even in the area marked as reserved forest in the cadastral map. Many of the settlers do not have the title deed of the land *(pattayam),* but enjoy rights of the land.

4.2 HUMAN RESOURCES

The total population of the panchayat (including institutional and houseless population) was 24934, out of which 12226 were men and 12708 were women. There were 2764 persons belonging to the age group 0-6 years, of which 1370 were male and 1394 were female. The Scheduled Caste population was 2043, of which 964 were male and 1079 females. There are only 2 Scheduled Tribe males in the panchayat, residing in ward II.

4.2.1 Literacy

The panchayat is not cent per cent literate. The total literate people in the panchayat are 20234 of which 10293 were men and 9941 were women (Table 1.). Among the 4700 illiterates in the panchayat 1933 were males and 2767 were females.

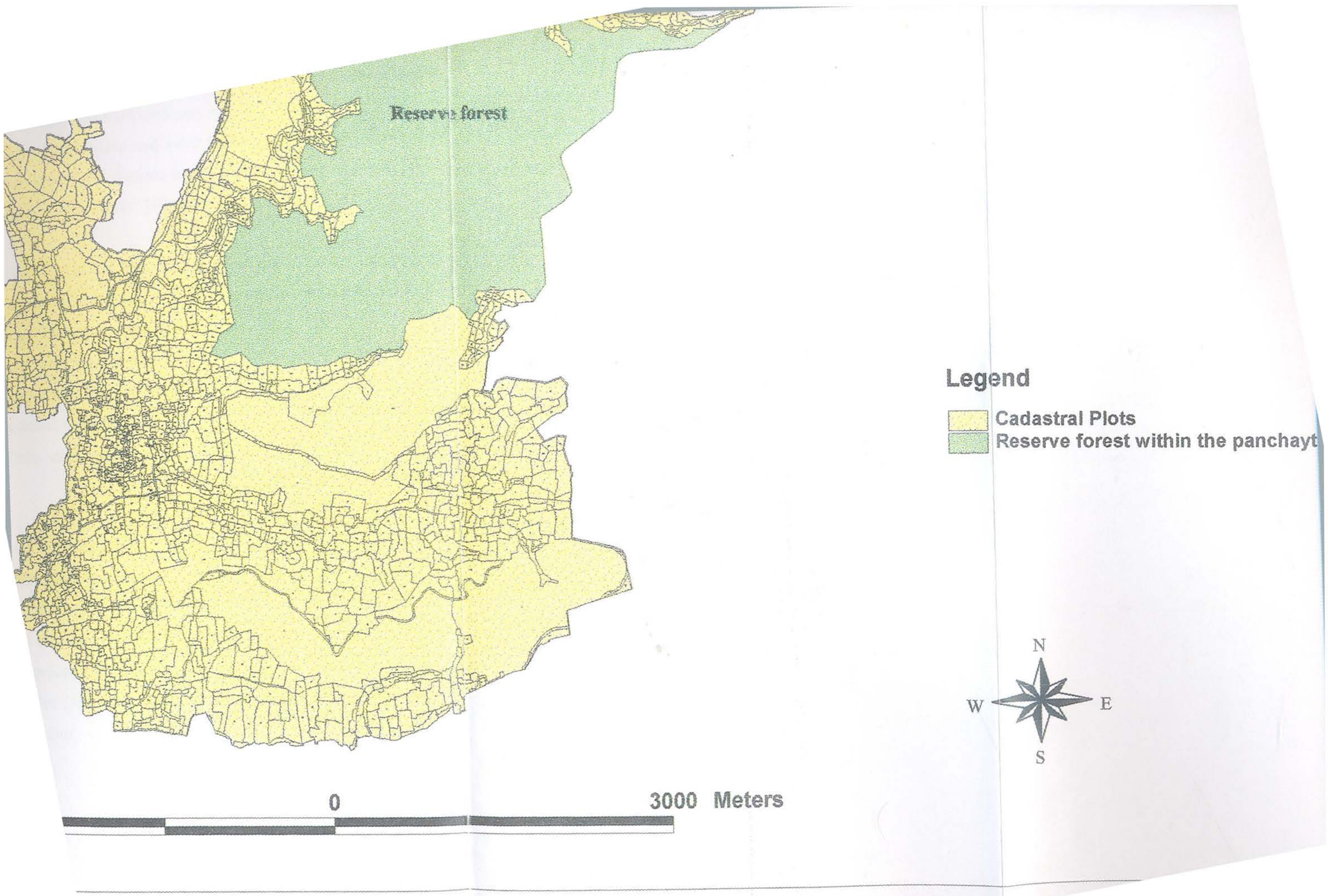


Fig. 9. Cadastral Map of Madakkathara Panchayat (GIS output)

4.2.2 Occupational Details

The total working population of the panchayat was 8894 in the year 2001 (Table 1). Working male population (6482) outnumbers the female (2412). There were 7509 people in the main worker category (5693 male and 1816 female). The main cultivators were 639 in total, of which the 577 persons were male and 62 were female. Main agricultural labourers were 679 in the panchayat divided as 413 males and 266 females. Three hundred and twenty nine persons in the panchayat are engaged in the household industry sector. 250 males and 79 females contribute to this sector. 4453 males and 1409 females comprise the main other workers category totaling to 5862 persons in the panchayat. 1385 persons of the panchayat were marginal workers with 789 males and 596 females.

Marginal cultivators in the panchayat were only 50. Forty of them were males and 10 females. 287 males and 281 females of the panchayat fall in the marginal agricultural labourers category. Non-working population in the panchayat was more than that of the working population. The non-working population of Madakkathara Panchayat was 16040 with 5744 male and 10296 females. The institutional population of the panchayat was 196 with 107 males and 89 females. Only one person in the panchayat located in ward II was houseless.

Table 2 shows the occupational details of the population of Madakkathara Panchayat as per the 1991 census. The total population of the panchayat was 20964 of which 10788 were female and 10176 were male. The total working population was 7170 in 1991, of which 2168 were women and 5002 were men. The non-working population of the panchayat was 13480 with females (8497) outnumbering the males (4983). There were 314 people partially working with 123 females and 191 males.

Table 2. Occupational details of Madakkathara Panchayat (1991 Census)

Sl. No.	Major employment	Female	Male	Total	%
1	Farmer	208	845	1053	14.7
2	Farm labourer	968	1199	2167	30.2
3	AH/Fishery	122	235	357	5.0
4	Quarrying/Mining	46	89	135	1.9
5	Small Scale Industry	28	72	100	1.4
6	Other than SSI	181	711	892	12.4
7	Masonry/Road work	69	176	245	3.4
8	Business	42	484	526	7.3
9	Transport	8	389	397	5.5
10	Other Services	496	802	1298	18.1
11	**Total Working Population**	**2168**	**5002**	**7170**	**100**
12	Partial working population	123	191	314	
13	Non working population	8497	4983	13480	
14	Total Population	10788	10176	20964	

4.3 SETTLEMENT PATTERN IN THE PANCHAYAT

The panchayat had 5665 households as per Census 2001, distributed in dispersed settlements, as is the general settlement pattern in Kerala. Number of households were 440, 443, 467, 462, 426, 516, 527, 491, 439, 531, 483 and 440 in wards I to XII respectively (Table 1).

4.4 LAND HOLDINGS AS PER DEVELOPMENT REPORT

The pattern of land holdings in the panchayat as per 1996 development report of Madakkathara Panchayat is presented in Table 3. There were 6325 land holdings in the panchayat, of which 5989 were in the range less than one hectare, 282 in the range of 1.0 to 2.0 ha whereas 54 holdings were above two hectares.

Table 3. Number and size of land holdings in Madakkathara Panchayat (1996)

Area (ha)	No. of Owners	Percentage
Less than 1 ha	5989	94.69
1.0 – 2.0	282	4.46
above 2	54	0.85
Total	6325	100

4.5 INFRASTRUCTURE DETAILS OF THE PANCHAYAT

Spatial distribution of some economic and social institutions are shown in the Fig. 10. Some of the major institutions and their numbers are listed in Table 4. The panchayat has two lower primary schools, one upper primary school, one high school and one higher secondary school. The panchayat has 22 religious institutions comprising of 16 temples, five churches and one mosque. Recreational facilities comprise nine arts and sports clubs, located in crowded areas. There are nine anganwadis, three hospitals two super markets and six libraries in the panchayat.

The panchayat is provided with nine ration shops and two post offices. There are thirteen hotels and three milk societies in the panchayat. The panchayat possesses three cooperative societies and three other societies.

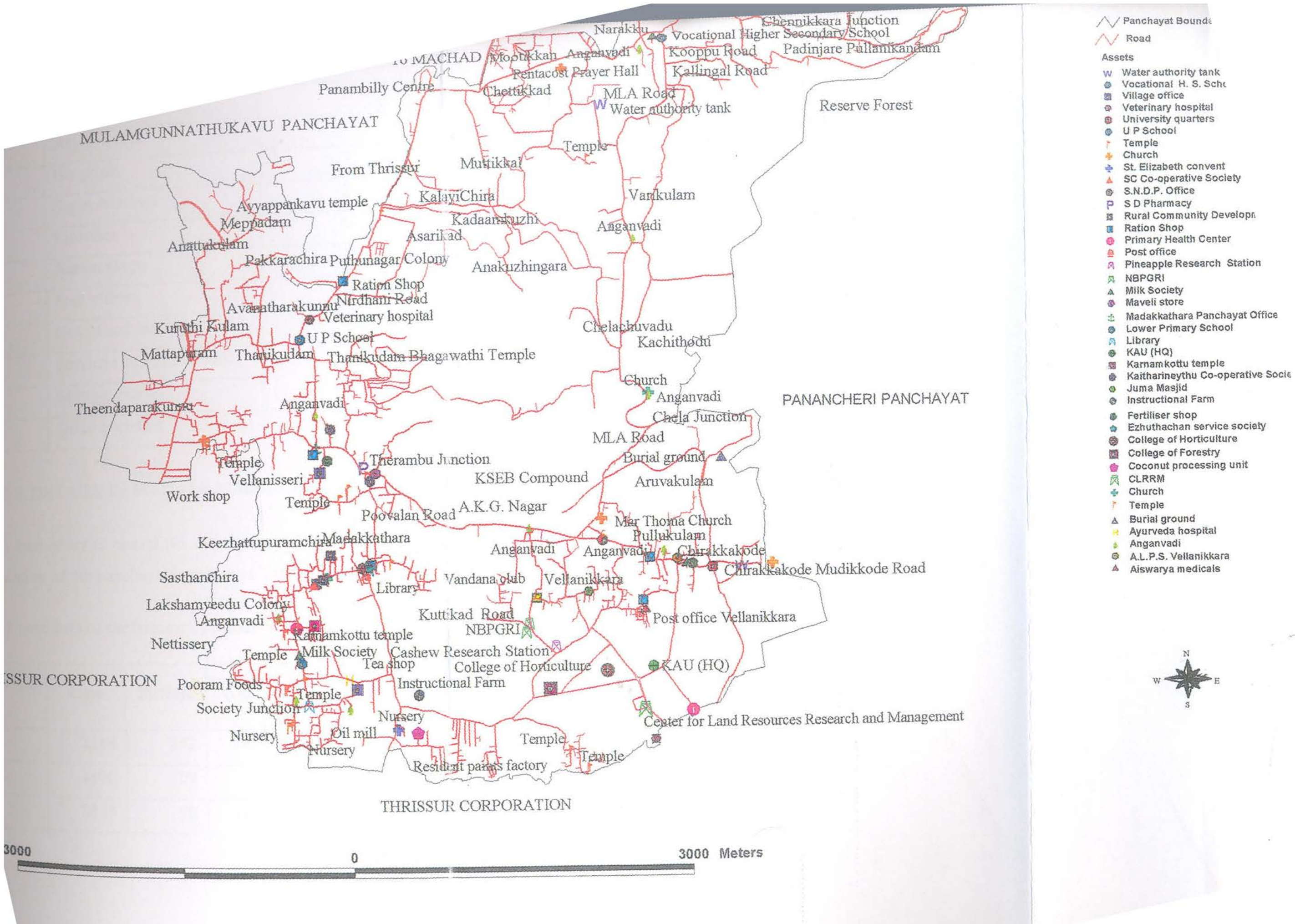


Fig. 10. Major economic and social institutions and network of roads in Mad…

Table 4. List of economic and social institutions of Madakkathara Panchayat

Sl. No.	Details	Number of Assets
1.	Schools	5
2.	Arts and Sports Clubs	9
3.	Temples	16
4.	Churches	5
5.	Mosque	1
6.	Anganwadis	9
7.	Hospitals	3
8.	Super Markets	2
9.	Libraries	6
10.	Ration shops	9
11.	Post offices	2
12.	Hotels and teashops	13
13.	Service cooperative banks	3
14.	Milk societies	3
15.	Other societies	3

4.6 LIVESTOCK DETAILS IN MADAKKATHARA PANCHAYAT

Animal husbandry is one of the major occupations in the panchayat. The livestock population of the panchayat is shown in Table 5.

Table 5. Year wise data of the livestock population of Madakkathara Panchayat

Year	Cow	Buffalo	Goat	Bullock and Ox	Pig	Poultry
1987	2518	262	1057	414	277	19798
1993	1400	109	794	41	20	4411
2001	2136	98	3132	123	1213	27998

It was observed that there has been an increase in population of cows, poultry, pig, goat and bullock from that of the year 1993 whereas there had been a decline in buffalo population.

4.7 SPATIAL AND ATTRIBUTE DATA GENERATED USING GIS

Spatial data was generated after digitisation of various maps, converting them into PC Arc/Info coverages and eventually into ArcView shape files. Relevant attribute information on each spatial entity are attached to the shape files as tabular database. The salient results obtained from spatial analysis of the GIS data on Madakkathara Panchayat are presented below.

4.7.1 Distribution of roads in the Panchayat

The distribution of roads in the Panchayat is depicted along with major assets of the GIS of the Panchayat. Names of important roads and some landmarks are shown in the map depicting the distribution of roads. Data on non-bitumenous roads could not be obtained. The spatial distribution of roads of the Panchayat is shown in Fig. 10.

4.7.2 Biophysical Resources

The biophysical resources of Madakkathara Panchayat inventoried as part in this study were the water resources and soil resources.

4.7.2.1 Water Resources

Water resources of Madakkathara Panchayat include the water bodies of the panchayat, dug wells of the panchayat and also the overall availability of water in the Panchayat.

4.7.2.1.1 Water Bodies of the Panchayat

Fig. 11. displays the spatial distribution of the streams, rivers, canals and ponds of Madakkathara Panchayat, compiled as a single theme. The most important river flowing through the panchayat is the Thanikudam River. The two irrigation canals traversing the panchayat are the Kole Canal and Vellanikkara Branch Canal.

4.7.2.1.2 Dug Wells in Panchayat

The spatial distribution of wells of Madakkathara Panchayat is shown as a separate theme in Fig. 12. There are 4565 wells in the panchayat. On observing the distribution pattern it can be seen that most of the wells are seen near the houses, contributing drinking and bathing water.

4.7.2.1.3 Water Availability

The water availability theme is shown separately in Fig.13. The water availability is consolidated on the basis of the details available from the Panchayat. As expected, the water availability is high in areas around the river and streams. Scarcity is observed in the areas uphill to the Kachithode dam due to the fact that most of the settlements lie higher than the dam.

4.7.2.2 Soil Resources of Madakkathara Panchayat

Soils of the panchayat have been classified by the Soil Survey Organization, Department of Agriculture (SC Unit), Government of Kerala. Soils of the panchayat had been included in the Madakkathara series by Soil Survey Organization, Kerala.

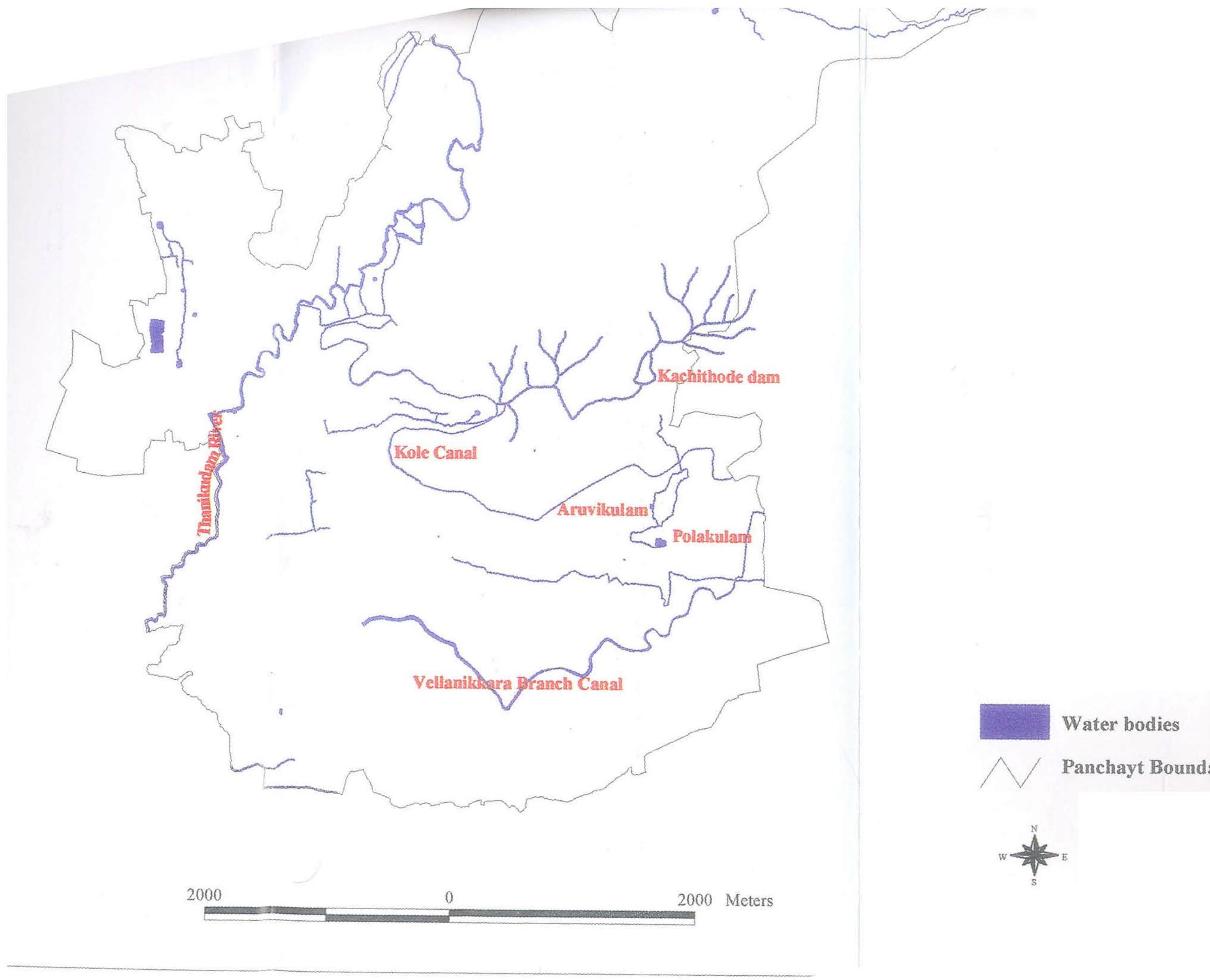


Fig. 11. Drainage pattern of Madakkathara Pan…

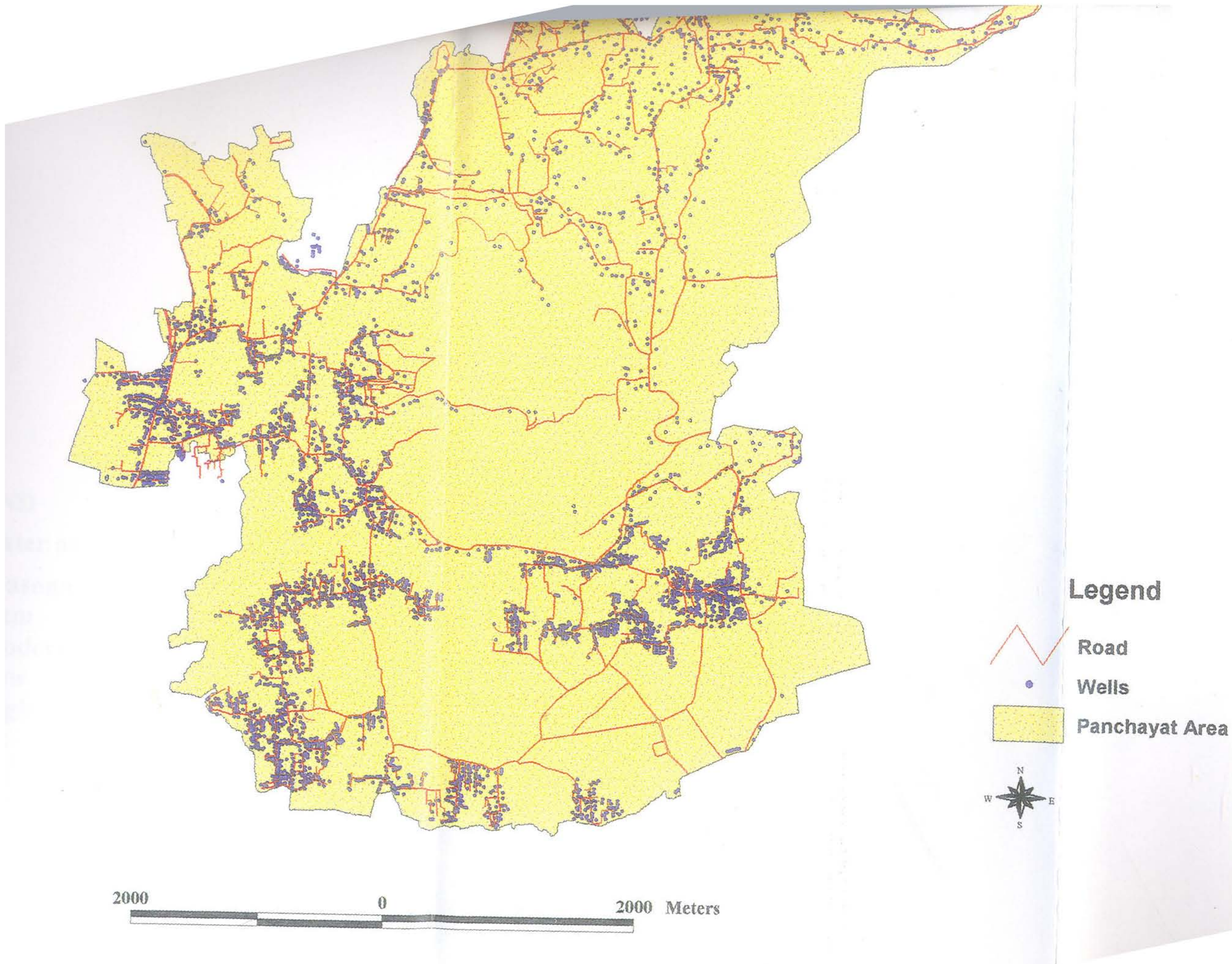


Fig. 12. Spatial distribution of wells of Madakkathara P

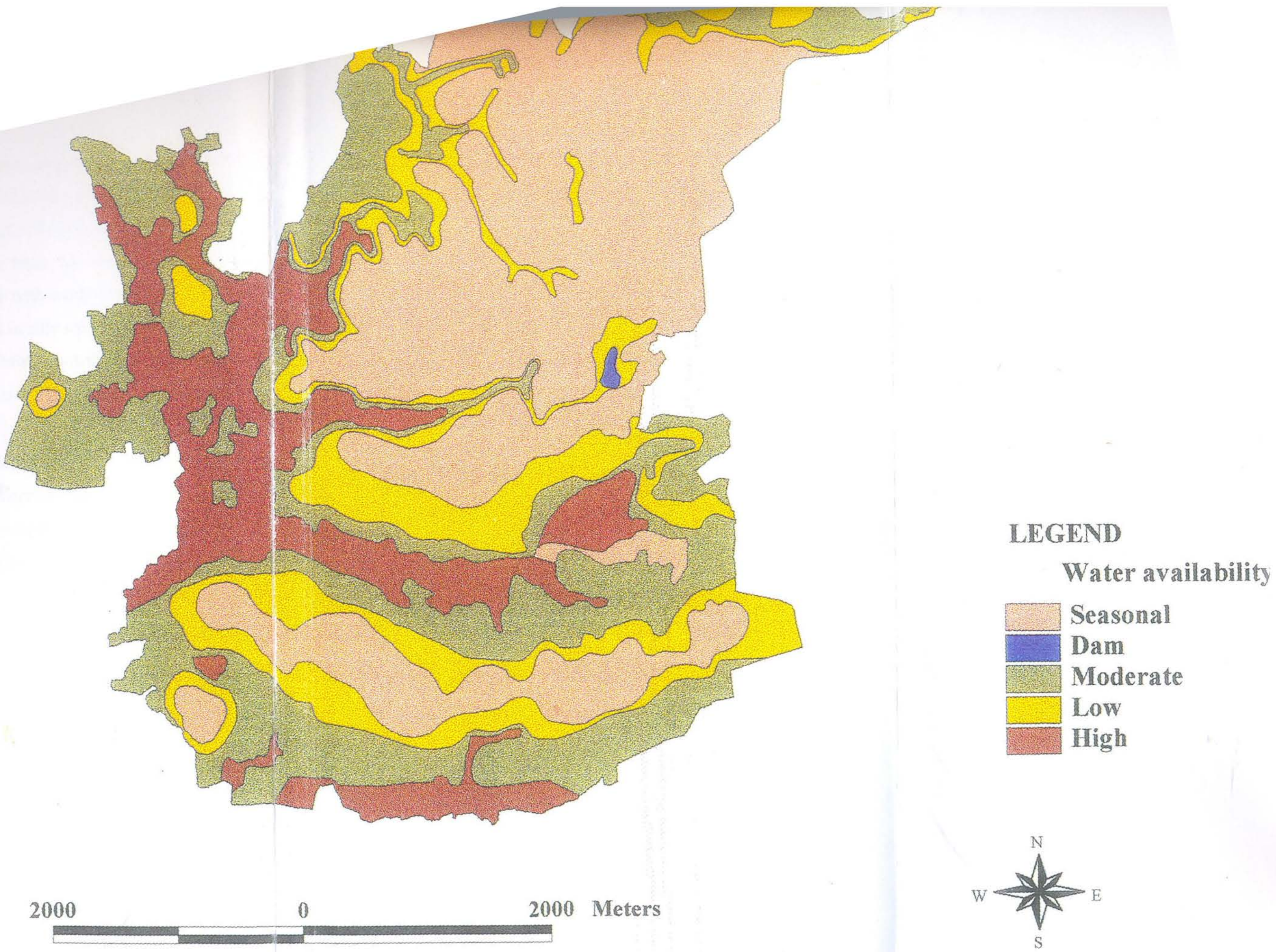


Fig. 13. Thematic map showing water availability status of different areas in Mad

4.7.2.2.1 General Description of the Soils of Madakkathara Panchayat

The general classification of soils of Madakkathara Panchayat and their spatial distribution are given in the Fig. 14. Soils of the Panchayat are divided into five general classes. They are Colluvium, Forest loam, Lateritic Soil, Riverine alluvium and Variable shallow soils. The extent of various soil types of the panchayat and their main features are given in Table 6.

Soils of Madakkathara are predominantly lateritic covering over 1242.58 ha followed by variable shallow soil in 648.65 ha. Forest loam occupies 253.9 ha, Riverine alluvium occupies 287.5 ha and colluvial soil occupies 59.38 ha. The laterite, variable shallow and colluvium types have sandy loam texture, while forest loams in the panchayat are gravelly with sandy loam texture. The texture of riverine alluvium, found in the panchayat is silty caly loam. Colour of the soils of Madakkathara panchayat varies as reddish brown (laterites and colluvium), greyish brown (variable shallow and forest loam) and brown (riverine alluvium).

Depths of the soils in Madakkathara Panchayat were 0.5 - 1.0, 0.50, 0.5 - 1.0, 0.35 - 1.0 and 1.0 - 1.5 m for Laterite, Variable Shallow, Forest loam, Riverine Alluvium and Colluvium respectively. Soils in the panchayat are well drained, except in the case of riverine alluvium, where drainage was observed to be poor.

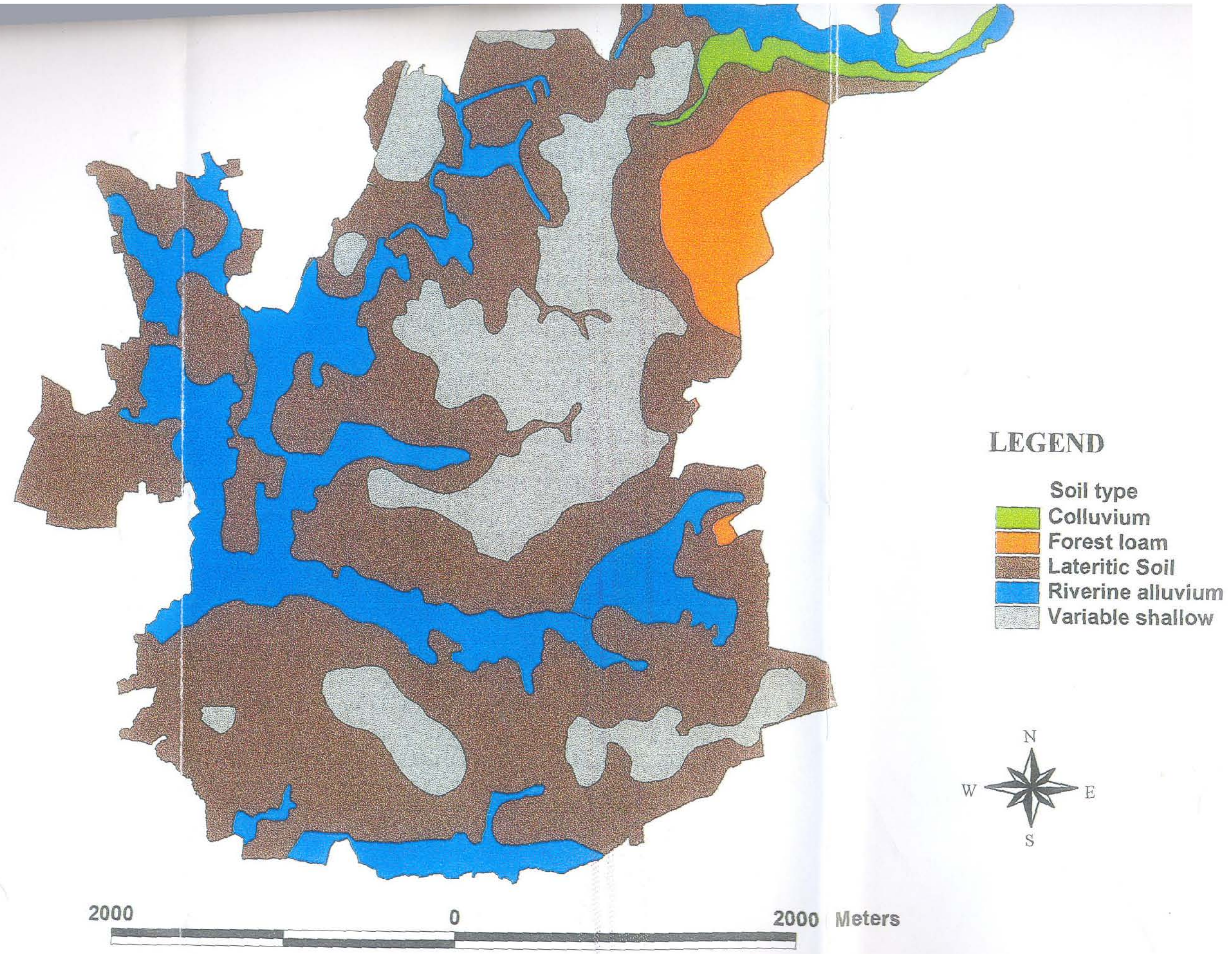


Fig. 14. Thematic maps showing soil type distribution in Madakkathara Panchayat (GIS output)

Table 6. Extent and main features of the soil types of Madakkathara Panchayat

Sl. No.	Soil type	Area (ha)	Texture	Colour	Depth (m)	Drainage
1	Laterite	1242.58	Sandy loam	Reddish Brown	0.5 - 1.0	Well
2	Variable Shallow	648.65	Sandy loam	Greyish brown	0.5	Well
3	Forest loam	253.90	Gravelly Sandy loam	Greyish brown	0.5 - 1.0	Well
4	Riverine Alluvium	287.50	Silty clay loam	Brown	0.35 - 1.0	Poor
5	Colluvium	59.38	Sandy loam	Reddish brown	1.0 - 1.5	Well

4.7.3 Land Use Pattern of Madakkathara Panchayat

The land use pattern of the Panchayat is given in the Fig.15. The theme land use pattern includes roads, streams, current land use and wastelands. The numbers of polygons created in various landuse types are shown in Table 7. The polygons represent the locations of different landuse types. The land use was also analyzed using the IRS –1C LISS III + PAN merged data and was found in conformity with ground truth analysis. Fig.16. depicts the satellite imagery of the panchayat and some major land use.

Table 7. Number of polygons created for displaying the landuse of Madakkathara Panchayat

Sl. No.	Land use type	No. of polygons in GIS
1.	River/stream	228
2.	Coconut	111
3.	Mixed Trees	72
4.	Mixed crops	272
5.	Banana	51
6.	Coffee	3
7.	Cashew	27
8.	Tapioca	16
9.	Rubber	50
10.	Arecanut	14
11.	Kharif Rice	80
12.	Converted land	7
13.	Road	134
14.	Wasteland	48
15.	Teak	5

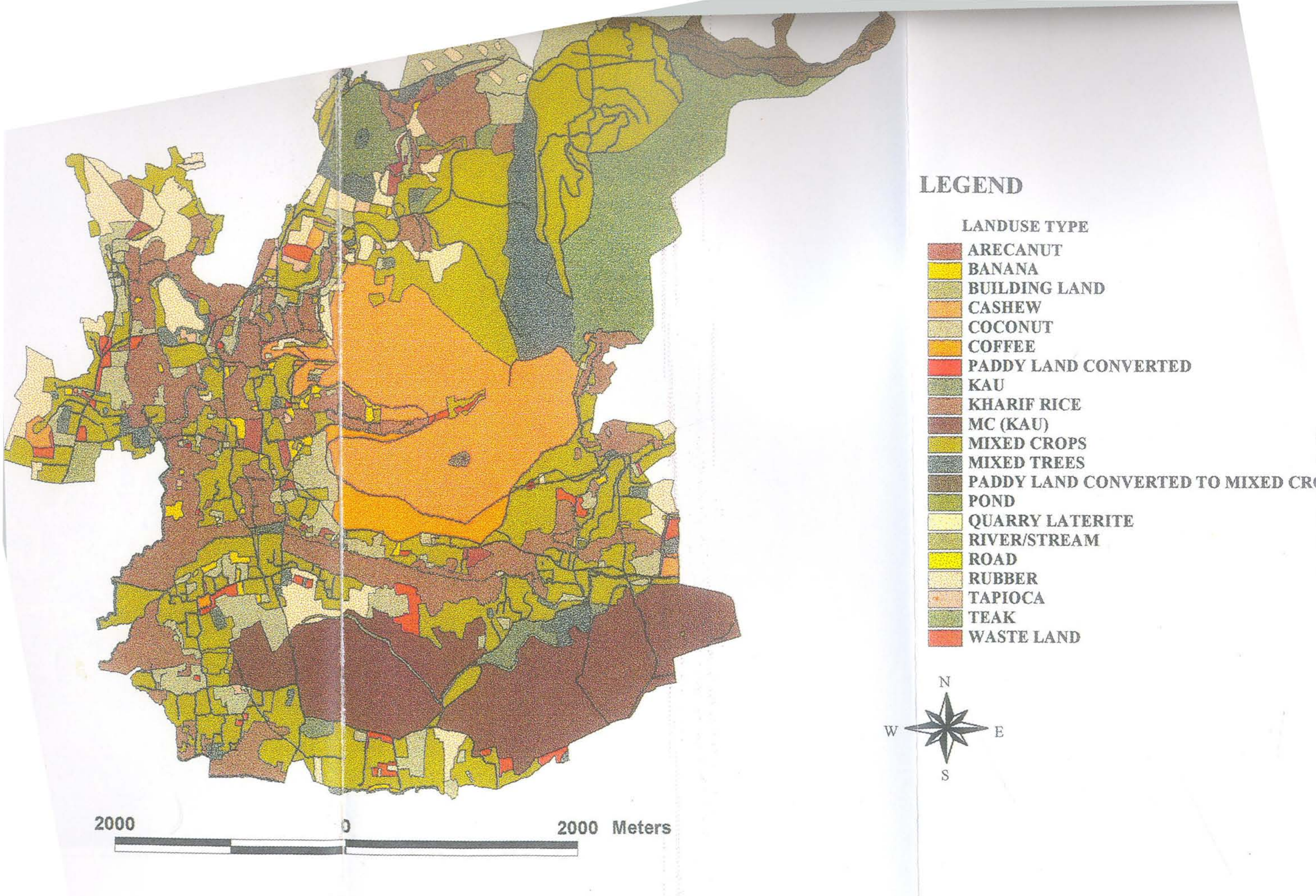


Fig. 15. Thematic map showing the landuse type in Madakkathara Panch...

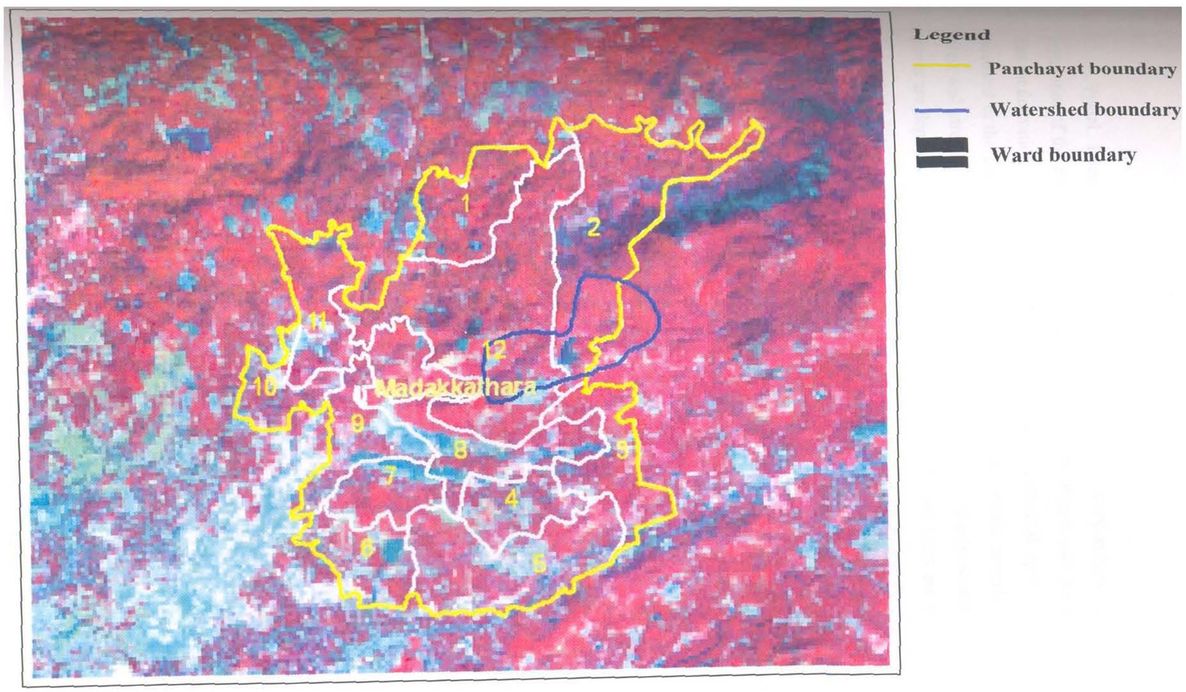


Fig. 16. Satellite imagery showing land utilisation pattern of Madakkathara Panchayat (LISS III + PAN merged data)

Visual interpretation of satellite imagery in conjunction with the inventories of the Panchayat and Kerala State Land Use Board was the source of data for derivation of landuse type of the panchayat. As indicated, spatial data was presented in the form of polygons in the shapefile. The results revealed that the rivers and streams can be located in 228 land premises. Predominant coconut groves are depicted in 111 polygons in the panchayat. Mixed trees are located in 72 holdings whereas mixed crops form the landuse in 272 locations. Predominant pure crops included banana, coffee, cashew, tapioca, rubber and arecanuts in 51, 3, 27, 16, 50, and 14 locations respectively. Five teak plantations were located in the panchayat during the survey. Paddy fields of the panchayat are in conversion. However, rice is grown in the Kharif season in 80 locations. Roads as a landuse type, is depicted as 134 polygons in the spatial data. These include bitumenous as well as non-bitumenous roads. The Panchayat contains a few locations that can be termed wasteland. There are 48 such polygons presented in the spatial data.

4.7.4 General Physiography of the Panchayat

The panchayat is characterized by varying topography. It is evident from the presence of hillocks and large area of low lands. Hillocks are predominantly seen in the North Eastern part of the panchayat. The physiography of the panchayat can be visualized using the contours and digital elevation model created using the contours.

4.7.4.1 Contour

The distribution of contour lines in the panchayat at 10 m interval derived from the 1:25000 toposheets of Survey of India is depicted in Fig.17. It can be inferred that the altitude of the panchayat ranges from less than 20 m to 320 m above mean sea level. The highest point of the panchayat lies at 360 m above mean sea level. The highest contour exists at 320 m above the mean sea level. As

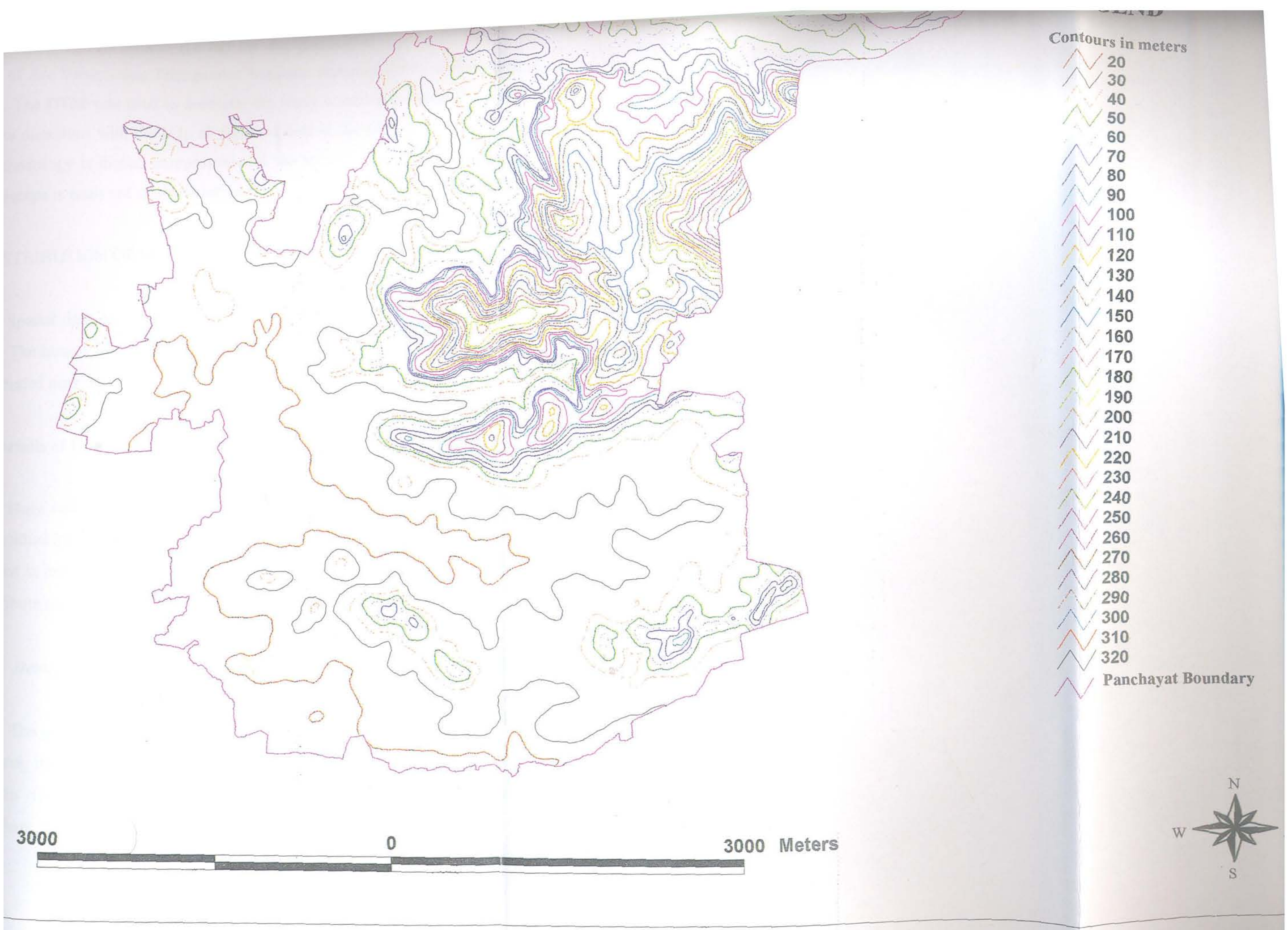


Fig. 17. Distribution of 10 m interval contours in Madakkathara Panchayat (GIS output)

evident, those areas where contour lines are nearer are steep slopes and wherever contour lines are sparse, the landscape is relatively plain.

4.7.4.2 Digital Terrain Model (DTM)

Digital Terrain Model (DTM) for the panchayat, generated by the 3D analyst of Arc View, using Triangulated Irregular Network (TIN) is illustrated in Fig. 18. The DTM was used to delineate the study watershed, locating ridgelines and flow directions with the help of digitised data in the GIS environment. Since the methodology is digital interpretation of the terrain, the accuracy with which the landscape is analysed could be increased to a great extent.

4.8 DISTRIBUTION OF HOUSES IN MADAKKATHARA PANCHAYAT

Spatial data on the distribution of houses in the panchayat are shown in Fig.19. The houses are more or less distributed through out the panchayat and are concentrated near the roads.

4.8.1 Details of Households of Madakkathara Panchayat

Huge volume of attribute data are collected and attached to the spatial data on individual houses of the panchayat in the GIS. The attached data were then re-tabulated in excel format and abstracted. The results inferred from the abstract of the attribute on spatial data on houses are discussed hereunder.

4.8.1.1 Demographic Details

The general demographic details of the panchayat are shown in the Table 8. Among the total 4738 respondents surveyed in the panchayat, there were two Brahmin families, 1808 Ezhava families, 359 Ezhuthachan families, 36 Kanakkan, 29 Kudumbis, 15 Kumbaran, nine Mannan, seven Moopan, nine

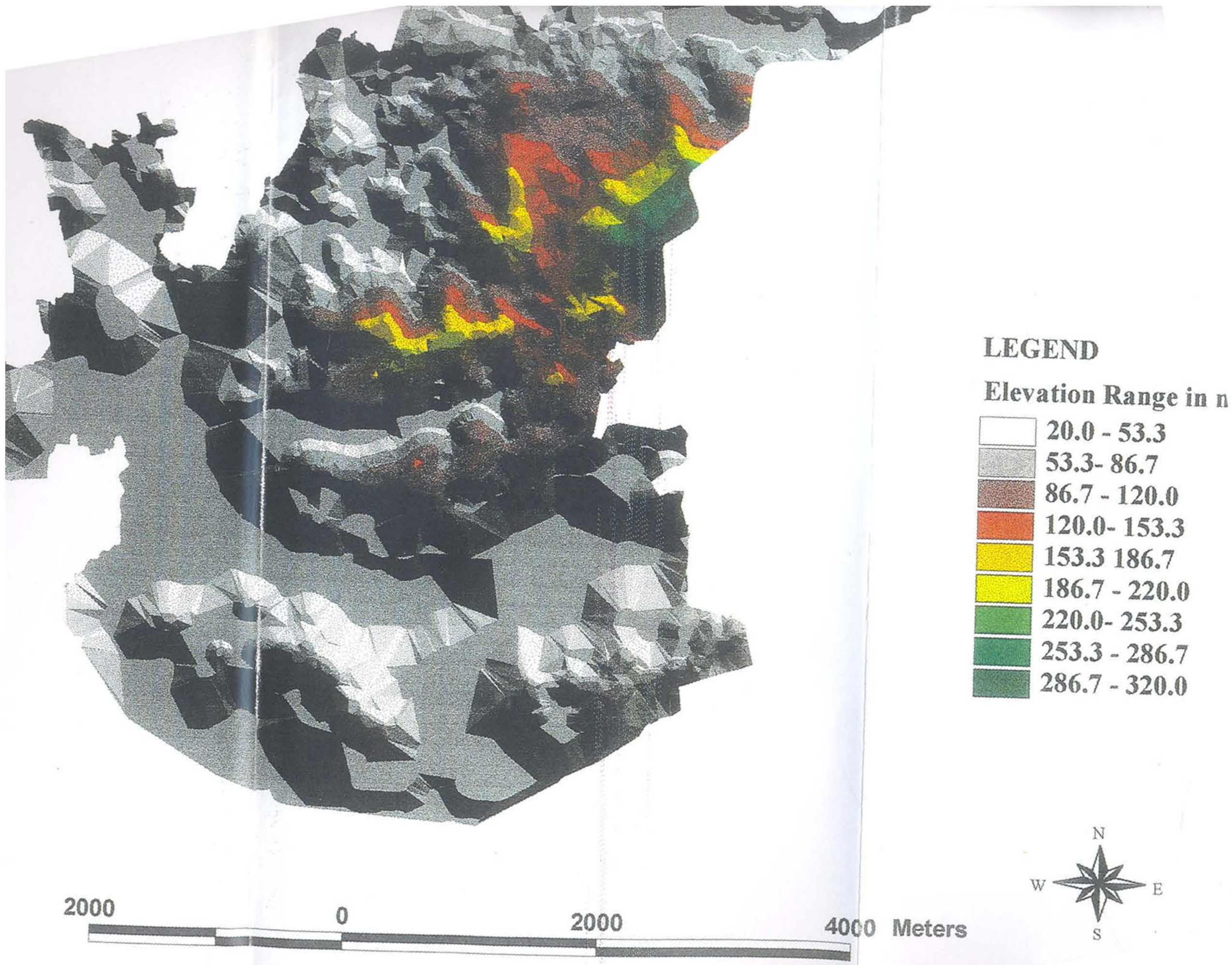


Fig. 18. Digital terrain model of Madakkathara Panchayat deriv

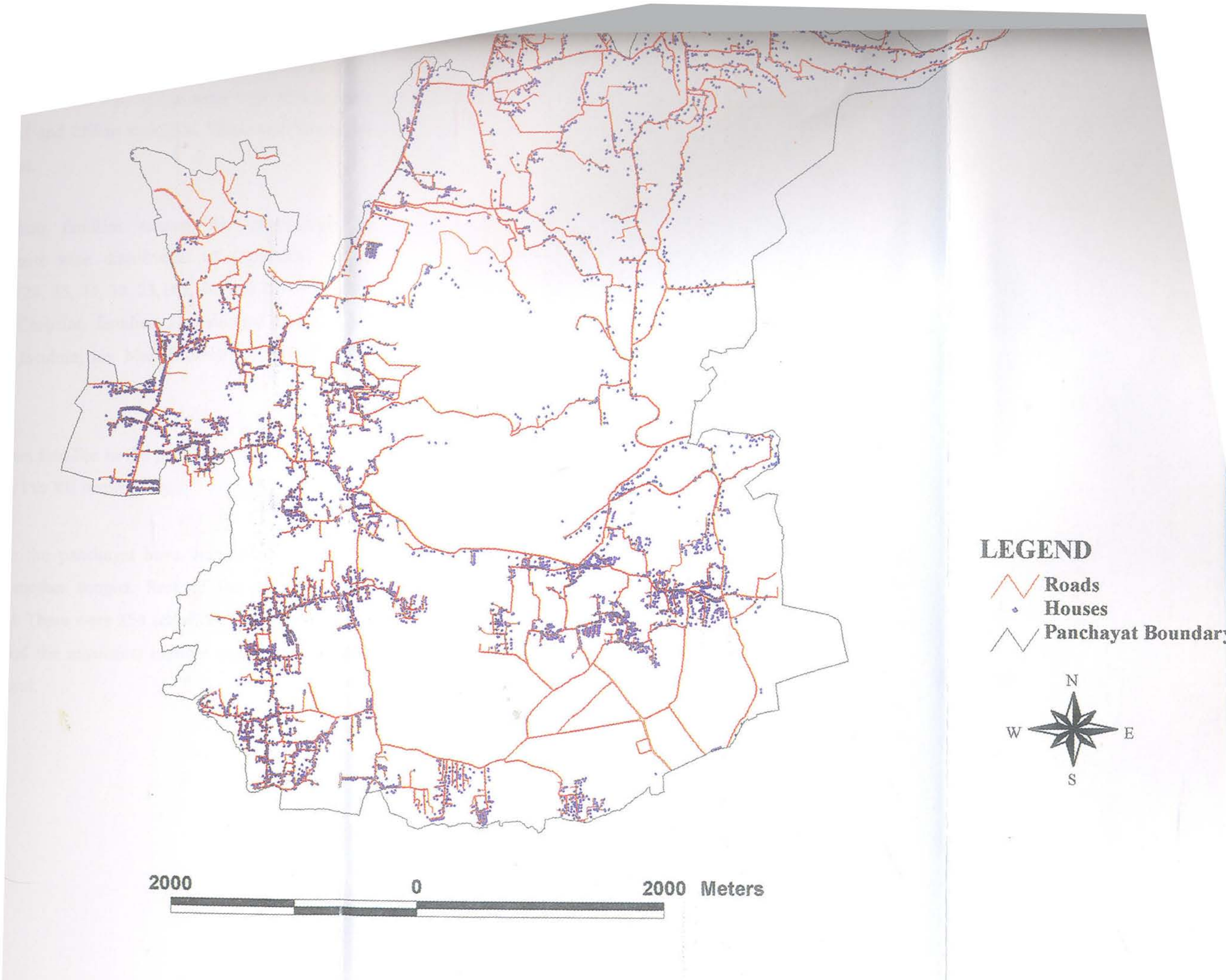


Fig. 19. Spatial distribution of houses in Madakkathara Panch...

Nadars, 209 Nairs, 10 Odans, four Panans, five Panikkan, 25 Parayan, 13 Perumannan, 82 Pulaya, three Veerasaiva, three Velan, 57 Vettuavan, eight Vilakkithala, 44 Viswakarma (Blacksmith), 56 Viswakarma (Carpenter) and six Viswakarma (Goldsmith). There were 502 Hindu families whose caste denominations could not be obtained. Altogether the Hindu family population of the panchayat were 204 in ward I, 100 in ward II, 348 in ward III, 331 in ward IV, 181 in ward V, 375 in ward VI, 421 in ward VII, 322 in ward VIII, 326 in ward IX, 248 in ward X , 235 in ward XI and 210 in ward XII. There were a total of 3301 Hindu families in the panchayat.

There were 1262 Christian families among the respondents in Madakkathara Panchayat. The ward wise distribution of Christians in the panchayat were, 159, 260, 56, 29, 124, 85, 74, 38, 23,165, 44, and 205 in wards I to XII respectively. Among the Christian families 21 belonged to the C.S.I denomination, 941 catholic, 237 Jacobite, six Mar Thomite, 30 orthodox, 25 Pentecost and two others.

There were only 130 Muslim families in the panchayat with 10, 1, 7, 43, 10, 9, 10, 34, 4, 0, 1 and 1 in wards I to XII respectively.

Seven families residing in the panchayat have their mother tongue as Tamil and one with Hindi as mother tongue. Rest of the population had Malayalam as their mother tongue. There were 254 scheduled caste or scheduled tribe families in the panchayat and the maximum number was concentrated in ward no. VII and IX of the panchayat.

Table 8. Demographic details of Madakkathara Panchayat derived from the attribute table of spatial data on houses

Particulars			Ward Numbers												Total
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Number of Households			375	362	420	403	321	471	505	395	353	427	281	425	4738
Religion	Hindu	Brahmin	0	0	1	0	0	1	0	0	0	0	0	0	2
		Ezhava	108	55	301	280	34	98	107	226	215	126	115	143	1808
		Ezhuthachan	3	0	0	1	2	135	151	24	23	0	18	2	359
		Kanakkan	18	1	0	2	0	1	2	0	1	1	0	10	36
		Kudumbi	27	0	0	0	0	0	0	1	0	0	0	1	29
		Kumbaran	0	0	0	0	0	0	15	0	0	0	0	0	15
		Mannan	2	3	0	0	0	1	0	0	2	1	0	0	9
		Moopan	7	0	0	0	0	0	0	0	0	0	0	0	7
		Nadar	0	1	2	3	1	0	0	2	0	0	0	0	9
		Nair	0	3	16	12	14	24	58	17	5	5	44	11	209
		Odan	0	8	0	0	0	0	0	0	1	1	0	0	10
		Panan	0	0	0	0	0	0	2	0	1	0	1	0	4

(Continued)

Table 8. Demographic details of Madakkathara Panchayat derived from the attribute table of spatial data on houses (Continued)

Particulars			Ward Numbers												Total
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Religion	Hindu	Panikkan	0	0	0	0	1	0	1	1	0	2	0	0	5
		Parayan	0	0	0	0	0	0	14	0	0	0	11	0	25
		Perumannan	0	2	0	0	0	0	5	0	5	0	0	1	13
		Pulayan	12	9	0	0	0	10	5	8	0	4	25	9	82
		Veerasaiva	0	0	0	0	0	0	2	1	0	0	0	0	3
		Velan	3	0	0	0	0	0	0	0	0	0	0	0	3
		Vettuvan	0	0	1	0	0	0	6	15	27	0	3	5	57
		Vilakkithala	0	0	0	0	0	2	1	1	0	2	0	2	8
		Viswakarma (Blacksmith)	5	3	3	0	0	4	11	2	6	3	3	4	44
		Viswakarma (Carpenter)	3	0	5	1	2	27	6	2	7	1	1	1	56
		Viswakarma (Goldsmith)	0	0	0	0	0	1	4	0	0	1	0	0	6
		Others	16	15	19	32	127	71	31	22	33	101	14	21	502
		Total	204	100	348	331	181	375	421	322	326	248	235	210	3301

(Continued)

Table 8. Demographic details of Madakkathara Panchayat derived from the attribute table of spatial data on houses (Continued)

Particulars			Ward Numbers												Total
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Relegion	Christian	C.S.I.	11	0	0	1	2	0	1	1	0	0	0	5	21
		Catholic	109	126	48	28	121	79	72	29	22	165	44	98	941
		Jacobite	36	116	8	0	1	2	0	2	0	0	0	72	237
		Mar Thomite	0	0	0	0	0	2	0	4	0	0	0	0	6
		Orthodox	2	14	0	0	0	0	0	0	0	0	0	14	30
		Pentacost	1	4	0	0	0	2	1	2	1	0	0	14	25
		Others	0	0	0	0	0	0	0	0	0	0	0	2	2
		Total	159	260	56	29	124	85	74	38	23	165	44	205	1262
Relegion	Muslim		10	1	7	43	10	9	10	34	4	0	1	1	130
Scheduled Caste/ Scheduled Tribe			30	22	1	2	15	12	39	23	39	6	39	26	254
No respondent			2	1	9	0	5	2	0	1	0	13	1	9	43
Mother tongue		Malayalam	373	362	420	402	319	470	505	395	353	425	281	425	4730
		Hindi	0	0	0	0	1	0	0	0	0	0	0	0	1
		Tamil	2	0	0	1	1	1	0	0	0	2	0	0	7

4.8.2 Socio-economic Pattern in Madakkathara Panchayat

The socio economic pattern of the respondent families was derived from the attributes of spatial data on the houses of Madakkathara Grama Panchayat. Table 9. shows the details on various aspects reflecting the socio economic pattern of the panchayat.

4.8.2.1 Land Holding Size

An important parameter that reflects the socio economic pattern of the panchayat was the distribution of land holding size (Table 9). The whole households were divided into three categories according to national standards namely marginal (below 250 cents), small (250 – 500 cents) and large (above 500 cents) based on the size of the land holding. Among the total respondents (4689 families) of the panchayat 4549 belong to the class of marginal land holdings (below 250 cents), 108 to the category small holding (250 – 500 cents) and 32 to the large holding category (above 500 cents).

4.8.2.2 Type of Resident Building

The respondents varied in the type of residential buildings they lived. The whole respondent population was classified based on the type of roof, wall, floor and plinth area of their houses.

4.8.2.2.1 Roof of Houses

The roof types most houses were concrete, sheet, straw, tiles and other materials including palm-thatched roof. Altogether there were 1962 concrete roofed building 128 sheet roofed, 95 straw roofed, 2469 tile roofed and 35 buildings that had roof other than the above materials. Ward wise distribution of concrete roofed building were 89, 114, 188, 171, 167, 274, 220, 180, 128, 200, 102 and 129 in ward no I to XII respectively.

The number of sheet roofed building in ward number I to XII were 13, 9, 6, 4, 8, 12, 22, 3, 7,12, 11, 21 respectively. Straw was laid as roof in 20, 4, 5, 3, 3, 2, 4, 7, 3, 1, 5 and 38 houses of ward I to XII respectively. Tiled roof were seen in 251, 234, 210, 225, 137, 145, 259, 204, 215, 201, 161 and 227 houses of ward number I to XII respectively. Other type of roof were seen only in certains wards of the panchayat that is one in ward number V, 33 in ward number VI and one in ward number XII

4.8.2.2.2 Wall of Houses

The most common wall type observed in buildings of Madakkathara Panchayat was made by bricks that was observed in 4150 houses followed by clay or mud walled buildings and then by others and lastly by straw. The distribution of brick walled houses were 300, 284, 366, 360, 294, 424, 457, 339, 317, 398, 256 and 355 in ward number I to XII respectively. Clay walled houses were 59, 67, 36, 37, 18, 20, 36, 50, 25, 14, 19 and 50 in numbers in ward numbered I to XII respectively in the panchayat. The wards wise distribution of straw thatched wall were 6, 2, 4, 1, 1, 1, 1, 1, 2, 0, 1 and 8 in ward number I to XII respectively. Other types of walls were 8, 8, 3, 5, 3, 21, 11, 4, 9, 2, 3 and 3 in wards I to XII respectively.

Table 9. Socio economic pattern derived from attribute table of the spatial data on houses in different wards of Madakkathara Panchayat

Particulars		Ward Numbers												Total
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Holding Size (cents)	< 250	361	325	398	398	310	460	501	388	352	411	269	376	4549
	250-500	10	27	9	3	0	5	4	5	1	3	10	31	108
	>500	2	9	2	2	6	1	0	1	0	0	0	9	32
Roof type	Concrete	89	114	188	171	167	274	220	180	128	200	102	129	1962
	Sheet	13	9	6	4	8	12	22	3	7	12	11	21	128
	Straw	20	4	5	3	3	2	4	7	3	1	5	38	95
	Tiles	251	234	210	225	137	145	259	204	215	201	161	227	2469
	Others	0	0	0	0	1	33	0	0	0	0	0	1	35
Wall type	Brick	300	284	366	360	294	424	457	339	317	398	256	355	4150
	Clay	59	67	36	37	18	20	36	50	25	14	19	50	431
	Straw	6	2	4	1	1	1	1	1	2	0	1	8	28
	Others	8	8	3	5	3	21	11	4	9	2	3	3	80

(Continued)

Table 9. Socio economic pattern derived from attribute table of the spatial data on houses in different wards of Madakkathara Panchayat (Continued)

Particulars		Ward Numbers												Total
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Floor	Cement	264	263	329	330	200	324	376	326	269	324	216	272	3493
	Clay	89	67	31	20	18	30	55	30	39	14	30	111	534
	Marble	7	20	27	28	48	47	32	21	11	28	16	19	304
	Mosaic	3	7	14	23	37	45	34	15	9	40	14	8	249
	Tiles	1	0	1	0	3	0	0	0	1	0	1	2	9
	Others	9	4	7	2	10	20	8	1	24	8	2	4	99
Plinth Area (Sq.ft)	< 100	16	20	13	10	4	20	10	19	14	7	4	30	167
	100-500	210	163	116	109	93	177	193	124	135	140	103	174	1737
	500-1000	119	121,	147	197	128	141	187	180	143	210	126	111	1810
	>1000	28	57	133	87	91	128	115	71	61	57	46	101	975

(Continued)

Table 9. Socio economic pattern derived from attribute table of the spatial data on houses in different wards of Madakkathara Panchayat (Continued)

Particulars		Ward Numbers												Total
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Source of drinking water	Pond	7	3	1	3	1	0	0	0	0	0	0	4	19
	Public pond	0	0	0	0	0	0	0	0	0	0	0	1	1
	Public tap	46	1	0	0	36	0	2	1	0	58	51	35	230
	Publicwell	12	15	15	3	3	28	41	39	18	27	14	25	240
	Stream	3	0	0	0	0	0	0	0	0	0	0	0	3
	Tubewell	18	9	1	2	0	0	3	0	0	6	3	6	48
	Well	134	209	318	324	206	406	368	295	289	290	177	227	3243
	Others	153	124	74	71	70	32	91	59	46	33	34	118	905
Source of bathing water	Pond	9	3	1	3	1	0	0	0	0	0	0	4	21
	Public pond	1	0	0	0	0	0	0	0	0	0	0	1	2
	Public tap	50	2	0	0	36	0	2	1	0	69	52	35	247
	Publicwell	12	14	15	3	3	27	40	39	17	23	14	25	232
	Stream	3	0	0	0	0	0	0	0	0	0	0	0	3
	Tubewell	19	9	1	2	0	0	5	0	0	7	4	5	52
	Well	135	210	318	324	206	408	366	295	290	286	178	228	3244
	Others	144	123	74	71	70	31	92	59	46	29	31	118	888

(Continued)

Table 9. Socio economic pattern derived from attribute table of the spatial data on houses in different wards of Madakkathara Panchayat (Continued)

Particulars		Ward Numbers												Total
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Latrine	Yes	89	112	187	171	166	426	471	178	303	198	102	127	2530
	No	284	249	222	232	150	40	34	216	50	216	177	289	2159
Choolah Type	Ordinary	264	225	218	200	156	226	225	200	199	106	137	284	2440
	LPG	108	135	191	203	160	240	277	190	154	307	135	132	2232
	Smokeless	1	1	0	0	0	0	3	3	0	1	7	0	16
	Kerosene	0	0	0	0	0	0	0	0	0	0	0	0	0
	Biogas	0	0	0	0	0	0	0	1	0	0	0	0	1
Availability of Boiled water	Yes	0	0	0	0	0	328	389	5	242	0	0	0	964
	No	373	361	409	403	316	138	116	389	111	414	279	416	3725
Scarcity of water	Yes	0	0	0	0	0	156	192	3	83	0	0	0	434
	No	373	361	409	403	316	310	313	391	270	414	279	416	4255

4.8.2.2.3 Floor Type of Houses

The flooring was dominated with cement in the buildings of Madakkathara Panchayat followed by clay, marble, mosaic, others and tiles. Cement floor was seen in 264, 263, 329, 330, 200, 324, 376, 326, 269, 324, 216 and 272 houses of ward number I to XII repectively. Clay floor was seen in 89, 67, 31, 20, 18, 30, 55, 30, 39, 14, 30 and 111 houses in wards I to XII respectively. Marble floored houses were 7, 20, 27, 28, 48, 47, 32, 21, 11, 28, 16 and 19 in ward number I to XII respectively whereas mosaic flooring was found in 3, 7, 14, 23, 37, 45, 34, 15, 9, 40, 14 and 8 houses of ward number I to XII repectively. Tiles were paved on the floor of 1, 1, 3, 1, 1 and 2 houses of ward number I, III, V, IX, XI and XII respectively. Other floor types were present in 9, 4, 7, 2, 10, 20, 8, 1, 24, 8, 2 and 4 houses of ward I to ward XII respectively.

4.8.2.2.4 Plinth Area of Houses

The houses were classified into four categories on the basis of plinth area in square feet, *ie.*, below 100 sq.ft., 100–500 sq.ft., 500-1000 sq. ft. and above 1000 sq. ft. The classes are given in Table No. 9. There were 167 houses in the range below100 sq. ft., 1737 in 100–500 sq.ft. category, 1810 in 500-1000 sq. ft. and 975 in the above1000 sq. ft. category. Ward wise distribution of the houses in the less than 100 sq. ft houses were 16, 20, 13, 10, 4, 20, 10, 19, 14, 7, 4 and 30 in wards I to XII and in 100 to 500 sq. ft category the distribution were 210, 163, 116, 109, 93, 177, 193, 124, 135, 140, 103 and 174 whereas in the 500-1000 category there were 119, 121, 147, 197, 128, 141, 187, 180, 143, 210, 126 and 111 houses respectively in wards I to XII and finally in the above 1000 sq. ft category there were 28, 57, 133, 87, 91, 128, 115, 71, 61, 57, 46 and 101 houses dispersed in ward number I to XII repectively.

4.8.2.2.5 Choolah Type in the Houses

There were five different types of choolahs in the panchayat. Among them 2440 houses depended on ordinary type, whereas 2232 used Liqufied Petroleum Gas (LPG), 16 used smokeless choolah and 1 used biogas for cooking. The wardwise distribution of ordianary type were 264, 225, 218, 200, 156, 226, 225, 200, 199, 106, 137, and 284 in wards I to XII respectively; 108, 135, 191, 203, 160, 240, 277, 190, 154, 307, 135 and 132 depended on LPG in wards I to XII respectively and 1, 1, 3, 3, 1, and 7 families depended on smokeless choolah in I, II, VII, VIII, X and XI respectively and one household in ward number VIII depended on biogas for cooking.

4.8.2.3 Source of Water and its Utilisation

Sources of water are divergent in the panchayat. Sources of dinking and bathing water for different families were studied. Pertinent observations are given below.

4.8.2.3.1 Source of Drinking Water

Among the respondent population of Madakkathara Panchayat 69 per cent depended on own wells for drinking water, whereas tube well accounted for one per cent. Ten per cent depended on public sources for drinking water. In most of the wards, the general trend was observed except in ward 1, where the residents depended on other sources of drinking water. Ponds were the source of drinking water in 7, 3, 1, 3, 1, and 4 houses in wards I to V and XII respectively. Only one family in ward XII depended on public pond for drinking water. The families that depended on public tap for their drinking water source were 46, 1, 0, 0, 36, 0, 2, 1, 0, 58, 51 and 35 in I to XII wards respectively. Public well formed the source of 12, 15, 15, 3, 3, 28, 41, 39, 18, 27, 14 and 25 houses of ward I to XII respectively. Stream as a drinking water source was used only in 3 families of ward I. 18, 9, 1, 2, 0, 0, 3, 0, 0, 6, 3 and 6 tube wells were seen in ward number I to XII respectively. The distribution of open dug wells were 134, 209, 318, 324, 206, 406, 368, 295, 289, 290, 177 and 227 in wards I to wards XII respectively. 153, 124, 74, 71, 70, 32, 91, 59, 46, 33, 34 and 118 depended on other wells as drinking water source.

4.8.2.3.2 Source of Bathing Water

In Madakkathara panchayat, 69 per cent depended on own wells for bathing water. Bathing water source also followed similar trend to that of drinking water. With regard to bathing water 9, 3, 1, 3, 1, and 4 houses in wards I to V and XII respectively used pond as their source. Public ponds were the source for one family each in ward I and XII and 50, 2, 0, 0, 36, 0, 2, 1, 0, 69, 52, and 35 in wards I, II, V, VII, VIII, X, XI and XII respectively used public tap as their bathing water source. Public well formed the source for 12, 14, 15, 3, 3, 27, 40, 39, 17, 23, 14 and 25 houses in wards I to XII respectively. Three houses in ward I depended on stream as the source for bathing water. Tube well formed the source for 19, 9, 1, 2, 5, 7, 4 and 5 houses respectively in wards I, II, III, IV, VII, X, XI, and XII. Wells were the sources for 135, 210, 318, 324, 206, 408, 366, 295, 290, 286, 178 and 228 houses in wards I to XII of the panchayat respectively and finally 144, 123, 74, 71, 70, 31, 92, 59, 46, 29, 31 and 118 houses had to depend on others' wells in wards I to XII respectively.

4.8.2.3.3 Use of Boiled Water

Among the total respondents (4689 families) only 964 used boiled water for drinking, whereas 3275 drank water without treating, indicating that the water available to them was potable. 328, 389, 5 and 242 houses in ward number VI, VII, VIII and IX respectively used to boil water before drinking and the rest of the population did not follow the practise.

4.8.2.3.4 Scarcity of Water

Water scarcity was dominant in 434 families of Madakkathara panchayat predominantly in ward number VI, VII and X. Water scarcity was not evident in ward number I, II, III, IV, V, X, XI and XII whereas 156, 192, 3, and 83 houses faced water scarcity in ward number VI, VII, VIII and IX respectively.

4.8.2.4 Government Schemes and Beneficiaries

There were different developmental schemes under implementation in the panchayat. The details regarding the number of beneficiaries among the respondents are given in Table 10.

There were 63 beneficiaries for the Antyodaya scheme, 22 for Annodaya scheme, 92 had received aid for building houses, 17 had received monetary aid from Government, 133 had received aid for making latrine and 21 had received aid for repair of their houses. Maximum beneficiaries were seen in ward IX followed by ward VII, ward VI, ward I and ward II. The respondents in the rest of the wards were not included as beneficiaries in different schemes in Madakkathara Panchayat.

4.8.3 Livestock Details

The distribution of livestock population among the responded families derived from the spatial data on houses of Madakkathara Panchayat is given in Table 11.

Table 10. Ward wise distribution of beneficiary families in different Government schemes of Madakkathara Panchayat

Government Schemes	Ward Number												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total
Andyodaya	0	0	0	0	0	47	7	0	9	0	0	0	63
Annodaya	0	0	0	0	0	2	1	0	19	0	0	0	22
Aid for house	0	0	0	0	0	23	32	0	37	0	0	0	92
Other aids from Government	6	1	0	0	0	0	6	2	2	0	0	0	17
Aid for latrine	0	0	0	0	0	26	58	0	49	0	0	0	133
Aid for house repair	0	0	0	0	0	0	11	0	10	0	0	0	21
Total beneficiaries	6	1	0	0	0	98	115	2	126	0	0	0	348

There were 2234 livestock in the panchayat. Poultry accounted for 36.7 per cent of the livestock. There were only 6 families involved in pig rearing in the panchayat. The population of cows, buffalo, goat, bullock, pig, poultry, and others were 489, 34, 447, 3, 6, 820 and 435 respectively. The most number of animals were seen in ward II followed by ward I and XII. The least population of animals was seen in ward V and ward IX.

4.9 WATERSHED DELINEATION

Kachithode-Kothara watershed was delineated using a Digital Terrain Model (DTM) developed from contour lines of 1:25,000 topographic maps numbered 58B/6/SW and 58B/2/SE of Survey of India. The watershed consists of *Kachithode* dam, a non-perennial stream originating from the Dam and its catchments. The rivulet originating from the dam ends in a canal within the boundary of the watershed area.

4.9.1 Watershed Details

Kerala State Land Use Board in association with Kerala State Remote Sensing and Environmental Center in 1996 delineated the study watershed in 1:50000 scale and had given the nomenclature as 18K40o. The watershed comprises of Ninukuzhi, Kachithode and some parts of Akkarapuram and Kallayi area of Madakkathara Panchayat. The watershed has Panancheri Panchayat in the east, parts of Vellanimala, Chenkallikunnu and Kallayi in the north, Kotharakunnu and Akkarapuram in the south and Kallyithodu in the west.

Table 11. Livestock details in different wards of Madakkathara Panchayat

Sl. No.	Livestock Type	Ward Number												Total
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
1	Cow	58	105	25	0	0	0	66	57	51	21	41	65	489
2	Buffalo	4	3	0	0	0	0	9	8	4	0	4	2	34
3	Goat	71	118	4	6	5	15	23	39	24	28	12	102	447
4	Bullock	0	0	0	2	0	0	0	0	1	0	0	0	3
5	Pig	3	2	0	0	0	0	0	0	0	0	0	1	6
6	Poultry	201	185	22	13	12	18	52	70	9	146	46	42	816
7	Duck	4	0	0	0	0	0	0	0	0	0	0	0	4
8	Other	7	5	125	167	18	65	27	5	0	10	6	0	435
9	Total	348	418	176	188	35	98	177	179	89	205	109	212	2234

4.9.1.1 Location of the Study Watershed

The watershed is located between the longitude 76^0 16$'$ 48$''$ E and 76^0 18$'$ E and 10^0 34$'$ 12$''$ N and 10^0 34$'$ 48$''$ N. Spatial location of the Kachithode - Kothara watershed and its location with respect to the Panchayat is depicted in the Fig. 2.

4.9.1.2 Physiography of the Watershed

The general physiography of the watershed is given by the distribution of contour lines inside the boundary of the watershed. The distribution of contour in the watershed is given in Fig. 20. The contours are spaced in 10-meter intervals. A DTM of the watershed area based on the contours of the watershed area is given in the Fig. 21. Land with altitude ranging from 20 to 300 m above mean sea level is seen in this watershed. The watershed has area with slope less than 5 ^{0} in the plains to slopes greater than 27 ^{0} in the hills.

4.9.1.3 Slope of the Watershed

The slope of the watershed is varying and a DTM built on the slope of the watershed is shown in Fig. 22. The slope range in the Kachithode-Kothara watershed was divided into nine classes in the slope map ranging from 0 to 90^o at 10^o interval. Since the terrain is undulating there area several hillocks and valleys in the watershed.

4.9.1.4 Current Land Use of the Watershed

The current land use of the watershed is shown in Fig. 23. The landuse type of the watershed is dominated by cashew plantation in the watershed. The other major land use type seen in the watershed were banana, coconut, kharif rice, mixed trees, teak and mixed crops. There was some wastelands in the lower

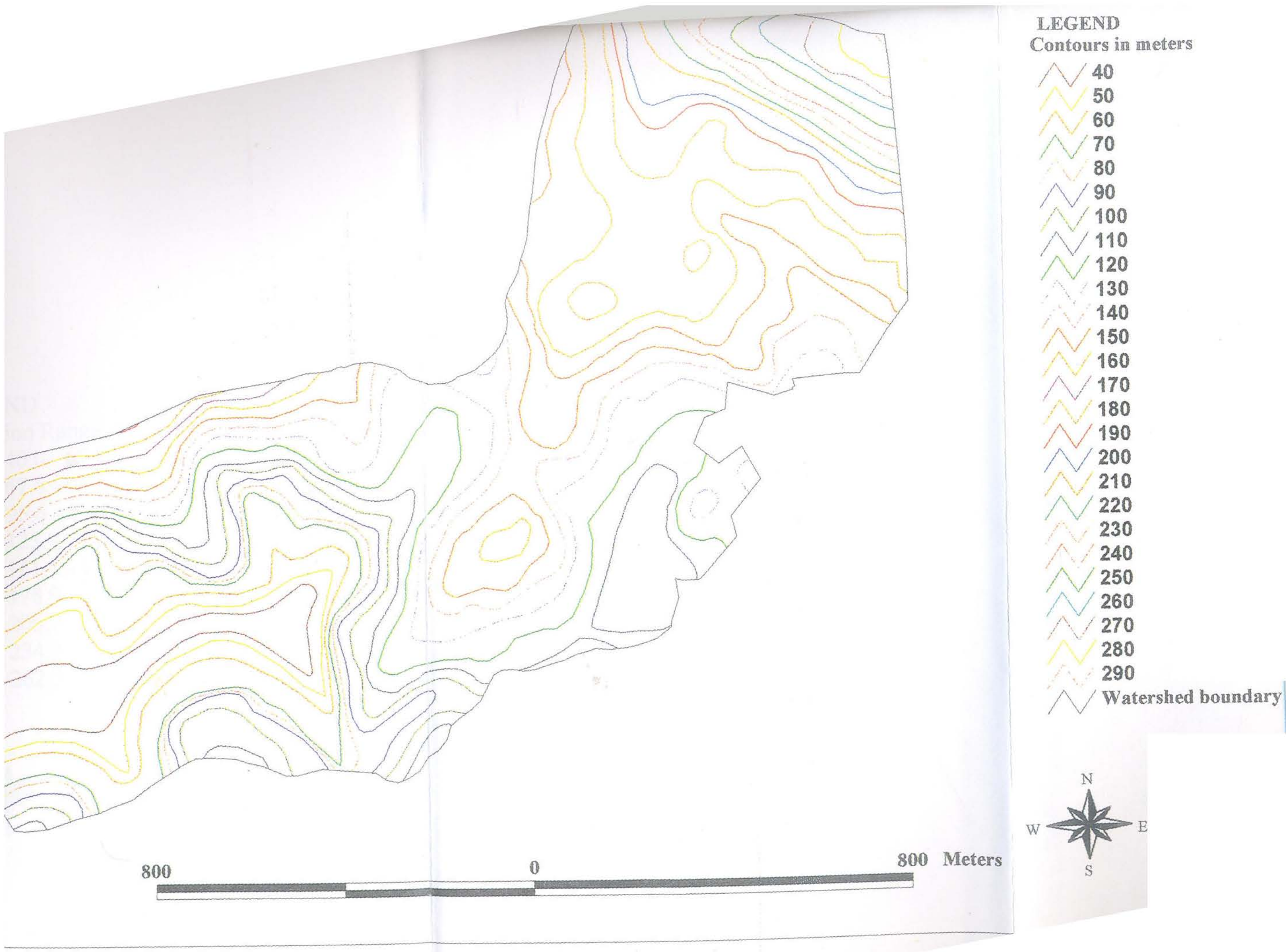
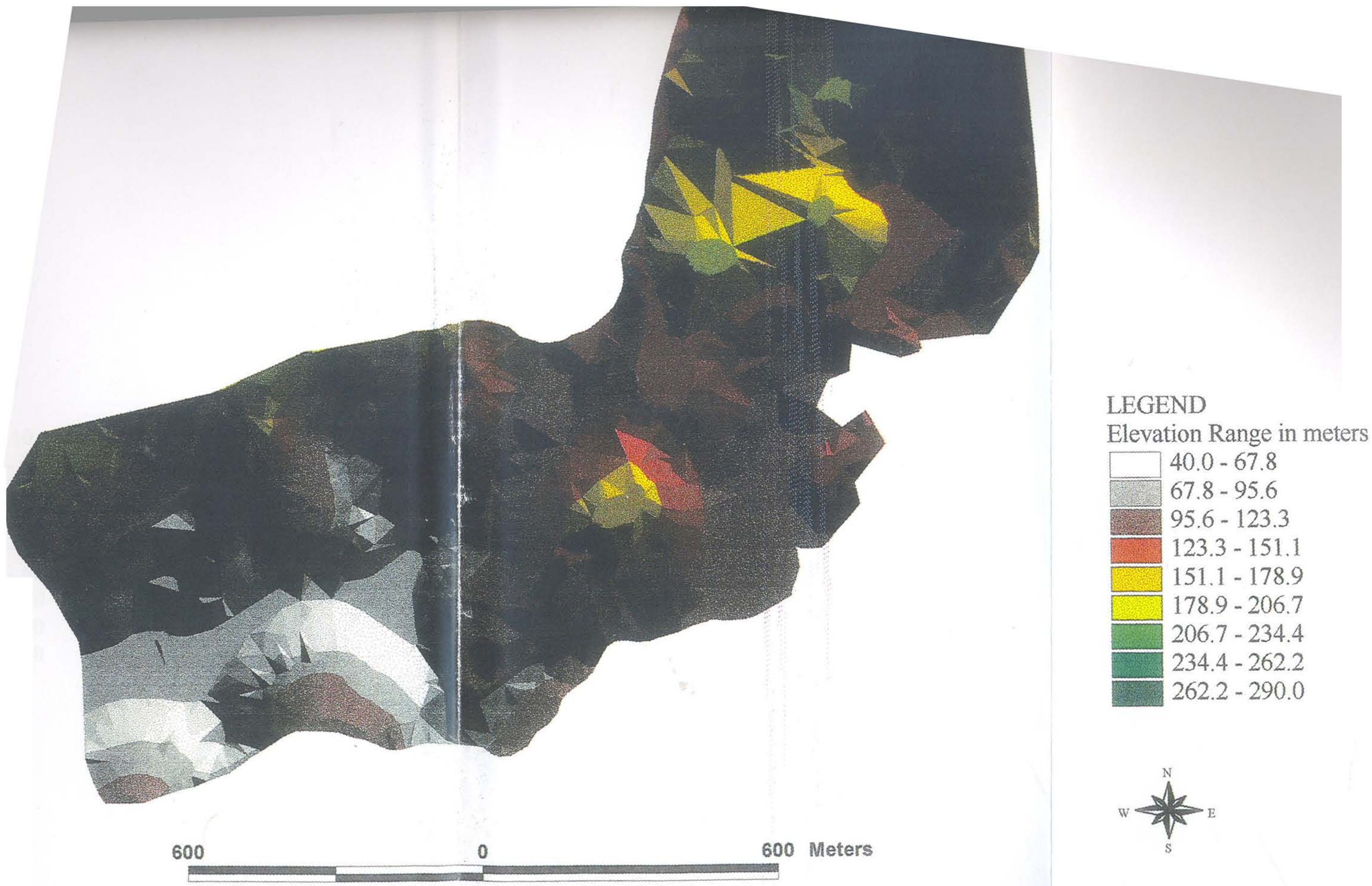


Fig. 20. Distribution of 10 m interval contours in Kachithode Kothara w...



...of Kachithode Kothara watershed showing elevation (GIS output)

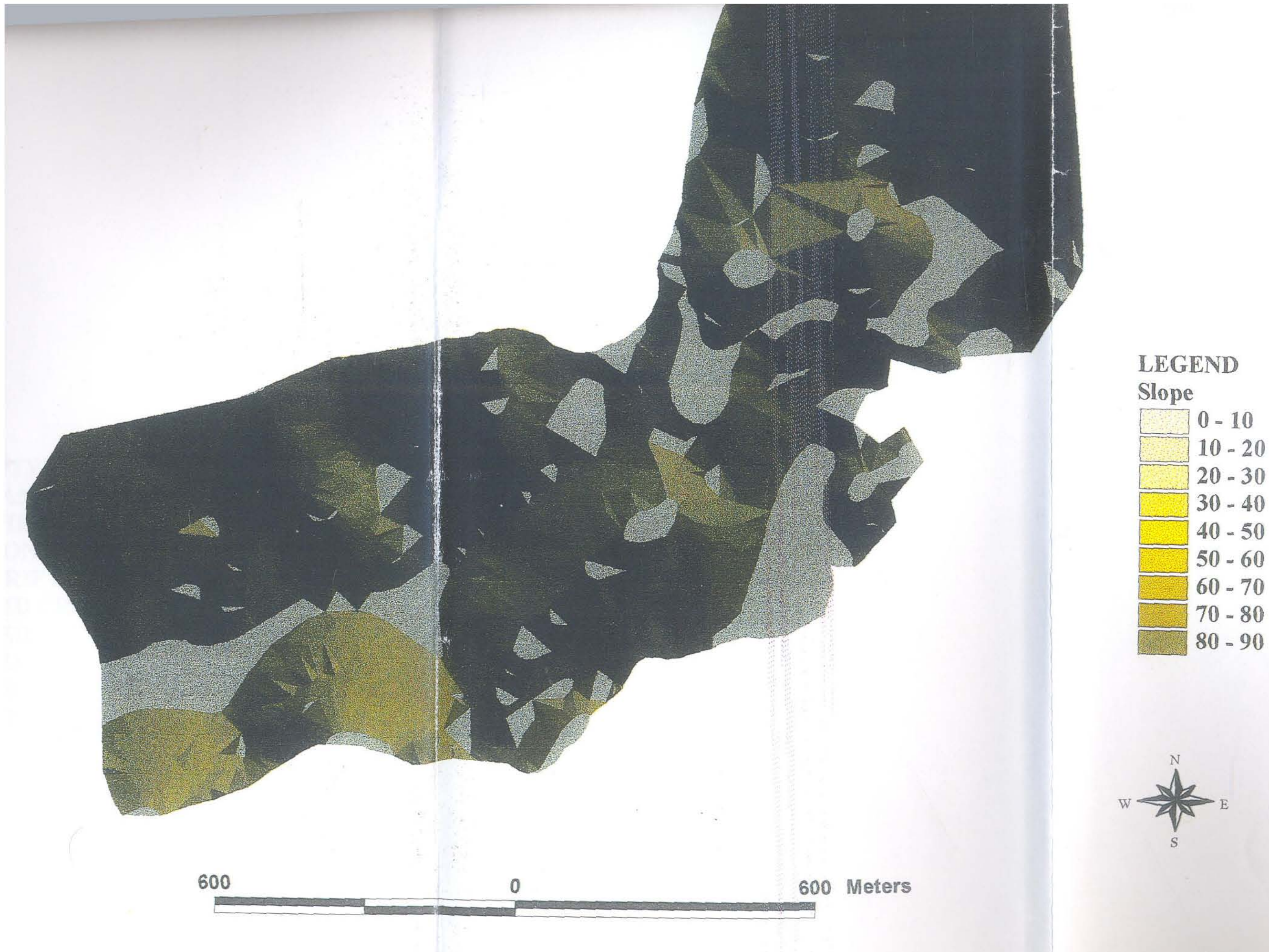


Fig. 22. Digital terrain model of Kachithode Kothara watershed showing the slope ranges (GIS output)

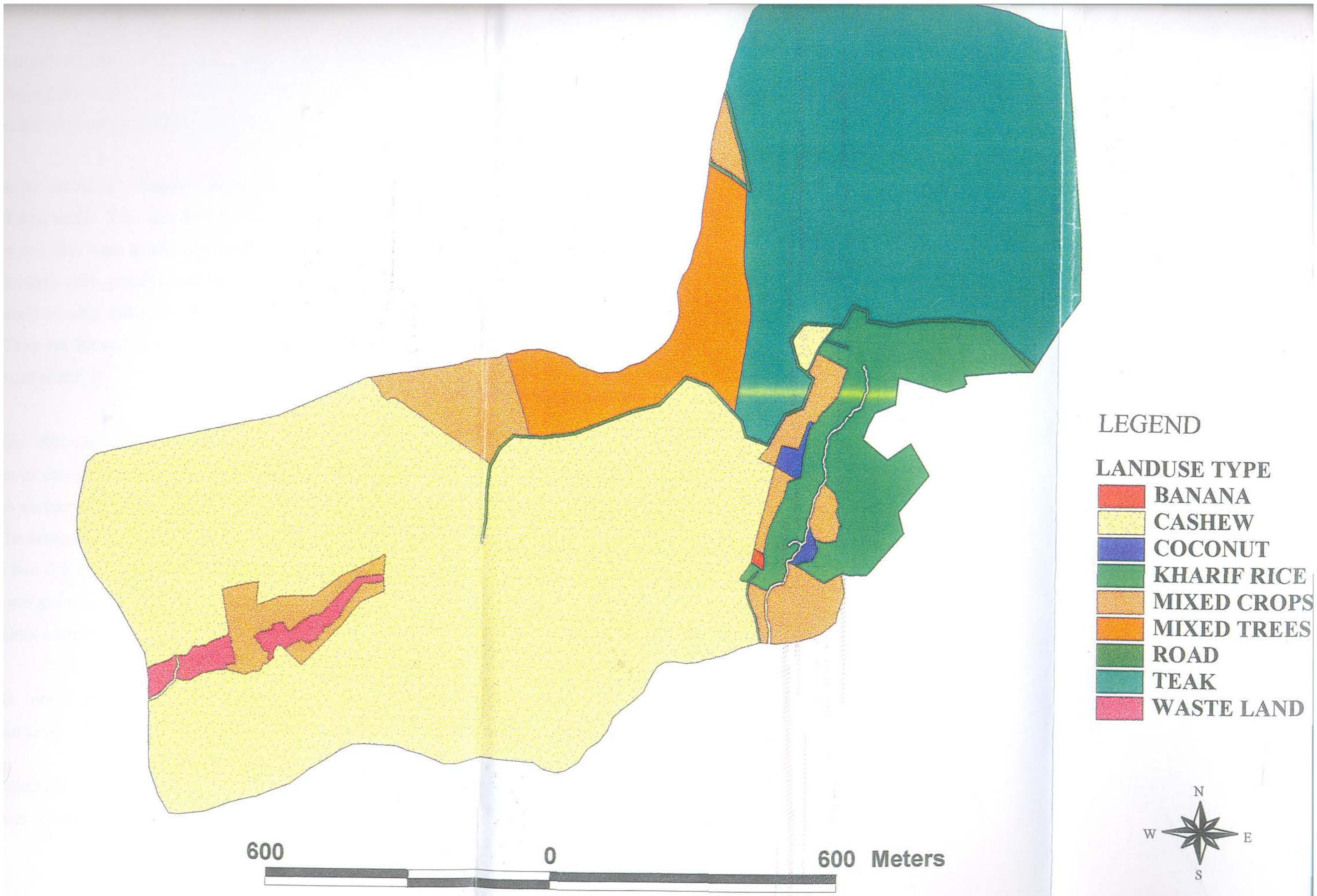


Fig. 23. Current landuse type of Kachithode Kothara wataershed (GIS output)

regions of the watershed. The area termed as mixed crops were predominantly homesteads.

4.9.1.5 Soil Characteristics of the Watershed

The soil of the Kachithode-Kothara watershed has been included in the Madakkathara series. The series was proposed by the Soil Survey Organization, Kerala. The typifying pedon studied was the Madakkathara clay loam, cultivated. The detailed description of the Madakkathara series is as follows.

Madakkathara series is a member of the fine, mixed, isohyperthermic family of Typic Kandiustalfs. This include very deep strongly acid, yellowish red to dark reddish brown, clay loam to silty clay loam surface soils underlain by dark reddish brown, strongly acid, gravelly clay loam to clay subsoils. They occur on nearly level to gently sloping narrow valleys in between strongly sloping to very steep low hills. They are formed in water worked sediments of the upper slopes under humid tropical climate.

The profile characteristics at various depths in accordance with the horizons are given in Table 12. The depth of the solum ranges from 120 to 200cm. The colour of the surface soil ranges in hue 5YR and 7.5 YR, value 3 to 5 and chroma 4 to 6. The texture ranges from clay loam to silty clay loam. The sub soil colour ranges in hue 5 YR and 10 YR with value 3 and 4 and chroma 3 to 6. Texture varies from gravelly clay loam to clay. Gneissic cobbles are noticed in some horizons below a depth of 150 cm.

The soils are imperfectly to moderately drained with moderate permeability. Main crops are paddy, coconut, arecanut and banana.

Type location for Madakkathara series is Madakkathara village, Thrissur Taluk and the series was proposed by Soil Survey Organization, Kerala.

4.9.1.5.1 Soil Physical Properties

Physical properties of the Madakkathara series as given by Soil Survey Organization (2003) are given in Table 13. Gravel was found in the first two horizons only. At 0 – 15 cm depth the content of gravel was 12.5 per cent where as at a depth from 15 – 32 cm the gravel content increased to 20 per cent. The content of very coarse sand was 10.72 per cent at 0 – 15 cm depth which increased to 13 per cent in the lower horizon (15 – 37 cm). The very coarse sand content was 6.29 per cent at the depth of 37 to 112 cm and 6.62 per cent beyond 112 cm depth. The coarse sand content varied from 7.57 per cent in 0-15 cm to 5.69 beyond 150 cm. The maximum percentage was observed at 37-112 cm, whereas 15-37 cm had 7 per cent coarse sand. The medium coarse sand was highest in 15-37 cm with 7.67 per cent followed by the lower horizon (37-112 cm) with 7.34 per cent. The lowest content was observed beyond 112 cm with 4.61 per cent. Howerver, the first horizon recorded 5.76 per cent coarse sand. The fine sand content was highest in the uppermost horizon with 8.77 per cent. The lower horizons recorded 5.82 per cent (15-37 cm), 7.26 per cent (37-112 cm) and 4.78 per cent (beyond 112cm). The very fine sand content of soils under Madakkathara series progressively declined from 10.13 per cent in the plough layer (0-15 cm) to 1.34 per cent in the horizon beyond 112 cm. The total sand content was highest in 15-37 cm horizon and least in the lowest horizon. The clay content of the soil increased from 33.09 per cent in 0-15 cm to 52.10 per cent in 112-150 cm horizon. The clay content in 15-37 cm and 37-112 cm were 39.11 and 45.50 per cent respectively. The silt content in the horizons were 23.96, 23.74, 21.77 and 24.86 in 0-15, 15-37, 37-112 and beyond 112 cms respectively.

4.9.1.5.2 Soil Chemical Properties

The chemical and electro-chemical properties of the Madakkathara series as given by Soil Survey Organization (2003) are given in Table 14. The organic carbon percentage showed a progressive decline from 1.93 at 0 –15 cm to 0.24 at 112-150 cm. The exchangeable sodium was 0.51, 0.30, 0.41and 0.46 cmol kg^{-1} in the horizons 0-15 cm, 15-37 cm, 37-112 cm and beyond 112 cms respectively. Similarly, exchangeable potassium was 1.04, 0.48, 0.74 and 0.75 cmol kg^{-1} at the horizons 0-15 cm, 15-37 cm, 37-112 cm and beyond 112 cm respectively. Exchangeable Ca content was highest at 0-15 cm with 2.14 cmol kg^{-1} and lowest at the horizon beyond 112 cm with 1.53 cmol kg^{-1}. The pH of the soil varied from 5.0 to 5.2 in the different horizons of the soil with highest at 0-15 cm and lowest at 37-112 cm and 112-150 cm. The base saturation percentage was 40 at 0-15 cm, 45 at 15-37 cm and 47 per cent beyond 37 cm.

4.9.1.6 General Soil Types of the Watershed

The spatial details of the general soil types of the watershed are given in Fig. 24. The watershed contain mainly three types of the soil namely lateritic soil and forest loam soils in areas on the upper reaches of watershed lying adjacent to forest area and variable shallow soils in the lower reaches of the watershed.

4.9.1.7 Drainage Pattern of the Watershed

Drainage pattern of the watershed is given in the Fig. 25. Several first order and second order streams are found in the drainage system of the watershed. The main stream drains into Vellanikkara branch canal. The streams are non-perennial in nature and they dry up during the summer months. The streams are active in the monsoon months and they drain out the excess of water from the Kachithode dam.

Table 12. Profile description of Madakkathara Soil Series

Horizon	Depth (cm)	Brief description
Ap	0-15	Yellowish red (5YR 5/6 D) dark reddish brown (5YR3/4 M) clay loam; moderate medium sub angular blocky; slightly hard, friable, slightly sticky and slightly plastic; many fine concretions; many very fine to fine roots; fine interstitial pores; moderate permeability; pH 5.2; clear smooth boundary
B1	15 -37	Dark reddish brown (5YR3/4 M) gravelly clay loam; moderate fine to medium sub angular blocky; friable slightly sticky, many fine and medium pores; many medium ferro manganese concretions; many fine quartz gravels; moderate permeability; pH 5.1; clear smooth boundary
B2	37-112	Dark reddish brown (5YR3/3 M0 clay loam medium to coarse subangular blocky; friable, sticky and plastic; common fine pores; many fine concretions; few fine quartz gravels; common medium distinct mottles (5 YR 5/2); moderately slow permeability; pH 5.1 clear smooth boundary
B3	112-150	Reddish brown (5YR 4/4 m) clay; medium coarse subangular blocky; friable, sticky and plastic; many medium iron concretions; few fine quartz gravels; many medium distinct yellowish red (5YR 4/6) and dark reddish brown (5YR 3/2) mottles; moderately slow permeability; pH 5.2

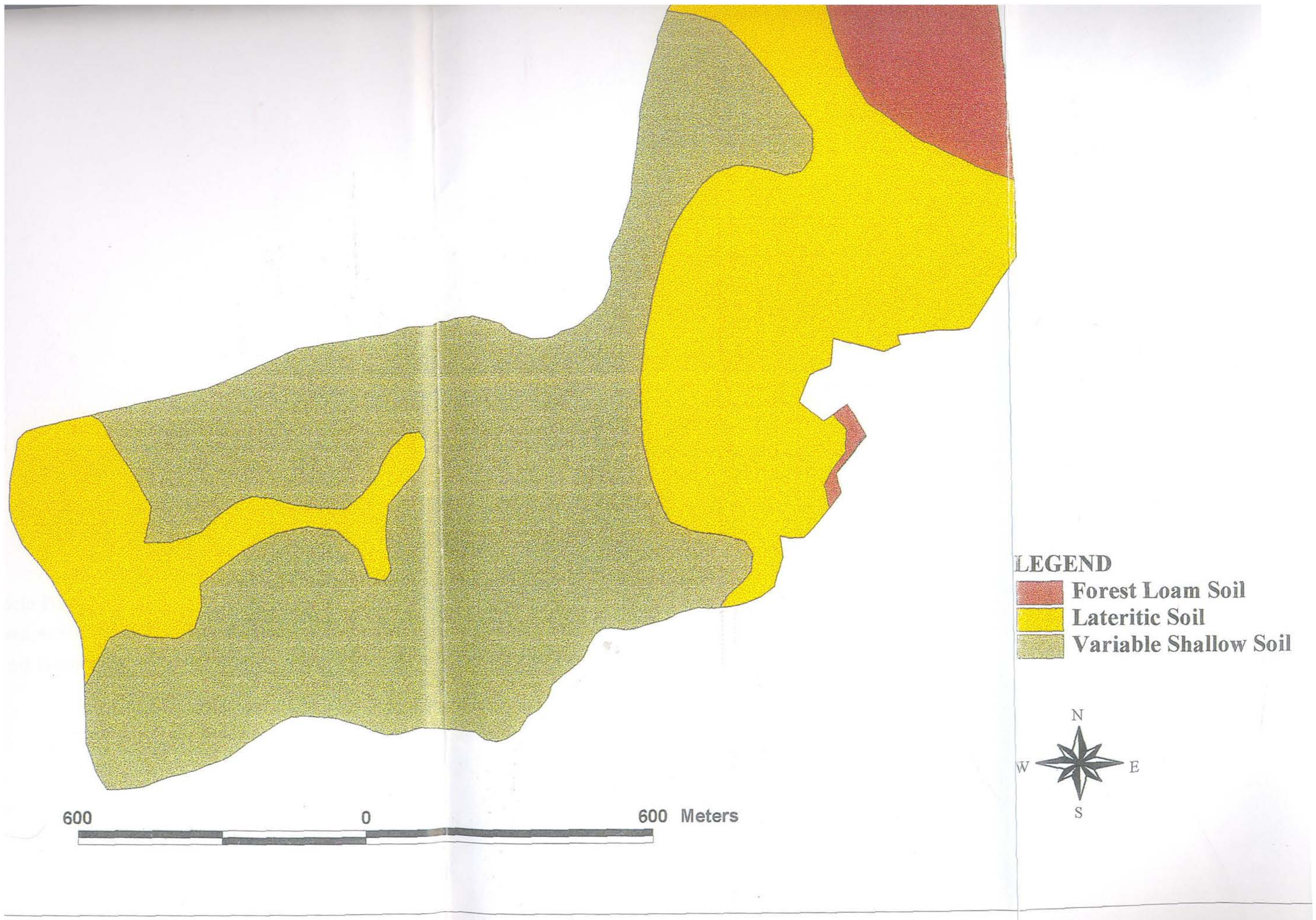


Fig. 24. Spatial distribution of major soil types in Kachithode Kothara watershed (GIS output)

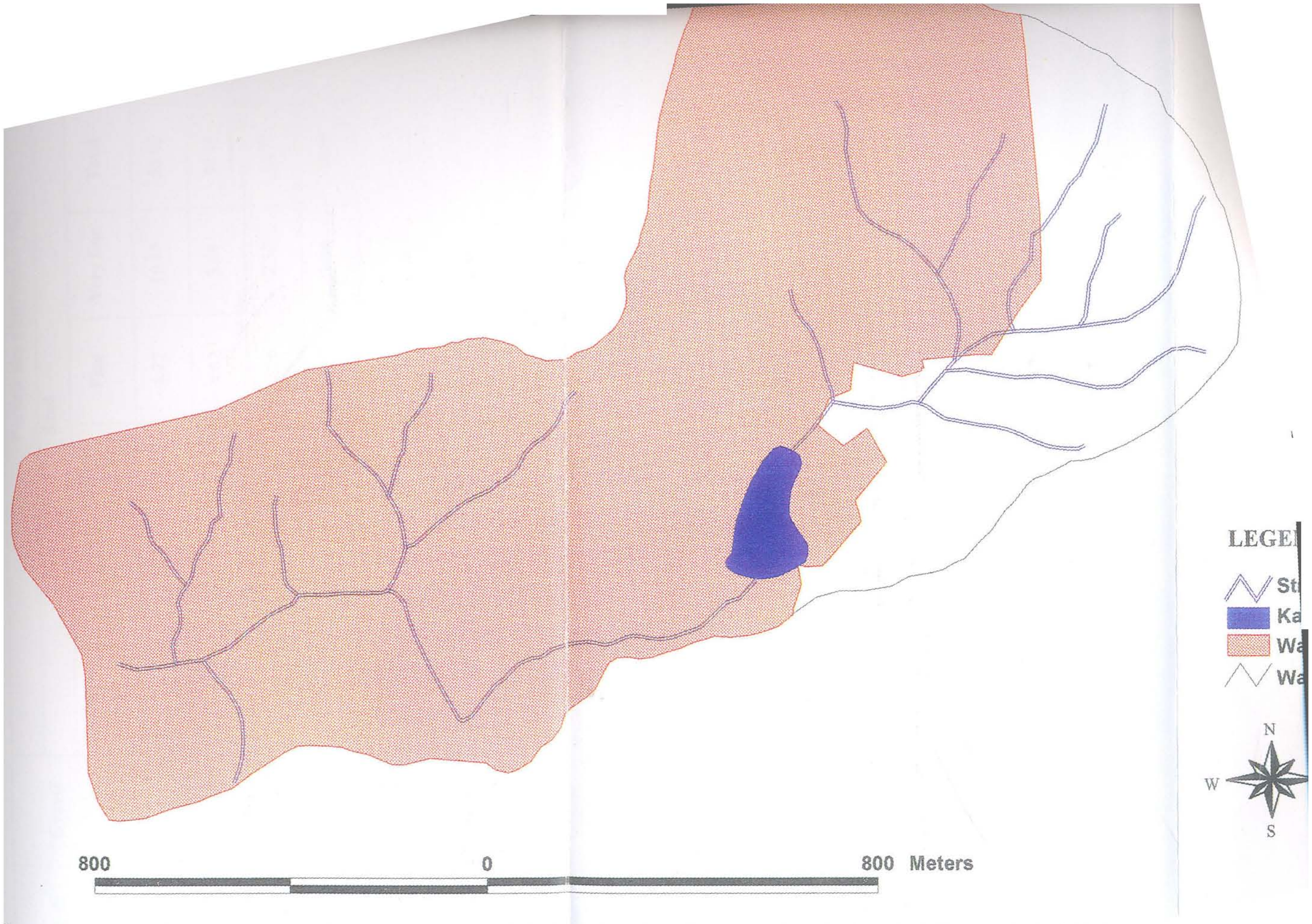


Fig. 25. Drainage pattern of Kachithode Kothara watershed

Table 13. Physical properties of the soils under Madakkathara series

Depth (cm)	Gravel (%)	Particle size distribution (%)							
		Sand						Clay	Silt
		Very coarse	Coarse	Medium Coarse	Fine	Very fine	Total		
0-15	12.50	10.72	7.57	5.76	8.77	10.13	55.45	33.09	23.96
15-37	20.00	13.00	7.00	7.67	5.82	3.66	57.15	39.11	23.74
37-112	0	6.29	9.54	7.34	7.26	2.30	32.73	45.50	21.77
112-150	0	6.62	5.69	4.61	4.78	1.34	23.04	52.10	24.86

Table 14. Chemical and electro-chemical properties of the soils under Madakkathara series

Depth (cm)	Organic carbon (%)	Exchangeable bases (cmol kg^{-1} soil)				cmol kg^{-1} soil				EC	BSP	pH
		Na^+	K^+	Ca^{++}	Mg^{++}	ECEC	CEC	Exchangable acidity				
								H^+	Al^{3+}			
0-15	1.93	0.51	1.04	2.14	0.09	4.30	5.0	0.73	0.52	0.1	40	5.2
15-37	1.28	0.30	0.48	2.09	0.09	3.61	6.6	0.78	0.13	0.0	45	5.1
37-112	0.26	0.41	0.74	1.98	0.08	3.67	6.8	0.65	0.45	0.0	47	5.0
112-150	0.24	0.46	0.75	1.53	0.11	3.50	6.1	0.93	0.65	0.0	47	5.0

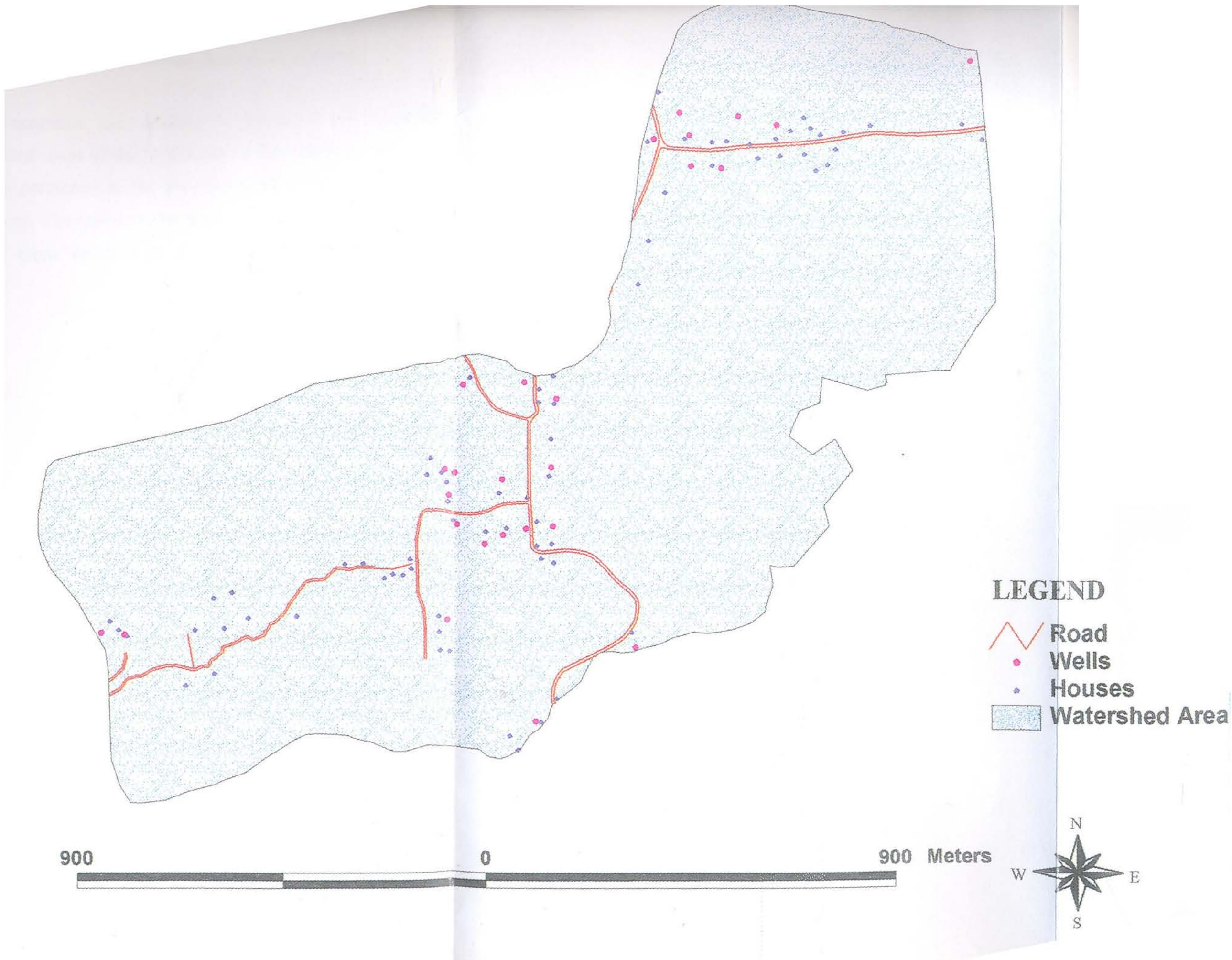


Fig. 26. Spatial distribution of wells in Kachithod

4.9.1.8 Distribution of Wells in the Watershed

There were 26 wells distributed in Kachithode-Kothara watershed for the 74 houses. The spatial distribution of wells in the watershed is given in Fig. 26. Most of the wells in the upper reaches of watershed dry up in summer causing water scarcity. 24 houses of the watershed owned wells, 3 depended on public wells and 29 depended on others well for meeting their needs of water.

The current investigation has resulted in generation of automated administrative and cadastral maps of the Madakkathara Panchayat as well as an array of thematic maps pertaining to the panchayat and Kachithode-Kothara watershed in the panchayat. The resuts can be used for effective, conceptualised decision-making by all those involved in planning for development of the panchayat.

Discussion

DISCUSSION

The need for spatial treatment of data, required for taking location/area specific decision related to rural development, cannot be over-emphasised. The planners and elected representatives often take area/location specific decisions under the Panchayati Raj system. They are always in need of maps at large scales, particularly at the Block panchayat and Grama panchayat levels. Therefore, there is a vast scope for the use of Geoinformatics in facilitating the decision making process at various levels of decentralised planning (Ajai, 2002). The strength of Geographic Information System (GIS) is its ability to integrate data from various resource disciplines, using a common geographical boundary of reference. These computerised systems which can produce geographic (spatial) information integrated with statistical and textual data, are becoming the most useful and powerful analytical tools for resource planners and managers (Mani, 2002).

The application of GIS and Remote Sensing (RS) technologies for assessment and monitoring of agricultural resources would facilitate scientific analysis of the resources and formulation of appropriate solutions to different resource management and development problems. Access to results from such analyses can lead to better decisions that will facilitate smooth implementation of projects and encourage wider participation of the stakeholders (Saifudeen, 2001; Nair and Saifudeen, 2004).

The results of the study would contribute significantly to the above proposition at Madakkathara Panchayat level and also at the Kachithode-Kothara watershed level. As stated, the objective of this thesis work was to integrate available data on the soil-related agricultural resources of Madakkathara Panchayat into a Geographic Information System (GIS) and to demonstrate the capability of GIS as a decision support system to design projects for integrated resource use and management, in a pilot watershed within the Panchayat. The objective was achieved in terms of the following.

i. Spatial database for various resources of Madakkathara Panchayat in general and Kachithode-Kothara watershed in particular was established through digital cartographic techniques available in different GIS softwares.

ii. Attribute information on the geographic entities were collected, tabulated, computerised and attached to the spatial database. Attribute data or tabular data describes the quantitative and/or qualitative characteristics of the spatial features. The attribute data of spatial features represented is one of the strengths of the GIS for the panchayat and the Kachithode-Kothara watershed. In fact, most of the tabular data currently used by planners and administrators are the attribute data of map features. But when they are used in tandem with the spatial feature it increases the efficiency of the programme.

iii. Above two components (spatial and attribute data) were integrated in GIS environment and outputs were created. The main task executed while preparing the GIS for Madakkathara Panchayat and the component watershed was the integration of spatial and non-spatial data. Such an exercise require database on status of development of at micro-level, identification of relatively underdeveloped or less developed micro-level units, data on existing natural resources and availability of infrastructural facilities and present form and pattern of utilisation of these resources (Singh, 1995).

iv. Salient outputs were reported as results of the study. The basic layers that were covered in the GIS for Madakkathara Panchayat are administrative boundaries of villages and wards, cadastral details, major economic and social institutions and road network. Thematic layers on drainage pattern, distribution of dug wells, water availability, soil type distribution, landuse types, contour intervals and a digital terrain model developed from the contours, and distribution of households were included for both panchayat and watershed levels. In addition, a satellite imagery of the panchayat (IRS 1C LISS III + PAN merged data) that was used for confirming current land use of the panchayat and pilot watershed was also included as a GIS layer. Similar data was collected for making a GIS for block level planning by Mani (2002).

Products of the thesis would enable spatial planning to be operational in the panchayat. The relevance of the results, for scientific appraisal and analysis of available resources of the panchayat and the pilot watershed (Kachithode-Kothara) for their rational utilization, are discussed under different sections in this chapter.

5.1 MICRO-LEVEL GIS FOR THE MADAKKATHARA PANCHAYAT

The digital interactive maps generated are illustrative of the capability of GIS to enable the decision makers to better visualise existing natural and infrastructural situations; integrate natural resource and socio-economic data and use the information thus gained for improved area-specific planning, programme monitoring and monitoring of natural resources.

5.1.1. Land Information System for the Panchayat Administration

The only sources of base maps available for micro level administration were the village level cadastral maps maintained by the Govt. departments of land records and revenue. The cadastral maps are generally old and have inaccuracies due to copying and regeneration over a period of time. These maps, although available in hard copy formats, were not being effectively used for decision making for planning at panchayat level (Chattopadyay *et al.*, 1999; Mani, 2002).

The thesis work being reported was however, benefited from the maps obtained from concerned village offices and Thrissur office of the Department of Survey and Land Records. The processing and re-creation process was for all the hard copy maps adapted for GIS preparation was described elsewhere. These maps and hard copy maps from other sources like Kerala State Land Use Board were used for preparing a GIS for the panchayat, where spatial data is automated at the level of details required for local administration, that is, at a scale of 1:4000. The administrative entities included as GIS coverages for the panchayat are spatial data on wards and villages of the panchayat and cadastral details of the panchayat, with geographic referencing and relevant attribute data.

Madakkathara panchayat comprised of three villages namely Kurichikkara Village, Madakkathara Village and Vellanikkara Village (Fig.7) and 12 wards (Fig.8) during the study period. The smallest administrative unit in the panchayat is the ward. For effective planning, geographical locations of the wards need to be known for the planners. The total area for the panchayat generated by GIS for wards is 26.1 sq. km with the individual wards possessing 2.1, 4.9, 1.8, 1.1, 2.7, 1.2, 1.0, 1.7, 1.3, 1.0, 2.3, and 5.0 sq km respectively. The computerised form of maps of these administrative units would enable measurements of areas and location of specific places. Since the ward boundaries are politically decided are often changing. However, GIS being dynamic facilitates editing and updation.

Another important layer in the GIS for Madakkathara Panchayat is the cadastral details (Fig.9). This GIS coverage would assist in monitoring tax collections and land transactions in the panchayat, with necessary updating. During the period of study, there were 1707 cadastral plots in the panchayat spanning over three villages and 12 wards. Some areas marked as reserve forest in village records, and therefore in the GIS layer, are now inhabited with settlers. They do not have the title deed but enjoy the right of the land. The ownership pattern of the individual plots could not be gathered from the village offices due to official restrictions. However, some information could be gathered during the survey. This particular layer in the GIS corroborates the initiatives of the state Government to computerise revenue records. Similar approach for digitising cadastral details for providing record of rights, tenancy and crops to farmers was successfully implemented in Karnataka state of India (Chawla and Bhatnagar, 2003)

5.1.2. Infrastructural details of Madakkathara Panchayat

Infrastructure details of the Madakkathara Panchayat include the network of roads and the major social and economical institutions of the panchayat. Although these two themes are developed as separate layers in the GIS, a combined output is generated (Fig.10) for easy comprehension.

The network of roads spread over 81 km include bitumen, non-bitumen and footpaths as per panchayat records. Only 27.3 km of the total road was in good condition. The panchayat possesses a wide array of economic and social institutions. Some of the major institutions are Kerala Agricultural University, 400kV substation, Vanaja mills, three service cooperative banks, nine ration shops, five churches, one mosque, 16 temples, six libraries, five schools, three government hospitals and several shops and hotels. There are other cooperative societies and cooperative institutions. The spatial distribution of these institutions and their characteristics as described in GIS database, would enable assessment of the development potential of the panchayat and for site selection for further infrastructural development.

5.1.3 Agricultural Resources of Madakkathara Panchayat

Lessons of the past have revealed that the strategy for agricultural growth has to be based on conservation and improvement of the productivity of natural resources namely soil, water and bio-diversity. Judicious integration of natural resources with socio-economic features of specific localities would help in maintaining ecological balance and so sustainable development (Nair and Saifudeen, 2004). Kerala State is well endowed with natural resources that can support the people to a large extent. But we need to discipline ourselves for managing our resources and environment judiciously.

The biophysical and socio-economic resources included in the GIS for Madakkathara panchayat as well as the pilot watershed are soil resources, landuse pattern, water availability, distribution of streams, rivers, ponds and wells and the contour of the area. Decisions on agricultural development planning for the panchayat can now be in the light of these GIS layers in conjunction with the administrative and infrastructural and other socio-economic details integrated in the GIS.

5.1.3.1 Terrain Features of Madakkathara Panchayat

The physiography of the panchayat was built using the projected contours at ten-metre interval (Fig. 17). A digital terrain model (DTM) was developed using the principles of triangulated irregular network (TIN) available with the 3D spatial analyst extension of arc view software (Fig. 18). The DTM revealed that the landscape of Madakkathara Panchayat is undulating with hills and valleys alternating each other. The land form is comprised of more than one facet laid out in a topo-sequence commencing from the ridge crests, moving downwards through slopes of varying degrees, and dropping into valleys of differing size which in turn terminate in drains of small or big dimensions. Typically four types of facets viz. the hill top, the upper slope, the lower slope and the valley could be distinguished on a slope continuum. The hill tops are distinguishable into flat plateau or gently sloping humps, the slopes are gentle and the valleys are broad.

The hills were concentrated more on Eastern and North eastern parts of the panchayat. Additional information that could be derived from the DTM was the slope aspect of the area that is depicted in Fig. 27. The aspect values were given in degrees that imply the direction of the hill facing the sun. The area having the value of zero degree face North, 90 degree face East, 180 degree face South and 270 degree face West. This information can be effectively used for selecting suitable area for various crops (ESRI, 1995).

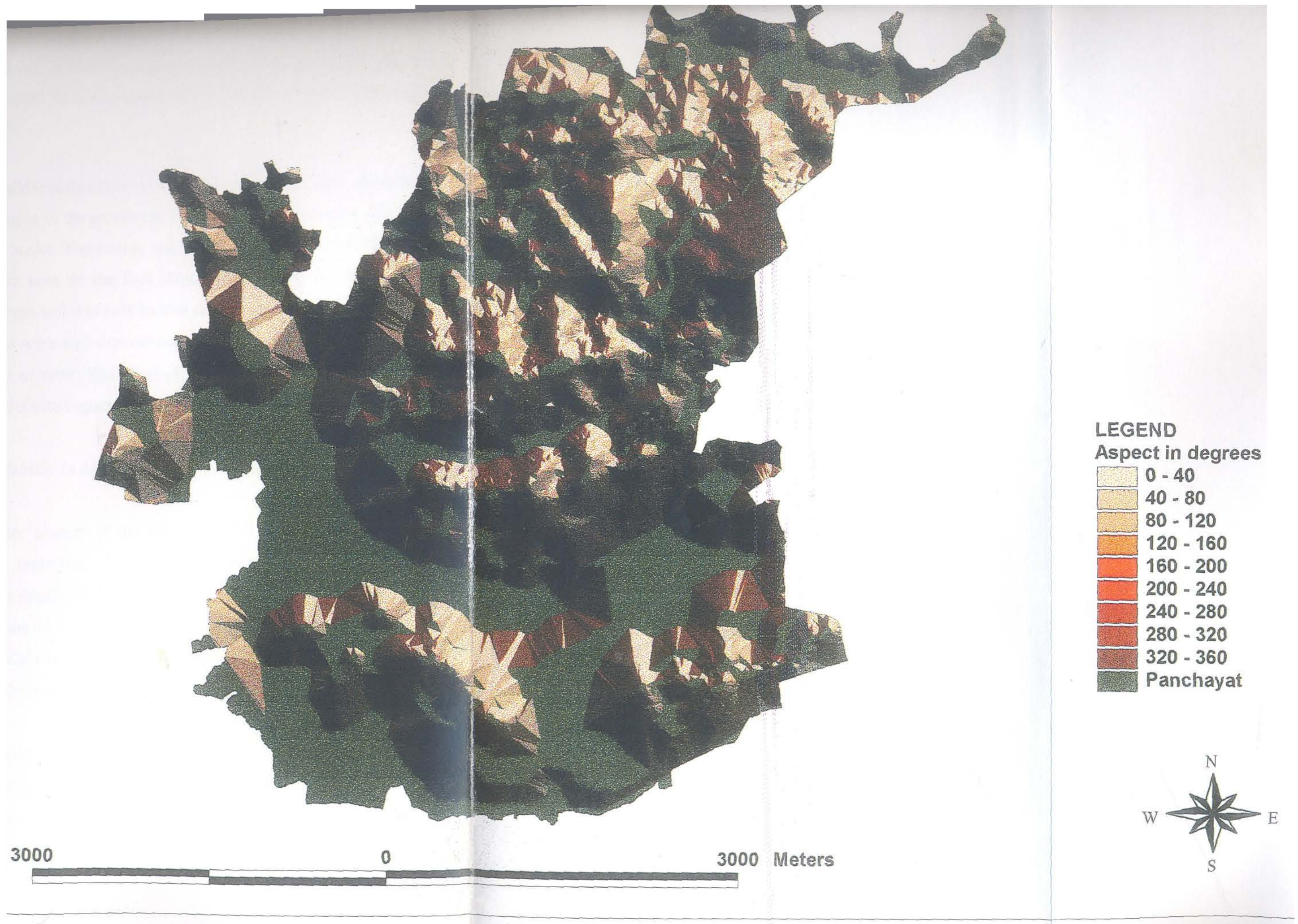


Fig. 27. Slope aspect details of the terrain in Madakkathra Panchayat

5.1.3.2 Soil Resources of Madakkathara Panchayat

Soils of the panchayat may be classified into five groups (Fig 14 and Table. 6). They were lateritic soils covering the maximum area of the panchayat spanning over 1242.58 ha in the panchayat, followed by variable shallow soils in 648.65 ha, then by riverine alluvium in 287.5 ha, and then forest loam in 253.9 ha and finally colluvial soil in 59.38 ha. Lateritic soil spreading nearly 50 per cent of panchayat area occupied the side slope of panchayat. The texture of this soil was sandy loam.

Variable shallow soils occupied around 26 per cent of the panchayat and were seen in side slopes of the panchayat. Riverine alluvium were mostly found in valleys and stream banks. The texture was silty clay loam for riverine alluvium. Colluvial soils were seen in the foot slopes of the north eastern part of the panchayat. Forest loam soil was seen in area adjacent to reserve forest area of the panchayat. The soils were well drained except the riverine alluvial soil due to the proximity to stream or river. Variations of soils are associated with geomorphic variation and have definite impact on the production potential of land.

5.1.3.3 Water Availability in Madakkathara Panchayat

Surface water sources of the panchayat include several streams, rivers, canals, ponds and reservoirs (Fig.11). Thanikudam river is the major river spanning the entire length of the panchayat with 8.5 km course in the western side. Two canal pass through the panchayat – the Vellanikkara Main Branch Canal and Peechi Kole canal. There are many streams and several ponds in the panchayat, so also the reservoir of Kachithode dam.

The panchayat has a well-distributed dug well system (Fig.12) with a density of 178 wells per sq. km. There were 4646 wells in the panchayat of which 740 wells dry up in summer. About 69 per cent of the house hold in the panchayat has their own well and 10 per cent depend on public sources for water, 20 per cent depended on others' well for water where as only one per cent depended on tube well for water.

5.1.3.3.1 Potential areas of water availability

The spatial depiction of areas of high, moderate, low and seasonal water potentiality of panchayat were shown in Fig. 13. On overlaying the digital terrain model (Fig.18) of panchayat on the drainage pattern, it can be inferred that the water availability was high in area adjoining Thanikkudam River and in the low lying basins of the panchayat. The areas having moderate potentiality of water lie along the slopes and foot slopes and the water availability was low in crests and steep to moderate sloping surfaces as the surface run off is high and infiltration capacity of the soil is low. Thus it can be suggested that moderate to steep sloping surfaces of the panchayat need more attention for rainwater harvesting. Similar approach for identifying sites for rain water harvesting was reported by Saraf and Choudhury (1998) and Malhotra *et al.* (2003).

Analysis of the agricultural resources in terms of land capability and crop suitability are not under the purview of this thesis work. There are Automatied Land Evaluation Systems now available, for these classifications. The database now developed, with necessary enrichment on climatic and other parameters, can enable the use of automated land evaluation software for suggesting alternate land use for the panchayat and pilot watershed. This task is suggested one of the future studies in this line.

5.1.4 Current Landuse in Madakkathara Panchayat

The undulating topography (valleys, slopes and hills), arising from geological formations, together with the variety of soil types, multiply into microenvironments, which foster crops requiring contrasting agronomic conditions (Fig.15). These natural endowments enable the panchayat to produce a variety of crops. The implications of these variegated physiographic endowments are very significant in planning for the sustainable development of the panchayat.

Agricultural land is mainly utilised for cash and plantation crops. Wetlands in northern part of the panchayat are getting reclaimed at rapid rate. The major seasonal crops cultivated were banana, paddy, tapioca and vegetables in home gardens.

The major tree crops grown in the area were arecanut, teak and some fruit trees seen in homesteads. These are grouped under mixed tree crops in the GIS. The major cash crops cultivated in the area under study are coconut, rubber, cashew and coffee, among which coconut occupied the maximum area. Analysis of the satellite imagery (Fig. 16), although the data was merged bands, could confirm the results of traditional survey for inventorying the current land use. Similar approach for confirming land use using satellite imagery was done by Rao, D. V. K. N. (2000).

Agriculture, practiced in the panchayat can better be characterised as farming system rather than just crop production. Farming in the homesteads of Madakkathara result in a basket of products, which include food grains, vegetables, fruits, cash crops ranging from coconut and arecanut to rubber and cocoa, livestock, and trees. This variegated production basket is basically attributable to the heterogeneity (in terms of agronomic conditions, especially moisture status) of the land resource base as a result of the high rainfall and undulating topography. Hence farming in the panchayat results in a resource use system rather than a few specific resource use activities.

5.1.5 Human Resources of Madakkathara Panchayat

Very often, there is conflict between physical and social assessment of land use options within a given area. The local community may decide, for socio-economic reasons, their own farming alternatives, irrespective of recommendations made. In order to link, in a mutually reinforcing manner, the ecological security of the agro-climatic conditions and livelihood security of the local population, it is essential that the land use options must ensure ecological sustainability, economic viability, social acceptability and gender sensitivity. For discussing the human resources of panchayat, ward-wise demographic characteristics of the panchayat were derived from Table 1 and are presented in Table 15.

Total population of the panchayat was 24934 of which 51 per cent were females. The sex ratio was 1040. The general trends in sex ratio observed in the state in favour of females were obtained in this panchayat also. The scheduled caste accounted for 8.2 per cent of the population. Highest percentage of scheduled caste population was observed in ward I and XII with 14.6 per cent.

Literacy per cent was only 81.2 in the panchayat with 84.2 per cent of males and 78.2 per cent of females being literate. There were 30.1 per cent of total population as main workers: 46.6 per cent among males and 14.3 per cent among females.

The socio-economic pattern presented in Table 9 reveals that ninety seven per cent of the total respondents possessed land less than 1 ha and 2.3 per cent possessed land between 1 ha to 2 ha and 0.7 per cent possessed land above 2 ha. The most common wall type observed in buildings of Madakkathara Panchayat was made by bricks that was observed in 4150 houses followed by clay or mud walled buildings and then by others and lastly by straw. Only one household is using biogas for cooking purpose. Since the livestock population is considerable in the panchayat, there is scope for this non-conventional energy source for cooking and lighting purposes.

The ward wise distribution of population density and household density is given in Table 16. Population density of the panchayat is 955 persons per sq. km. It varies from 889 persons in ward I to 385 in ward XII. The ward wise population density of the panchayat were 889, 392, 1136, 1899, 672, 1978, 2285, 1211, 1618, 2310, 931 and 385 respectively.

There were two wards with population density more than 2000, five wards with population density more than 1000 but less than 2000 and five wards with population density less than 1000. The lowest population density of 385 and 393 were observed in ward XII and ward II which is the high altitude area of the panchayat lying next to reserve forest, indicating that the people preferred to settle over the low land area to avail the proximity to amenities. Similar results were obtained by Chattopadyay *et al.* (1999). The sex ratio was 1040 for Madakkathara panchayat. The household density of the panchayat varied from 88 in ward XII to 531 per square kilometer with an average for the panchayat being 217.

Table 15. Ward wise demographic characteristics of Madakkathara panchayat

Ward	Total population			Scheduled caste (%)			Literate (%)			Total workers (%)			Main workers (%)		
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
I	1866	934	932	14.6	13.0	16.3	83.2	86.1	80.4	39.5	58.1	20.9	38.8	57.1	20.5
II	1923	957	966	4.4	4.2	4.7	81.1	84.1	78.1	33.9	54.3	13.6	25.8	44.5	7.3
III	2045	982	1063	1.5	1.7	1.2	80.3	84.2	76.7	36.3	56.5	17.7	34.4	54.5	15.8
IV	2089	1101	988	4.5	5.1	3.9	81.9	87.7	75.4	34.9	45.1	23.5	31.7	41.7	20.5
V	1814	881	933	12.3	12.1	12.5	80.3	80.9	79.7	35.6	51.2	20.9	24.0	35.9	12.8
VI	2373	1152	1221	7.2	7.0	7.4	82.6	85.2	80.3	35.1	54.2	17.0	29.2	46.9	12.4
VII	2285	1107	1178	9.2	9.8	8.7	78.9	81.8	76.2	38.3	56.3	21.4	34.3	52.9	16.7
VIII	2059	1029	1030	7.0	6.8	7.3	81.3	84.3	78.3	27.1	37.7	16.6	25.0	35.6	14.5
IX	2104	996	1108	12.2	11.1	13.1	78.6	82.7	74.8	40.2	58.7	23.5	28.8	47.3	12.3
X	2310	1112	1198	4.6	4.6	4.7	85.2	86.5	84.1	32.1	51.0	14.5	30.7	49.4	13.4
XI	2141	1043	1098	14.6	14.0	15.1	80.2	83.3	77.3	37.9	53.9	22.7	24.1	36.1	12.8
XII	1925	932	993	7.0	6.0	7.9	79.7	82.6	77.0	37.6	60.8	15.8	34.5	57.4	13.1
Total	24934	12226	12708	8.2	7.9	8.5	81.2	84.2	78.2	35.7	53.0	19.0	30.1	46.6	14.3

Table 16. Ward wise densities of population and households in Madakkathara Panchayat

Ward	Area	Population	Population density	Number of households	Household density
I	2.1	1866	889	440	210
II	4.9	1923	392	443	90
III	1.8	2045	1136	467	259
IV	1.1	2089	1899	462	420
V	2.7	1814	672	426	158
VI	1.2	2373	1978	516	430
VII	1.0	2285	2285	527	527
VIII	1.7	2059	1211	491	289
IX	1.3	2104	1618	439	338
X	1.0	2310	2310	531	531
XI	2.3	2141	931	483	210
XII	5.0	1925	385	440	88
Total	**26.1**	**24934**	**955**	**5665**	**217**

Due to high population density and the demands consequent to modernisation of social life, Madakkathara Panchayat is also facing pressure on land. Therefore, marginal soils are put to intensive agriculture, resulting in soil degradation. Hence it is essential that the land qualities be scientifically correlated while suggesting farming alternatives.

5.2 MICRO-LEVEL GIS FOR KACHITHODE-KOTHARA WATERSHED

Watersheds are the natural units for resource-based development in any part of the world. Micro-watersheds provide an organic linkage between individual farmsteads in any landscape in Kerala or anywhere and have to be viewed on an area development perspective, wherein common facilities and services have to be provided for conservation and management of the total resources of the watershed. Soil and moisture conservation, water harvesting, irrigation structures and general land use recommendations have to be provided at this level.

Delineation of micro-watersheds is possible in different ways. But, the application of GIS tools such as DEM/DTM, used in the current study enables quick and accurate separation of these natural development units with reference to satellite imagery or contour maps. The digital terrain model generated from the 10 m contours of the panchayat was used for delineating Kachitode-Kothara watershed. The process of watershed delineation was simplified by using the DTM of the panchayat which otherwise would have been cumbersome. Several workers had done delineation of watershed using DTM (Adinarayana, 1995; Sarkar *et al.*, 2001; Mahajan *et al.*, 2001; Kalra, 2002 and Gosain and Rao, 2004). The delineated watershed boundary was in conformity with the Survey of India's topographic map numbered 58B/6/SW at 1:25000 scale. The terrain of the watershed is undulating and the area has hills, and valleys. The stream that originates from the dam flows through the valley. The watershed has contours ranging from 40 m above mean sea level to 290 m above mean sea level.

A GIS was developed exclusively for the Kachithode-Kothara watershed in similar line with that of the Madakkathara Panchayat, but with additional data on the soil and water resources and socio-economics. The watershed area within the panchayat, lie in ward number II and XII of Madakkathara Village. There were only 51 cadastral plots in the watershed area.

5.2.1 Agricultural Resources of Kachithode-Kothara Watershed

The spatial data on agricultural resources of Kachithode-Kothara watershed include soil resources, landuse pattern, water availability, distribution of streams, rivers, ponds and wells and the contour of the area.

5.2.1.1 Soil Resources of Kachithode- Kothara watershed

The soil of this watershed was named by Soil Survey Organisation, Kerala as Madakkathara series and is a member of the fine, mixed, iso hyperthermic family of Typic Kandiustalfs. The profile studied contained four horizons namely Ap, B1, B2 and B3. The thickness of the solum ranges from 120 to 200 cm. The surface soil texture range from clay loam to silty clay loam. Sub soil texture varies from gravelly clay loam to clay. Gneissic cobbles are noticed in some horizons below a depth of 150 cm. A much more general classification was done to typify the soil of the watershed. There were three types of soil in the watershed namely, forest loam soil, lateritic soil and variable shallow soil. The soils are well drained and are put into a variety of use. The forest loam soil was found in the North Eastern side of the watershed lying adjacent to reserve forest area.

5.2.1.2 Water Availability

The water availability of the watershed area could be grouped into two classes – surface water and subsurface water. Surface water sources of the watershed area include the non-perennial streams that feed the reservoir of the Kachithode dam and the streams that drain water into the dam and from the dam. The streams are non-perennial as the dam blocks the course of the stream. The streams drain the water that overflows from the dam.

Subsurface water sources of the watershed include wells. There are only 26 wells in the watershed for 75 houses.

The spatial depiction on the water availability in the watershed was presented in Fig. 28. There is acute water shortage in the watershed as evident from the fact that the maximum area of the watershed falls in category moderate. There are some areas with low water potentiality. The water availability was low

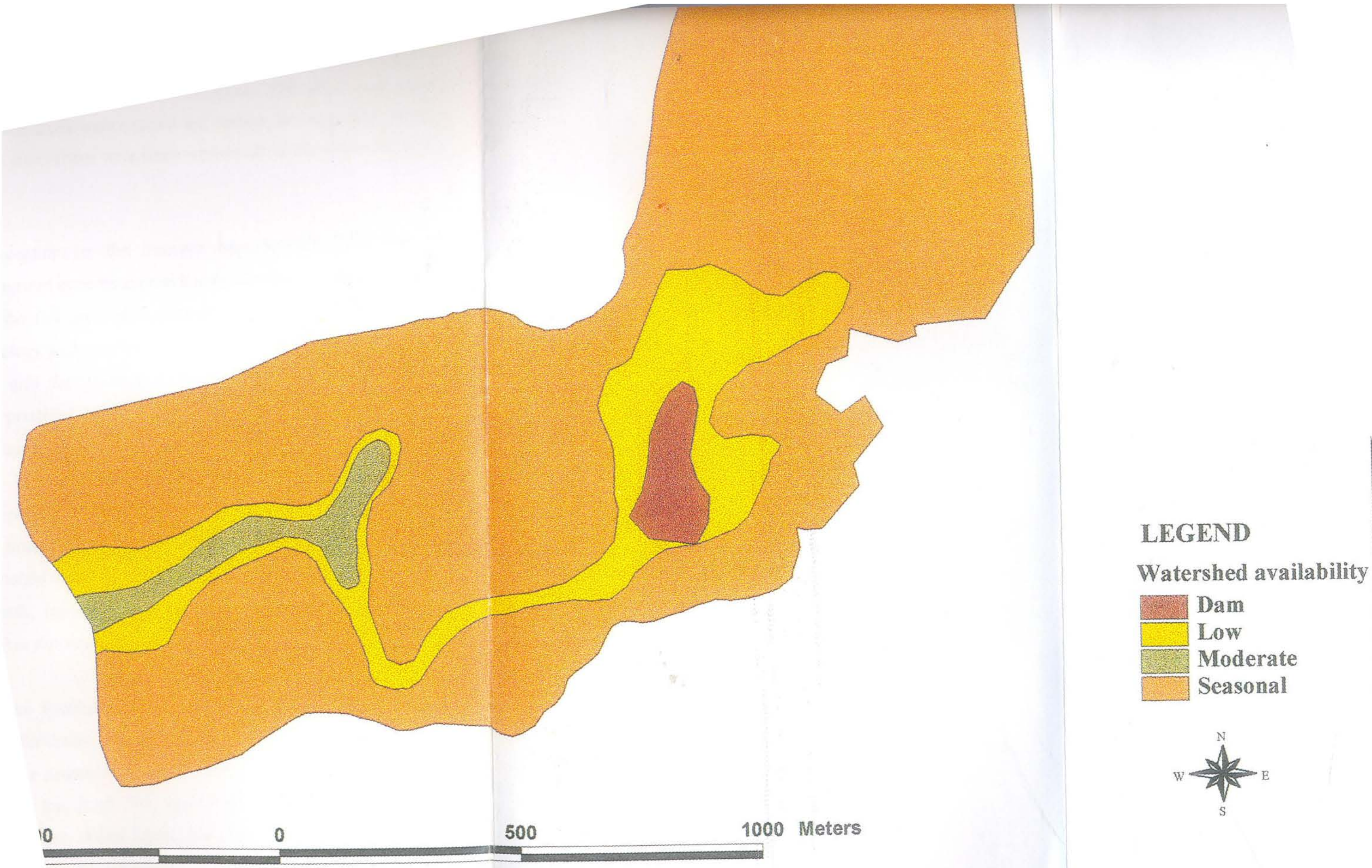


Fig. 28. Thematic map showing water availability status of different areas in Kachithode Kothara watershed

in area adjoining the Kachithode dam due to the fact that the places experiencing water shortage were at a higher elevation than the dam.

5.2.2. Landuse in Kachithode-Kothara Watershed

Agricultural land is mainly utilised for cash and plantation crops. The major seasonal crop cultivated was banana. The major tree crops grown in the area were teak and some fruit trees seen in homesteads. The major cash crops cultivated in the area under study were coconut and cashew, among which cashew occupied the maximum area. There were some wastelands in the watershed area, which may be utilised.

A holistic perception on the resource base spatially identified as watersheds, and an integrated systems approach to its management are imperative for the utilisation of the full production potentials and ensuring returns on a sustained basis. Technology packages are to be evolved for the resource system as such and not limited only for utilising the individual facets within the slope continuum as is being practiced currently by and large. Technologies evolved on crop basis confine the application to the facets only and not to the system.

A systems approach to the farming practices in the panchayat and watershed involving integrated attention to crop, livestock, agro-forestry and aquaculture would generate more jobs, maximise income and protect the resource-health in the watersheds, especially in the Kerala context where agriculture is better be characterised as *farming systems* rather than just crop production.

At the Gramma Panchayat level, public investments on agricultural services like credit, fertilisers, plant protection equipment and chemicals, machinery etc have to be organised. Necessary market facilities, road net works, etc are also planned at this level. The agricultural human resources namely, technocrats, farm technicians, skilled labour, etc also have to be organised at this level. Multi criteria analysis capability in GIS environment could organise and derive required information from voluminous data available within the GIS, which can be used for micro-level planning (Sahoo *et al.*, 2000).

Whether it is in natural spatial entity (micro-watershed) or political divisions (Grama Panchayat), planning for sustainable agricultural development at micro-level can be greatly facilitated by Geographic Information Systems (GIS) and satellite Remote Sensing (RS) (Adinarayana, 1995; Ajai, 2002; Mani, 2002). In recognition of the fact that soil, water and biodiversity are finite resources for agricultural development, these have to be used on the basis of sound principles of resource management, so as to enhance productivity, prevent degradation and pollution and also to reduce the loss of good agricultural lands to non-farm purposes. Data on local resources and environment are, in general, available, but they are dispersed among many agencies and cannot be quickly compiled for multi-sectoral, problem-oriented analyses. Thus, the ability to respond to the information needs of planners and decision-makers at micro-level is limited.

The computerised GIS systems, which can produce geographic (spatial) information integrated with statistical and textual data, are becoming the most useful and powerful analytical tools for resource planners and managers. The study reported has resulted in a functional GIS that can be effectively used by all those interested in agricultural and overall development of Madakkathara Panchayat and Kachithode-Kothara watershed.

Let us together look forward to the day when GIS technology will be part of the decision support environment of everyone who makes decisions that affects either the natural world or the built-up world. For that day to come, GIS technology must be more widely known, more widely understood, and more widely appreciated.

Summary

6. SUMMARY

The present study entitled "A geographic information system for micro-level decision making in the agricultural sector of Central Midlands of Kerala" was carried out in the Centre for Land Resources Research and Management and Department of Soil Science and Agricultural Chemistry, College of Horticulture, Kerala Agricultural University, Thrissur during the period 2001 to 2004 with the objective of developing a Geographic Information System (GIS) on Madakkathara Panchayt and demonstrating the capability of the GIS to design projects for integrated resource use. The study was conducted in Madakkathara Panchayat with special emphasis on the Kachithode Kothara watershed.

Cadastral maps (1:3960 scale) of Kurichikkara, Madakkathara and Vellanikkara villages and the land use and assets map of Madakkathara Panchayat were used as base maps for the study. These maps were scanned, joined, digitised and projected to be used as the input for the study. Primary as well as secondary information regarding the Panchayat were collected and tabulated using appropriate database management software. Both the digital cartographic data and the tabular data were integrated to prepare the GIS of Madakkathara Panchayat. Terrain analysis of the Panchayat was undertaken using the 10 m interval contours derived from the topographical map of Survey of India. Landuse type of the panchayat was confirmed using the IRS-1C-LISS III + PAN imagery acquired on 12 January 2002. Salient results of the study include the following:

a) Spatial database for various resources of Madakkathara Panchayat in general and Kachithode-Kothara watershed in particular was established through digital cartographic techniques available in different GIS software.
b) Attribute information on the geographic entities were collected, tabulated, computerised and attached to the spatial database.
c) Above two components (spatial and attribute data) were integrated in state of the art GIS environment and outputs were created

d) Salient outputs were reported as results of the study. The basic layers that are covered in the GIS for Madakkathara Panchayat are administrative villages and wards, cadastral details, major economic and social institutions and road network. Thematic layers on drainage pattern, distribution of dug wells, water availability, soil type distribution, landuse types, contour intervals and a digital terrain model developed from the contours, and distribution of households were included for both panchayat and watershed levels. In addition, a satellite imagery of the panchayat (IRS 1C LISS III + PAN merged data), which was used for confirming current land use of the panchayat and pilot watershed is also included and a GIS layer.

The GIS on the panchayat comprises of spatial as well as attribute data that could be used by the grass root planners. The spatial data on administrative wards are supported by the demographic statistics of individual wards of the Panchayat. There were 24934 persons residing in the panchayat. 51 per cent of the total population was females and the rest males. The occupational details of the panchayat could be derived from the database of the wards of the panchayat. Only 36 percent of the total population was working, of which 73 per cent were males and the rest females. The non-workers of the panchayat were more (64 per cent) than the working population. The non-working population was dominated by women (64.2 per cent).

The spatial data on cadastral map of the Panchayat is now available in digital format, which can be used by the revenue officials for planning purpose. The cadastral maps could be overlaid with other thematic maps of the panchayat to arrive at conclusions required for taking decisions. Thus the spatial data on soils when overlaid on cadastral data would yield a combined spatial data with the database of both themes joined. On utilising the querying facility of the GIS software, suitable conclusion may be derived regarding the soil type of individual plots, which may be used for planning. Similar procedure may be adopted to find the land utilisation pattern of the cadastral plots.

The settlement pattern of the Panchayat could be queried from the database attached to the spatial data on wards. The population density of the panchayat was 955 with 217 households per sq. km. The distribution of houses followed the general pattern of the State with houses concentrated near the roads and in the plain area of the Panchayat. This information could be used in planning of new roads and finding suitable locations for other amenities.

The land holding pattern of the panchayat could be inferred and it followed the general trend of dispersed settlements in the State. Spatial details on major economic and social institutions are available in the GIS. This can be used for different GIS analysis based on the need of the user of data.

The network of roads in the panchayat has been digitally mapped and referenced geographically. The biophysical resources of the panchayat that is digitally captured include soil resources of the panchayat and water resources of the panchayat.

The spatial distribution of wells in the panchayat is also included as a separate theme in the GIS. The distribution of rivers, stream, canal, ponds and dams of the panchayat was digitally cartographed and geographically referenced. The course of Thanikudam River flowing through the Panchayat was mapped. The course of Vellanikkara branch canal, Kole canal and other streams and location of ponds featured in this theme.

The overall availability of water through out the panchayat had been identified and mapped. The locations of low, moderate, high and seasonal water availability can easily be identified for planning purpose. The area with low water availability could be identified and appropriate water harvesting measures may be planned based on the terrain of the panchayat. And the location of water harvesting structures could be made using the information available with this GIS.

The spatial distribution of various soil types of the panchayat has been identified. There were five major soil types namely, lateritic soil, forest loam soil, variable shallow soils, riverine alluvium soils and colluvial soils, in the panchayat. Lateritic soils covered the most of the panchayat area. The general land utilisation pattern of the panchayat has been incorporated in the GIS of Madakkathara Panchayat. The land utilisation pattern revealed that coconut was the major cultivated single crop. On overlaying the soil type data and land utilisation pattern of the panchayat, the suitability of crops grown may be identified. The spatial data on soils and land use type of the panchayat could be used by scientists of Kerala Agricultural University and the Agricultural Officer for implementing schemes and projects.

The general physiography of the panchayat has been prepared from the 10 m interval contour of the panchayat. Digital terrain model of Madakkathara Panchayat was created for terrain analysis of the Pancahayat from the contours of the Panchayat. The DTM of the panchayat revealed that the terrain was undulating and contains areas with steep slopes and plains. This information was used for identifying watershed.

Spatial distribution of houses in the panchayat had been created along with socio-economic database as attribute. The socio economic pattern of the panchayat was determined by abstracting the attribute data of houses of the panchayat. List of beneficiaries for different development programmes of the State Government can be queried from the attribute data on houses of the panchayat. Caste and religion wise segregation could be made by the local planners using the attribute data of houses in the panchayat. Such information would be useful for analysing social and cultural features before finalising any developmental project.

Delineation of Kachithode-Kothara watershed was done using the digital terrain model of the panchayat. Physiography and slope of the watershed was determined using the GIS. The most important feature of the watershed was the presence of a Perennial dam and streams contributing water to the dam. The drainage pattern of the watershed was spatially cartographed and georeferenced for further planning. The drainage of the watershed includes sevaral first order and second order streams. The main stream drains into Kallayithodu. The main stream of the watershed is non-perennial as the Kachithode dam blocks its course. Now it drains the overflow water of the dam during monsoon.

Soil resources of the watershed were digitised. The distribution of general soiltypes of the watershed was spatially mapped and displayed. There were three soil types in the watershed namely variable shallow soil, Lateritic soil and forest loam soil. The Soil series of the soil in the watershed was identified and the important characteristics of the soil profile collated. The soil of the watershed was classified as a member of the fine, mixed, iso hyperthermic family of Typic Kandiustalfs. The soil of the watershed was acidic with the pH ranging from 5.0 to 5.2 in different horizons of the profile. The upper reaches of water being hilly faces the threat of soil erosion due to the mixed cropping of erosion permiting crops. Suitable corrective measures could be devised for the area by scientists based on the slope and elevation of the area.

Based on the salient findings of the thesis it may be concluded that micro level data integration is a must for arriving at various decisions for integrated resource utilisation in the panchayat.

Suggested future line of work:

- Only certain specific examples had been worked out to demonstrate the capability of GIS to help in Panchayat. Future researchers can tailor this data for their need.
- Updating of this data using high resolution satellite imagery may be taken up

- Plotwise soil test values may be generated keeping this GIS in mind to develop soil health card and effective fertiliser recommendation.
- Methods to curtail soil erosion in the sloping terrains in the panchayat and Kachithode-Kothara watershed can now be better decided in the light of slope and aspect information on specific localities.
- Further studies may be conducted to identify the potential or alternate use of the dam for revenue generation.

The study reported has resulted in a functional GIS that can be effectively used by all those interested in agricultural and overall development of Madakkathara Panchayat and Kachithode-Kothara watershed.

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A GEOGRAPHIC INFORMATION SYSTEM FOR MICRO-LEVEL DECISION MAKING IN THE AGRICULTURAL SECTOR OF CENTRAL MIDLANDS OF KERALA

By

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ABSTRACT OF THE THESIS

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Abstract

The present study was carried out in the Centre for Land Resources Research and Management, Department of Soil Science and Agricultural Chemistry, College of Horticulture, Kerala Agricultural University, Thrissur during the period 2001 to 2004 with the broad objective of integrating available data on the land and agricultural resources of Madakkathara Panchayat into a Geographic Information System (GIS) and to demonstrate the capability of GIS as a decision support system to design projects for integrated resource management.

Cadastral maps (1:3960 scale) of the Panchayat and the land use and assets map of the Panchayat were used as base maps for the study. These maps were processed, traced, scanned, joined and digitised. Various features were digitised as separate themes. The digitised maps were then projected and converted to shape files using PC ARC/INFO resulting in the spatial data. Primary and secondary information on watershed and panchayat were collected and tabulated using MS Access and MS excel to form the attribute data of the respective themes. Then spatial and attribute data were integrated to prepare the GIS of Madakkathara Panchayat.

Physiography of the Panchayat was studied using the 10 m interval contours from the topographical map of Survey of India. Landuse type of the panchayat was confirmed using the IRS-1C-LISS III + PAN imagery acquired on 12 January 2002 that was analysed using ERDAS Imagine 8.4 software. The GIS analysis and display of output was done using ArcView 3.1 software.

In the present study the major outputs generated on panchayat were the administrative wards and villages, cadastral map of the panchayat, spatial location of some social and economic institutions, the network of roads and spatial distribution of houses. The thematic maps generated on panchayat during the study were water availability, drainage pattern of the panchayat, soil type land use type, distribution of wells and contours of the panchayat.

The cadastral map had in its attribute table the survey number. Details regarding the ownership could not be obtained due to official restrictions. However ownership of some plots could be obtained from the primary data collected. The panchayat consisted of 12 wards in three villages during the study period.

The human resources of the panchayat or the people component of the GIS need a mention. The total population of the panchayat was 24934. The panchayat had a population density of 955 persons per sq. km and 217 houses per sq. km. 51 percent of the total population was female. Only 36 percent of the total population was working, of which 73 percent were male. The non-workers of the panchayat were more (64 per cent) than the working population. The non working population was dominated by women (64.2 percent). This indicates that there is ample scope of empowering the women in the panchayat.

Geo-refernced data on houses and its attribute data revealed the socio economic pattern of the Panchayat. The attribute database on houses could be queried for the list of beneficiaries for different development programmes of the State Government, caste and religion wise segregation, source of drinking and bathing water, type of roofs, walls and floor of houses, scarcity of water, livestock details of the family, and so on. These information could be used by the local planners for analysing social and cultural features before finalising any developmental project.

The thematic maps on soil type of panchayat revealed the presence of five types of soil and their characteristics. The important soil types in the panchayat were lateritic soil, variable shallow soils, colluvial soils, riverine aluvium and forest loam soils. The spatial extent of their distribution revealed that lateritic soil dominated the panchayat in spread, riverine aluvium was seen in area adjoining Thanikudam river and some streams, forest loam adjacent to the reserve forest area in the north eastern part of the panchayat, colluvial soils near Katilapoovam area and variable shallow soils in the slopes and valleys of the panchayat.

The thematic map on the land use pattern of the panchayat revealed the major cropping pattern of the panchayat as coconut based. Cash crops especially cashew and rubber were also seen. Important seasonal crops were rice, banana and tapioca. Paddy field conversion was also seen. Major tree crops grown were, arecanut, cashew, fruit trees and mixed cropping was dominant in the homesteads. The water availability theme was also presented. The potential areas of water were spatially identified in the following classes, high, moderate, seasonal and low. The water drained mainly into Thanikudam River through a network of streams although some water was held in Kachitode dam and some ponds. Kole canal and Vellanikkara branch canal pass through the panchayat

The physiography of the panchayat was undulating with hills, hillocks and valleys. The contours of the panchayat ranged from 20 m above mean sea level to 320 m above mean sealevel. The digital terrain model (DTM) of the panchayat was created using the GIS and was used to delineate the Kachithode-Kothara watershed. The watershed consisted of a perennial dam and streams contributing water to the dam. Water drained through several first order and second order streams in the watershed. The main stream of the watershed is non-perenial and drains the overflow water of the dam during monsoon to Kallayi thodu.

Land use type of the watershed and the distribution of well and houses were also incorporated in the GIS of the panchayat. Unlike the panchayta, watershed area had only 26 wells for the 74 houses distributed in the panchayat. On overlaying the cadastral details it could be inferred that there are only 51 plots in the watershed area and there are residents in the area without title deed of the land.

Soil types were three namely variable shallow soil, Lateritic soil and forest loam soil in the watershed. The soil of the watershed is a member of the fine, mixed, isohyperthermic family of typic Kandiustalfs. The soil of the watershed was acidic in reaction with the pH ranging from 5.0 to 5.2 in different horizons of the profile. The upper reaches of water being hilly faces the threat of soil erosion due to the mixed cropping of erosion permitting crops. Appropriate conversion measures should be adopted based on the slope and elevation of the area. The water availability of the water shed was low in the upper areas of the watershed due to the fact that the settlements were higher than the dam. These area require attention in rain water harvesting methods.

Based on the salient findings of the thesis it may be concluded that micro level data integration is needed for arriving at various decisions for integrated resource utilisation in the Panchayat and the study reported has resulted in a functional GIS that can be effectively used by all those interested in agricultural and overall development of Madakkathara Panchayat and Kachithode-Kothara watershed.

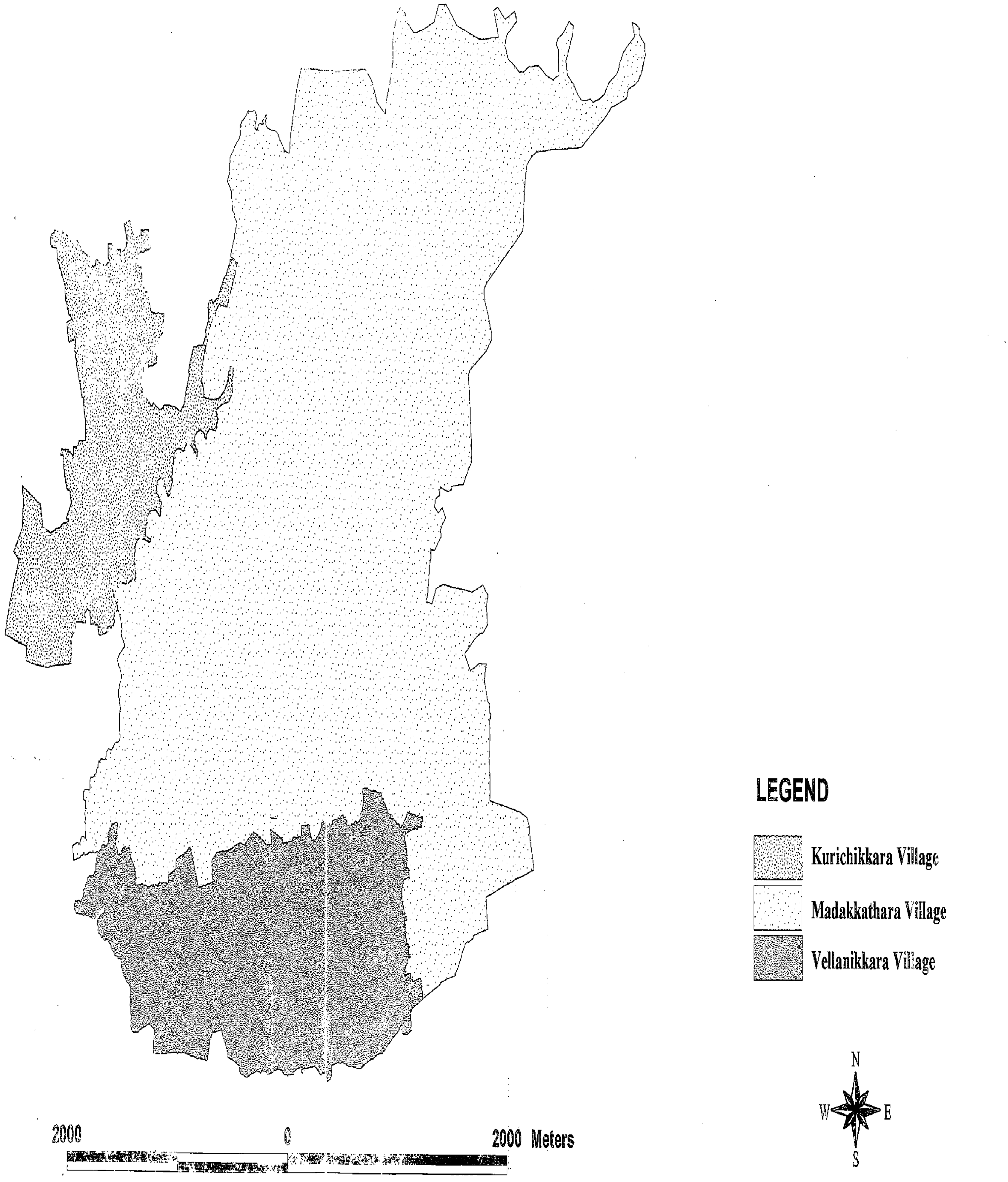

Fig. 7. Administrative villages comprising Madakkathara Panchayat (GIS output)

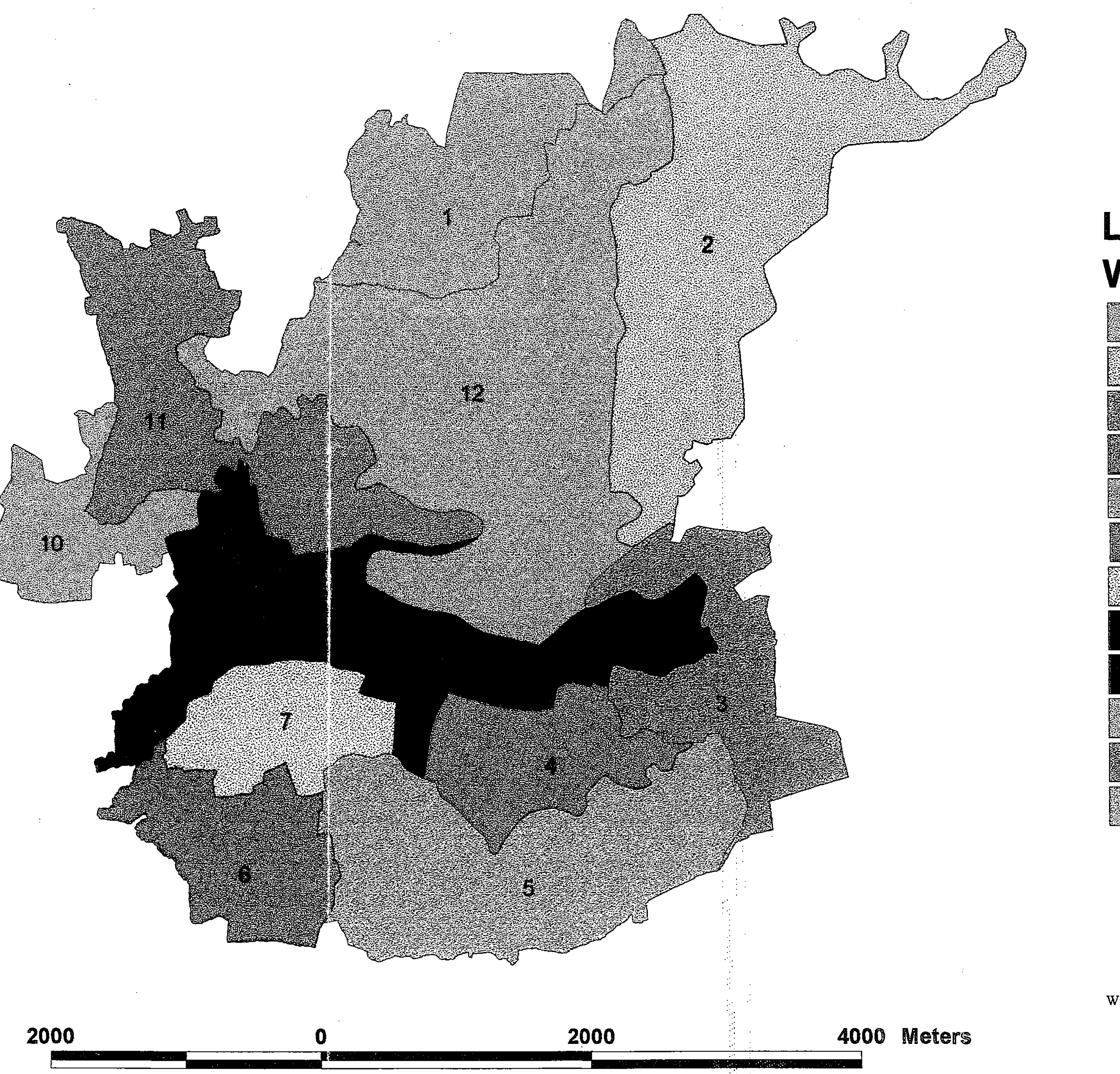

Fig. 8. Administrative wards of Madakkathara Panchayat (GIS output)

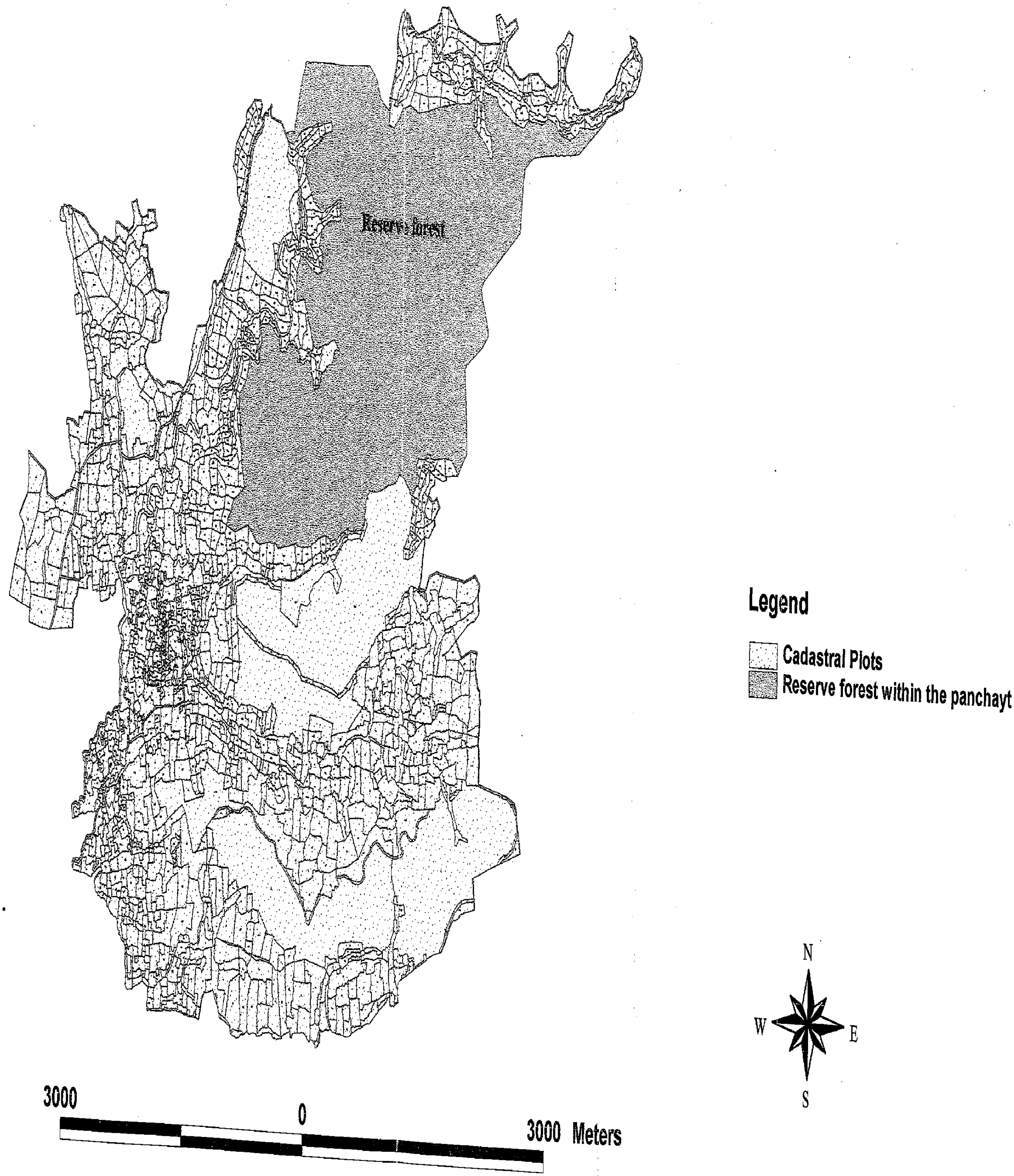

Fig. 9. Cadastral Map of Madakkathara Panchayat (GIS output)

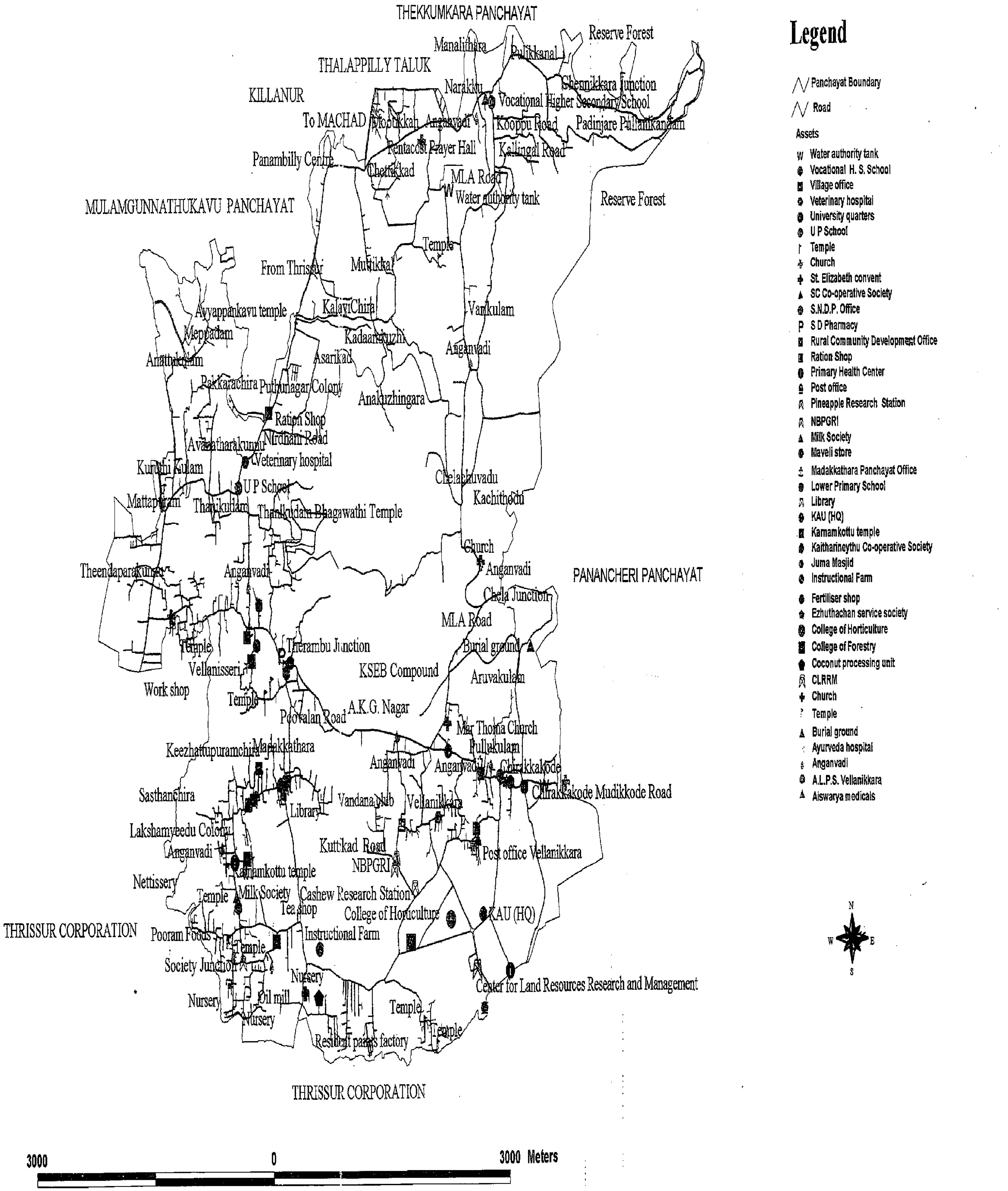

Fig. 10. Major economic and social institutions and network of roads in Madakkathara Panchayat (GIS output)

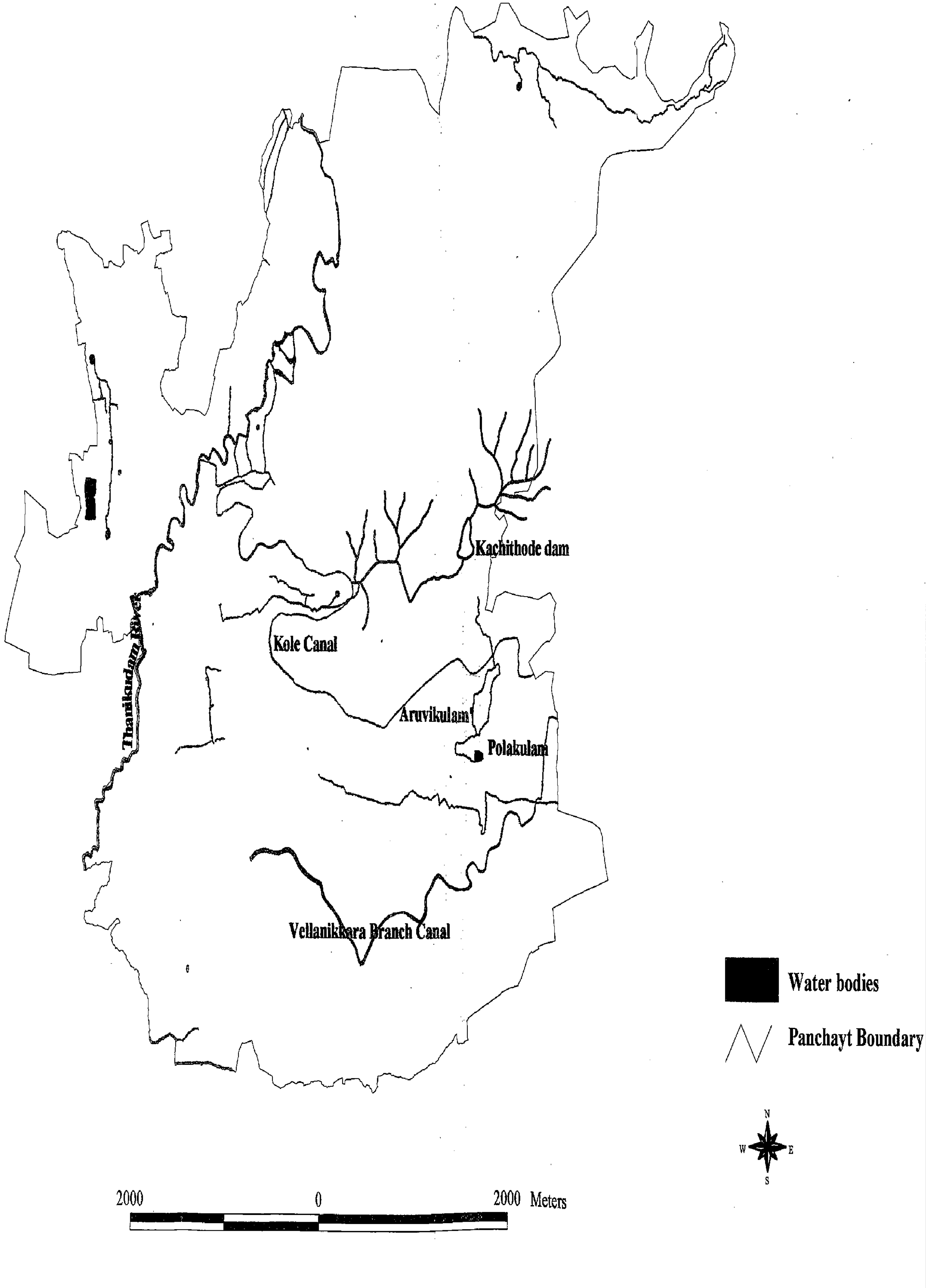

Fig. 11. Drainage pattern of Madakkathara Panchayat (GIS output)

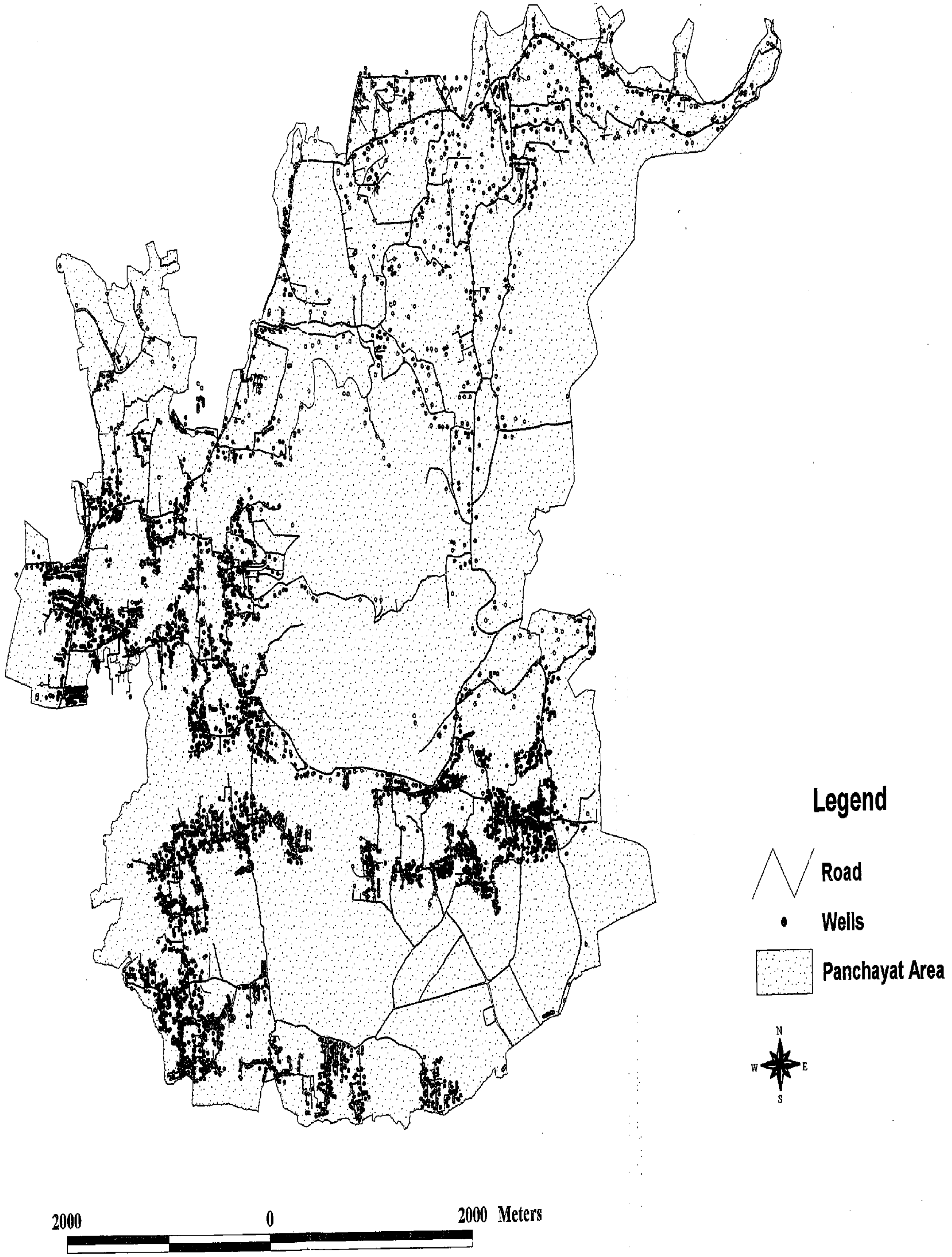

Fig. 12. Spatial distribution of wells of Madakkathara Panchayat (GIS output)

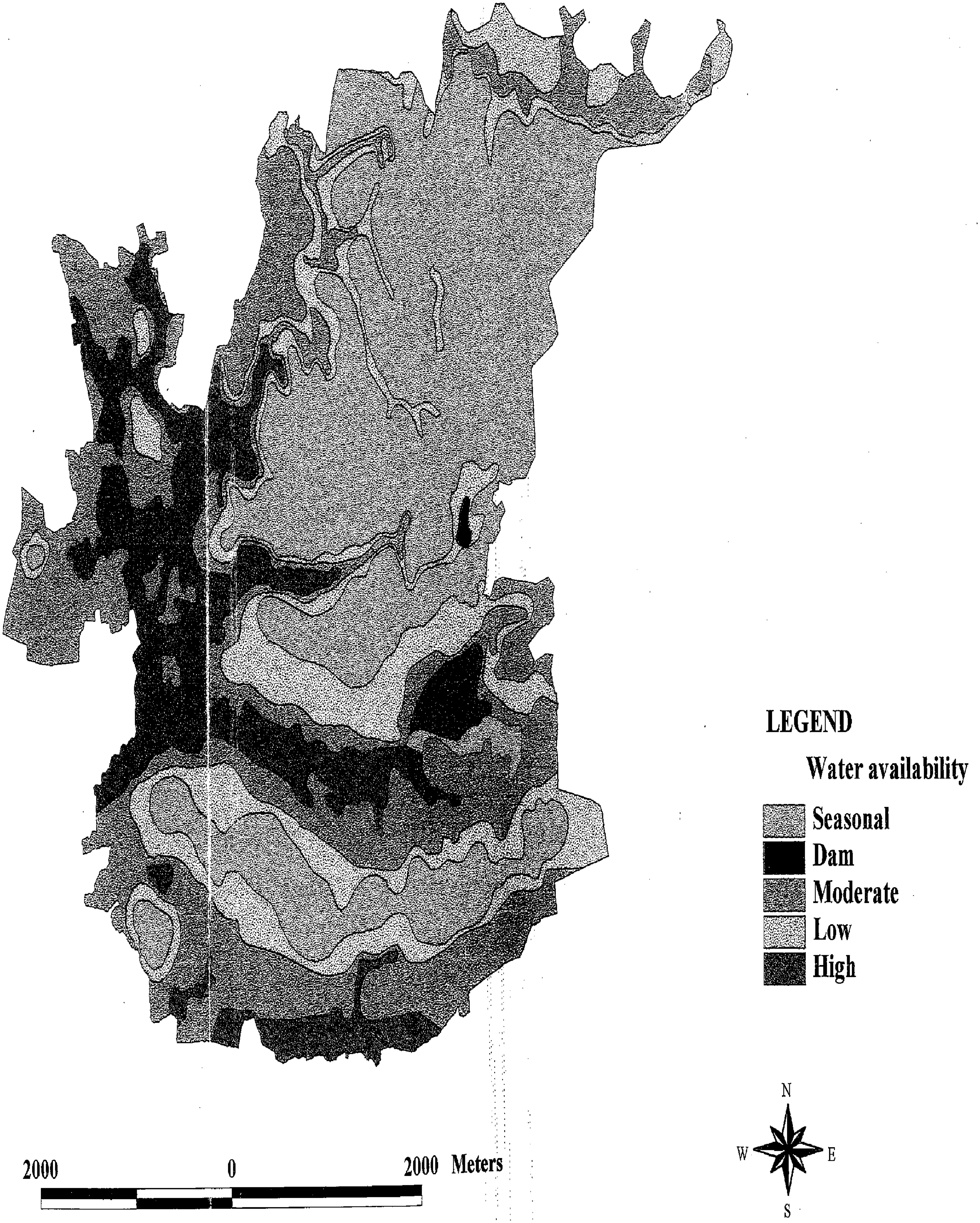

Fig. 13. Thematic map showing water availability status of different areas in Madakkathara Panchayat (GIS output)

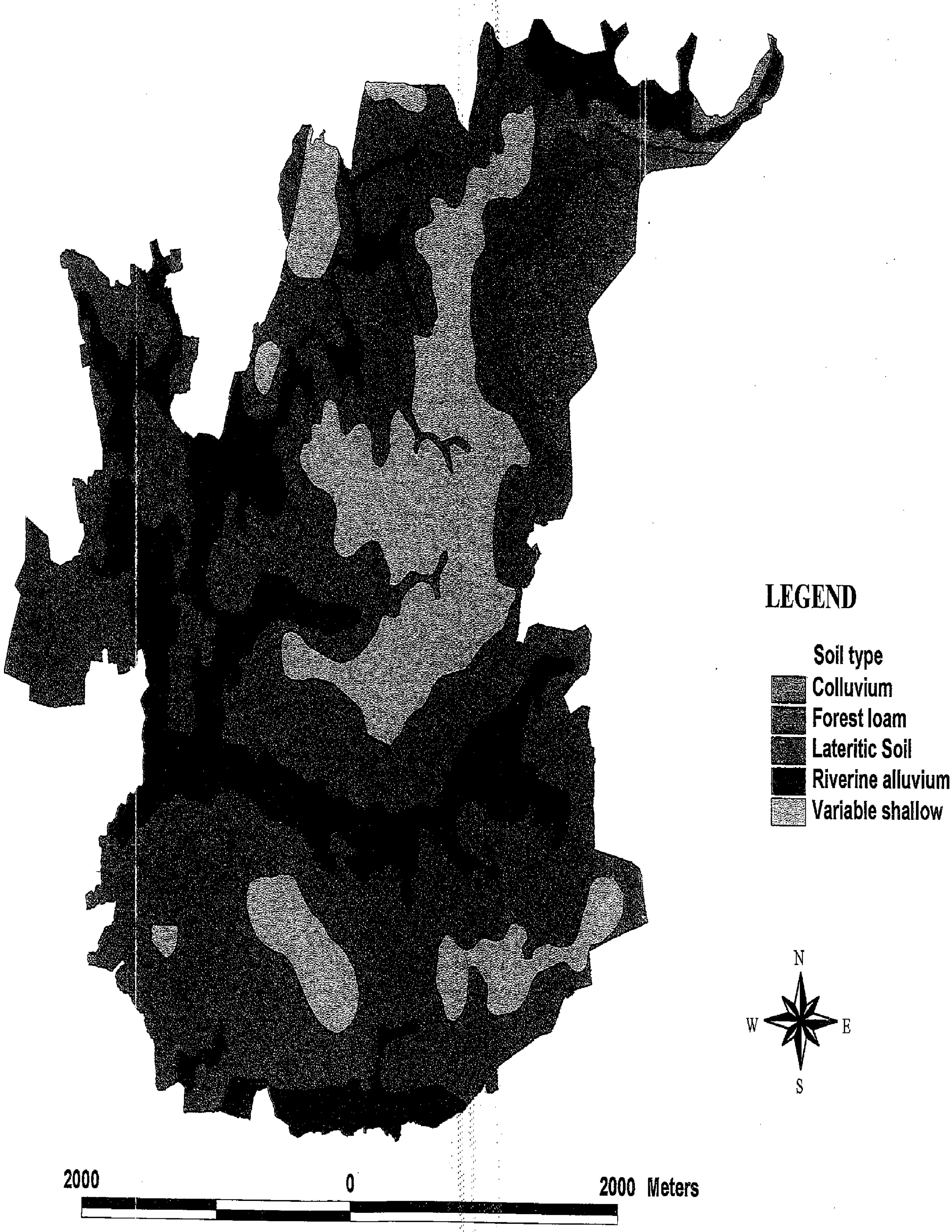

Fig. 14. Thematic maps showing soil type distribution in Madakkathara Panchayat (GIS output)

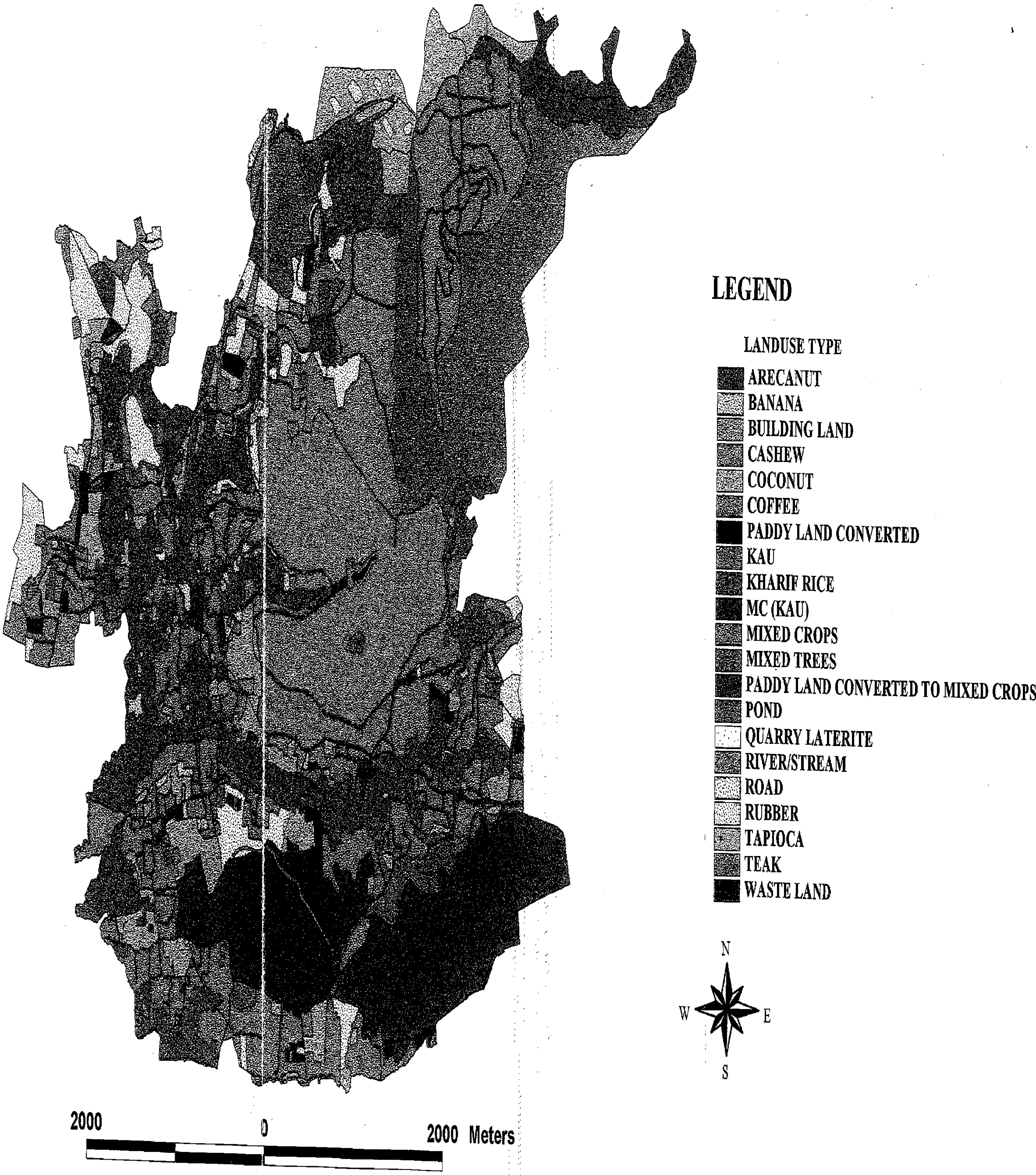

Fig. 15. Thematic map showing the landuse type in Madakkathara Panchayat (GIS output)

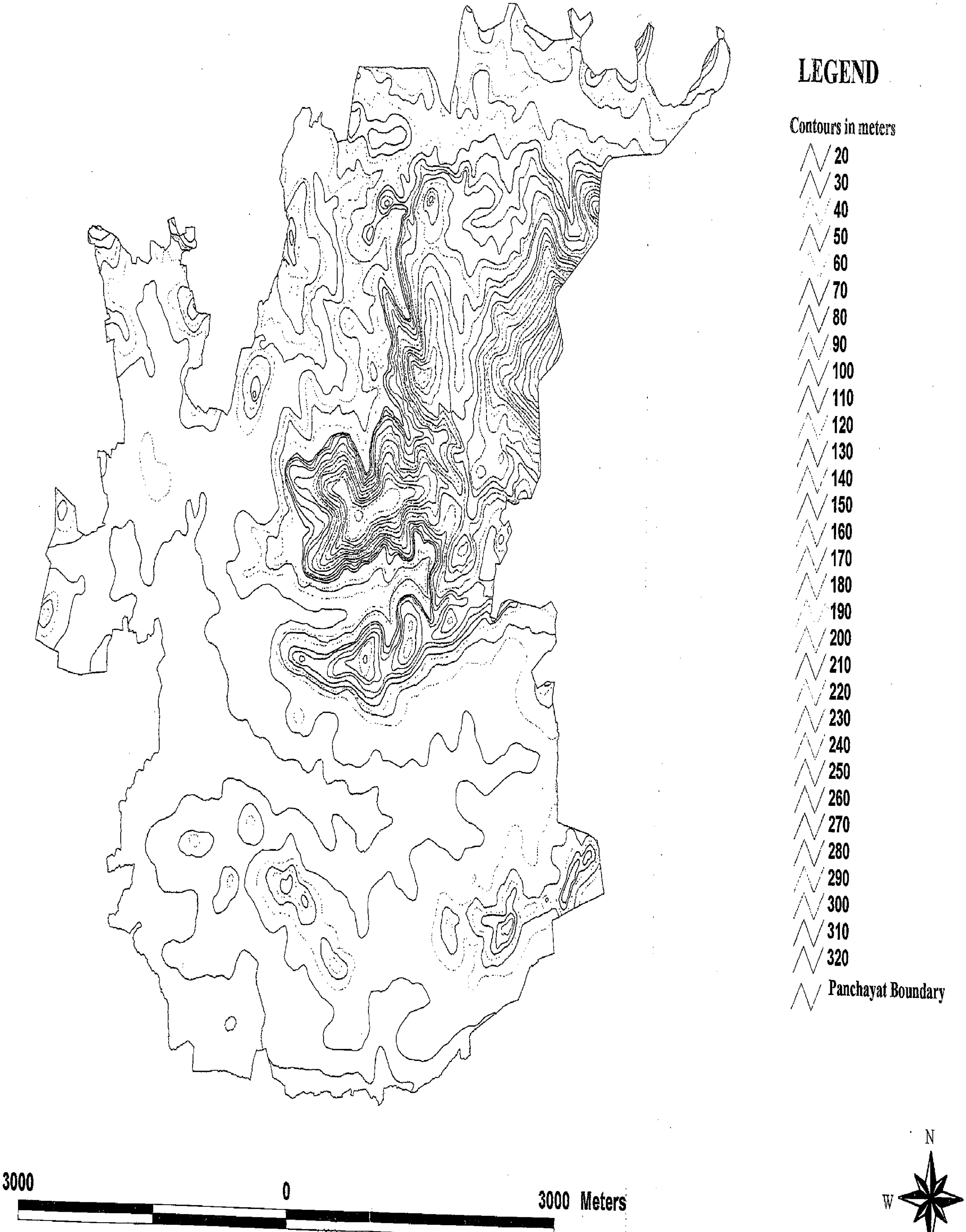

Fig. 17. Distribution of 10 m interval contours in Madakkathara Panchayat (GIS output)

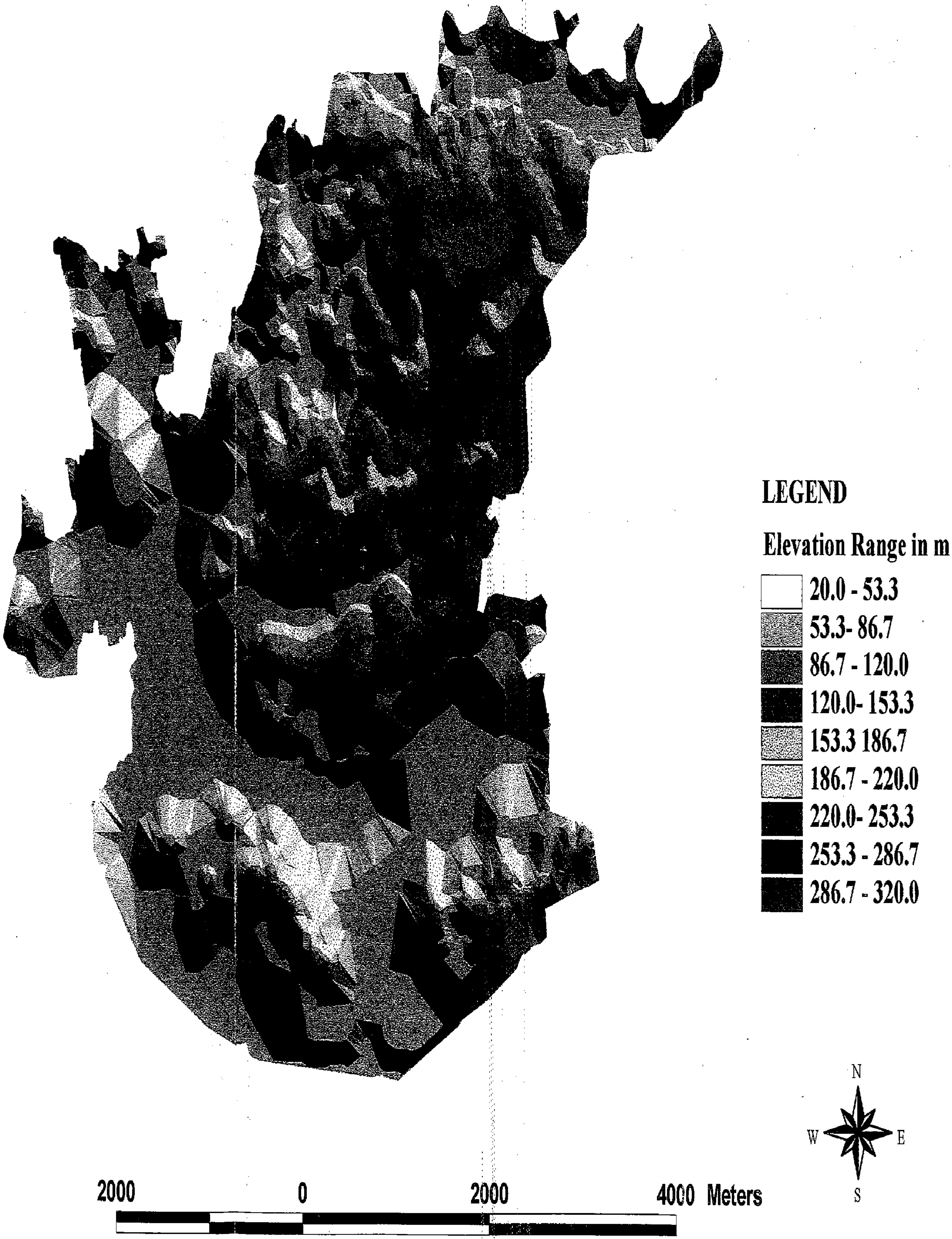

Fig. 18. Digital terrain model of Madakkathara Panchayat derived from the contours (GIS output)

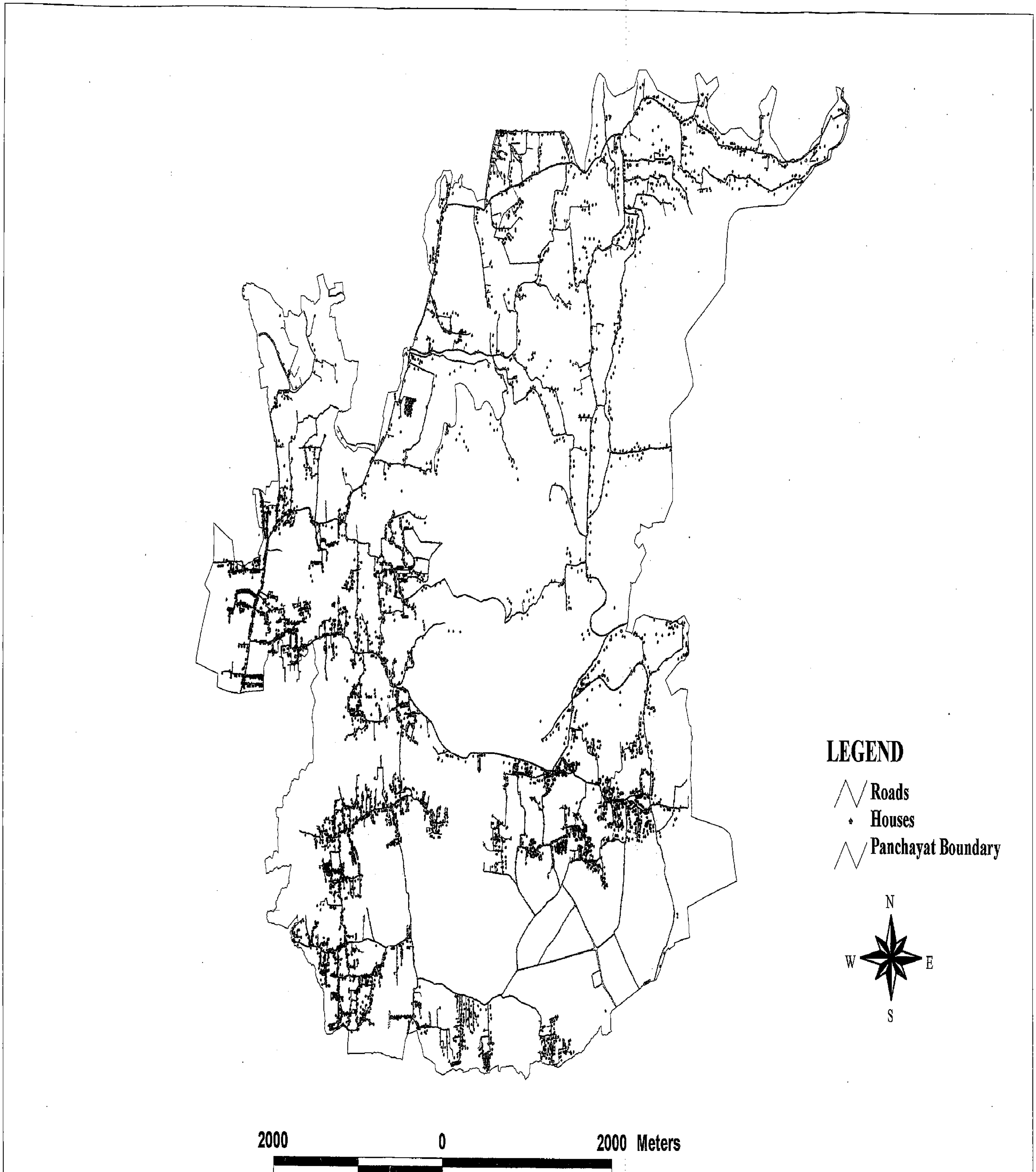

Fig. 19. Spatial distribution of houses in Madakkathara Panchayat (GIS output)

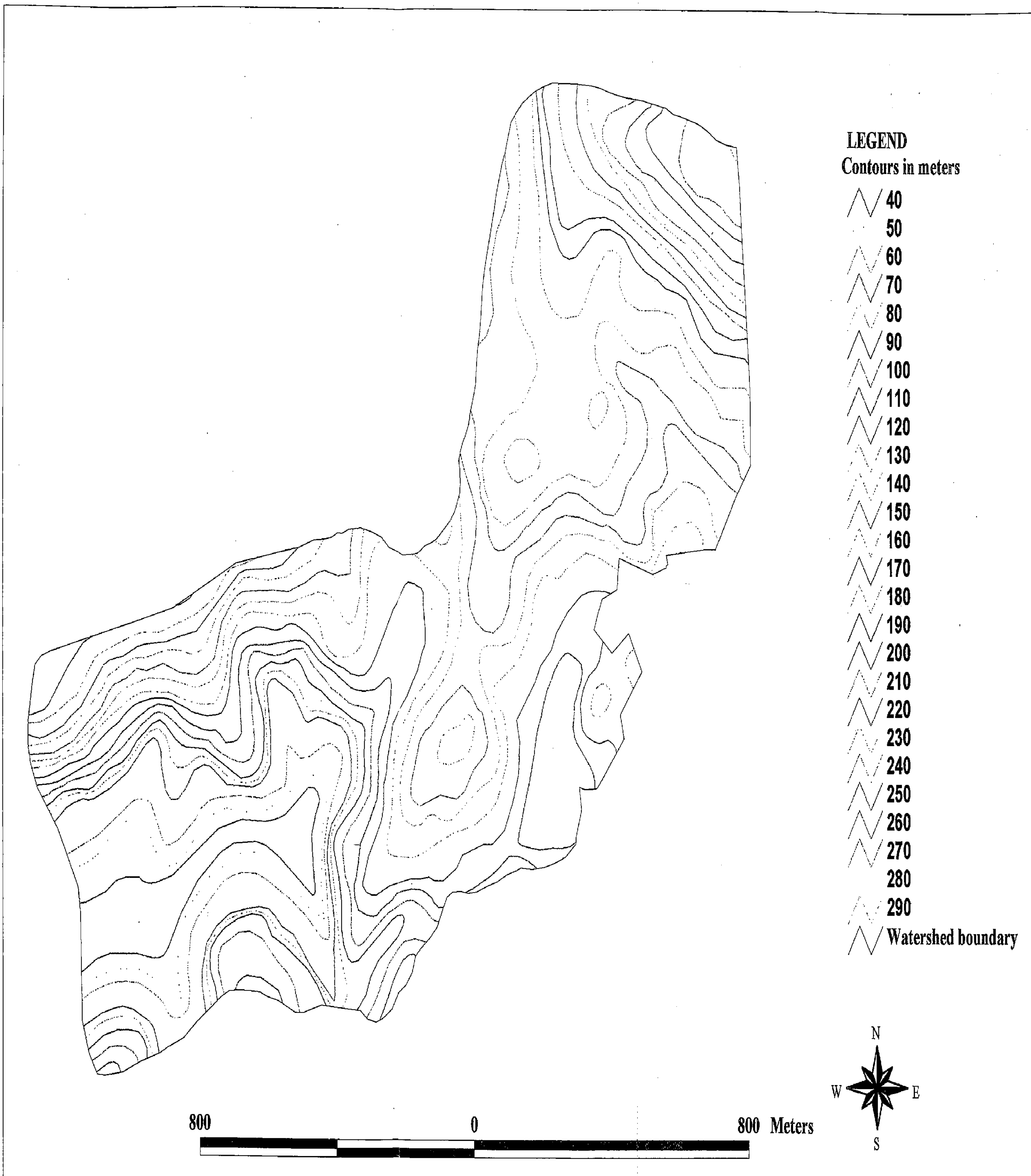

Fig. 20. Distribution of 10 m interval contours in Kachithode Kothara watershed (GIS output)

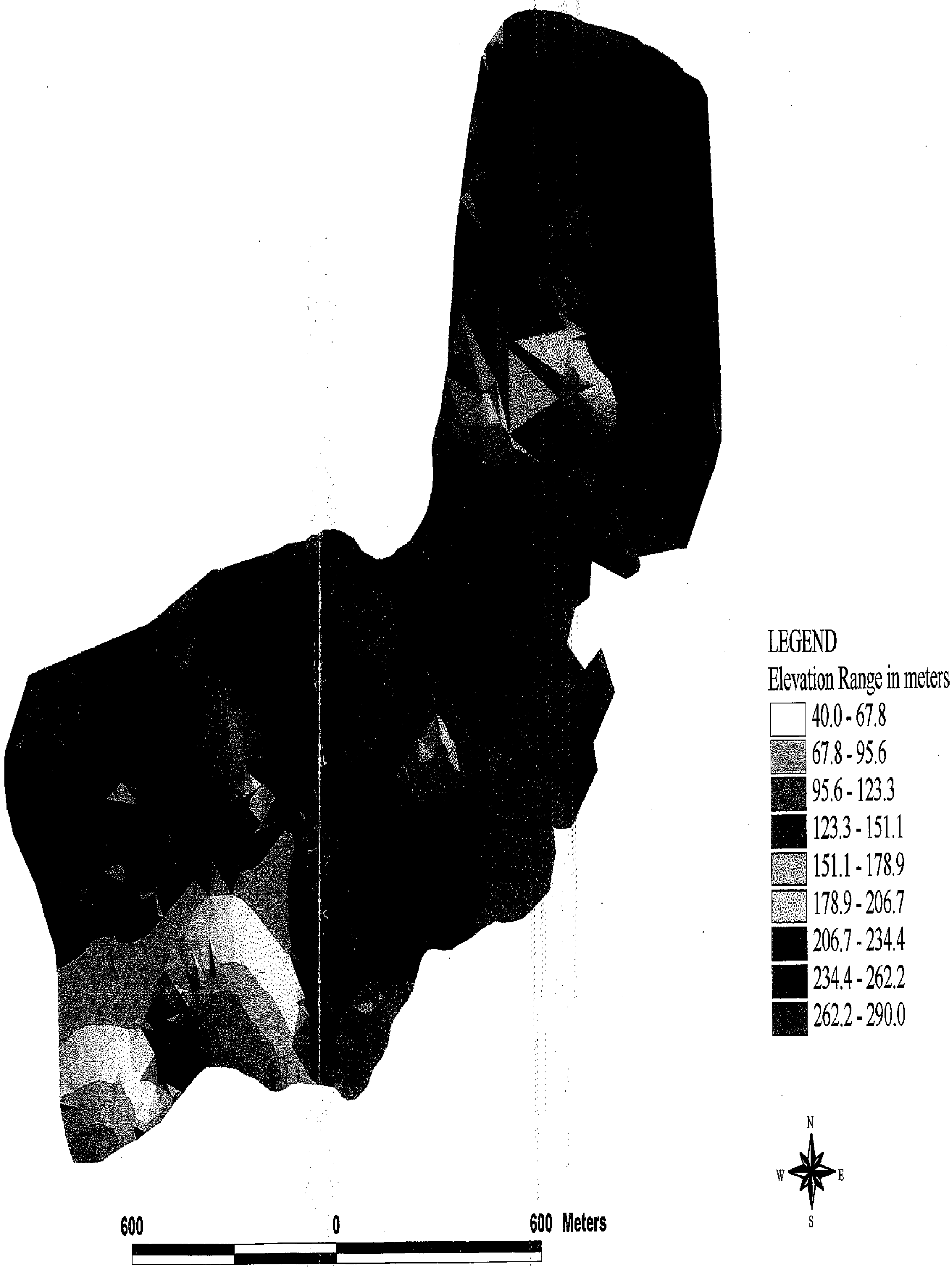

Fig. 21. Digital terrain model of Kachithode Kothara watershed showing elevation (GIS output)

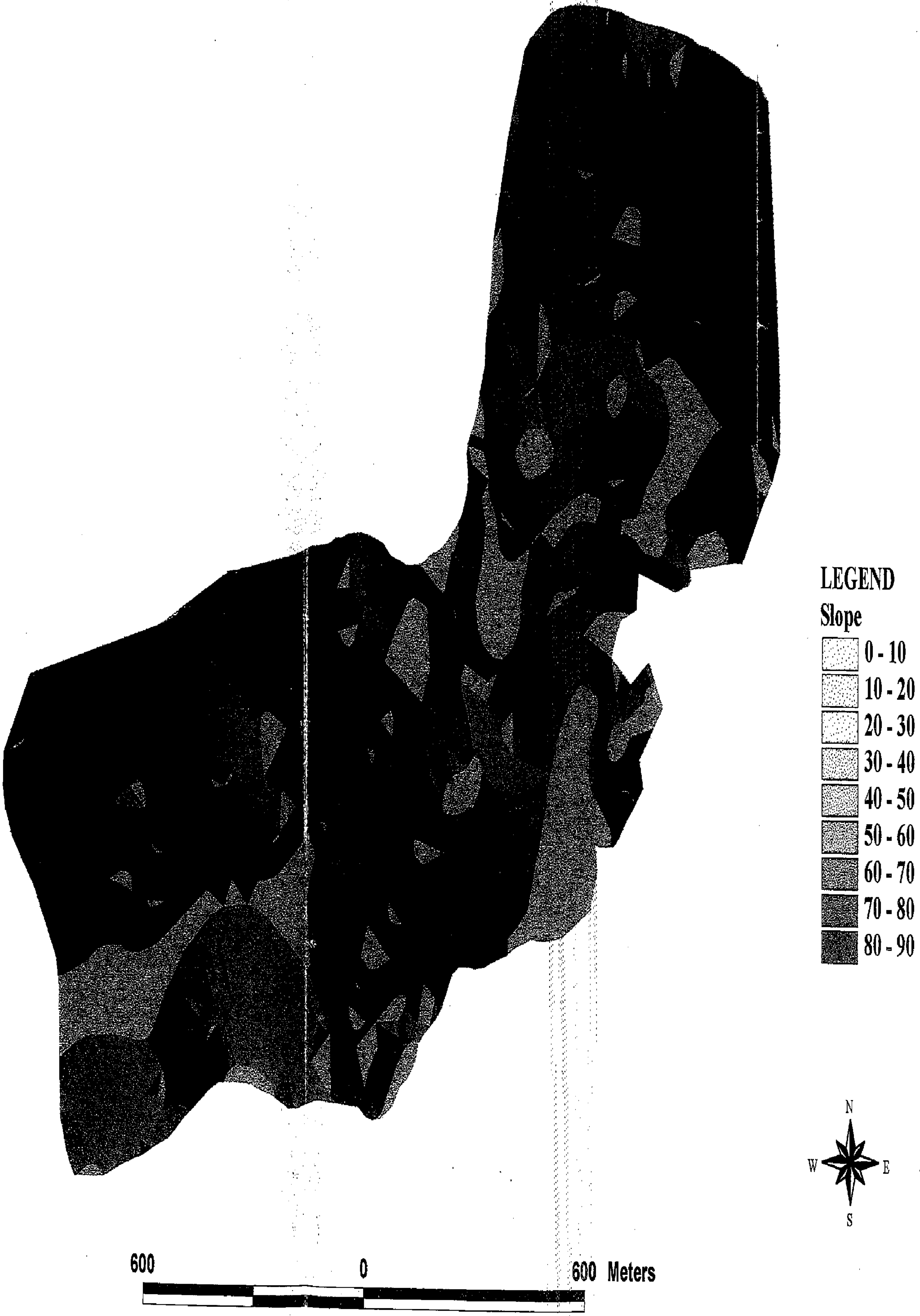

Fig. 22. Digital terrain model of Kachithode Kothara watershed showing the slope ranges (GIS output)

Fig. 23. Current landuse type of Kachithode Kothara wataershed (GIS output)

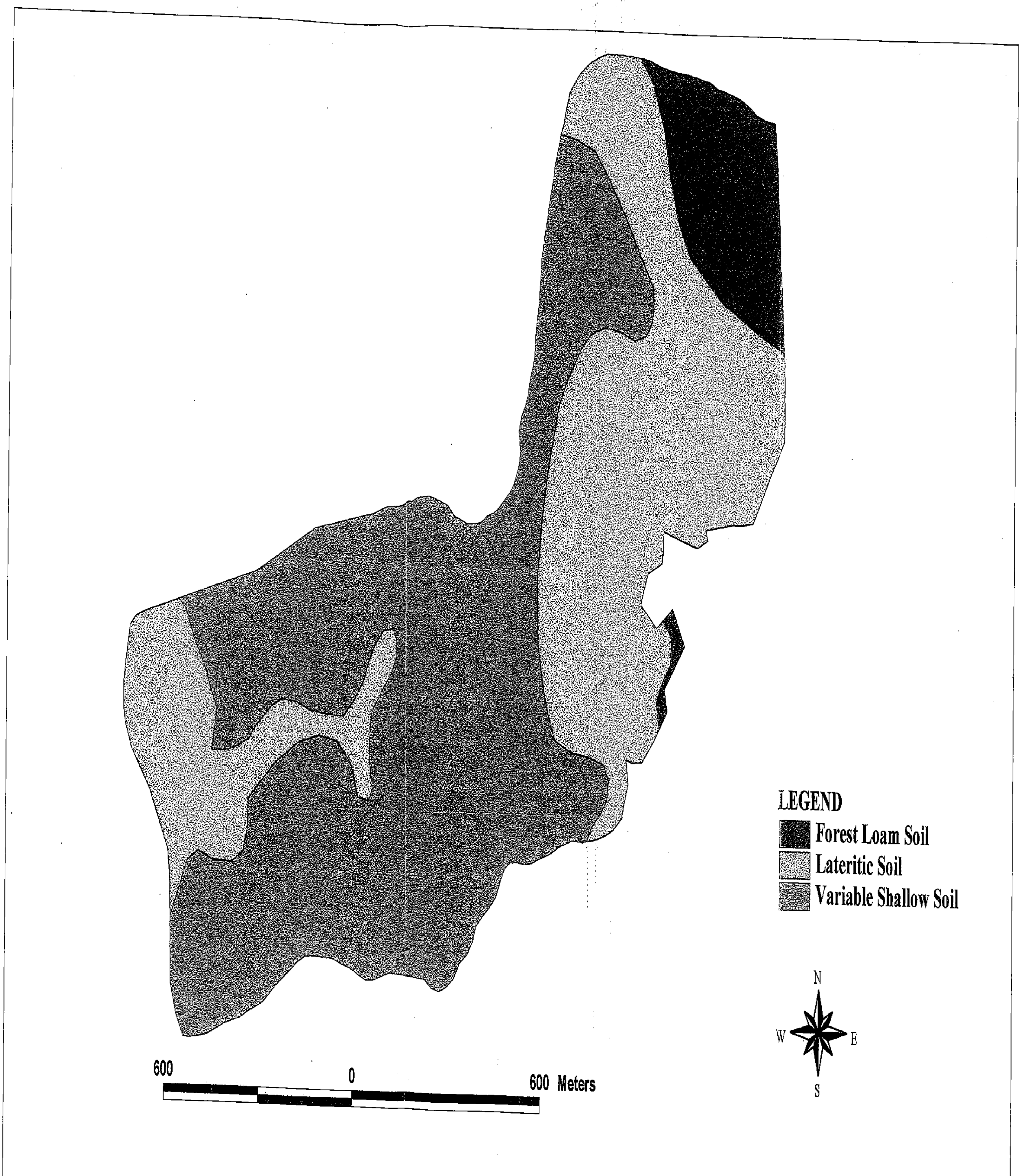

Fig. 24. Spatial distribution of major soil types in Kachithode Kothara watershed (GIS output)

Fig. 25. Drainage pattern of Kachithode Kothara watershed (GIS output)

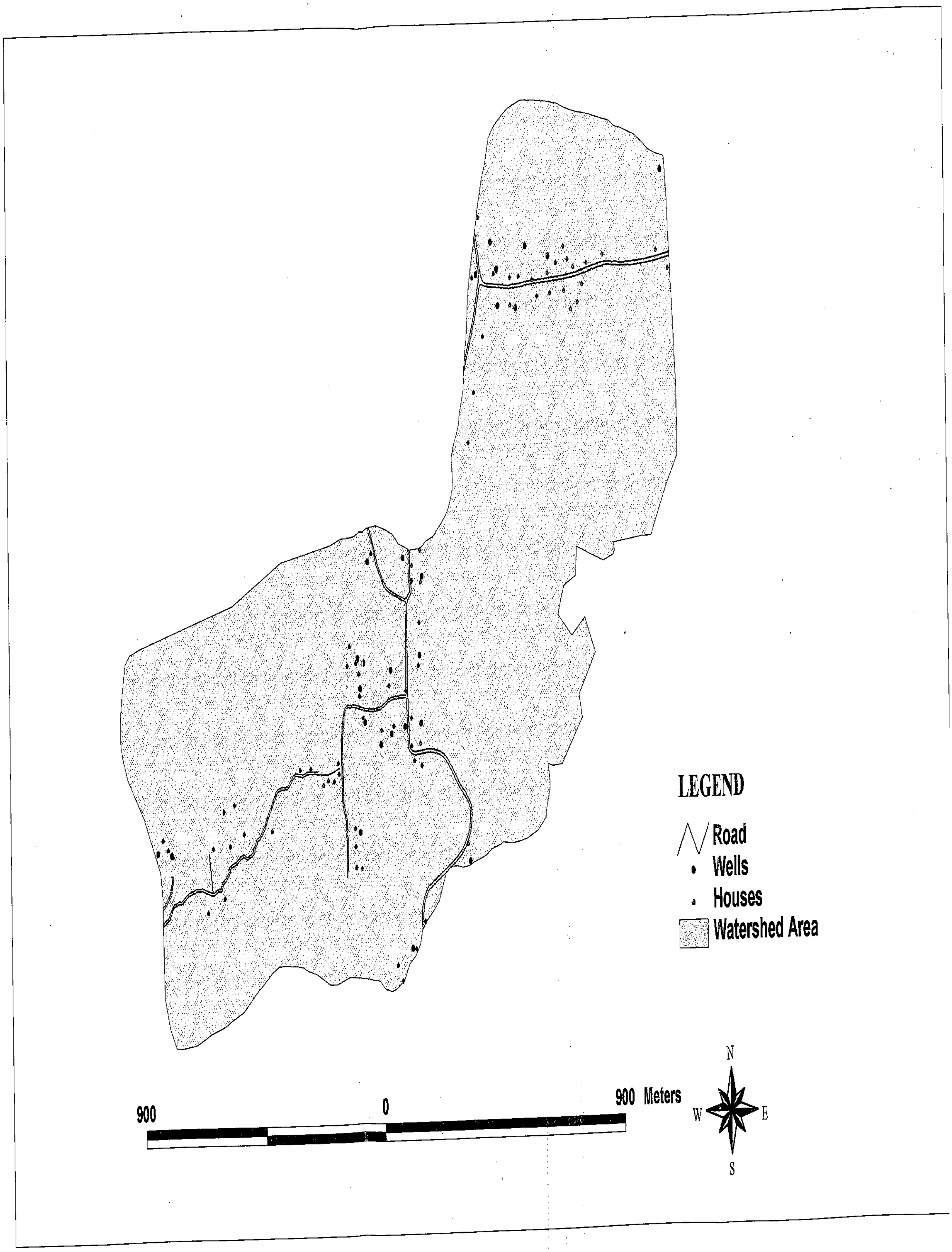

Fig. 26. Spatial distribution of wells in Kachithode Kothara watershed (GIS output)

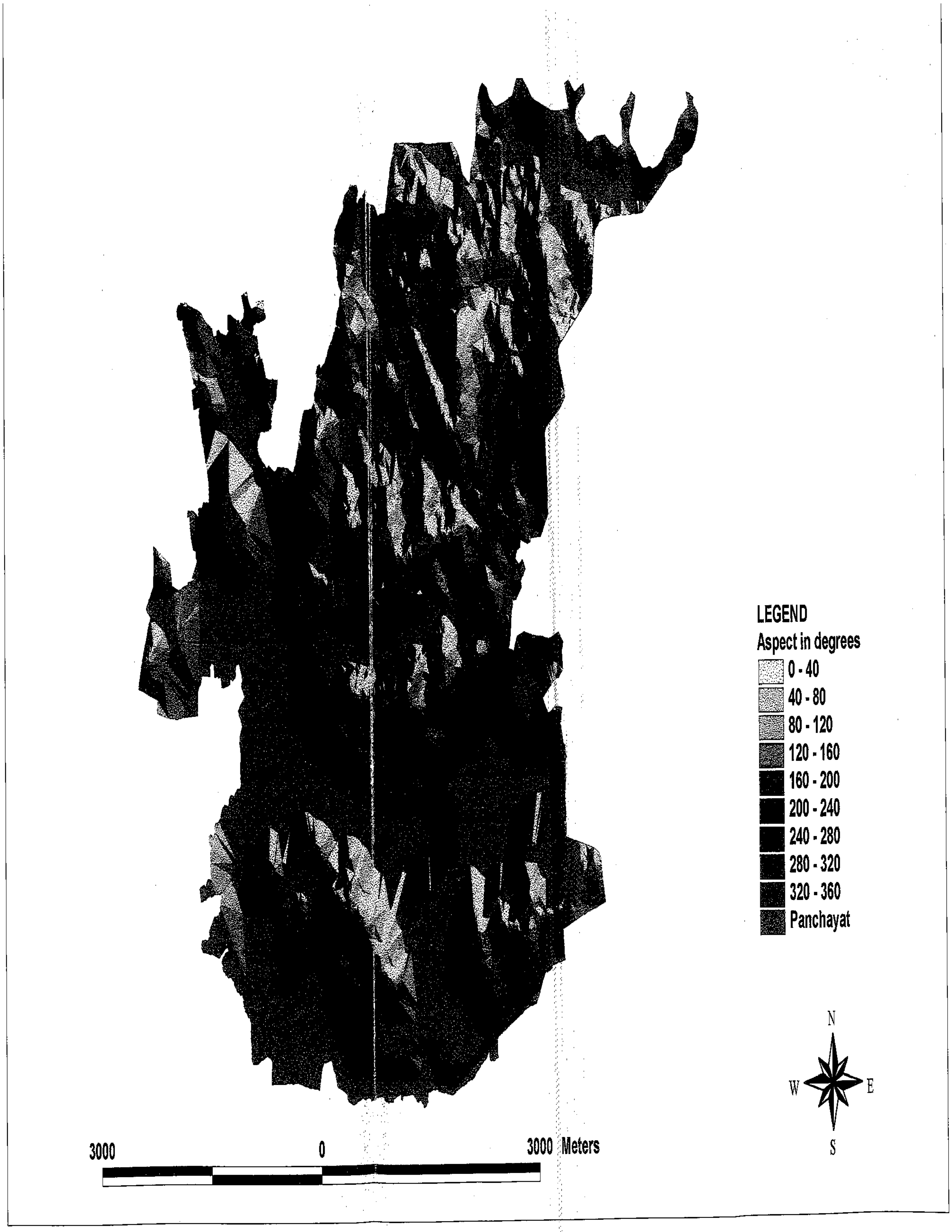

Fig. 27. Slope aspect details of the terrain in Madakkathra Panchayat

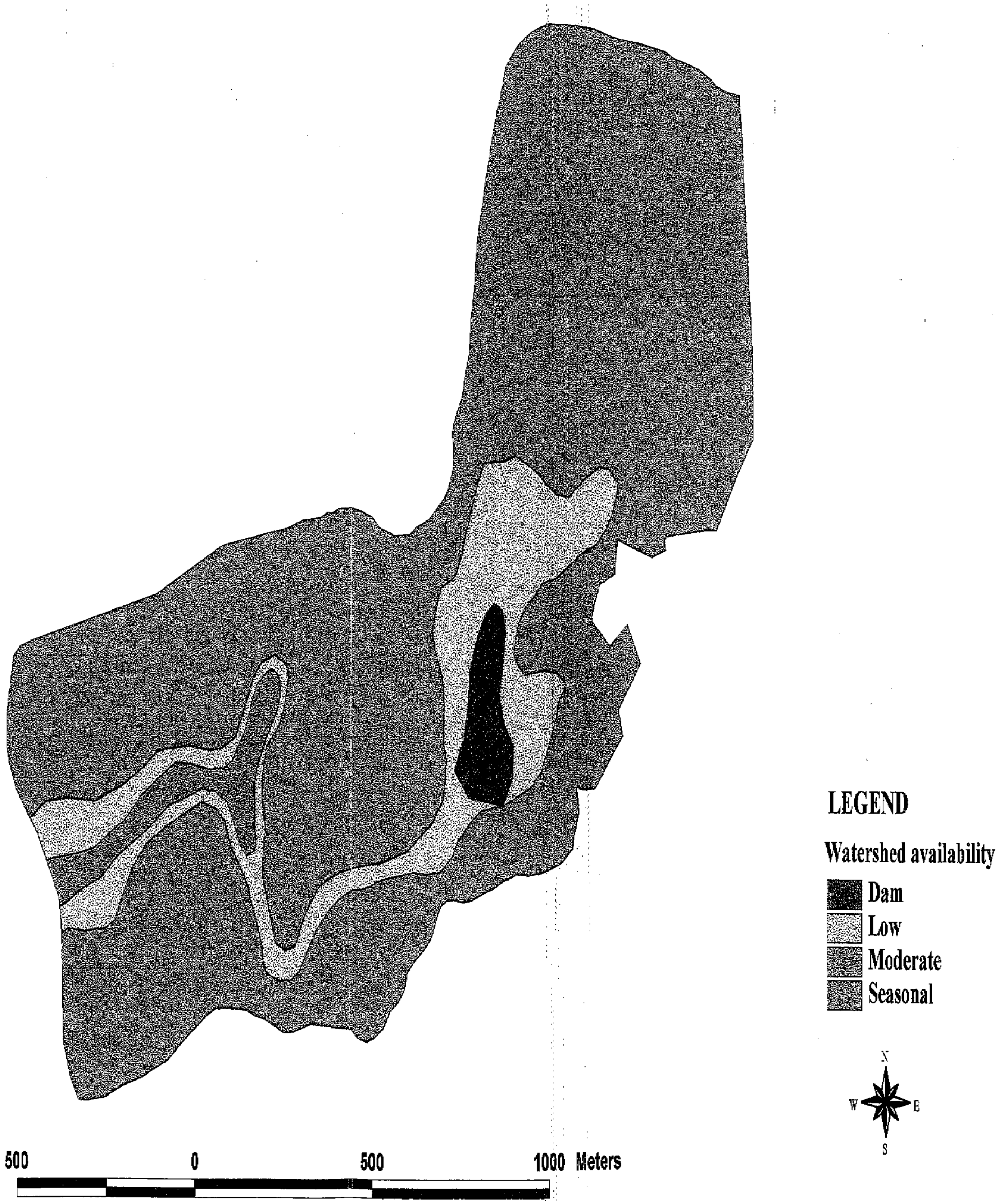

Fig. 28. Thematic map showing water availability status of different areas in Kachithode Kothara watershed (GIS output)