Natural Resource Management Strategies in a Climate Change Scenario

Lecture notes

ICAR-Winter School

12 Nov to 2 Dec 2013

भाकृअनुप
ICAR

KERALA AGRICULTURAL UNIVERSITY

Indian Council of Agricultural Research, New Delhi
Centre of Excellence in Environmental Economics
Kerala Agricultural University, Thrissur,Kerala

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Preface

Despite phenomenal growth in the agricultural sector during the green revolution era and later on, India still houses the largest population of poor in the world. The fruits of development can be equitably distributed only if the growth in primary sector is higher and sustainable. *Realizing that nearly 70 per cent of our population is still rural with farming as the principal source of livelihood and employment, employing 60 per cent of our labour force, "Faster and More Inclusive Growth", as highlighted in the XI Plan Approach Paper, cannot be achieved unless the agriculture sector registers the stipulated growth rate of 4.1 per cent and above.*

Degradation of natural resource base has been attributed as one of the key factors for the stagnant production performance in agricultural sector. The Approach Paper also notes that *"economic development will be sustainable only if it is pursued in a manner which protects the environment"*. Hence natural resource management is given priority, in the efforts to boost agricultural production and thus achieve our goals of a welfare state.

The concept of natural resource basically can be considered as the same as that of the concept of *Panchbhoothas*. Natural resources are all naturally occurring substances that are found to be essential and useful in their original form. The implicit value attached to these resources is often difficult to value by the conventional approach. The value that is directly related with the amount of the material available and the demand for it is associated with its usefulness to production. But the intangible benefits it offers through various services (provisioning, regulating and protecting) form the basis of sustainable existence of all life forms.

Natural resource management refers to the management of natural resources such as land, water, soil, plants and animals in a sustainable perspective. The complex and intrinsic relationship between man and ecosystem is the basis of such a management approach. It combines the physical, biological and social sciences. The fact that people and their livelihoods rely on the health and productivity of the ecosystem is acknowledged here. The anthropological interventions and its impact on the quality of the ecosystem, thus decides the quality and sustenance of life.

The demographic forces, social factors and developmental strides and climate change effects have exerted great pressure on the natural resources and the quality and quantity of these resources have been at risk. While the former can be considered as directly anthropogenic in nature, the climate change impacts on natural resources are not directly attributable to human factors though it is true that the climate change itself is caused by human factors. The specific impacts of climate change on the economy can be both positive and negative. However many of the studies across the globe predict net negative impacts which include, falling crop yields, shifts in cropping patterns, changes in land use, rising sea levels, social conflicts/unrest, migration, forced dislocation, poverty, health damages, loosing habitats, militancy and slow down of economic growth. Thus, the impact on quality of life is mainly through the damage to the natural resources and the ecosystem functions they provide. *Because of their geographic exposure, low incomes and greater reliance on climate sensitive sectors such as agriculture, impacts in developing economies are proportionally greater and the ability to adapt smaller. For low-income countries, major natural disasters today can cost an average of 5% of GDP. Health and agricultural incomes will be under particular threat from climate change. Falling farm incomes will increase poverty. The cost of climate change in India and South East Asia is estimated to be as high as 9-13% loss in GDP by 2100 compared with what could have been achieved in a world without climate change.* These projections highlight the necessity for immediate action to combat and mitigate the effects of climate change on various sectors of the economy of India, we being in a growth process.

This Winter School addresses these issues scientifically and analyses the mitigating and adaptation strategies, focusing on the primary production sector. The topics are handled by scientists/experts in the field along with practitioners and policy makers in respective areas. The programme is scheduled to give ample opportunities of field exposure and direct interaction with the stakeholders. This book is a compilation of lectures in the winter school which is supported by Indian Council of Agricultural Research and organized by Centre of Excellence in Environmental Economics, Kerala Agricultural University.

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12..11..2013

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Natural Resources in India: Current Status, Threats and the concepts of Natural Resource Management

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"A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise"
Aldo Leopold (1949)

Introduction

Natural resources (NR) include anything that comes from nature, which people can use; for e.g., land, water, air, minerals, forests, fisheries, and wild flora and fauna. A common classification of natural resources (de Zeeuw, 2000) is: non-renewable and non-recyclable resources such as fossil fuels; non-renewable but recyclable resources such as minerals; quickly renewable resources such as fish; slowly renewable resources such as forests; environmental resources such as air, water and soil; and flow resources such as solar and wind energy. Natural resources provide fundamental life support in the form of both consumptive and public-good services and comprise of the ecosystem services that underpin human life, ecological processes that maintain soil productivity, nutrient recycling, cleansing of air and water and the climatic cycles.

Natural resource management (NRM) refers to the management of natural resources such as land, water, soil, plants and animals, with a particular focus on how management affects the quality of life for both present and future generations (stewardship). Natural resource management deals with managing the way in which people and natural landscapes interact. It brings together land use planning, water management, biodiversity conservation, and the future sustainability of industries like agriculture, mining, tourism, fisheries and forestry. It recognizes that people and their livelihoods rely on the health and productivity of our landscapes, and their actions as stewards of the land play a critical role in maintaining this health and productivity. This paper aims to discuss the current status and threats in respect of natural resources with special reference to agriculture and forestry in India, examine how these challenges can be managed, and review the concepts and approaches of natural resource management. Aspects relating to non-renewable, quickly renewable and flow resources are clearly outside the scope of the paper.

Natural Resources in India: Current Status and Threats

India is endowed with an array of natural resources and is often termed as one of the megabiodiversity regions of the world. Degradation and erosion of natural resources, however, are one of the major problems that confront this country. Land, water, forest, biodiversity (plant, animal and microbial genetic resources), livestock and fisheries along with air and sunlight that are used to produce food and other valued goods and services and which are essential for our subsistence, are under major stress in this country. Furthermore, the ever-increasing human and animal population exerts greater demands for food, fibre, feed and fodder and imperils the already scarce natural resources.

Challenges and threats to the natural resources base of India

Increasing population pressure and rising food requirements

The human population of India is estimated to increase to 1.6 billion in 2050 from the current level of 1.2 billion and the food grains (cereals and pulses) would be 405 million tons (NCAP 2013) compared to the current level of 257 million tons. Food demand is likely to further increase because calorie consumption will be around 2825 kcal/person/day in 2050 as compared to 2300 kcal/person/day currently (FAO 2012). This additional food requirement will have to be produced from 142 million ha of cultivated lands. However, the fact that per capita land holding will go down to as low 0.087 ha (CSSRI 2013), is a matter of grave concern.

Shrinking land resources: During the five decades from 1950-51 to 2004-2005, area under agriculture increased by 23 million ha from 119 million ha to 141 million ha, while uncultivated area declined by 22 million ha from 49 million ha to 27 million ha (GOI 2011). Presently, the net sown area is 46.3%, which along with fallow land of 25 million ha accounts for 54.5% of the total land use. It is estimated that per capita land availability, which was 0.32 ha in 2001 as compared to the world average of 2.19 ha, will decrease to 0.23 ha in 2025 and 0.09 ha in 2050 (GOI 2011). Increasing demand of land for many non-farm sector activities like mining, tourism, oil exploration and other industrial/infrastructure developments is likely to place additional pressures on the availability of arable land in the years to come.

Land degradation and soil erosion: Sharma (2006) estimated that croplands will decline by 20% in 2050 due to land degradation, urban expansion and conversion of crop land to non-food production. The total extent of degraded lands is estimated to be 121 million ha (ICAR 2010). About 68.4% (83 million ha) of that is affected by water erosion of moderate (>10 t ha^{-1} yr^{-1}) to very severe (>80 t ha^{-1} yr^{-1}) intensities, followed by chemical degradation (25 million ha), wind erosion (12 million ha) and physical degradation (1.1 million ha). As per recent estimates (CSWCRTI 2012), the Indian annual soil loss rate is about 15.35 t ha^{-1}, accounting for 5.37 to 8.4 million tons of nutrients and causing 1 to 2% reservoir capacity loss annually. Faulty land use including conversion from natural to managed ecosystems, and extractive farming practices based on low external inputs are responsible for these high rates of land degradation.

Among the negative impacts of soil erosion by water, loss in crop productivity, disruption of nutrient cycle, alteration in water and energy balances, pollution of water bodies, deterioration in water quality, reduction of reservoir capacity, loss of biodiversity, and natural disasters like floods and droughts have a strong bearing on the national food and environmental security are the major ones (NBSSLUP 2013). It also tends to deplete the terrestrial carbon pools. Globally, the soil pool loses 1.1 Pg C into the atmosphere as a result of soil erosion and another 0.3 to 0.8 Pg C yr^{-1} to the ocean through erosion-induced transportation to aquatic systems (Lal 2011). Erosion/climate change studies also indicate that increased rainfall amount and intensities will lead to greater rates of erosion (CSWCRTI 2013). This will result in significant increase in water erosion-caused land degradation, unless ameliorative measures are undertaken.

Projections of monsoon rainfall pattern over the Indian subcontinent indicate that by 2050, a 10% increase in the amount and 10% increase in the intensity of rainfall are very likely due to climate change, leading to increase in erosive power of rainfall. Sharda and Ojasvi (2006) projected a 1.0% increase in rainfall intensity may increase rainfall erosivity by 2.0%. Another study on inter rill erosion (Ojasvi et al. 2006) indicated that 1% increase in rainfall intensity may increase soil loss from croplands by 1.5%. By 2050, the erosion rates of water erosion class 5 to 10 t ha^{-1} yr^{-1} are expected to increase to more than 10 t ha^{-1} yr^{-1}, which is presently considered as the land degrading soil erosion rate. Hence, about 66 million ha area under the erosion class of 5 to 10 t ha^{-1} yr^{-1} that covers mostly croplands will be additionally affected by higher rates of erosion due to changes in rainfall patterns (NBSSLUP 2013).

Production losses due to soil erosion: Erosion induced reduction in crop productivity may vary from <5% to >50% (CSWCRTI 2013). Sharda et al. (2009) estimated that 27 major rainfed crops (8 cereals, 10 oilseeds and 9 pulses) cultivated on alluvial, black and red soils in the country as a whole suffer a production loss of 16%, which in actual physical terms works out to 13.4 million tons. Cereals contribute 66% to the total production loss followed by oilseeds (21%) and pulses (13%).

Salt affected soils: While salt affected soils currently constitute 6.73 million ha in different agro-ecological regions, the area is likely to almost treble to 20 million ha by 2050 (CSSRI 2013).

Maintaining soil health and productivity: *Soil organic carbon, which is a seat of major soil processes and functions is < 5 g/kg in rainfed soils whereas the desired level is 11 g/kg. Even though, about 80 million tons of crop residues are produced annually in rainfed areas, their recycling is not done due to competitive uses and burning (CRIDA 2013). Soil crusting in red and black soils, shallow depth, poor drainage in heavy textured soils of Madhya Pradesh, Maharashtra, Chhattisgarh, Northern Karnataka and Eastern Maharashtra; sodic soils of*

Haryana, Tamil Nadu and Andhra Pradesh; universal deficiency of macro- and micro-nutrients (Zn, B); are also major issues.

Climate change and climate variability: Using four Representative Concentration Pathways (RCPs) and 18 General Circulation Models (GCMs), Chaturvedi et al. (2012) reported that under the business-as-usual scenario, mean warming in India is likely to be in the range 1.7 to 2°C by 2030s and 3.3 to 4.8°C by 2080s relative to pre-industrial times (1880). Warming is likely to be more over northern parts of India. A rise in night temperatures is also likely over India except in some small pockets in the peninsular region. Atmospheric concentration of GHG would reach almost 685 parts per million (ppm) CO_2-equivalents by 2050 (CRIDA 2013). This is well above the 450 ppm mark thought to provide a 50% chance of stabilising the climate at a 2°C global average temperature increase, the goal set at the 2010 United Nations Framework Convention on Climate Change (UNFCCC). Rainfall is likely to decline by 5 to 10% over the southern parts of India whereas 10 to 20% increase is likely over other regions. There is a probable decrease in the number of rainy days over major part of the country pointing at likely increase of extreme events. The recent ensemble models projected that the frequency of extreme precipitation days (e.g. 40 mm/day) may likely rise (CRIDA 2013).

Direct effects of climate change on agriculture will be through changes in temperature, precipitation, length of growing season, and timing of extreme or critical threshold events relative to crop development, as well as through changes in atmospheric CO_2 concentration (which may have a beneficial effect on the growth of many crops). Indirect effects will include potentially detrimental shifts through increased incidence of disease, pests and weeds, although such ill effects have not yet been quantified. It is estimated that in the tropics where some crops are near their maximum temperature tolerance and where dry land agriculture predominates, yields are likely to decline. CRIDA (2013) reports that rise in temperature will adversely affect the potential as well as water limited yields of crops across the regions, while any decline in rainfall will have more adverse effect in relatively low rainfall areas having light textured soils, such as the arid regions. In particular, changes in yield of wheat, rice and maize the top three food grain crops in India will be affected adversely in 2050 and the most affected crop will be maize with close to 10% yield loss. Irrigated rice yields are expected to reduce by 2050. The likely yield loss would be 7% at country level. However, at regional level, states like Punjab and Haryana the yield loss would be 15 to 17%. Temperature is likely to play a major role in reducing the yields of irrigated rice. Rainfed rice yields in parts of southern India (Andhra Pradesh, Tamil Nadu and Karnataka) are projected to benefit by ~10 to 15%. However, in all other regions, projected reduction stands at 6 to 18% with more impacts in central and eastern India (CRIDA 2013).

Land resources, their distribution and quality, and land use in India will be hit hardest by climate change (NAPCC 2009). This could bring in bigger declines in crop yields and production.

Declining Water Availability: Out of the total annual precipitation of 4000 billion cubic meters (BCM), the utilizable water resources of the country have been estimated as 1123 BCM, of which 690 BCM is from surface water and 433 BCM from groundwater sources (DWM 2013). Availability of renewable water resources in India has declined from 2100 m^3/capita/year in 1992 to 1582 m^3/capita/year in 2009. It has been projected that population and income growth will increase the water demand in future. The projected total water demand of 1447 BCM in 2050 will outstrip the present level of utilizable water resources (1123 BCM), of which 1074 BCM will be for agriculture alone (DWM 2013). Since the total projected demand will be 324 BCM more than the present level of utilizable water resources, the challenge will be to: (i) produce more from less water by efficient use of utilizable water resources in irrigated areas, (ii) enhance productivity of challenged ecosystems, i.e., rainfed and water logged areas, and (iii) utilize a part of grey water for agriculture production in a sustainable manner (DWM 2013).

Per capita water availability has also come down from 5177 m^3 in 1951 to 1588 m^3 in 2010 and is projected to further reduce to 1465 m^3 and 1235 m^3 by the year 2025 and 2050, respectively (Navalawala, 2000). Furthermore, climate change is likely to adversely affect the volume, seasonality and spatial distribution of precipitation. The Central Water Commission has projected that total water demand at 1069 km^3 for 2050, compared to the present water demand of 656 km^3 (DWM 2013). However, water demand for agriculture sector will be around 75% of the total water demand (present share is around 85%).

The contribution of irrigated agriculture to overall agricultural production of the country is 58% (Planning Commission, 1999). Gross irrigated area in the country has increased from 22.56 million ha in 1950-51 to 86.4 million ha in 2009-10 (CWC, 2010). However, the irrigation sector in the country is suffering from several pitfalls (DWM 2013). The utilization of already created irrigation potential is only 74% and the gap between irrigation potential created (IPC) and its utilization (IPU) is increasing. For the country as a whole, about 88% of the ultimate irrigation potential (UIP) has already been developed through different major, medium and minor irrigation schemes, which limits further large scale expansion of irrigation infrastructure. Thus, improving the utilization of already created irrigation infrastructure by removing existing operational and maintenance inefficiencies will contribute positively for agricultural growth. Most of the irrigation projects are operating at an overall efficiency of only about 30 to 35% against the achievable efficiency of more than 50%. Thus, there is enormous scope to improve the productivity and efficiency of irrigation systems which can be achieved both by technological as well as social interventions (DWM 2013).

Presently, groundwater is the largest source of irrigation contributing about 64% of the net irrigated area of the country, while at global level, 38% of total irrigated area is irrigated using groundwater (DWM 2013). Excessive reliance on groundwater, which often results in rapid decline in groundwater level, is a cause of concern. The 'tube well explosion' in many pockets of the country has raised sustainability issues on groundwater resources. However, over-exploitation of groundwater resources (higher withdrawal than recharge) in north-western states coexist with its under-utilization in the water abundant Eastern Region.

The quality of water has become a serious problem in river basins. About 70% of the surface water resources and large proportions of ground water reserves have been contaminated due to indiscriminate discharge of wastewater from the industry, agriculture, and households sectors which contain biological as well as toxic organic and inorganic pollutants. Ground water is also polluted due to point and non-point source pollution. In the canal irrigated lands of Haryana, Punjab, Delhi, Rajasthan, Gujarat, Uttar Pradesh, Karnataka, and Tamil Nadu, ground water is affected due to high salinity, the affected area being over 19.3 million ha (Thatte et al. 2009).

Modest forest cover and degradation of natural ecosystems: The forest and tree cover of the country has been estimated to be 78.29 m ha, which is 23.81% of the geographic area (FSI 2011). This includes 2.76% of tree cover. In comparison to the 2009 assessment, there is a decrease of 367 km^2 in country's forest cover. Fifteen states have registered aggregate increase of 5000 km^2 in forest cover with Punjab leading with increase of 100 km^2. Twelve states/UTs (mainly the NE states) have shown decrease to the extent of 867 km^2. Decline in forest cover of north-eastern states (549 km^2) is particularly due to prevailing practice of shifting cultivation in this region. The state of Madhya Pradesh has the largest forest cover in the country at 77,700 km^2 followed by Arunachal Pradesh at 67, 410 km^2. The total growing stock of India's forests and trees outside forests is estimated as 6047.15 million cu m i.e. 4498.73 million cu m inside the recorded forest area and 1548.42 million cu m outside the recorded forests (FSI 2011).

Forests occupy about 21% of our geographical area. However, most of this has been degraded as exemplified by 'open forests' (Table 1). Although the 2011 forest cover is an improvement of the previous assessment, this is a far cry from the targeted 1/3rd national forest cover. Furthermore, India's forest cover is modest compared to many other countries of the region as well as the world average (Table 2).

Table 1: Forest cover as per 2011 assessment

Class	Area (km^2)	Percentage of geographic area
Forest cover		
Very dense forest	83,471	2.54
Moderately dense forest	3,20,736	9.76
Open forest	2,87,820	8.75
Total forest cover	6,92,027	21.05
Tree cover	90,844	2.76
Total tree and Forest cover	7,82, 871	23.81
Scrub	42,177	1.28
Non-Forest	2,553,059	77.67
Total	3,287,263	100.00

Source: Forest Survey of India (FSI) 2011. The State of Forest Report, Dehra Dun, India

Table 2: Forest cover and area per 1000 people in major regions/countries of the world.

Region/Country	Forest area (1000 ha)	Percentage of forest cover to land area	Area per 1000 people (ha)
Africa	674,419	23	683
Asia	592,512	19	145
Bangladesh	1,442	11	9
China	206,861	22	154
Europe	1,005,001	45	1373
India	68,434	23	58
Indonesia	94,432	52	415
Japan	24,979	69	196
Malaysia	20,456	62	757
Nepal	3,636	25	126
Pakistan	1,687	2	10
Sri Lanka	1,860	29	93
USA	304,022	33	975
World	4,033,060	31	597

Source: State of the World Forests, FAO, Rome, 2011.

Although India's forest resource base has stabilized (annual forest cover change, 2000–2010: +0.5%), it has low forest cover (21% forests), and degradation is a critical issue (9 million ha of forests lost annually). About 300 million Indian people depend on forests for at least a part of their livelihoods, which is one of the principal drivers of degradation. With 41 Mg ha^{-1} of C stock and a total stock of 2.8 Pg C, the Indian forests also have relatively low C sequestration potential (FAO 2011). The National Forest Commission (MOEF, 2006) estimated that about 41% of the country's forest cover has already been degraded and dense forests are losing their crown density and productivity continuously. Reduction in carbon density is yet problem. About 70% of forests have no natural regeneration and 55% are fire-prone but are home to around 100 million people and provide sustenance to them. Between 1951 and 1980 a total of 4.3 million ha of Indian forests were diverted/lost. Between 1980 and 2007 another 1.14 ha of forest land were diverted for non-forest purposes and 311,220 ha were cleared between 2003 and 2007.

Growing demand for wood and wood products in India: Estimates of wood production and use statistics are somewhat uncertain in view of the general lack of precision in data collection and reporting, which ignores the production/demand for timber and firewood in the unorganised sector. Despite this uncertainty, a perusal of the Food and Agriculture Organization (FAO) database indicates that domestic production of most forest products have been stagnant except in respect of paper, paper boards and newsprint during the 2007-2011 quinquennium (Table 3).

Table 3. Changes in Indian forest products production scenario 2007 to 2011.

Forest products	Year-wise production					
	Units X 1,000	2007	2008	2009	2010	2011
Roundwood	Cubic meter	330210	330974	331737	332499	331969
Industrial roundwood	Cubic meter	23,192	23,192	23,192	23,192	23,192
Sawlogs and Veneer logs	Cubic meter	22,390	22,390	22,390	22,390	22,390
Pulpwood (round and split)	Cubic meter	624	624	624	624	624
Other industrial roundwood	Cubic meter	178	178	178	178	178
Wood fuel	Cubic meter	307,018	307,782	308,545	309,307	308,776
Wood chips and particles	Cubic meter	-	-	-	-	-
Wood residues	Cubic meter	-	-	-	-	-
Wood charcoal	Metric ton	2,880	2,880	2,880	2,880	2,880
Sawnwood	Cubic meter	14,789	14,789	14,789	14,789	14,789
Sawnwood (coniferous)	Cubic meter	9,900	9,900	9,900	9,900	9,900
Sawnwood (non-coniferous)	Cubic meter	4,889	4,889	4,889	4,889	4,889
Wood- based panels	Cubic meter	2,592	2,592	2,964	2,964	2,964
Veneer sheets	Cubic meter	285	285	290	290	290
Plywood	Cubic meter	2,154	2,154	2,154	2,154	2,154

Particle board	Cubic meter	24	24	24	24	24
Fibreboard	Cubic meter	130	130	130	130	130
Wood Pulp	Metric ton	2,308	2,308	2,308	2,308	2,308
Mechanical wood pulp	Metric ton	479	479	479	479	479
Semi-chemical wood pulp	Metric ton	166	166	166	166	166
Chemical wood pulp	Metric ton	1,407	1,407	1,407	1,407	1,407
Dissolving wood pulp	Metric ton	255	255	255	255	255
Other fibre pulp	Metric ton	1,995	1,995	1,995	1,995	1,995
Recovered paper	Metric ton	850	850	850	850	850
Paper and paperboard	Metric ton	4,781	7,941	7,789	10,809	10,870
Newsprint	Metric ton	1,039	1,104	952	1,259	1,320
Printing and writing paper	Metric ton	1,606	2,850	2,850	4,170	4,170
Other paper and paperboard	Metric ton	2,136	3,987	3,987	5,380	5,380

Source: FAO stat: http://faostat.fao.org/site/626/default.aspx#ancor

Traditionally forests have been the principal source of wood and wood products in India and elsewhere. However, in the past our forests were destroyed at an alarming rate for various reasons, which continues unabated even today. With little over 2% of the total geographical area of the world and about 15% of its human and livestock population, India experiences a critical imbalance in its natural resource base, and any further destruction of its forests will lead to severe environmental disasters. Consequently, total or partial bans were imposed on logging in natural forests by several states, ostensibly to protect or conserve forests or reduce floods, landslides and land degradation. Timber and firewood availability from the natural forests, however, declined in that process.

Another significant aspect of the Indian forest production dilemma is the increasing dependence on imported wood and other forest products. There is increasing dependence on imported wood and wood products and the consequent drain on our foreign exchange reserves is quite substantial (Table 4).

Table 4. Import of Forest Products in India

Forest products	Year-wise production					
	Units X 1,000	2007	2008	2009	2010	2011
Roundwood	Cubic meter	4,734	4,806	5,985	6,100	6,326
Industrial roundwood	Cubic meter	4,654	4,792	5,972	6,091	6,321
Industrial roundwood (Coniferous)	Cubic meter	795	747	1,026	1,348	1,799
Industrial round wood (non-Coniferous)	Cubic meter	3,859	4,045	4,946	4,743	4,522
Wood fuel	Cubic meter	79	13	13	9	5
Wood chips and Particles	Cubic meter	1	1	1	2	1
Wood residues	Cubic meter	8	5	4	3	4
Wood charcoal	Metric ton	0	2	3	2	2
Sawnwood	Cubic meter	101	106	163	238	456
Sawnwood (coniferous)	Cubic meter	56	50	72	122	299
Sawnwood (non-coniferous)	Cubic meter	45	56	91	117	157
Wood- based panels	Cubic meter	276	164	302	352	600
Veneer sheets	Cubic meter	17	25	26	29	134
Plywood	Cubic meter	37	57	92	147	90
Particle board	Cubic meter	87	39	90	78	187
Fibreboard	Cubic meter	135	43	94	98	189
Wood Pulp	Metric ton	458	530	661	800	876
Mechanical wood pulp	Metric ton	4	5	15	25	8
Semi-chemical wood pulp	Metric ton	45	41	20	52	75
Chemical wood pulp	Metric ton	308	381	458	590	646
Dissolving wood pulp	Metric ton	100	103	168	133	148
Other fibre pulp	Metric ton	10	5	1	2	8
Recovered paper	Metric ton	1,782	1,740	2,162	1,963	2,079
Paper and paperboard	Metric ton	1,387	1,774	1,507	1,931	2,494
Newsprint	Metric ton	812	1,110	743	1,228	1,407
Printing and writing paper	Metric ton	423	456	488	495	647
Other paper and paperboard	Metric ton	153	208	276	208	441

Source: FAOstat: http://faostat.fao.org/site/626/default.aspx#ancor

Managing the challenges

Improved water management: Water being a major limiting factor in producing enough food, improved water management like provision of more storage, water conservation by minimizing water losses, increasing food production per unit of water, transferring water to users with higher socioeconomic returns and reusing saline, sewage and industrial effluents (DWM 2013). Efficient conjunctive management of water resources at regional level should receive the maximum priority. The situation can be improved through strategies involving river basin as planning unit, community participation in the development and management of water resources, appropriate water pricing policy to encourage resource conservation, rainwater and roof water harvesting, watershed management and inter basin water transfers. Key strategies for efficient management of waste water need to focus on augmentation of collection, treatment and safe disposal of waste water; recycling and reuse of municipal and industrial waste water; provision of appropriate sanitation facilities; and strengthening of institutional and regulatory mechanisms (DWM 2013).

Watershed management: Although agricultural productivity is largely dependent on efficient management and utilization of water resources, refining and upscaling of technologies and models from micro to macro scales across different agro-ecological regions needs more attention. The potential of rainwater management and utilization through micro-irrigation and integrated farming systems, groundwater recharge, estimating runoff and soil loss on regional basis, assessment and monitoring water availability, impacts of resource conservation technologies and watershed development programmes, hydrological implications of upstream-downstream linkages of habitations, impacts of watershed development programmes on flow regimes and perenniality of streams and rivers (including drying of springs), and development of stream bank protection structures also needs attention (CSWCRTI 2013).

Rainwater harvesting (RWH): RWH covers a broad spectrum of technologies from simple measures such as micro-catchments to more complex structures such as dams (CSWCRTI 2013). It provides a multitude of physical and social benefits like enhancing crop productivity, food supply and income, increasing water and fodder for livestock, increasing rainfall infiltration, thus recharging shallow groundwater sources and base flow in rivers, reducing flood incidence, reducing soil erosion and sedimentation, and boosting water supply during droughts and dry spells.

Bio-engineering measures - Green technology for rehabilitation: Resource conservation technologies such as contour farming, tillage, mulching, vegetative barriers, crop geometry, inter cropping/mixed cropping etc. on 2 to 8% sloping lands have reduced runoff by 8 to 40% and soil loss by 6 to 35% (NBSSLUP 2013). The corresponding increase in productivity was 3 to 28%. Innovative practices such as agroforestry have tremendous scope for increasing productivity and conservation of natural resources. Conservation agriculture/horticulture technologies like organic farming, mulching, tillage, micro irrigation, fertigation and canopy management also hold promise. Integrated nutrient and micro-irrigation systems need to be dovetailed with different farming practices for wider adaptability on watershed basis. Use of nano-technologies in resource conservation, for sediment/pesticide filtering to improve water quality, artificial recharge filters and sealing for water storage structures is another promising area of research (NBSSLUP 2013).

Utilization of indigenous mineral and by-product sources: Fluctuating oil and consequently the fertilizer prices in the international markets have led to nutrient insecurity in Indian agriculture. Also, fertilizer imports (Table 5) result in a huge burden to the exchequer and a subsidy burden of thousands of crores of rupees. Although, India has 2000 million tonnes of glauconite, 16000 million tonnes of polyhalites, and 2000 million tonnes of silvite minerals which could make India self-reliant in potassic fertilizers, the technology to convert these mineral resources into fertilizers is not presently available (IISS 2013). Similarly, around 310 million tonnes of rock phosphates deposits occur in India. Development of technology for utilization of these mineral resources as source of plant nutrients poses a great challenge.

Table 5. Import, Production and Consumption (000 tonnes) of primary nutrients

Nutrients	Import	Production	Consumption
N	5577	12288	17300
P_2O_5	4264	4364	7914
K_2O	2557	-	2575

Source: Fertilizer Statistics: 2011-2012, The Fertilizer Association of India, New Delhi.

Furthermore, as fossil reserves (for manufacturing nitrogenous fertilizers) and the mineral deposits of phosphates and potash are getting progressively depleted, a fertilizer crisis may be emerging. For instance, fossil fuel reserve depletion times for oil, coal and gas as approximately 35, 107, and 37 years, respectively (Shafieea and Topal 2009), the implications of which are startling. Likewise, it is unlikely that phosphate rock deposits may last beyond another100 years (Herring and Fantel 1993). With this projected fertilizer crisis, agroforestry focussing on fertilizer trees and other resource conservation and sharing mechanisms are likely to get better attention in future (Kumar et al. 2012).

Waste recycling: Enormous quantities of Municipal and Solid Wastes (MSW) are generated in India annually (IISS 2013). Total waste generated in urban India is estimated to be 188,500 tonnes per day (TPD) or 68.8 million tonnes per year (TPY). Organic wastes are increasingly finding their use in power generation and other alternative uses. Likewise, crop residues are often burnt. It would be prudent if these wastes are recycled back in to agriculture. At the present level of crop production, crops remove around 31 million tonnes of NPK, whereas the consumption of fertilizer is around 28 million tonnes which leaves a gap of 3 million tonnes (IISS 2013), implying the potential of organic manures from waste materials to bridge this gap.

Tackling environmental contaminants and developing climate resilient agriculture: Due to increased anthropogenic activities, several pollutants like pesticides, herbicides, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, heavy metals and many inorganic salts find their way into the soil. These pollutants adversely impact the soil physico-chemical environment, nutrient cycling/transformation processes, soil biodiversity, plant growth, food quality through contamination etc. Mining, manufacturing, and the use of synthetic products (e.g. pesticides, paints, batteries, industrial wastes, and land application of city and industrial sludge) in future can result in heavy metal contamination of urban and agricultural soils (IISS 2013).

Adaptation and management of natural resources to climate change will require halving CO_2 emissions by 2050 compared with 1990 levels. Improved cropland and livestock management, forestry and agroforestry and tillage practices have great potential for carbon sequestration

(Kumar and Nair 2011; Nair et al. 2011). This not only helps to maintain soil organic C but also enhances it by at least 15 to 20%. Degraded lands and disturbed ecosystems (i.e. mined lands) are particularly important in this respect. An important and upcoming incentive for investment in soil restoration is carbon trading through clean development mechanisms, which has the potent to enhance farmers' incomes but still not widespread due to certain intrinsic constraints.

Ameliorating salt affected lands: Increase in irrigated area would lead to secondary salinization. Preventing productive lands turning into saline lands would be the key to sustain irrigated agriculture. Technological interventions, development of high yielding varieties, efficient nutrient management, conjunctive use of surface and ground water, application of sprinkler and drip irrigation systems, watershed management, drainage of waterlogged saline soils, utilization of treated waste waters, increased use of bio-fertilizers and policy reforms (subsidies and pricing of water) will be required to maintain higher water use efficiencies and meeting higher food grain requirement. So far, about 1.85 million ha salt affected mainly alkali soils have been reclaimed. Considering the future projections, an area of about 11 million ha is likely to be affected by the problems of water logging and soil salinity in the irrigation commands of India by 2025 and around 20.0 million ha by 2050 (CSSRI 2013).

Enhancing fuel wood supply: Nearly 80% of India's population depends on fuel wood as a source of energy; however, only 10% of this demand is sustainably harvested from the forests. Areas identified as suitable sites for afforestation include salt affected community lands and other degraded lands including undulating lands subjected to saline seeps, strips along canals/branches/distributaries and coastal saline areas including salt flats. Nitrogen-fixing trees hold special promise in these degraded lands (NRCAF 2013). Silvopastoralism involving N fixing woody perennials and leguminous pastures will additionally improve soil and forage quality and serve as additional sinks for carbon and thus help temper the global warming trends.

Adaptation and mitigation of climate change: On a global scale in the mid-1990s, it has been estimated that the increase in atmospheric carbon dioxide emissions due to deforestation was of the order of about 1.6 GtC per year (giga tonne carbon= 1×10^{15}g C i.e., a peta gram carbon or PgC) and that of industrial emissions, a whopping 5.5 GtC per year. Since the 'forest trees' accumulate carbon in their wood for more than a century, it is perhaps obligatory that the C stocks in our natural forests should be preserved and improved through conservation. Therefore, it is unlikely that forest trees will continue to be a major source of commercial timber and firewood in future. Agroforestry, however, will be a major avenue for this. Three basic approaches for using land use options as a means of mitigating climatic change are:

- maintaining or increasing existing stocks of carbon in forests that are currently threatened
- creating new stocks in growing trees (e.g. agroforests and forest plantations)
- substitution of energy demand materials (fossil fuels) by renewable natural resources (fuelwood crops)

Multiple use forestry: Forestry is the scientific management of forests for the continuous production of these goods and services. Forestry so defined, is more than the utilization of such products as the wild and unmanaged forests may furnish -- for it assumes skilful planning for the production of the goods and services. Also, the general public is starting to demand a wider range of environmental and social benefits from forests than solely timber, which has been traditionally emphasised. Indications are that pressures to introduce alternatives to over exploitation of our natural forests for timber, as in other parts of the world, will increase. Multiple use forestry implies that forests are concurrently managed for diverse purposes such as sustainable production of forest resources, biodiversity conservation especially wildlife conservation and the role of natural forests in providing cover to the wild fauna.

Concepts and approaches of NRM

Natural resource management is congruent with the concept of sustainable development, a scientific principle that forms a basis for sustainable global land management and environmental governance to conserve and preserve natural resources. Environmental management is also similar to natural resource management. The emphasis on sustainability can be traced back to early attempts to understand the ecological nature of North American rangelands in the late 19th Century, and the resource conservation movement of the same time. This type of analysis coalesced in the 20th Century with recognition that preservationist conservation strategies had not been effective in halting the decline of natural resources. A more integrated approach was implemented recognizing the intertwined social, cultural, economic and political aspects of resource management. A more holistic, national and even global form evolved, from the Brundtland Commission and the advocacy of sustainable development (United Nations 1987). Natural systems (forests and other wildland ecosystems) and managed systems (agriculture, forestry etc.), apparently follow different NRM paradigms. Human influence on natural systems has often been portrayed as destructive; however, it is not exempted. Although the early paradigms on land use have focused on complementarity of agriculture and forestry, monospecific production systems were promoted during the 20th Century—under the garb of increasing productivity. This has resulted in high rates of tropical deforestation and loss of biodiversity and also degradation of the natural resources both in the managed and natural systems.

Natural resource management approaches can be categorized according to the kind and right of stakeholders, and the nature of the resources (Hardin 1968; Ostrom 1999; Agarwal and Elbow 2002; FAO 2002; Chapin et al. 2009):

State Property Regime: Ownership and control over the use of resources is in hands of the state. Individuals or groups may be able to make use of the resources, but only at the permission of the state. National forests and National parks are some examples;

Private Property Regime: Any property owned by a defined individual or corporate entity. Both the benefit and duties to the resources fall to the owner(s);

Common Property Regimes: It is a private property of a group. The group may vary in size, nature and internal structure, e.g. indigenous tribe, neighbours of village. Some examples of common property are community forests and water resources;

Non-property Regimes (open access): There is no definite owner of these properties. Each potential user has equal ability to use it as they wish. These areas are the most exploited. It is said that "Everybody's property is nobody's property". An example is a lake fishery. This ownership regime is often linked to the tragedy of the commons (Hardin);

Hybrid Regimes: Many ownership regimes governing natural resources will contain parts of more than one of the regimes described above, so natural resource managers need to consider the impact of hybrid regimes. An example of such a hybrid is native vegetation management in NSW, Australia, where legislation recognises a public interest in the preservation of native vegetation, but where most native vegetation exists on private land.

Management approaches

Natural resource management issues are inherently complex as they involve the ecological cycles, hydrological cycles, climate, animals, plants and geography etc. All these are dynamic and inter-related. A change in one of them may have far reaching and/or long term impacts which may even be irreversible. Natural resource management also involves various stakeholders and their interests, policies, politics, geographical boundaries, economic implications and the like. It is very difficult to satisfy all aspects at the same time. This results in conflicting situations. After the United Nations Conference for the Environment and Development (UNCED) in Rio de Janeiro in 1992, most nations subscribed to principles of integrated management of land, water, and forests. The various approaches applied to natural resource management (IFAD 2006; Castella et al. 2007) include: top-down or command and control, bottom-Up (regional or community based NRM), adaptive management, precautionary approach, integrated approach (INRM).

Top-down or Command and control: This approach applied to natural resource management envisages that a problem is perceived and a solution for its control is developed and implemented. The expectation is that the solution is direct, appropriate, feasible, and effective over most relevant spatial and temporal scales. Most of all, command and control is expected to solve the problem either through control of the processes that lead to the problem (e.g., good hygiene to prevent disease) or through amelioration of the problem after it occurs. The top-down proponents assume that the responsibility of resource management should be handled by experts who have a better knowledge of how it should be managed (Bookrags 2001). It was later discovered that such state-run conservation strategy has failed to reflect local realities of the targeted communities (Brown 2002). The perceived failure and limitations of the traditional top-down, experts' oriented approach led to the emergence of Community Based Natural Resource Management (CBNRM) as a bottom-up approach in natural resources management (Jordan and Volger 2003).

Regional or Community Based NRM: This approach is aimed at the devolution of decision making power to the grass root communities over the use and management of their own natural resources (Nhantumbo et al., 2003). The community based NRM approach combines conservation objectives with the generation of economic benefits for rural communities. The three key assumptions: locals are better placed to conserve natural resources, people will conserve a resource only if benefits exceed the costs of conservation, and people will conserve a resource that is linked directly to their quality of life. When a local people's quality of life is enhanced, their efforts and commitment to ensure the future well-being of the resource are also enhanced.

The United Nations advocates community-based NRM in the Convention on Biodiversity and the Convention to Combat Desertification. Unless clearly defined, decentralised NRM can result an ambiguous socio-legal environment with local communities racing to exploit natural resources while they can e.g. forest communities in central Kalimantan (Indonesia). A problem of community based NRM is the difficulty of reconciling and harmonising the objectives of socioeconomic development, biodiversity protection and sustainable resource utilisation. The concept and conflicting interests of community based NRM show how the motives behind the participation are differentiated as either people-centred (active or participatory results that are truly empowering) or planner-centred (nominal and results in passive recipients). Understanding power relations is crucial to the success of community based NRM. Locals may be reluctant to challenge government recommendations for fear of losing promised benefits.

Participatory approach has been promoted in India through Joint Forest Management (JFM) for the last 10 to 15 years, but more than 30% of NRM programmes continue to be under top-down approach. Institutionalization of participatory approach has thus not yet taken place on large scale even in programmes where participatory guidelines are used. This has resulted not only in continued over exploitation of the natural resources due to low emphasis on proper management of the resources, but also in non-inclusive growth and greater inequity.

Precautionary approach: The Precautionary Principle is one of the key elements for policy decisions concerning environmental protection and management. It is applied in the circumstances where there are reasonable grounds for concern that an activity is, or could, cause harm but where there is uncertainty about the probability of the risk and the degree of harm. The

Precautionary Principle has been endorsed internationally on many occasions. At the Earth Summit meeting at Rio in 1992, World leaders agreed Agenda 21, which advocated the widespread application of the Precautionary Principle in the following terms:

'In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.'

Adaptive Management: This approach includes recognition that adaption occurs through a process of 'plan-do-review-act'. It recognises seven key components that should be considered for quality natural resource management practice: determination of scale, collection and use of knowledge, information management, monitoring and evaluation, risk management, community engagement, and opportunities for collaboration.

Integrated natural resource management (INRM): A process of managing natural resources in a systematic way, which includes multiple aspects of natural resource use (biophysical, socio-political, and economic) meet production goals of producers and other direct users (e.g., food security, profitability, risk aversion) as well as goals of the wider community (e.g., poverty alleviation, welfare of future generations, environmental conservation). It focuses on sustainability and at the same time tries to incorporate all possible stakeholders from the planning level itself, reducing possible future conflicts. The conceptual basis of INRM has evolved in recent years through the convergence of research in diverse areas such as sustainable land use, participatory planning, integrated watershed management, and adaptive management. INRM is being used extensively and been successful in regional and community based natural management.

Various terms have been coined to describe this new management philosophy, including managing for biodiversity, ecosystems management, an ecosystems approach to management, holistic management, or an ecological approach to management. Whatever term is used, the focus is centered on a philosophical switch from Gifford Pinchot's ideas of sustained. yield

(McClure and Cheryl 2008) to Aldo Leopold's and John Muir's ideas of land or environmental ethics. Leopold (1949) eloquently summarized the concept: "If the land mechanism as a whole is good, then every part of it is good, whether we understand it or not. If the biota, in the course of eons, has built something we like but do not understand, then who but a fool would discard seemingly useless parts? To keep every cog and wheel is the first precaution of intelligent tinkering."

Conclusions

Land use changes engineered by rapid human population increases have altered the ecosphere (geosphere-biospheric complex), including its climatic history. As natural resources are degraded, ecological security of the region and livelihood security of the people are threatened. Pressures from rising human and livestock populations and sophisticated technology will also place greater and greater demands on natural resources and ecosystem services in future. The challenges to natural resource managers for more intensive management and more accurate predictions of environmental impacts are unprecedented in the history of mankind and this has led to shifts in natural resource management paradigms. The general effect of human-induced climate change is that the risk of extinction will increase for those species that are already vulnerable. Natural resource management therefore should focus on a scientific and technical understanding of the resources and the ecology and life-supporting capacity of these resources.

References

Aggarwal S. and Elbow K. 2006. Lessons Learned: Property Rights and Natural Resource Management (GLT 2) USAID Burlington, USA

Bookrags Staff. 2001. The scientific revolution and philosophical rationalism. [Online] Available: http://www.bookrags.com/research/scientific-revolution-este-0001_0004_01 (15 July, 2010).

Brown, K. 2002. Innovations for conservation and development. The Geograph. J., 168(1), 6-17.

CAZRI (Central Arid Zone Research Institute). 2013. Vision 2050, Jodhpur.

Castella, J-C., Kam, S.P., Quang, D.D., Verburg, P.H. and Hoanh, C.T. 2007. Combining top-down and bottom-up modelling approaches of land use/cover change to support public policies: Application to sustainable management of natural resources in northern Vietnam. Land Use Policy 24(3): 531-545.

Central Pollution Control Board (CPCB). 2009. 'Status of waste supply, wastewater generation, and treatment in class I cities and class II towns of India', available at http://www.cpcb.nic.in/oldwebsite/Newsperent20Letters/Latest/sewagepollution.html.

Central Water Commission (CWC). 2010. Water and related statistics, Government of India, available at http://cwc.gov.in/main/downloads/

Centre for Science and Environment (CSE). 2010. Do it yourself recycle and reuse waste water. New Delhi.

Chapin, F.S., Kofinas, G.P., Folke, C. 2009. Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World. Springer

Chaturvedi, R.K., Joshi, J., Jayaraman, M., Bala, G. and Ravindranath, N.H. 2012. Multi-model climate change projections for India under representative concentration pathways. Current Sci. 103: 791-802.

CRIDA (Central Research Institute for Dryland Agriculture). 2013. Vision 2050, Hyderabad.

CSSRI (Central Soil Salinity Research Institute). 2013. Vision 2050, Karnal.

CSWCRTI (Central Soil and Water Conservation Research and Training Institute). 2012. Annual Report 2011-12, Dehradun.

CSWCRTI (Central Soil and Water Conservation Research and Training Institute). 2013. Vision 2050, Dehra Dun.

DWM (Directorate of Water Management). 2013. Vision 2050, Bhubaneswar.

European Commission (2002) Analysis of Selected Concepts on Resource Management: A Study to Support the Development of a Thematic Community Strategy on the Sustainable Use of Resources. DG Environment, European Commission.

FAO 2012. FAO Statistical Yearbook 2012: World Food and Agriculture. FAO, Rome. Italy. 366p.

Food and Agriculture Organization. 2002. Land Tenure and Rural Development, FAO Land Tenure Series 3. Rome: FAO.

GOI (Government of India). 2011. State of Indian Agriculture 2011-12. Ministry of Agriculture, GOI, New Delhi, India. 294p.

Hardin, G. J. 1968. The tragedy of the commons. Science 1621: 243-8.

Herring, J.R. and Fantel, R.J. 1993. Phosphate rock demand into the next century: Impact on world food supply. Natural Resource. Res. 2(3): 226–246.

ICAR. 2010. Degraded and wastelands of India: Status and spatial distribution. Indian Council of Agricultural Research, New Delhi, India, 167p.

IFAD 2006. Community-Based Natural Resource Management: How knowledge is managed, disseminated and used. IFAD, Rome.

IISS (Indian Institute of Soil Science) 2013. Vision 2050. Bhopal

Jordan, A. and Volger, J. 2003. Governance and environment. In: F. Berkhout, M. Leach and Scoones (eds). Negotiating Environmental Change: New Perspectives from Social Science. Northampton: Edward Elgar, 137-158.

Kumar, B.M. and Nair, P.K.R. (eds). 2011. Carbon Sequestration Potential of Agroforestry Systems: Opportunities and Challenges. Volume 8 in the Book Series "Advances in Agroforestry". Springer Science, The Netherlands, 307p.

Kumar, B.M., Singh, A.K., and Dhyani, S.K. 2012. South Asian agroforestry: traditions, transformations, and prospects. In: Agroforestry: The Future of Global Landuse. Nair, P.K.R. and Garrity, D.P. (eds.), Springer, The Netherlands pp 359-389.

Lal, R. 2011. Soil carbon sequestration. SOLAW Background Thematic Report - TR04B, Food and Agriculture Organization of the United Nations, Rome, 36p.

Leopold, Aldo. 1949. A Sand County Almanac and Sketches Here and There. Oxford University Press, NY., 288 pp.

McClure, R. and Cheryl, M. 2008. For the Greatest Good: Early History of Gifford Pinchot National Forest, Publisher: Northwest Interpretive Association, USA

MoEF (Ministry of Environment and Forests) 2006. Report of the National Forest Commission, MoEF, Govt of India, 421p.

Nair, P.K.R., Nair, V.D., Kumar, B.M., and Showalter, J.M. 2010. Carbon sequestration in agroforestry systems. Adv. Agron. 108: 237–307.

NAPCC (2009). Ministry of Environment, Government of India, pp2.

NCAP (National Centre for Agricultural Economics and Policy Research) 2013. Vision 2050. New Delhi

Navalawala, B. N. 2000. Ground water over exploitation. Yojana, August 2000, p. 49-52.

NBSSLUP (National Bureau of Soil Survey and Land Use Planning) 2013.Vision 2050, NBSSLUP (ICAR), Nagpur

Nhantumbo I., Norfolk, S. and Periera J. 2003. Community-based natural resource management in Mozambique: A theoretical or practical strategy for local sustainable development? The case study of Derre Forest Reserve. Sustainable livelihoods in Southern Africa Research paper 10, Institute of Development studies Brighton.

NRCAF (National Research Centre on Agroforestry). Vision 2050, Jhansi

Ojasvi, P.R., V.N. Sharda, and Om Prakash. 2006. Evaluation of inter rill erodibility parameter for soil erosion estimation. Part I. Development of model using simulated rainfall data. Indian J. Soil Cons., 34(3): 178-182.

Ostrom, E.. 1999. Private and Common Property Rights. In Boudewijn, Bouckaert and Gerrit De Geest (eds) Encyclopedia of Law and Economics, Vol. 1 The History and Methodology of Law and Economics, Edward Elgar and The University of Ghent, pp 332-379. http://encyclo.findlaw.com/2000book.pdf

Planning Commission. 1999. Ninth Five Year Plan 1997-2002 Vol. I&II. Planning Commission, Government of India, New Delhi.

Shafieea, S. and Topal, E. 2009. When will fossil fuel reserves be diminished? Energy Pol. 37(1): 181–189.

Sharda, V.N., and Ojasvi, P.R.. 2006. Development of daily rainfall erosivity model for sub-humid climate of outer Himalayas. Indian J. Soil Cons., 34(3): 199-203.

Sharda, V.N., Ojasvi, P.R., Dogra, P., Prasher, S.O., and Patel, R. 2009. Scenario-based assessment and management of water resources in mid-Himalayan micro-watersheds with limited data availability. Hydrol. Sci. J., 54(6), 1018-1034.

Sharma, 2006. Population and economic growth as drivers of future land use in India. In F. Browser and B.A. McCarl (Eds.). Agriculture and Climate beyond 2015. Springer Publication, pp.131-146.

Thatte, C.D., Gupta, A.C. and Baweja, M.L. 2009. Water resources development in India, Indian National Committee on Irrigation and Drainage, New Delhi.

United Nations 1987. Report of the World Commission on Environment and Development: Our Common Future. Oxford University Press, UK. Zeeuw, A.de 2000. Resource Management: Do we need public policy? DG Environment, European Commission.

Climate Variability and Climate Change – Causes and its Impacts on Crop Production

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Climate change and variability are concerns of humankind. The recurrent drought and desertification threaten seriously the livelihood of over 1.2 billion people who depend on land for most of their needs. The global economy has adversely been influenced by droughts and floods, cold and heat waves, forest fires, landslips and mud slips, ice storms, dust storms, hailstorms, thunder clouds associated with lightning and the sea level rise. The year 1998 was the warmest and declared as the weather-related disaster year, which caused hurricane havoc in Central America and floods in China, India and Bangladesh. Of course, 2010 was the warmest year in India, followed by 2009, while 2010, was the second warmest and the wettest globally.

The year 2005 was another historic third worst warmest year on record for hurricanes. The hurricane Katrina over new Orleans (USA) in August; the hurricane Rita in Texas, Central and Western Cuba and Southern Florida and typhoon over Hainan Province in South China and Vietnam during the last week of September, while early October over Mexican's Gulf coast; heavy downpour over Mumbai on 26th July, 2005 (Single-day the highest record rainfall of 944 mm) and 3rd September, 2005 over Bangalore; severe tropical storms in Andhra Pradesh in September; floods in Kerala, Karnataka, Maharashtra, Gujarat, Orissa and Himachal Pradesh during the Southwest monsoon (June-September), 2005 in India devastated cropped area to a large extent in addition to losses of thousands of human lives. In contrast, it was declared as a famine year in 24 sub-Sahara African countries due to drought and attack of locusts in 2005. Similarly, Australia experienced a severe drought in 2002 and 2006 and heavy crop damage was .noticed. Similar was the case during monsoon 2007, causing floods across several continents (Hurricane Dean in August slammed into Mexico) including India and Bangladesh. Torrential downpour in June, 2007 over Kerala, Karnataka, Andhra Pradesh and Maharashtra while in July and August over Gujarat, West Bengal, Orissa, Bihar, Uttar Pradesh and Assam, led to floods. Heavy rains again in September in Andhra Pradesh, Karnataka and Kerala led to floods and thus the year 2007 can be declared as the flood year in India. A huge crop loss was noticed in several states of the Country due to floods in *kharif*, 2007. A major food shortage is expected in majority of African countries due to heavy floods, which devastated several crops in the region. Mali, a West African country more often plagued by droughts, received unprecedented rains during 2007. Similar was the case in Algeria, Uganda, Sudan, Ethiopia and Kenya.

Greenhouse effect

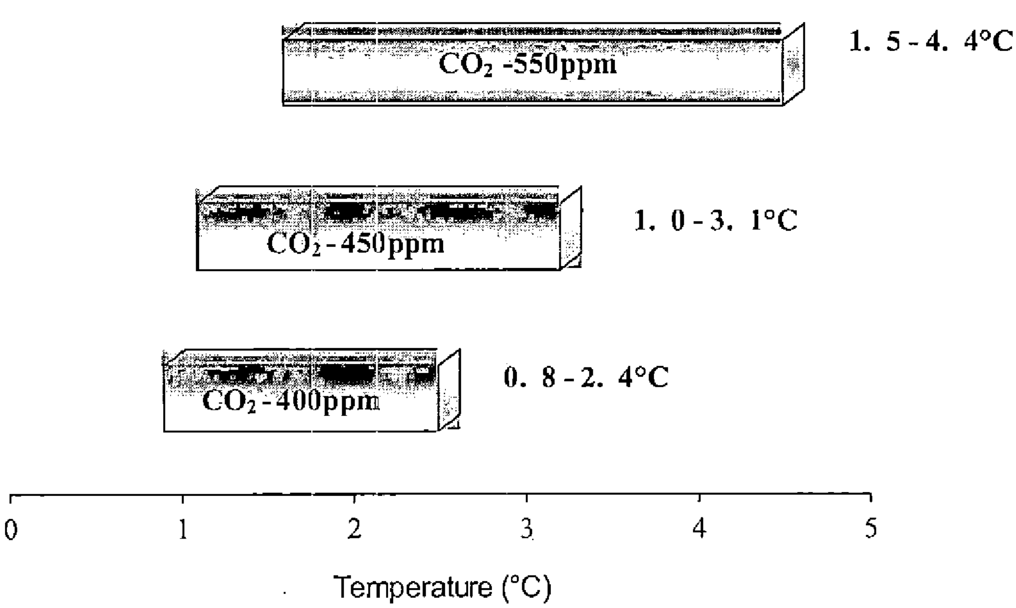
Carbon dioxide, water vapour, methane, carbon monoxide, sulphur and nitrous oxides, chlorofluorocarbons and chlorofluoromethanes are the atmospheric constituents of major importance. Incoming shortwave radiation is not absorbed by the above atmospheric constituents and the outgoing long wave radiation from the earth is absorbed by them and reradiate back to the earth surface. In this process, earth warms up and its temperature rises. It is also known as the glasshouse effect, as property of glass is that it allows solar radiation through it and disallows long wave radiation from earth, thereby warming takes place. The atmospheric constituents which have the property of absorbing long wave radiation and transparent to shortwave radiation are known as the greenhouse gases (GHG). Human activities like fossil fuel combustion, production of synthetic chemicals, biomass burning, deforestation, excess use of chemical fertilizers and pesticides change the chemical composition of the atmosphere, thereby enhancing the greenhouse effect. The frequent eruption of volcanoes in different parts of the globe in recent times is one of the predominant factors that change the chemical composition of atmosphere of which our knowledge is limited. The present growth rate of GHG is 1% in CH_4, 0.4 - 0.5% in CO_2 and 0.2 - 0.3% in N_2O as per the Intergovernmental Panel on Climatic Change (IPCC, 2007). In addition to the above, chlorofluorocarbons and chlorofluoromethanes contribute significantly to the greenhouse effect. Is the greenhouse effect mitigated by regional cooling effect from aerosols like black carbon? New research showed that the aerosol effect could dominate the greenhouse effect over the continents and by and large the effect of greenhouse will be slowed down. In contrast, the ozone - friendly substitutes for chlorofluorocarbons (CFCs) like hydrofluorocarbon (HFCs), hydrochlorofluorocarbons (HCFCs) and perfluorocarbons (PFCs) are also powerful greenhouse gases that contribute to global warming. There is also evidence that the faster rate of global warming since 1976, is human-induced.

Global warming

Global warming is the biggest long term threat to life on earth. Rise in temperature may drive thousands of species to extinction, trigger more frequent floods and droughts and sink low lying islands and coastal areas by rising sea levels. It is the result of rising atmospheric content of CO_2 mainly owing to burning of hydrocarbons or fossil fuels like petrol and diesel. Destruction of forests and their degradation too contribute to rise in carbon dioxide levels. The IPCC (2006) projected the rate of warming for the 21st century to be between 0.8 and 4.4 ° C at various stabilized CO_2 levels in atmosphere and it is most likely to be 3°C by end of this century. It could cost global economy almost $7 trillion by 2050, is equivalent to a 20% fall in growth if no action is taken on greenhouse gas emissions (Fig. 1).

Fig. 1. CO_2 versus Temperature rise and its economics

Economics of climate change: It could cost the global economy almost $7trillion by 2050 - equal to a 20% fall in growth – if no action is taken on greenhouse gas emissions. Taking action now could cost just 1% - $350 billion – of global GDP (Source: Stem report, IPCC, DoE, 2006)



If action is taken, it will cost only $350 billion due to climate change already taken place, just 1% of the global GDP. The winter 2007 was the warmest and recorded 0. 85° C above average of 12° C and the previous highest was 0.71° C, which occurred in 2002 in Northern Hemisphere. The entire European Union recorded the warm winter, having more than 2° C above average. New York experienced the highest temperature of 21.7° C on a day in January, 2007 and the second highest was recorded as 17.2° C in 1950. As predicted, whether the year 2007 could overtake 1998 to become the warmest year on record? However, floods and excess rains were also noticed due to hurricanes and tropical storms worldwide in 2007.

The increase in all-India mean temperatures is almost solely contributed by increase in maximum temperature (0.6° C/100 years) with minimum temperature remaining practically trendless. Consequently, there is a general increase in diurnal range of temperature. In rainfall, there was a decrease over the last 50 years. A marked increase in rainfall and temperature is projected in India during the current century. The maximum expected increase in rainfall is likely to be 10-30% over central India. Temperatures are likely to increase by 3 - 4° C towards end of the Century. It is more pronounced over Northern parts of India. The mean sea level rise is likely to be slightly less than 1 mm/year along the Indian coast. Greater number of high surges and increased occurrences of cyclones in post-monsoon period along with increased maximum wind speed are also expected as per Ministry of Environment and Forests (MoEF), Govt. of India and Department of Environment, Food and Rural Affairs (DEFRA), U.K. This phenomenon of climate change threatens the area of land availability for farming. It would cause a worldwide drop in cereal crops between 20 and 400 million tonnes, put 400 million more people at risk of hunger and put up to 3 billion people at risk of flooding and without access to fresh water supplies. The crop production losses due to climate change may also drastically increase the number of undernourished people, severely hindering progress in combating poverty and food security. The severest impact is likely to be in sub-Saharan African countries, which are the least able to adapt to climate change or to compensate for it through increase in food imports. In 2004 and 2005, 24 sub-Saharan African countries faced food emergencies, caused by a lethal combination of locusts and drought. In addition, adverse hot and dry weather in United States and drought conditions in parts of the European Union lowered cereal output during 2005 when compared to that of 2004. The simulation models also indicate that the global warming leads to reduction in rice and wheat production in northern parts of India.

Atmospheric carbon dioxide (CO_2)

CO_2 being an efficient absorber of long wave radiation from earth, it is of great climatic significance. Carbon dioxide has important absorption peaks at about 2, 3 and 4μ and a major absorption peak at about 15μ. This gas emits half of the absorbed heat back to earth, influencing flow of energy between earth and atmosphere. CO_2 is a very important atmospheric constituent in the heat budget of earth and atmosphere. There is a sharp increase in carbon dioxide in recent decades due to human-made interventions in terms of burning fossil fuels like coal, oil and natural gases. The projected concentration of CO_2 in the atmosphere by 2050 is as follows:

Table 1.Projected concentration of CO_2 in the atmosphere

Period	**CO_2 concentration**
Before pre-industrial revolution	250-290 ppm
1958	315 ppm
1984	354 ppm
2005	379 ppm
Projection by 2050	>450 ppm

The concentration of carbon dioxide in atmosphere was on a steady state at 280ppm till the pre-industrial period, 1950. It is rising since then at the rate of 1.5 to 1.8 ppm/year. The concentration of carbon dioxide in the atmosphere increased from 280 before 1950 to 370 ppm in 2000. It is likely to be doubled by the end of the 21st century if preventive steps are not taken. Measurements at IARI, New Delhi showed that the concentration of carbon dioxide increased from 330 to more than 370 ppm, indicating similar trend of global phenomena. Over the same period, atmospheric concentrations of methane and nitrous oxide increased by 151 and 17%, respectively. This resulted in an increase of global temperature by 0.6° C, causing global warming. As a result of warming, the global mean sea level rose between 10 and 20 cm. The rise is as much as 10 times the average increase in the last 3000 years. An increase of 2.5 mm/year is noticed in sea level of the Indian Ocean since 1950s. The trend appears to be higher on the East coast when compared to that of the West Coast. It is likely that the rate and duration of warming of 20th century were larger than at any other time during the last 1000 years.

In temperate soils, unexpected loss of carbon is taking place due to global warming. It leads to more carbon dioxide in the atmosphere, which means even more global warming. The findings showed that the carbon was being lost from soil at an average of 0.6% a year; richer the soils, higher the rate of carbon loss. There was no single factor other than global warming that could explain such losses in non-agricultural soils.

Aerosols and global cooling

Climate change is usually associated with increasing levels of greenhouse gases; a large amount of soot and other pollutants into the atmosphere in the form of tiny particles, known as aerosols. Aerosols can, however, be produced naturally too. There is a great variation in the amount of aerosols around the globe and are unevenly distributed. They change from time to time depending on the type of aerosols and quantities in which they are present. Many aerosols are invisible to naked eye and are microscopic. They include sea salts from breaking sea waves, pollen, fine seeds of plants, spores, bacteria and various organisms lifted by wind, smoke, and black carbon (soot) from fires, tiny sand particles, volcanic ashes and meteoric dust. Likewise, sulphur-containing compounds known as sulphates arise by natural processes and plants release organic materials. Aerosols in the process of scattering, contribute to the varied colours of red and orange at sunset and sunrise. Blue of the sky is also due to selective scattering by microscopic dust particles.

From the global warming point of view, these tiny soot particles are very important. They absorb a part of incoming shortwave solar energy, thereby heating up the lower atmosphere and totally burning off clouds that might have formed. The combined effect of increasing greenhouse gases and human-induced soot in the warming of lower atmosphere could be as much as 0.25 degrees Celsius/decade (positive effect). Aerosols are tiny particles, of about one micron, which scatter sunlight back to space and then cause a regional cooling effect (negative effect). Such aerosols are sulphates, soot, organic carbon and mineral dust. Black carbon absorbs solar radiation in visible spectrum and reduces amount of radiation reaching earth surface. Increase in black carbon alters large scale atmospheric circulation and hydrological cycle. Black carbon is a product of incomplete combustion of coal, diesel fuels, biofuels and outdoor biomass burning generated from industrial pollution, traffic, outdoor fires and household burning of coal and biomass fuels. The imbalance between positive (warming effect) and negative (cooling effect) effect of aerosol forcing may slow down sometimes the global warming or may lead to global cooling. As the life span of human-induced aerosols in the atmosphere is short-lived (one to three weeks) while the long-lived greenhouse gases may persist and thereby accumulate, leading to overall global warming. Many models indicate that global warming would increase rainfall over India while decrease in rainfall was noticed when the effect of aerosols was introduced. The gradual decrease in rainfall over India since last fifty years supports the theory of effect of aerosols on decline in rainfall. If that is the case, frequency of droughts in India could increase in coming decades if pollution continued unabated.

Clouds and global warming/cooling

Hygroscopic aerosols act as nuclei for cloud formation. Clouds would not form if there were no fine particles in the atmosphere around which water vapour could condense into droplets. Brown clouds contain a variety of aerosols, including sulphates from coal combustion, nitrates produced by vehicular emissions, and soot resulting from fossil fuel combustion and the burning of biomasses. They enhance warming quite a bit in lower atmosphere. Clouds play a dual role in cooling and warming of the earth. If the sky is totally covered with clouds, clouds act as an active surface instead of earth surface. The incoming solar radiation is reflected back to a large extent from top of clouds and thus low solar radiation reaches earth surface. This keeps the planet cool. On the other hand, they absorb long wave radiation and emit back in all directions and transmit little long wave radiation to space. In the process, atmosphere traps huge amounts of heat emitted from earth's surface and clouds, leading to greenhouse effect. Clouds are known as warm clouds in the tropics while cold clouds in temperate zones. Clouds over the oceans differ in character and heating effects to that of clouds over the continents. Their nature and effects also vary with season and time of day. Tropical clouds trap three times as much heat as clouds trap on a global average, but also reflect so much sunlight that the heating effect is cancelled out. Since the tropics account for 20% of earth's surface and the effects of tropical cumulonimbus clouds are disproportionate, the delicate heat balance they maintain is critical. A warmer ocean would be likely to cause more clouds to form, increasing both their heating and cooling effect. Analysis of satellite data also showed that the clouds like stratocumulus over temperate regions reflect enough sunlight to exert a net cooling effect locally, and this appears to account for clouds overall cooling effect worldwide. The behaviour of disproportionate cooling and heating may change itself under global warming, perhaps. If it is understood, climatologists may be able to forecast the timing and extent of expected global warming with far more confidence than today.

Ozone depletion and UV radiation

The greatest concentration of ozone is at an average height of 25 km and above in the stratosphere. The ozone molecule is made up of three atoms of oxygen. It is the most efficient absorber of ultraviolet radiation from the sun and thus protects all life forms in planet earth. Ozone depletion due to industrialization in recent decades is the concern of humankind and biological activities. Release of compounds like chlorofluorocarbons (CFCs), carbon tetrachloride and methyl chloroform could significantly deplete ozone layer that shielded the planet from ultraviolet radiation. The CFCs are used in a variety of industrial, commercial, and household applications. These substances are non-toxic, non-flammable and non-reactive. They are used as coolants in commercial and home refrigeration units, aerosol propellants and electronic cleaning solvents.

The global average thickness of ozone is 300 Dobson units, equivalent to 3 mm. In contrast, it is about 100 Dobson units, which alarm us that we are in great danger if precautionary steps are not taken up. The ozone level fell to 90 Dobson Units, which was the lowest value recorded on 30-09-98 nearly equalled to the lowest value ever recorded 88 Dobson Units on 28-09-94 over Antarctica. The ozone losses are caused by chlorine and bromine compounds released by chlorofluorocarbons and halons. Year-to-year variation of size and depth of ozone hole depend on variations in meteorological conditions. The unusual cold temperature by 5-9° F over Antarctic zone enables greater activation of reactive chlorine that ultimately causes more ozone loss and lower ozone levels. Increase in chlorine levels should peak in the Antarctic stratosphere within a few years (Shashi et al. 2002).

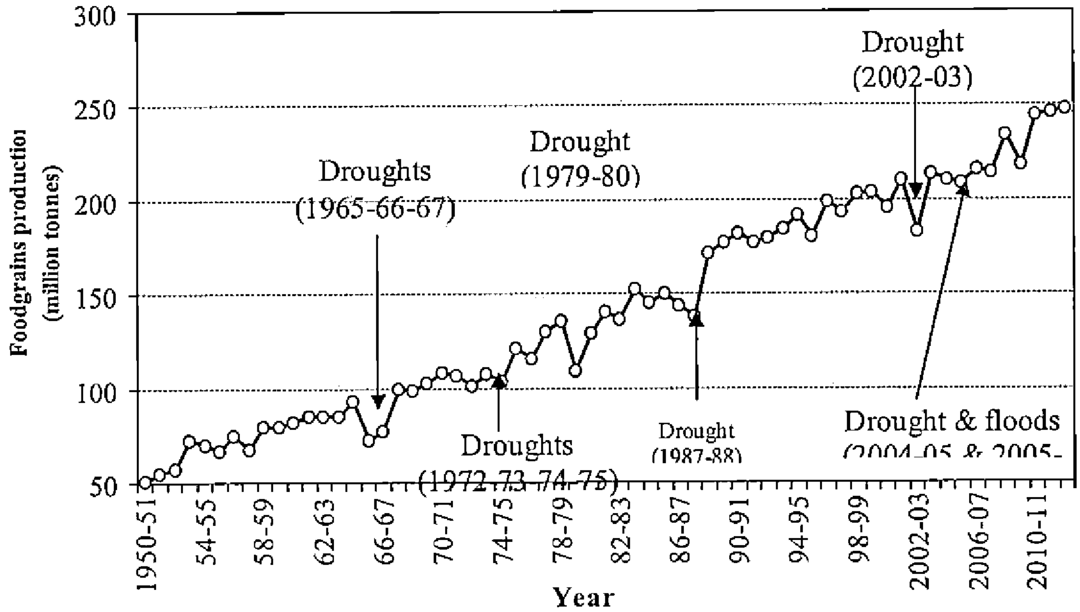
Among UV radiations, UV-B radiation in the range of 280-320 nm is more sensitive to ozone fluctuations and reaches earth surface. A global network is created to monitor UV-B filtered radiation in terms of Minimum Erythema Dose (MED). The human-made interventions in industrial development lead to ozone depletion; thereby filtered UV radiation reaches the ground, resulting in various human, animal, and crop diseases. The ozone loss has the potential to increase incidence of skin cancer, cataracts and damage to people's immune system, harm some crops and interfere with marine life. However, little is known on impact of ozone depletion and increasing UV-B radiation on ontogeny of tropical plants and human and animal diseases since studies in this direction are lacking. Because CFCs remain in the atmosphere for 100 years, continued accumulation of these chemicals pose ongoing threats, even after their use is discontinued.

Increase in aerosols (atmospheric pollutants) due to emission of greenhouse gases including black carbon and chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs, hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs), Ozone depletion and UV-B filtered radiation, eruption of volcanoes, the "human hand" in deforestation in the form of forest fires and loss of wetlands in the process of imbalanced development are causal factors for climate variability and change. The loss of forest cover and wetlands, which normally intercept rainfall and allow it to be absorbed by the soil, causes precipitation to reach across the land, eroding top soil, causing floods and droughts. Paradoxically, the lack of trees also exacerbates drought in dry years by attaining soil to dry out more quickly.

Impact of climate variability on Indian food grains production

The Indian economy is mostly agrarian based and depends on onset of monsoon and its further behaviour. The year 2002 was a classical example to show how Indian food grain production depends on the rainfall of July and it was declared as the all-India drought, as the

Fig. 2 Impact of droughts on Indian foodgrains production from 1950-51 to 2012-'13



rainfall deficiency was 19% against the long period average of the country and 29% of area was affected due to drought. The *kharif* food grains production was adversely affected by a whopping fall of 19.1%. Similar was the case during all-India drought in 2009 and 2012. Occurrences of droughts and floods during South West monsoon across the Country affect food grains production to a greater extent as evident in Fig. 2. It is one of the reasons that the food grains production is not in tune with plan estimates.

Impact of climate variability on Monsooned Malabar Coffee

The "Monsooned Malabar Coffee" is processed at Mangalore, located in Coastal Karnataka. The processing location experiences heavy rainfall of more than 1000 mm in July, followed by 957 mm in June and 605 mm in August. Out of 3264 mm of annual rainfall, 2852 mm is received during the monsoon period. It accounts to more than 80% of annual rainfall. Similar is the case over Kasaragod District, adjoining to Mangalore. The maximum temperature round-the-year varies between 29 and 33.5° C. April is the hottest month while January is the coldest (around 20°C). The night temperature round-the-year ranges from 20 to 26° C. Being located in the tropics along the West Coast, the crop processing environment in terms of surface air temperatures is relatively uniform throughout the year. However, the maximum temperature dips during monsoon months irrespective of coastal or high lands and the difference in day and night temperatures is relatively less (5-7°C) when compared to that of other months. The monthly temperature range appears to be high (around 12°C) in December. It reveals that continuous high rainfall (>2500 mm) together with moderate night and day temperatures (24-30°C) during monsoon season appears to be conducive for coffee bean processing as the processing units are located along coastal belt. The acidity content is likely to increase and sugar content decrease in the absence of continuous wet spell during the processing period of coffee that is in July/August to September/October. When the deficit monsoon rainfall was noticed in monsoon 2002 during the process of coffee beans, the quality of Monsooned Malabar coffee was declined and it was a huge loss to the coffee industry.

Effect of maximum temperature in March 2004 on Apple and Tea in Himachal Pradesh

About 50% reduction in green tea leaves was noticed in April 2004 when compared to 2003 and 2005 in Himachal Pradesh due increase in maximum temperature of the order of 2.1 to 7.9° C in March (Prasad and Rana, 2006). In apple, flowering was advanced by 15 days and fruit set was very poor.

Apple	Tea
Flowering was early by 15 days	About 50% reduction in green tea leaves in April when compared to 2003 and 2005
Large – scale flower drop due to acute moisture stress	The yield reduction was seen only after one month.
heavy rainfall during second fortnight of April accompanied by sharp fall in temperature caused poor fruit set	Heavy losses in yield were noticed in Potato (matured ahead), vegetables and pea
Optimum temperature for fruit blossom and fruit set is 24° C while the region experienced above 26° C for 17 days	

Irrigation during cool dry season (mid-January to mid- March) will not produce desired effect on production as temperature is the limiting factor during the period. Irrigation during hot and dry period (March to September) that occurs frequently in Nilgiris will be beneficial in crop production. The taste of apples becomes tad due to climate variability/change. It is the result based on the studies taken up in Japan.

Climate variability and cocoa productivity

Rainfall preferably between 1500 and 2000 mm annually with a dry season of not more than three months with less than 100 mm/month and temperature varying between 30-32° C as mean maximum and 18-21° C mean minimum with an absolute minimum of 10° C are the climatic boundaries desirable for growing cocoa. The loss of apical dominance in cocoa is seen constantly at a temperature of above 32°C. Loss of apical dominance means development of side shoots of plant. As in other fruit crops, duration of pod, its size and quality and pod development are controlled by surface air temperature. A decline of 39% in annual cocoa yield was noticed in 2004 when compared to that of 2003 due to rise in maximum temperature of the order of 2-3° C from 14th January to 16th March, 2004 along with prolonged dry spell. Such trends were noticed whenever summer temperature shoots up by 2-3° C when compared to that of normal maximum temperatures of 33-36.5° C. The adversity of weather aberrations on rhythm of normal growth of cocoa is reflected in yield after a lag period of 4-5 months.

High rainfall has a malevolent effect, where crop is grown under waterlogged conditions while summer rainfall has a benevolent effect with yield. On augmenting dry season's rainfall by irrigation, the results have not always been very marked; because the water lost from the leaves is so high with low humidity that the roots cannot match the loss. Crop yields are very low with heavy shade and increase with increasing light up to 50% level. Cocoa yield is affected by presence or absence of fertilizer if the level of light is above 50%. With added fertilizer, yields increase almost up to full light, whereas in absence of fertilizer, yields fall off. The theory has therefore been advanced that the light regime for optimum yield of cocoa is a function of its mineral nutrition.

Impact of climate change on coconut

The coconut is a tropical tree plant as its distribution in the world is confined almost entirely to the tropical zone. In fact, it is highly adaptable to a variety of environmental conditions though it does exhibit some growth preferences. In the West Coast of India, the major coconut belt of the country, rainfall varies from 1500 to 3500 mm or more/annum and the crop is grown under rain fed conditions. Within the State of Kerala, the per palm production is much better towards South due to uniform distribution of rainfall as the palm grows under rain fed conditions. High rainfall during heavy rain months (June-August) adversely affects coconut yield due to waterlogging and lack of aeration. Heavy button shedding is likely under waterlogged and severe soil moisture stress conditions. In non-traditional areas like Tamil Nadu, Andhra Pradesh and Karnataka, coconut palms are grown commercially under irrigated conditions only; otherwise crop does not come up due to climate extremes in terms of surface air temperature and poor annual rainfall of about 1000 mm. Of all the climatic factors affecting the coconut, rainfall appears to be the most important under rain fed cultivation. There is a lag period between influence of meteorological variables and crop yield in coconut as initiation of primodium takes place 44 months before harvest. The yield of a particular year was influenced by January to April rains for two years prior to harvest together with rains during same period of the year of harvest (Patel and Anandan, 1936). Park (1934) found that severe drought experienced in Puttalam (Srilanka) affected yield of nuts for a period of about two years with the maximum effect at about 13 months after conclusion of drought. Decline in monthly nut yield was noticed in the following year from February 1984 to January 1985 due to severe drought of summer 1983. The effect of drought on monthly nut yield was noticed in the eighth month after drought period was over with a maximum (64.1%) reduction in nut yield in July 1984 (i.e., 13 months after the drought period was over) and the minimum (23.6%) in January 1985. Similar was the case during 1988-89. The recent summer drought during summer 2004 also adversely affected coconut yield to some extent over Kerala. In the semiarid tropics like Tamil Nadu, heavy crop loss was reported due to continuous failure of rains in 2001 and 2002 and lack of irrigation due to poor water recharge in wells. It was similar in 2012-13. Models indicate that the climate change is likely to affect the coconut production adversely.

Coconut palms show the following characteristics under severe soil moisture stress depending upon duration and intensity of drought (Rao, 2002).

- Withering and mortality in young seedlings under poor management
- Drooping, wilting and drying of lower whorl of leaves

- Breakage of leaves at petiole or just above it
- Spindle leaf breaking which lead to mortality in senile palms under conditions of poor management
- Abortion of spadices, starts from October/ November onwards
- Button shedding and immature nut fall
- Nut size decline, and
- Finally decline in nut yield in subsequent year up to 50% depending upon the type of management and genotype

The second phase of nut development in coconut is sensitive to heat units since it is the critical phase, which finally decides nut size in coconut. If the number of heat units during second phase of nut development (4-7 months old nut) is more the final nut size may be diminished. Due to high maximum temperature and low humidity, oil content is relatively less in non traditional areas. It clearly indicates that number of heat units influence crop duration, nut size, oil content and nut yield to a large extent. The genetic coefficients are derived for each crop based on thermal units and used in crop growth simulation models, which are widely operational for decision making. Strong winds are not desirable as they considerably damage coconut plantations. They not only uproot or break the stem but also twist the crown or break the leaves and destroy considerable part of the crop. Heavy and extensive damage to coconut palms due to cyclones are reported from Philippines, South India and Jamaica due to strong winds.

Impact of climate variability (cold wave) on fruit crops

The unprecedented cold wave during winter 2002-03 in northern parts of India adversely affected the fruit crops in terms of quality and quantity. The damage was more in low-lying areas, where cold air settled and remained for a longer time on ground. However, the temperate fruits such as apple, plum and cherry gave higher yield due to extended chilling (Table 1). Mango was the worst affected due to cold wave (Samara et. al. 2004). Though ill-effects of abnormal weather events are well understood in agricultural sector at the field level, it is difficult to quantify the same at the zonal/state level based on secondary data. Hence, a realistic scientific method is to be evolved as such no technique is available to project future crop trends based on climate variability/change.

Models on global warming indicate that the rise in temperature is likely to be around 3° C by end of this century. It is likely that the extreme weather events like droughts and floods, cold and heat waves increase in coming decades. The human and crop losses are likely to be heavy. The global economy will be adversely affected as mentioned in the latest report of IPCC. If the sea level increase as projected, the coastal areas which are thickly populated will be in peril and for the existing population, the safe drinking water will be a great problem.

The whole climate change is associated with increasing greenhouse gases and human-induced aerosols and the imbalance between them may lead to uncertainty even in year-to-year monsoon behaviour over India.

Table 1.Occurrence of cold wave (frost and cold spell) during December-January 2003 and its effects (after samra et al 2004)

States affected	Crops suffered	Percentage loss	How to reduce the impact (?)
Parts of Jammu, Punjab, Haryana, Himachal Pradesh, Bihar, Uttar Pradesh and North Eastern States	Mango, Litchi, Guava, Papaya, Ber, Kinnow, Pine apple, Sapota, Amla, Assam lemon, Jack fruit and Peach	10-100% depending upon crop and variety within the crop (mango)	Proper selection of fruit species /varieties, wind breaks or shelter belts, frequent irrigation, smoking, covering young fruit plants with thatches or plastic shelter and air mixing
	Fruit size and quality were affected in horticultural crops	Damage is more in low-lying areas where cold air settled and remain for a longer time on ground Temperate fruits such as apple, plum and cherry gave higher yield due to extended chilling	Weather forewarning

Therefore, there should be a determined effort from developed and developing countries to make industrialisation environment-friendly by reducing greenhouse gases pumping into atmosphere. In the same fashion, awareness programmes on climate change and its effects in various sectors viz. , agriculture, health, infrastructure, water, forestry, biodiversity and sea level and the role played by human beings in climate change need to be taken up on priority. In the process, life style of people should be changed so as not to harm Earth-Atmosphere continuum by pumping CFCs into atmosphere. From the agriculture point of view, effects of extreme weather events on crops are to be documented so that it will be handy to planners in such reoccurrence events for mitigating the ill effects. Also, there is need to guide planners on projected future crop scenarios based on climate change events, which will be more realistic at field level as models always overestimate the impacts. Finally, we have to foresee these extreme events and prepare ahead to combat them so that the losses can be minimised.

Suggested Readings

IPCC (Intergovernmental Panel on Climatic Change) 2006. The Economics of Climate Change: Stern Review. The Summary of conclusions. Survey of the Environment 2007, The Hindu, pp141-145.

IPCC (Intergovernmental Panel on Climatic Change) 2007. Climate Change: The Physical Science Basis. Extracts from the IV Assessment Report. Survey of the Environment 2007, The Hindu, pp147-155.

Nybe, E. V. and Rao, G. S. L. H. V. P. 2005. Drought management in plantation crops. Kerala Agricultural University, Thrissur, Kerala, India, 176p

Park, M. 1934. Some notes on the Effect of drought on the yield of coconut palm *Trop. Agriculturist*, 83:141-150.

Patel, J. S. and Anandan, A. P. 1936. Rainfall and yield in coconut. *Madras agric.* J. 24: 5-15

Prasad, R and Rana, R. 2006. A study on maximum temperature during March 2004 and its impact on rabi crops in Himachal Pradesh. *J. of Agrometeorology*, 8(1): 91-99

Ramakrishna, Y. S., Rao, G.G.S.N., Rao, S.G. and Vijayakumar, P. 2006. Impact of climate change in Agriculture. In: Environment and Agriculture (eds. Chadha, K. L. and Swaminathan, M.S.). Malhotra Publishing House, New Delhi, pp. 1-30

Rao, G. S. L. H. V. P. 2008. Agricultural Meteorology. PHIndia (Pvt.) Ltd. New Delhi India, 364p

Rao, G. S. L. H. V. P. 2010. Impact of Climate Change on Agriculture and allied sectors. Scientific Publishers, Jodhpur, India, 316p

Rao, G. S. L. H. V. P. and Nair, R. R 988. Agrometeorology of Plantation Crops. Kerala Agricultural University, Thrissur, Kerala, India. 187p

Rao, G. S. L. H. V. P, Rao, G. G. S. N. and Rao, V. U. M. 2011. Climate Change and Agriculture over India. PHIndia (Pvt.) Ltd. New Delhi India, 320p

Samra, J.S., Singh, G and Ramakrishna, Y.S. 2004, Jan.10 cold wave during 2002-03 over north India and its effect on crops. *The Hindu*. p. 6.

Shashi, K., Pathak and Mason, N. J. 2002. Our shrinking ozone layer: General perspectives and remedial measure. Resonance, December pp. 71-80

Shukla, P. R., Sharma, S. K and Ramana, V. P. 2002. *Climate Change and India - Issues, Concerns and Opportunities*. Tata – McGraw-Hill Publishing Company Ltd, New Delhi, 14p.

Ecosystem Services- Alternative Approaches to Conceptualization and Assessment

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Conceptualizing ecosystem services

Evolution of theconcept of ecosystem services in interdisciplinary terms since 1980s is noteworthy. Equally noticeable is the extraordinary pace with which the concept with a growing focus on monetary valuation of ecosystems services has made entry into national and international policy frameworks and academia. Its application ranges from looking at health of the planet to impact on human health.

Conventionally, valuation of ecosystem services has been synonymous with estimating the economic (monetary) value of the services. Though, such valuation of ecosystems in economic terms has helped in communicating the worth and criticality of these services to the public at large, it leaves a number of ambiguities and shortcomings in methods, practice and outcomes in social justice. These short-comings if not completely addressed, need to be acknowledged before the methods are adopted in relevant policies. Frameworks thus incomplete have resulted in several cases for payments for ecosystem services, though their role in livelihoods or sustaining ecosystem services remains questionable.

Thus market-based approaches with their built-in limitations (Daly 1997) overlook the impact on socio-cultural dynamics, resulting mostly in skewed outcomes reflecting the existing power paradigms. Therefore, in many environmental disputes, monetisation aimed at resolving a conflict in the use of ecosystem services may, in fact, lead to perpetuation of the conflict (Martinez- Alier 2002) and could be disastrous to the services themselves. Linked to this is the growing concern that marketing and 'commodifying' ecosystem services (Kosoy and Corbera, 2010) and putting price tags can exacerbate the growing rift between nature and human society.

Thus questions like who provides and who benefits from the service and whose rights are protected or violated become central to the discussion.

Such challenges in conceptualizing ecosystem services will form the discussion in the first session. The obsession with pragmatism and the ease of interpretation that justifies the use of money metrics in valuation also results in the neglect of alternate approaches. The search for alternatives towards addressing the multi-dimensional complexity in the ethics and pragmatics of ecosystem services forms the content of the next session. Following sections indicates some of these alternatives for a production landscape.

Approaches to assessing the impact of change in ecosystem services

Several methodologies have been employed to estimate monetary values of individual ecosystem servicesin both protected and production landscapes including quantitativetechniques that estimate production functions and marginal outputs of an ecosystem good/service; or more indirect methods including contingent valuation, avoidance costs and hedonic pricing (Hanley et al 2007; Costanza et al 1997). Valuation exercises in the agricultural context have been adopted to estimate the value of a given ecosystem service (for example, pollination (Olschewski et al 2006); or biological control services (Losoy et al 2006)), or for assessing a chosen agro-ecosystem as a whole (for example, Sandhu et al (2008)).

More conventional approaches to assessing agricultural systems (such as cost-benefit analysis or efficiency analysis) tend to focus only on the production aspect, viewing agricultural systems solely as the source of food/crop produce. Typically, they seek to understand the relative benefit of different land use practices in terms of marginal changes in a given agricultural output. As discussed in the earlier section, given the limitations associated with the process of valuation and amidst the growing degradation of agricultural landscapes, it is imperative to evolve measures that help to assess and highlight the 'value' of agro-ecosystems beyond short term maximization of production; so as to informintegrated policies and sustainable land use strategies.

Assessing agro-ecosystems in social-ecological terms with a multi-dimensional perspective that account for inter-linkages and trade-offs envisages an overarching framework. The Ecosystem Services (ES) framework developed by the MEA (2005) and Land Use Functions (LUF) approach espoused by Perez-Soba et al (2008) are two potential approaches to be used in such contexts. By the manner in which the system's functions (and/services) are depicted and understood, it may be argued that the LUF framework is more adaptable to modified ecosystems in general. This is because in addition to the identified problems associated with the ES framework, there are gaps like the inability to reflect dis-services to communities (e.g; crop loss due to forest fire or wild animal attacks).

Techniques to evaluate changes in agro-ecosystems without relying exclusively on the money metric, include participatory impact assessment (Purushothaman et al 2012a); multi-criteria analysis(Purushothaman et al 2012b); quantitative comparative statics approach (Purushothaman et al 2012c)and bio-economic models (Patil et al 2012).

The second session will discuss whether unlike monetary valuation that are best used in attracting public and policy attention; these alternate approaches reveal disaggregated impacts on individual components of any change in a social-ecological system. Such assessment approaches could provide useful information for strategies towards sustainability including designing policies, crafting institutions as well as market-based and fiscal instruments.

References:

Brondizio, E.S. and F.W. Gatzweiler. 2010. Socio-cultural context of ecosystem andbiodiversity valuation. In: The economics of ecosystems and biodiversity: The ecological andeconomic foundations. (ed. Kumar, P.). Pp 150–181. London: Earthscan Publications.

Constanza, R, D'Arge, R, De Groot, R, Farber, S, Grass, MO, Hannon, B, Limburg, K, Naeem, S, O'Neill RV, Paruelo, J, Raskin, RG, Sutton, P, Van Den Belt, M. 1997. The value of the world's ecosystem services and natural capital.*Nature* 387: 253–260.

Daly, H. 1996. *Beyond Growth*. Beacon Press.

Gomez-Baggethun, E., R. de Groot, P.L. Lomas and C. Montes. 2010. The history ofecosystem services in economic theory and practice: From early notions to markets andpayment schemes. *Ecological Economics* 69: 1209 – 1218.

Hanley, N, Shogren, J and White, B. 2007. Environmental Economics in Theory and Practice, Palgrave, London.

Kosoy, N., and E. Corbera. 2010. Payments for ecosystem services as commodity fetishism.*Ecological Economics* 69: 1228–1236.

Lele, S, Springate-Baginski, O, Lakerveld, R, Deb, D, and Dash, P. 2012. Ecosystem Services: Origins, Contributions, Pitfalls and Alternatives. *Conservation and Society.Forthcoming.*

Losey, JE and Vaughan, M. 2006. The economic value of ecological services provided by insects.*Bioscience* 56, 311–323.

Martinez-Alier, J. 2002. The environmentalism of the poor: A study of ecological conflictsand valuation. Cheltenham: Edward Elgar Publishing.

Millennium Ecosystem Assessment (MEA) 2005.Ecosystems and human well-being. Washington, D.C: Island Press.

Olschewski, R, Tscharntke, T, Benítez, PC, Schwarze, S and Klein, A. 2006. Economic evaluation of pollination services comparing coffee landscapes in Ecuador and Indonesia. *Ecology and Society* 11(1): 7. [online] URL: http://www.ecologyandsociety.org/vol11/iss1/art7/

Patil, S., et al., (2012) Comparing conventional and organic agriculture in Karnataka, India: Where and when can organic farming be sustainable? *Land Use Policy*, doi:10.1016/j.landusepol.2012.01.006

Purushothaman, S, Patil, S, Francis, I, Konig, HK, Reidsma, P, and Hegde, S. 2012a. Participatory Impact Assessment of agricultural practices using Land Use Functions framework – A case study from India. *International Journal for Biodiversity Science, Ecosystem Services and Management.*

Purushothaman, S, Patil, S and Francis, I. 2012b. Impact of policies favouring organic inputs on small farms in Karnataka, India - a Multicriteria approach. *Environment, Development and Sustainability* 14: 507-527.

Purushothaman, S, Patil, S and Francis, I. 2012c. Assessing the impact of policy driven agricultural practices in Karnataka, India – a comparative statics approach. Under review - *Sustainability Science*,

Sandhu, HS, Wratten, SD, Cullen, R and Case, B. 2008. The future of farming: The value of ecosystem services in conventional and organic arable land. An experimental approach. *Ecological Economics* 64, 835-848.

Valuing Ecosystem Services - Methods and Approaches

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We must begin to give the natural capital stock that produces the services, adequate weight in the decision making process, otherwise current and continued future human welfare may drastically suffer. One way to look at this comparison is that if one were to try to replace the services of ecosystems at the current margin, one would need to increase global GNP by at least US$33 trillion, partly to cover services already captured in existing GNP and partly to cover services that are not currently captured in GNP. This impossible task would lead to no increase in welfare because we would only be replacing existing services, and it ignores the fact that many ecosystem services are literally irreplaceable. (Costanza, 1997)

1. Introduction

The services of ecosystems are often enjoyed as part of daily life, without deliberate acknowledgement and have been considered as free goods. These include the productive, consumptive and assimilative functions i.e. the regulation of environment, assimilation of waste, provision of wildlife habitat, carbon cycling, trapping of nutrients, flood control, balancing of life forms etc. Thus, ecosystems, such as wetlands, forests, mountains, grass lands or estuaries can be characterized by the processes, or functions, that occur within them.

In the conventional anthropocentric approach, goods and services were valued on the basis of market prices and hence, economic goods/services only were brought in the regime of valuation. The challenges to estimation of true value were often the instances of market imperfections and policy failures. Later the skewness in the supply of natural resources and ecosystem services (productive, assimilative) gradually shifted the status of such goods/services to that of economic, than free good/service. This naturally necessitated its valuation as the value is to be accounted in production cost for just decision making and efficient resource allocation. Therefore, economic valuation can be useful, by providing a way to justify and set priorities for programs, policies, or actions that protect or restore ecosystems and their services. Further, valuation establishes ecosystem values that allocate improvement of a country's national accounts sometimes known as "greening" and creation of enhanced indicators of changes in welfare and well-being.

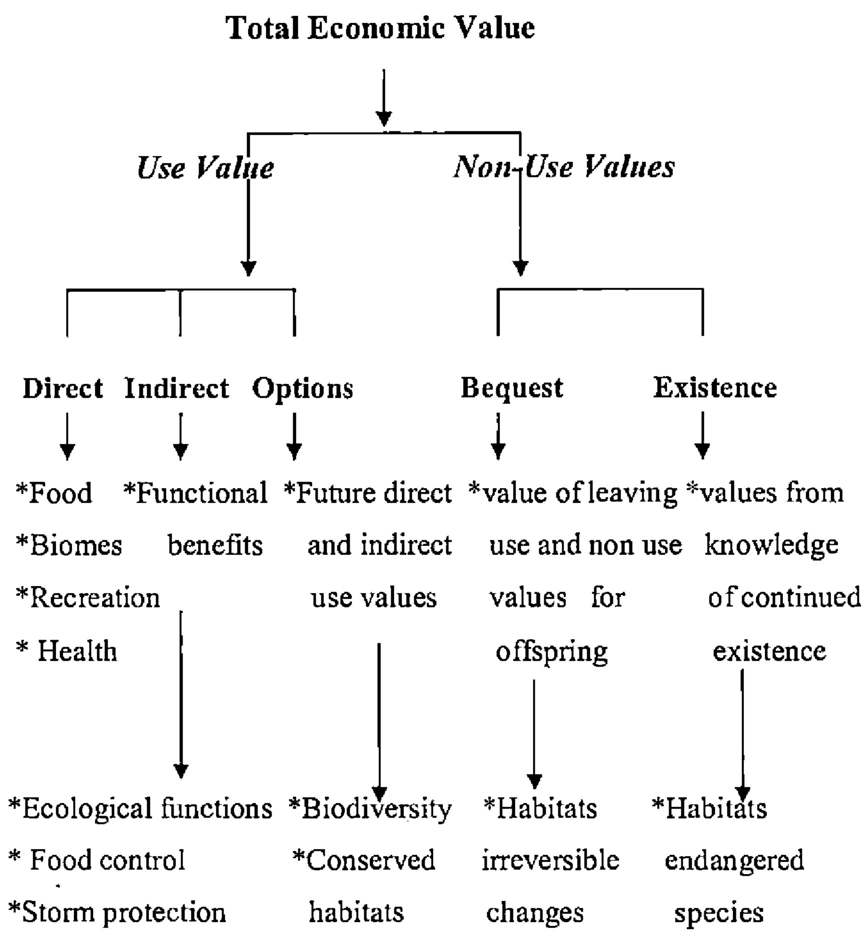
The Millennium Ecosystem Assessment (MA) give strategies to use valuation as a tool that enhances the capacity of decision-makers to evaluate trade-offs between alternative ecosystem management regimes and courses of social actions that amend the use of ecosystems and the services they provide. This assessment analyses the change in the mix of services offered by an ecosystem resulting from a given change in its management. The change in the value of ecosystem benefits concerns quantifying change in the physical flow of benefits and quantifying chain of casualty between changes in ecosystem condition and human well-being. Economic valuation is undertaken for assessing the overall contribution of ecosystems to social and economic well-being, to comprehend how and why economic factors use ecosystems and finally to assess the relative impact of alternative actions to direct decision-making. But better valuation of the services provided by a given ecosystem does not guarantee that it will be conserved, as conservation measures are expensive but it definitely certifies that the loss will be very little than otherwise.

Many services provided by ecosystems tend to be underpriced or not priced at all, leading to the inefficient and unsustainable use of resources. The valuation helps to reveal policy and institutional failures such as open access, public goods and externalities, or missing markets, provide useful policy information on alternative intervention options for rectifying them, such as creating markets or improving incentives.

The MA uses valuation mainly for the assessing the impacts—the gains and losses—of alternative ecosystem management regimes. This act as a tool to enhance the capability of decision-makers to appraise trade-offs between alternative ecosystem management regimes and courses of social actions that modify the use of ecosystems and the various services they provide. The criticism towards the attempt to fix price tags for the natural resources and the services are often raised against the economists. But the current political system necessitates such approach as to facilitate economically efficient and sustainable resource management. But valuation of these services *per se* created challenges to the economist, as most often markets do not exist for such goods and services or there are market imperfections or policy failures. These include the facts that: (i) many ecosystems provide services that are public goods; (ii) many ecosystem services are affected by externalities; and (iii) property rights related to ecosystems and their services are often not clearly defined.

2. The TEV frame work and approaches to valuation

Ecosystems and the various provisioning, regulating, cultural, and supporting services they provide have economic value to human societies by the utility we derive from their actual or



potential use, either directly or indirectly, which is known as use values. People also value ecosystem services they are not using currently, but may in future. The concept of total economic value (TEV) is widely used for utilitarian value of ecosystems (Pearce and Warford, 1993).TEV is divided into use value and non use value. Use value refers to the value of ecosystem services that are used directly or indirectly by humans for consumption or production purposes. It includes both tangible and intangible services of ecosystems. The use value is further divided into direct use value, indirect use value and option values. Non use values are known as existence value or passive use value. Human beings establish certain values to the resources that exist even when it is not used directly by them. These are non use values.

3. Methods of Valuation

Two approaches are generally followed for economic valuation of ecosystem services: the stated preference and revealed preference. The former is based on actual observed behavior of the stakeholders and depend on market prices when ecosystem services are privately owned and traded in functioning markets. Similarly, in instances where the environmental quality changes are reflected in the market price, this method is widely employed i.e. it normally applicable to consumptive use, where goods are extracted from ecosystems and traded in markets. Indirect observed method uses observation on actual behavior in a surrogate market, which is hypothesized to have a direct relationship with the ecosystem service value. Hedonic pricing, travel cost method and replacement cost are few examples of indirect observed method.

The second approach in valuation is based on hypothetical behavior. The response to direct questions describing hypothetical markets or situations is used to arrive at values. This method can be further subdivided into direct hypothetical, like contingent valuation, where respondents are asked directly how much they would be willing to pay for particular benefits and indirect measures of Willingness to Pay (WTP) or Willingness to Accept (WTA) such as contingent ranking or conjoint valuation, where in respondents are asked to rank different bundles of goods. WTP or WTA compensation is used as measures for welfare change for particular goods which have no direct market value. In practical situation, WTA estimate is higher compared to WTA, so WTP are most often used in valuation.

3.1. Revealed Preference Methods

3.1.1.Market Based Methods

Market based valuation describes the valuation principles that can be used when the demand and supply curves for commodities are known. In a well functioning market, prices reflect values. In the presence of market demand and supply we use price changes to value benefits and costs and use market prices to determine values. The implicit assumption is that these prices reflect both economic scarcity and consumer's willingness to pay.

Productivity change method

The level of output is decided by the level of input use, management and the environmental services. This method tries to analyse the level of productivity change due to changes in environmental attributes and value this change based on market prices to estimate the value of the ecosystem service or cost of its damage. The cost of illness method employed in health economics studies use this approach (Gupta, 2004; Devi, 2007).

Defensive Expenditure Method

This involves three techniques, which use information on potential expenditures to value a development impact on the environment. Each of these techniques-the replacement cost approach, the relocation cost approach, and the shadow project technique-examines the costs of replacing the environmental services or natural resources that were damaged or destroyed by development projects. An implicit assumption in using these methods is that the natural resources and the environmental services under consideration can be artificially replaced when they are destroyed i.e. perfect substitutability relationship exists between marketable commodities and environmental services.

Replacement Cost Method

The basic premise of the replacement cost approach is that the costs incurred in replacing productive assets damaged by a project can be measured and that these costs can be interpreted as an estimate of the lower bound of the benefits presumed to flow from measures taken to prevent that damage. Theoretically this approach represents the case of perfect substitute for an environmental input in production or household production function. It does not deal with potential damage, rather it deals with the damage that actually occurred and the true costs of replacement.

The assumptions implicit in the application of this method are:

- The magnitude of damage is measurable.
- The replacement costs are calculable and are not greater than the value of the productive resources destroyed that and therefore it is economically efficient to make the replacement. If this assumption is not true, it would not make sense to replace the lost resource.
- There are no secondary benefits associated with the replacement expenditure.

Opportunity Cost Approach

This approach is based on the concept that the cost of using resources for unpriced or non-marketed purposes (for example, preserving land for a national park rather than harvesting its trees for timber) can be estimated by using the foregone income from other uses of the resource as proxy. Rather than attempting to measure directly the benefits gained from preserving a resource for these unpriced or unmarketed purposes, we measure what has to be given up for the sake of preservation. The opportunity cost approach is therefore a way of measuring the 'cost' of preservation.

3.1.2. Methods based on Proxy /Surrogate Markets

Here, we try to mimic the market counterpart or to utilize revealed preference information as much as possible to derive the values of non-marketed goods. We accomplish this task by considering the non-market good's relationship with a conventional market good. Non- market goods can be inputs in the production of market goods. They can be either substitutes or complements in the consumption of market goods. These different relationships lead to different non-market valuation techniques under different assumptions.

Hedonic Pricing

The basic economic theory says that consumers buy different products in order to obtain utility. However, according to the hedonic model, product characteristics, rather than the product itself, provide the utility. In this context, the total amount of utility, a consumer enjoys from the purchase of products depends upon the total amount of product characteristics. At the equilibrium, the price paid by the consumer equals the sum of marginal monetary values of the product characteristics. It has been shown that the marginal monetary value of the product characteristic is the product of the marginal unit of the characteristic in the commodity and the marginal implicit prices of the characteristic. Hedonic property value models are employed for valuing the changes in environmental quality in scenic beauty or qualitative aspects of the environment through the property values in the market. Among other characteristics (proximity to amenities/characteristic of the houses) the environmental attributes (water front, quality air) also decides, the value of a house in market. This method, tries to segregate the implicit value associated with this environmental quality, in the total value of the property. The method was employed in studies like Gundimeda and Kathuria (2004) and Bockstael and McConnell (2007).

On a similar way, hedonic wage models are employed to assess the value of danger/risk in a situation by capturing the wage differentials of the workers. Here the assumption is that the wage of the worker is decided by the job characteristics, worker characteristics and the work environment. Devi (2011) have employed the tool to assess whether the wage differentials among farm workers (pesticide applicators) compensate for the health damage due to pesticide exposure.

3.2 Stated Preference -Constructed Markets

Contingent Valuation Method

The survey technique that attempts to obtain stated preferences is known as the Contingent Valuation Method (CVM). The word 'contingent' is used here to reflect that the preferences are stated for a described hypothetical situation. In other words, the stated preferences in CVM are contingent upon the described situation. There are two types of questions: willingness to pay (WTP) and willingness to accept compensation (WAC) in CVM surveys. If the individual had the right to sell the public good (which means he holds the property right to it), then the WAC measure would be appropriate, where as if the individual had to buy it to enjoy it, WTP would be the correct measure.

Since this method is very much sensitive to the situation of conducting the survey, the design and implementation is to be done with extreme care and scientific vigour. Large number of studies is seen reported in this aspect (Bateman *et al.*, 1992; Stevens *et al.*, 1995; Oglethorpe and Miliadou, 2000; Wattage and Mardle, 2008) which often has direct and immediate relevance in policy decisions.

Choice experiments, which can be considered as an extension/modification of CVM is employed often to arrive at socially preferred and ecologically sustainable management options for natural resources when property rights are not well defined or when it is Common Property Resource. Hema (2013) employs the technique for suggesting the appropriate management options for the mangroves of Kerala.

4. Ecosystem approach in agriculture management

Agriculture production process is complex and involves the interaction of diverse life and nonlife forms. The challenges while managing this system, hence needs research support from an ecosystem perspectiv . The major research challenges are

1. The valuation of externalities associated with the agricultural technologies and net impacts

- chemical fertilizers (the effect on soil flora and fauna, acidity, leaching and run off loss and resultant soil and water contamination
- pesticides in agriculture (direct and indirect, long term and short term health impacts, biodiversity loss, damage to beneficial organism, minor pest emerging as major pest, resistance to chemicals)
- organic agriculture (organic manure production and methane release, soil quality and net effects)
- biofertilisers and biocontrol agents (net impacts on ecosystem, chemical fertilizer replacement, carbon trading prospects)
- mechanisation and externalities (soil health, net impact on environment)
- biotechnology interventions (human health impacts and valuation, production impacts like threat to other life forms, genetic erosion, biodiversity loss)

2. Farming systems, agro ecosystems and environmental impact valuation

- mixed farming and net environmental gains

-homesteads

- enterprise or crop rotations (rice legume rotations, rice fish rotation)

- rice fields as wetland ecosystems and net ecological value

- plantation sector and carbon sequestration

3. Forest types and Total Economic Value

- economic value of different forest ecosystems

- minor forest produce extraction and trade and economic value (loss in biodiversity, genetic erosion)

4. Value of environmental impact of land use changes

-wetlands to commercial uses

-forests for non forest purposes

- agricultural land to non agricultural uses

-cropping pattern changes

5. Ecosystem valuation and policy impacts

-Payment for Ecosystem Services (PES) for conservation (eg. mangroves, sacred groves)

- PES for rice farming (wetland conservation)

-PES in agroforestry systems, treefarming (carbon sequestration functions, ecosystem regulation)

- environmental cess for sand mining and clay mining activities

- damage cost realization in waste disposal, pollution

6. Climate change impacts on ecosystem and its valuation

- on health

- livelihood

-soil and water systems

-biodiversity

- ecosystems (coastal, mountain, wetlands)

-agricultural systems

7. Methodological challenges to valuation of ecosystems

5. Conclusion

The agricultural production, when it was subsistence in scale was sustainable in nature, due to its minimum damages to the nature. The technological developments and practices thereof have caused serious blows to the quality of the ecosystem services. This naturally is being reflected as falling /plateauing crop yields. The problems like waste accumulation, quality decline of water resources, air pollution and similar issues are of major concern now. The rejuvenation of environmental health and its sustenance can be ensured only if our macroeconomic decisions are taken based on microlevel aspects of ecosystem health. Valuing the ecosystem services assumes significance in this regard. Greening our accounts form the basic step in this goal.

References

Bateman, I.J., Willis, K.G., Garrod, G., Doktor, P. and Turner, R.K. 1992. A Contingent Valuation Study of the Norfolk Broads. *Report to the National Rivers Authority*, England, 403p.

Bockstael, N.E. and McConnell, K.E. 2007. Hedonic wage analysis. Chapter 7 of Environmental and Resource Valuation with Revealed Preferences: A Theoretical Guide to Empirical Models (Volume7 in the series The Economics of Non-Market Goods +and Resources). Springer:Netherlands

Costanza, R.; Arge, R.; Groot, R.; Farberk, S.; Grasso, M.; Hannon, B.; Limburg, K.; Naeem, S.; O'Neill, R.; Paruelo, J.;Raskin, R.; Suttonkk, P. and Belt, M. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387:253-260.

Devi, P.I. 2007. Pesticide Use in the Rice Bowl of Kerala: Health Costs and Policy Options. Working Paper No. 20. South Asian Network for Development and Environmental Economic, Kathmandu, Nepal.

Devi, P.I. 2011. Is farm labour compensated for occupational risks? An attempt employing hedonic wage model. ICSSR Report, Indian Council of Social Science Research, New Delhi, 55p.

Gundimeda, H. and Kathuria, V. 2004. Can Markets value water scarcity and quality: an analysis using hedonic approach, Project report submitted to the South Asian Network for Economic Institutions, August 2004.

Gupta, P. 2004. Pesticide Exposure- Indian scene. *Toxicology*, 198 (1-3):83.

Hema, M. 2013. Economic valuation of mangrove ecosystems in Kerala. Ph.D thesis, Kerala Agricultural University, 196p.

Oglethorpe, D.R. and Miliadou, D. 2000. Economic valuation of the non-use attribute of a wetland: A case study for Lake Kerkini. *J. Environ. Plan. Manag.* 43: 755-767.

Pearce, D.W and Warford, J.W.1993.World Without End: Economics, Environment and Sustainable Development .Oxford University Press.

Stevens, T.H., Benin, S. and Larson, J.S. 1995. Public attitudes and values for wetland conservation in New England. *Wetlands* 15(3): 226-231.

Wattage, P. and Mardle, S. 2008. Total economic value of wetland conservation in Sri Lanka identifying use and non- use values. *Wetl. Ecol. Manag.* 16: 359-369.

Climate Change and Water Quality

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Introduction

Anthropogenic climate change has a significant role on physical and biological systems all over the globe. In the last century the global average surface temperature has risen by 0.74°C. A few degree change in temperature can attribute marked difference in global environment. The Sea Levels at that time were 4 to 6 M higher than the present. The sea level rise was 1.7 mm during the period 1870 to 1993. Whereas during the year 1993-2007 the average rise in sea level per year is 3.4 mm. Warming of the Oceans and melting of ice are expected to lead to continued sea– level rise of 18 to 79 cm in this century. Inter-governmental panel on climate change has estimated a sea level rise of 21 to 71 cm in the year 2070 due to thermal expansion of Oceans as well as melting of glacier (Sundaresan and Patel., 2011).

The major cause to climate change has been ascribed to the increased levels of GHGs present in the atmosphere beyond their natural levels. Increasing evidence over the past few decades indicate that significant changes in climate are taking place worldwide due to enhanced anthropogenic activities and indiscriminate use of fossil fuels, producing more and more GHGs (Joseph. et al., 2011). Since the late 19th century, the average global surface air temperature has increased by 0.74^0C ± 0.18^0C. The linear warming trend over the last 50 years is nearly twice that for the 100 years previous to that. The rate and duration of warming of the 20th century has been found to be greater than any other time during the last 1000 years (IPCC, 2007).

In India, for the period of 1901-2009 the annual mean temperature has risen by 0.56^0C. Annual mean temperature has been generally above normal (normal based on period, 1961-1990) since 1990. Warming trend over the globe of the order of 0.74^0C has been reported by IPCC (2007). Mean annual temperature shows significant positive (increasing) trend over most parts of the country except over parts of Rajasthan, Gujarat and Bihar, where significant negative (decreasing) trends were observed. Season wise, maximum rise in mean temperature was observed during the Post-monsoon season (0.77^{0}C) followed by winter season (0.70^{0}C), Pre-monsoon season (0.64^{0}C) and Monsoon season (0.33^{0}C) (Attri and Ajit Tyagi.2010).

Even though the temperature in Kerala does not go to extremes as in other States; there are still spatial and temporal variations in temperature. The annual average ambient temperature in Kerala is 27.5^{0}C. There is spatial variation in annual mean temperature ranging from 25.5 to 27.5^{0}C in the coastal belt, 27.5 to 29.5^{0}C in the central region and 17.5 to 21.5^{0}C in the hilly areas. The mean maximum temperature is about 33^{0}C during the hottest period (March–April) and 28.5^{0}C in July. In Kerala, the maximum temperature increase was 0.64° C and increase in minimum temperature was 0.23° C during the period of 49 years. Overall, increase in annual average temperature was 0.44°C

Water Resources

Floods and droughts are the main impacts of climate change on water availability. Climate warming observed over the past several decades is consistently associated with changes in a number of components of the hydrological cycle and hydrological systems such as: changing precipitation patterns, intensity and extremes; widespread melting of snow and ice; increasing atmospheric water vapour; increasing evaporation; and changes in soil moisture and runoff (IPCC, 2008). Warmer temperatures increase the rate of evaporation of water into the atmosphere, in effect increasing the atmosphere's capacity to "hold" water. Increased evaporation may dry out some areas and fall as excess precipitation on other areas. Changes in the amount of rain falling during storms provide evidence that the water cycle is already changing. Over the past 50 years, the amount of rain falling during the most intense 1% of storms increased by almost 20%. Warming winter temperatures cause more precipitation to fall as rain rather than snow. Furthermore, rising temperatures cause snow to begin melting earlier in the year. This alters the timing of stream flow in rivers that have their sources in mountainous areas (EPA).

In the recent times, several studies show that climate change is likely to impact significantly upon the availability of freshwater resources in India. The main water resources of India consists of the precipitation on the Indian territory which is estimated to be around 4000 km^3/year, and trans-boundary flows which it receives in its rivers and aquifers from the upper riparian countries. Out of the total precipitation, including snowfall, the availability from surface water and replenishable groundwater is estimated as 1869 km^3. Due to various constraints of topography, uneven distribution of resources over space and time, it has been estimated that only about 1123 km^3 including 690 km^3 from surface water and 433 km^3 from groundwater resources can be put to beneficial use. Extreme conditions exist in the country – there are floods followed by droughts. Due to excess rainwater, floods occur in certain parts. It has been estimated by Rashtriya Barh Ayog (RBA) that 40 m ha of area is flood-prone and this constitutes 12% of the total geographical area of the country. Droughts are also experienced due to deficient rainfall. It has been found that 51 m ha area is drought prone and this constitutes 16% of the total geographical area (MoWR, 2008).

Kerala experiences a humid tropical climate. The average annual rainfall of the State is 3060mm, of which about 70% is received during the southwest monsoon, 15% during the northeast monsoon and the remaining 15% during winter and summer seasons. Though Kerala is endowed with plenty of rainfall (2.57 times the national average), the State often experiences scarcity of water in the midst of abundance (Joseph et al., 2011).

The hydrologists are yet to translate what climate change means for the water availability, its distribution in time and space, and changes in demand. An increase in mean temperatures would increase the energy flux for evapotranspiration. The increased potential evapotranspiration in the forests could trigger major changes in the environment and it would result in an increased crop water requirement in the farms. The changes in seasonal temperatures could change the crop seasons. In the post-climate change scenario, systems that are more resilient will fare better than systems that are less resilient. Engineering infrastructure that enables the water managers to store and transfer water with greater certainty can reduce the impact of uncertainty

Impact of Climate change on Water Quality

Potential impacts of climate change on water availability have received much attention, but relatively fewer studies focus on changes in water quality. Climate change could have significant impacts on water quality. Water quality is important for ecosystems, human health and sanitation, agriculture and other purposes. Increases in temperature, changes in precipitation, sea level rise and extreme events could diminish water quality in many regions.

Temperature is a main factor affecting almost all physicochemical equilibriums and biological reactions. It is well known that all physicochemical "constants" vary with temperature, and frequently increasing endothermic reactions. Consequently, several transformations or effects related to water will be favoured by water temperature increase such as dissolution, solubilisation, complexation, degradation, evaporation, etc. This phenomenon globally leads not only to the concentration increase of dissolved substances in water but also to the concentration decrease of dissolved gases. This last point is very important with respect to dissolved oxygen in water. In fact, its saturation concentration decreases of almost 10% with a 3 °C increase (10 mg/L at 15 °C). Remind that, whatever the IPCC scenario, the average global air temperature should increase between 1.8 and 4.0 °C during the 21stcentury (Delpla et al., 2009). Climate change results in deterioration of water quality in terms of reduction in DO concentration, high levels of which are needed to sustain aquatic life. These adverse effects will worsen with changes in river flow and increased pollutants (Rehana, S and Mujumdar, 2011).

A climate-related warming of lakes and rivers has been observed over recent decades. As a result, freshwater ecosystems have shown changes in species composition, organism abundance, productivity (including earlier fish migration). Also due to warming, many lakes have exhibited prolonged stratification with decreases in surface layer nutrient concentration, prolonged depletion of oxygen in deeper layers and an increased release of phosphorus from the sediments (IPCC. 2008).

A warmer climate will create indirect impacts on water bodies like an increase nutrients load in surface and groundwater. Indeed, higher temperatures will increase mineralization and releases of nitrogen, phosphorus and carbon from soil organic matter. Moreover, an increase in runoff and erosion due to greater precipitations intensity should result in an increase in pollutants transport, especially after a drought period. Higher ammonium concentrations could be observed in rivers with a reducing dilution capacity caused by droughts. Furthermore, release of phosphorus from bottom sediments (Delpla, et al., 2009).

Increased temperature also affects in-lake chemical processes. There have been decreases in dissolved inorganic nitrogen from greater phytoplankton productivity and greater in-lake alkalinity generation and increases in pH in soft-water lakes. Decreased solubility from higher temperatures significantly contributed to 11–13% of the decrease in aluminum concentration, whereas lakes that had warmer water temperatures had increased mercury methylation and higher mercury levels in fish. A decrease in silicon content related to regional warming has been documented in Lake Baikal, Russia. River water-quality data from 27 rivers in Japan also suggest deterioration in both chemical and biological features due to increases in air temperature (IPCC 2008).

Climate change affects groundwater recharge rates (i.e., the renewable groundwater resources) and depths of groundwater tables. Groundwater aquifers are recharged mainly by precipitation or through interaction with surface water bodies. The direct influence of climate change on precipitation and surface water ultimately affects groundwater systems. However, knowledge of current recharge and levels in both developed and developing countries is poor; and there has been very little research on the future impact of climate change on groundwater, or groundwater–surface water interactions. In coastal areas, rising sea levels may have negative effects on storm-water drainage and sewage disposal and increase the potential for the intrusion of saline water into fresh groundwater in coastal aquifers, thus adversely affecting groundwater resources. For two small and flat coral islands off the coast of India, the thickness of freshwater lenses was computed to decrease from 25 m to 10 m and from 36 m to 28 m, respectively, for a sea-level rise of only 0.1 m. In inland aquifers, a decrease in groundwater recharge can lead to saltwater intrusion from neighboring saline aquifers (IPCC, 2008).

In India, rising temperatures will also contribute to a rise in the snowline, reducing the capacity of these natural reservoirs, and increasing the risk of flash floods during the wet season. Increase in temperatures can lead to increased eutrophication in wetlands and fresh water supplies (CPCB, 2011).

The threats to water quality will also be contributed from untreated industrial effluents and municipal wastes from habitations, pollution from open defecation, and run-off from farms containing fertilizers and pesticides (Planning Commission, 2008).

Some of the likely impacts of climate change on rivers are summarized below: (Whitehead et al, 2008):

- Water quality will be affected by changes in flow regime.
- Enhanced growth of algal blooms in rivers, lakes and reservoirs could affect DO (dissolved oxygen) levels and water supply.
- Increased storm events, especially in summer, would lead to more frequent incidences of combined sewer overflows, discharging highly polluted waters into receiving water bodies.
- The most immediate reaction to climate change is expected to be an increase in river and lake water temperatures.
- More intense rainfall and flooding could result in increased suspended solids, sediment yields and associated contaminant metal fluxes.
- Nutrient loads are expected to increase.
- Potential impacts on urban water quality will be largely driven by changes in short duration rainfall intensity overwhelming drainage systems, as well as rising sea levels affecting combined sewerage outfalls.
- Floods and droughts will also modify water quality by direct effects of dilution or concentration of dissolved substances. Kerala Rivers are not having enough water to dilute the pollutants throughout the year.

A decline in water quality can result from the increase in runoff and precipitation- and while the water will carry higher levels of nutrients, it will also contain more pathogens and pollutants. These contaminants were originally stored in the groundwater reserves but the increase in precipitation will flush them out in the discharged water (IPCC 2007). Similarly, when drought conditions persist and groundwater reserves are depleted, the residual water that remains is often of inferior quality. This is a result of the leakage of saline or contaminated water from the land surface, the confining layers, or the adjacent water bodies that have highly concentrated quantities of contaminants. This occurs because decreased precipitation and runoff results in a concentration of pollution in the water, which leads to an increased load of microbes in waterways and drinking-water reservoirs (IPCC 2007).

Extreme meteorological events can easily disrupt water purification and storm water and sewage systems, as well as contaminate uncovered wells and surface water, leading to an increased risk of illness. These risks are even higher when a population lives in a low-lying area, where the land's hydrology causes draining tributaries to meet.

Increased carbon dioxide concentrations in sea water may cause oceans to grow more acidic and is likely to contribute to adverse ecosystem changes in the world's tropical oceans. This would have potentially dramatic implications for fisheries and the food supply in certain regions of the world. Major regional ecosystem stresses may result in mass population movement and conflict, with significant health effects. Some of these concerns are low-probability high-impact events and could have significant health impacts on a global scale (Climate and Health Program, 2010).

Climate change and quality of water resources of Kerala

Kerala is one of the most thickly populated states in the country and many people depend on homestead open wells for domestic purposes. The density of open wells is very high in Kerala, with an average of 200 wells/km^2. Even in the urban areas more than 50% of the population depends on wells.

In Kerala, groundwater occurs under phreatic, semi-confined and confined conditions. The groundwater resources are largely concentrated in the sedimentary aquifers of the coastal regions. The groundwater resources are tapped mainly for drinking and irrigation purposes. The groundwater potential of Kerala is very low as compared to that of many other States in the country.

As part of the project on Water Quality Monitoring Programme for the Kerala State carried out by Centre for Water Resources Development and Management (CWRDM), it indicated that the pollution load of rivers was found be high due to insufficient water for dilution during post monsoon and pre monsoon seasons.

Generally, the localised groundwater problems in Kerala are due to the presence of excess salinity, iron, fluoride, hardness and coliforms. Seawater intrusion, domestic sewage, mineralogical origin, agricultural and industrial activities are the major causes. Low pH, high iron content, high hardness, high TDS, and salinity are common quality problems in the coastal areas. Excess chloride concentration is reported from the coastal zone.

Kerala has the largest coverage of individual household latrines in India. Out of the 65.95 lakh households in the State 57.17 lakh (86 per cent) have sanitary latrine facilities. Though the sanitation coverage is relatively high, there is general lack of awareness on the potential health risks from unhygienic latrine, (which is estimated to account for over 60 per cent of the total household latrines) when located close to unprotected open dug wells.

Safe drinking water and better sanitation are essential requisites for healthy and sustainable life for human beings. In spite of many initiatives to provide protected water supply, the rural section depend on open dug wells or other ground resources. Preliminary investigations suggested that single pit/double pit latrines and even sometimes unscientifically constructed septic tanks are not safe enough to prevent contamination of open well. CWRDM had carried out a study (CWRDM 2006) to examine the bacterial contamination in drinking water wells in rural Kerala by selecting 936 sites distributed in the 13 Agro ecological zones across the state. Wide variations in the level of faecal coliforms and faecal streptococci were observed both spatially and temporarily. During the period of observation (2005) faecal coliforms ranged from 1 to 240000 MPN/100ml and faecal streptococci ranged from 1 to 1100 MPN /100 ml of the water sample. High levels of contamination of >10000 MPN was recorded for both Faecal Coliforms (FC) and Faecal Streptococci (FS) to the tune of 3.9 and 2.6% of the samples analysed respectively. High values of the order MPN> 1000 were observed for over 19% and 17% of the samples for FC and FS respectively. Overall results indicated that around 82 % of the samples showed E. coli positive. The presence of E. coli indicates recent contamination. Seasonal trends indicated that 85.9%, 82.6% and 77% of the observation wells revealed the presence of E. coli during monsoon, pre monsoon and post monsoon seasons respectively. Wells with parapet walls (no platform) have a highly significant reduction in contamination compared to open wells. Distance between wells and latrines are highly significant and reduction in contamination level increases with distance in the case of FC. The wells near the double pit latrines and septic tanks exhibited lower levels of FS than wells near single pit latrines. In case of both FC and FS, turbidity level and pH appear to increase the levels of FS contamination. Sanitary survey results indicated that only inadequate drainage at the site in which water stagnates nears a well contributes significantly. Higher population density in Grama Panchayaths increases the FC level.

In many parts of Kerala, especially in laterite and areas near the paddy fields, during summer period water quality problems due to excess iron is reported. The soluble ferrous iron is oxidized on contact with air to form insoluble ferric iron which is seen as brown or reddish precipitate. A scum from iron bacteria is also seen on the surface of the contaminated well as an oily layer.
The lower reaches of the rivers in Kerala face the water quality problems. The rivers come under the classification of "B" or "C" due to faecal contamination. The organic load to the Rivers is comparatively less. The upstream part of the Rivers has fair water quality, which means that they are occasionally threatened. However, stations in the downstream showed marginal water quality, which indicate that they are frequently threatened. The pilgrimage stations near the rivers indicate pollution due to organic contamination. The short, fast flowing, monsoon-fed rivers of Kerala often encounter salinity intrusion into their lower reaches during the summer months. When the fresh water flow reduces, two major problems are encountered in these water bodies:

i. Salinity propagates more into the interior of the river.
ii. The flushing of the system becomes less effective.

Both these aspects have an impact on drinking water supply in addition to other schemes in the downstream reaches.
Reclamation is one of the major problems faced by the backwaters of Kerala. Indiscriminate discharge of municipal waste, agrochemicals, oil from ships & fishing vessels are contributing to the pollution of the backwaters. Pollution due to industrial wastes is considerable in some backwaters. Coir retting processes result in release of polyphenols along with hydrogen sulphide creating anoxic conditions in many of the backwaters.

Pollution at Pamba-Thriveni, the confluence of the streams of Kakki and Kochupamba is noticed during the Sabarimala pilgrimage season in October-January every year. The bacteriological pollution noticed in the river is reported and by applying Qual 2E Model, the assimilative capacity of the river at various discharges was simulated. To bring down the observed coliform count (46000 MPN/100 ml) to the maximum permitted level of 500/100 ml (as per the Central Pollution Control Board criteria) the discharge in the main stream has to be increased from an observed value of about 4 m^3/sec to the order of about 28-35 m^3/sec (Harikumar and Madhavan 2006). If this may not be practically possible, the assimilative capacity of the river should be enhanced by implementing appropriate sewage treatment methods and sanitation facilities especially in the pollution prone areas of Pamba River.

Conclusion

The impacts of meteorological changes on water quality issues can be divided into different categories such as: surveillance and monitoring and infrastructure and development (Jennifer Fricas and Tyler Martz, 2003). Among surveillance recommendations, the areas which have to be focused which policymakers and program planners need to address are: climate-related surveillance, water quality monitoring and disease surveillance. Ideally, these three surveillance and monitoring activities would be planned and conducted in a multi-sectoral fashion, gathering input from each of the relevant and responsible sectors. The monitoring has to be undertaken by multiple disciplines, with the aim of detecting various large climate events (and smaller physical changes) that could indicate future problems. At the micro level, surveillance efforts should monitor for increased temperatures as well as changes in sea water salinity, nutrient concentrations and plankton blooms.

Policymakers and program planners must recognise that improved water and sanitation access cannot completely mitigate the impact associated with water contamination, especially in the event of climate changes. Policymakers and program developers should address sustainable development, conservation and construction of durable water systems and should allow community input into water system planning.

Water and sanitation systems need to be strategically designed and placed to prevent or reduce contamination or destruction during climatologic events. While improving access to hardware (wells, latrines and sewage systems) is essential, the long-term success of these improvements depends on community participation in the decision making processes as well as continued infrastructure and program maintenance backed by political commitment. The potential impacts created by climate change need to be clearly defined prior to the development of systems to help ensure sustainability.

Some of the recommendations for managing the impacts of climate change on water quality are suggested below:

River basins need immediate attention in the following areas:

- Proper reservoir operation
- Ensure environmental flow
- Water safety plan - vulnerable Areas
- Technological options - Liquid/Solid Waste treatment
- Scientific operation of barrages/bunds
- Regulation of tourism
- Urbanisation-planning
- Carrying Capacity based Planning

Institutional mechanism shall be developed in the following areas:

- Adequate infrastructure for water quality testing
- Address water quality problems
- Epidemiological research
- Regulatory approaches - land use
- Scientifically-based assessment of vulnerability of water supply addressing key factors such as hydrogeology, land use patterns and well characteristics is urgently needed
- Epidemiological research on water quality/waterborne diseases
- Develop necessary public participation
- Information, education, communication development and capacity building in the area of water quality management and climate change
- Integrate activities of various water resources departments
- Strengthen research and development activities in water sector

References

Attri, S. D., and AjitTyagi., 2010.Climate Profile of India. India Meteorological Department

Central Pollution Control Board (CPCB). 2011. Status of Water Quality in India- 2010, Central Pollution Control Board, Ministry of Environment & Forests, New Delhi. Series: MINARS/ /2010-11

Climate and Health Program (Nov 2010), Center for Disease Control and Prevention; http://www.cdc.gov/climateandhealth/effects/default.htm

Confalonieri, U., Menne B., Akhtar, R., Ebi, K.L., Hauengue, M., Kovats, R.S., Revich, B. and Woodward, A. 2007. Human health. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, 391-431

CWRDM (2006) Study to assess the groundwater contamination due to onsite sanitation, final report submitted to Govt of Kerala

Delpla, I., Jung, A. V., Baures, E., Clement, M., and Thomas. O. 2009. Impacts of climate change on surface water quality in relation, Environment International 35 (2009) 1225–1233

EPA.Climate Impacts on Water Resources. United States Environmental Protection Agency http://www.epa.gov/climatechange/impacts-adaptation/water.html

Harikumar P S and Madhavan K, Estimation of Water Pollution and Assimilative Capacity of River Pamba, Kerala, Pollution Research 25(4), 2006. pp 707-710.

http://planningcommission.nic.in/plans/planrel/fiveyr/11th/11_v3/11v3_ch2.pdf

Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2001: Synthesis Report—Summary for Policymakers*, accessed online at www.ipcc.ch/pub/un/syreng/spm.pdf, on July , 30,2013

IPCC ,2007. Climate change 2007: The physical science Basis. Summary for Policy Makers Group I. Fourth Assessment Report of the Intergovernmental Panel on Climate Change , IPCC Secretariat, Geneva, Switzerland.

IPCC. 2008. Climate Change and Water, IPCC technical Paper VI, Intergovernmental Panel on Climate Change , IPCC Secretariat, Geneva, Switzerland.

Jennifer Fricas and Tyler Martz, The Impact of Climate Change on Water, Sanitation, and Diarrheal Diseases in Latin America and the Caribbean; http://www.prb.org/Publications/Articles/2007/ClimateChangeinLatinAmerica.aspx
Retrieved on July 30 2013

Joan B. Rose., "Climate Variability and Change in the United States: Potential Impacts on Water- and Foodborne Diseases Caused by Microbiologic Agents," *Environmental Health Perspectives* 109, suppl. 2 (2001): 211-21.

Joseph E. J., Anitha A. B., Jayakumar. P., Susanth C. M and Jayakumar K. V. 2011.Climate Change and Sustainable Water Resources Management in Kerala. Centre for Water Resources Development and Management (CWRDM), Kozhikode.

Ministry of Water Resources (MoWR), 2008. Comprehensive Mission Document Comprehensive Mission Document of National Water Mission under National Action Plan on Climate Change, Ministry of Water Resources, Government of India, New Delhi, Volume II

Rehana, S and Mujumdar P.P. 2011. River water quality response under hypothetical climate change scenarios in Tunga-Bhadrariver, India. Hydrological Processes.Wiley Online Library. DOI: 10.1002/hyp.8057

State of Environment Report - Kerala Vol – IV Environmental Indicators (Forest and Bio-diversity, Water Resources & Coastal and Marine Environment), Kerala State Council for Science, Technology and Environment 2007

Sundaresan, J and Lavkush Kumar Patel., 2011. Climate change impact – A novel, initiative for Kerala Indian Journal of Geo-Marine Sciences Vol. 40(4), August 2011, pp. 483-486

Whitehead, P., Butterfield, D. and Dr Wade, Potential impacts of climate change on river water quality Science Report – SC070043/SR1, Environment Agency, Environment Agency, UK , 2008

Air Quality- Pollution –Threats & Management

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Air pollution has been aggravated by urbanisation and industrial activities. The 'WHO' has defined 'air pollutants' as substances put into air by activities of mankind in such concentration which are sufficient to cause harmful effect to human health, vegetations, property or to interfere with the enjoyment of property.

Air pollutants change the composition of air. The high density of population in urban areas, increasing traffic, growing city, higher level of energy consumption, unplanned industries and economic development activities lead to the increase of air pollution in urban areas.

The burning of fuels for industrial activities and transportation lead to a plethora of combustion products. The major pollutants of concern are particulate matter, Oxides of Sulphur & Nitrogen, Ozone, hydrocarbons, Oxides of Carbon etc. Pollutants are also formed in the atmosphere by the reaction of primary pollutants in the presence of sunlight which are known as photochemical reaction products. These are more dangerous than the original pollutants and may affect the biological system at extremely low concentration.
Meteorological parameters such as wind velocity, direction, humidity, turbulence, etc. play a vital role in the transportation of pollutants.

The important environmental legislations in force in India for the control of air pollution are the Air (Prevention & Control of Pollution) Act, 1981 and The Environment (Protection) Act, 1986. Emission standards have been fixed to facilitate air pollution control. Concentration based standards with respect to specific industrial units have been notified in the Environment Protection rules till date. National Ambient Air standards have been notified by Ministry of

Environment & Forest. The permissible limits for the pollutants, particulate matter, Nitrogen dioxides, Sulphur dioxides, Carbon monoxide, Ammonia, Lead, Ozone, Benzene, Arsenic and Nickel are fixed (Refer annexure).

The effects of major pollutants on Environment and its control measures are tabled below

World's Primary Air Pollutants – Their Sources , Effects on Environment and Control Measures			
Pollutant	Sources	Known or Suspected effect	Control Measures
Carbon monoxide (CO)	Fuel-rich and stoichiometric combustion mainly from motor vehicles	Reduces the oxygen carrying capacity of the blood by combining with haemoglobin, thus deprives tissues of O_2	Improved engine design for ensuring complete combustion of fuel
Nitrogen oxides (NO) and (NO_2)	Lightning and bacterial activity in soils. High-temperature combustion mainly from motor vehicles, thermal power plants	Cause eye, throat and lung irritation. Primary pollutants that produce photochemical smog and acid rain, destroy ozone at the stratosphere. Deteriorate fabrics and fade dyes. Corrode metals (due to nitrate salts formed from nitrogen oxides). Reduce visibility. Seriously injure vegetation at certain concentrations. Effects include: • Bleaching or killing plant tissue. • Causing leaves to fall. • Reducing growth rate	Selective Catalytic reduction (SCR technology) Selective non Catalytic reduction (SCNR technology) Combustion control
Particulates	Forest fires, wind erosion and volcanic	Breathing difficulties, Lung cancer	Introduction of dust collector such as

	eruptions. Coal, waste and fossil burning, industries for the manufacture of construction materials such as granite, aggregates Cement, bricks etc. Mining operation, tyre manufacturing units.		cyclonic & bag filter equipments such as Electrostatic precipitator, scrubber in the emission line
Sulphur dioxide (SO_2)	Volcanic eruptions and decay. Coal Combustion, ore smelters, petroleum refineries and diesel engines, Sulphuric acid plants	Causes eye, throat and lung irritation. Primary pollutants that produce acid rain. Sulfur dioxide easily injures many plant species and varieties, both native and cultivated. Increase in sulfur dioxide concentrations accelerates the corrosion of metals, probably through the formation of acids.	Use of low sulphur content fuel for combustion, Alkaline Scrubbing
Ozone (O_3)	Lightning and photochemical reactions in the troposphere. Product of photo chemical reactions in photochemical smog	Causes eye, throat and lung irritation, impairs lung function	Reduction of NOX and hydrocarbon in the emissions
Carbon dioxide (CO_2)	Animal respiration, decay and release from oceans. Fossil-fuel and wood combustion	Partly responsible for the atmospheric greenhouse effect	Planting of trees, reduction of combustion activities, absorption

volatile organic compounds	Biological Process. Incomplete combustion and volatiles, paints adhesives, air fresheners, major industries, refinery, petrochemical waste, vehicular exhaust	Primary pollutants that produce photochemical smog, eye and nose irritation, nausea, dizziness, Benzene, Toluene, Xylene in these group are harmful toxic pollutants, carcinogenic in human body	Recovery of volatile emissions
Hydrogen Sulphide H_2S	Paper mill, tanneries, petroleum refineries, sewage treatment plant, bio mass putrefaction	Eye irritation, cough, nausea and breathing difficulty	Amine absorption, partial combustion to produce sulphur filtration through impregnated activated carbon
Nickel	Municipal incineration plants, burning of fuel oil, nickel, metal, refining steel plants, coal combustion	Human carcinogen	Use of low nickel fuel oil, particulate matter control for the flue gas
Lead	Lead acid battery, lead smelters, paints	Affects central nervous system, behaviour and learning problem in chlorine	Recovery of metal from the flue gas of smelters through dust collectors
Arsenic	Coal & oil combustion in electric power plants & industrial plants, metallurgical operations, kiln operations in cement plants, refine incineration cotton ginning process.	Contamination of soil and uptake by food chain	Particulate matter control, absorption
Ammonia	Fertilizer plants, putrefaction of nitrogenous matter.	Exposure to high concentration, cancer, lung damage & diseases	absorption

Conclusion

The government has taken a number of measures such as enforcement of environmental legislation, implementation of special action plan in problematic areas, promotion of environmental awareness, enforcement of time bound implementation of environment friendly technologies, targeted efforts for the banning of use of severe toxic components etc. Despite all the above, pollution problems still exist.

By the regular ambient and source air quality monitoring, along with the strict enforcement of environment legislation and continued effective mass awareness programmes, the environmental problems are expected to be under control.

Biodiversity – Status and Threats in the Light of Climate Change

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Biodiversity – Status

Biological diversity or biodiversity refers to the variety and variability of life on earth and includes the variability among living organisms and their habitats, diversity within species between species and within ecosystems. There is an estimated 8.7 million species on Earth out of which 2.2 million live in the ocean. Only 1.75 million species has been formally documented and more than 91% of marine species are yet to be discovered. The areas earmarked as Biodiversity Hotspots cover only 2.3% of the Earth's land surface but over 50% of the world's plant species and 42% of all terrestrial vertebrate species are endemic to the 34 biodiversity hotspots.

Biodiversity of India and Kerala

India ranks among the top ten species-rich nations with over 91,200 species of animals and 45,500 species of plants in its ten bio-geographic regions and also shows high endemism. India is recognized as one of the eight Vavilovian centres of origin and diversity of crop plants, which are still evolving under natural conditions. The mountain ecosystems of India are largely described under two global hot-spots, viz., the Eastern Himalayas, and the Western Ghats. The extent of species endemism in vascular plants alone ranges from 32 to 40% in the mountain ecosystems. India presently has 26 sites designated as Wetlands of International Importance, by Ramsar convention, with a surface area of 689,131 hectares. Out of the 39 serial sites listed in Western Ghats world heritage system, 19 are located in Kerala. Ashtamudi Wetland, Vembanad-Kol Wetland, Sasthamkotta Lake located in Kerala has been recognised as Ramsar sites for the conservation and wise use of wetlands. Kuttanad's below sea level farming system has been identified as site for FAO's Globally Important Agricultural Heritage Systems (GIAHS).

Climate change – Causes, Effects and Projections

Environment and Earth's Climate is undergoing natural changes over the centuries with the most profound changes occurring during the past few decades. In the atmosphere, greenhouses gases as water vapour, carbon dioxide, ozone and methane trap heat which remains in the atmosphere for more than 100 years progressively warming the planet. The natural levels of these gases are being supplemented by human interference and developmental activities such as the burning of fossil fuels, farming activities and land-use changes. According to the Intergovernmental Panel on Climate Change (IPCC) Working Group I (WGI) the average global temperature increased by about 0.76°C and global mean sea level rose by 12 to 22 cm during the last century. The global warming due to greenhouse gas is triggering and further accelerating the amplitude of climate variability and rate of climate change.

Drivers of Biodiversity loss

The Millennium Ecosystem Assessment reports that climate change is likely to become the dominant direct driver of biodiversity loss by the end of the century. Climate change is already forcing flora and fauna to adapt either through shifting habitat, changing life cycles or the development of new physical traits.

Influence of Climate change on Biodiversity in India, Kerala

The impact of Climate change is being felt in India with melting of the Himalayan glaciers and gradual disappearance of moist savannah forests. About 75% of India forests are expected to change in nature by the end of the century. Higher elevation >1800m of Western Ghats feature shola forests and grassland which are highly sensitive to Climate change. They are the only habitats of the Nilgiri tahr which will be greatly affected by Climate change. Warmer temperature could facilitate the spread of invasive woody plants. Birds that prefer warm or hot climates are increasingly migrating to Kerala. Birds from climatic zones of Siberia and North India as common Stonechat, Bluethroat, wheatear, Buntings are increasingly spotted in Kerala. Peacocks which prefer dry hilly areas are now spotted in Kovalam and Kollam. Delayed blooming of Kanikonna is another indicator of climate change. The species most at risk from climate change are amphibians and reptiles.

Effect of Climate change on Species extinction

Extinction is the gravest aspect of the biodiversity crisis, an irreversible and permanent loss. While extinction is a natural process, human impacts have elevated the rate of extinction by a much higher rate. It is èstimated that 10-15% of the world's species will be committed to extinction over next 30 years. About two-thirds of Central and South America's 110 harlequin frog species are believed to have vanished during the 1980s and 1990s. The primary culprit is the pathogenic chytrid fungus Batrachochytrium dendrobatidis, which has been favoured by global warming. Golden Toad Bufo periglenes once abundant in the rainforests of Costa Rica is not seen since 1989.

Effect of Climate change on Avian fauna

Birds suffer from climate change effects and bird extinction rates could be as high as 38% in Europe and 72% in north-eastern Australia, if global warming exceeds by 2 ° C. Migratory, mountain, island, wetland, Arctic, Antarctic and seabirds are highly vulnerable to climate change. Life cycles of birds are tied to seasonal events such as flowering, seeds, insect emergence, etc. Many bird species now arrive in spring breeding grounds earlier and lay eggs earlier, in response to warming. These effects are expected to disrupt the structure and functioning of the world's ecosystems. Birds may come into contact with different prey species, predators, parasites and competitors.

Climate change and Animals

Climate fluctuations in North America reduce plankton populations, the main source of food of the North Atlantic right whale. Only about 300 individuals remain at present. Warmer temperatures in the Pacific regions could reduce the number of male sea turtle offspring as the sex of sea turtle hatchlings is dependent on temperature, with warmer temperatures increasing the number of female sea turtles. Asia's only ape – the orang-utan – is being threatened by a range of pressures including climate change, putting the animal at risk of extinction within a few decades. Climate change is affecting home range, abundance and breeding cycles of many frog species. Pikas small mammals with short, rounded ears and an invisible 'buried' tail that live in higher elevations are especially vulnerable to climate change as their habitat is restricted to small, disconnected 'islands' in numerous mountain ranges. Penguins are at risk as the

Antarctic Peninsula is warming faster than anywhere else in the Southern Hemisphere. Arctic sea ice is melting at a rate of 9% per decade with far reaching consequences to the polar bear which could disappear in the wild.

Climate change and Plants

Plant function is inextricably linked to climate and atmospheric carbon dioxide concentration. Bluebell Hyacinthoides non-scripta is one of the many plants affected by warmer springs in Britain. Aloe dichotoma, Quiver tree found in South Africa has begun to respond to climate-induced stress indicating that even biodiversity in desert ecosystems may be under threat from climate change. Platathera leucophaea a North American threatened orchid is extremely vulnerable to drought.

Climate change and Humans

Climate change is likely to increase the frequency and strength of extreme events (such as floods, droughts and storms) that threaten human health. A warmer climate is expected to both increase the risk of heat-related illnesses and air quality. Climate changes may allow spread of vector-borne diseases. Lyme disease (carried by ticks) is spreading north into parts of Canada that used to be too cold for the ticks. Dengue is spreading more rapidly in Bolivia as high rainfall allows the mosquito population to grow. Malaria may expand into new regions where temperatures become warm.

Effect of climate change on Ecosystems

The changing environmental attributes affect the species spectrum and the ecosystem adversely. Forests are threatened by the impacts of climate change, but also have the potential to mitigate climate through carbon sequestration. Climate change will alter the frequency and intensity of forest disturbances, such as wildfires, storms, insect outbreaks and the occurrence of invasive species. The productivity of forests could be affected by changes in temperature, precipitation and the amount of carbon dioxide in the air.

Mountain ecosystem covers about 27% of the earth's surface. The conservation of mountain biodiversity is a key option for the adaptation to climate change. Over 50% of the world's population is directly dependent on freshwater from the mountains. The shrinking of glaciers modifies the water-holding capacities of mountains, affecting the quantity of freshwater available. Many millions of people are projected to be flooded due to sea-level rise by the 2080s. Sea level rise also leads to coastal erosion and eliminate wetlands. The ocean has already absorbed up to 93% of the heat generated by greenhouse gases. Warmer and more acidic oceans are likely to disrupt coastal and marine ecosystems. The rising concentration of CO2 in the atmosphere has increased the absorption of CO2 in the ocean making the oceans more acidic which will affect plankton, mollusks, and other shellfish. Coral reefs, the "tropical rainforests of the ocean cover 0.2% of the world's sea floor and provides shelter to about 25% of marine species. Higher sea surface temperatures and ocean acidification would increase the risks of coral bleaching events that can lead to loss of critical habitat. Corals are vulnerable to thermal stress and have low adaptive capacity. It becomes difficult for them to create and maintain the skeletal structures needed for their support and protection. Australia's Great Barrier Reef could lose up to 95% of its living coral by 2050 due to changes in ocean temperature and chemistry.

The main threats to island ecosystems are the rise in sea level and the increase in the frequency of storms. Island ecosystem provides protection against extreme climatic events, provide habitat for marine animals and reef fish. Island ecosystems are especially vulnerable to climate change because island species populations tend to be small, localized, and highly specialized and thus can easily be driven to extinction.

Biodiversity of inland waters is an important source of food, income and livelihood, maintenance of hydrological balance, retention of nutrients and sediments and provision of habitats for various flora and fauna. Wetlands are the world's primary carbon sequestration mechanism. Inland water ecosystems are vulnerable to climate change because freshwater species are experiencing declines in biodiversity far greater than those in most terrestrial ecosystem.

Climate Change Mitigation

Mitigation refers to efforts to reduce or prevent emission of greenhouse gases. Protecting natural carbon sinks like forests and oceans, or creating new sinks through silviculture or green agriculture are also elements of mitigation. **Adaptation** is the adjustments that society or ecosystems make to limit negative effects of climate change. Adaptation options include the establishment of additional protected areas, mountain watershed management and the establishment of migration corridors, both horizontal and vertical and planting drought resistant crops.

Role of Biodiversity in Mitigation and Adaptation

Ecosystem-based adaptation, which integrates the use of biodiversity and ecosystem services into an overall adaptation strategy, can contribute to the conservation of biodiversity at the same time mitigate climate change. It includes the sustainable management, conservation and restoration of ecosystems to provide services that help people adapt to the adverse effects of climate change. Conserved habitats can remove carbon dioxide from the atmosphere, help to address climate change by storing carbon and reduce emissions from deforestation and forest degradation. Establishment of diverse agro-forestry systems can help to cope with increased risk from changed climatic conditions. Conservation of agro-biodiversity can provide specific gene pools for crop and livestock adaptation to climate change tolerant of heat, drought and water logging from heavy rainfall or flooding. Protection of migration corridors will allow species to migrate as the climate changes. Promote land and wildlife management practices that enhance ecosystem resilience. Plant trees and expand green spaces in urban settings to moderate heat increase. Redesign protected area network taking into consideration ecosystem changes due to climate change, coastal defence through the maintenance and/or restoration of mangroves and other coastal wetlands, coral reefs will facilitate reduction of coastal flooding and coastal erosion.

Conclusions

Habitats and ecosystems are likely to change character in response to Climate change. This may have profound influence on Flora and Fauna leading to higher rates of species extinction. Thus Climate change has been identified as the dominant direct driver of biodiversity loss by the end of the century and over a period of time will undermine our efforts for the conservation and sustainable use of biodiversity. Biodiversity also has an important role in climate change adaptation and mitigation. Healthy ecosystems can help mitigate climate change impacts, by Carbon sequestration, by absorbing excess flood water or buffering against coastal erosion or extreme weather events. Therefore ecosystems based approaches should be an integral part of the overall adaptation and mitigation efforts.

Forest Wealth of India: Changing Status and Approaches to Management

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Introduction

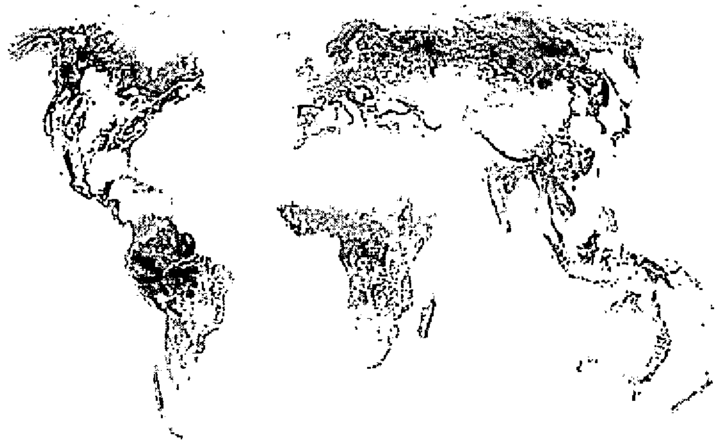
Forests are always in the news locally, nationally and globally; most often these relate to the human onslaught on forests – forest clearance for agriculture, reservoir projects, roads and other infrastructure projects, mining, poaching, logging, abrogation of the rights and displacement of forest dwelling communities, human-wildlife conflicts and so on - affecting societal well-being directly or indirectly. On the positive side is the enormous awareness about the multiple benefits from forests (*"money does grow on trees"*) and there are innumerable initiatives by local communities, individuals, governments and civil society organizations to conserve and manage forests sustainably.

Rapid social and economic changes in India would imply that the pressure on natural resources, including forests, will continue to increase in the coming decades. Conflicts on the use of forests are bound to intensify and the state of forests at any point of time will be decided by the historical changes as influenced by the divergent demands made by society. Added to this is the multitude of uncertainties on various fronts – economic, social and environmental. Climate change related problems and our responses will be one of the most important drivers affecting all land uses including forests.

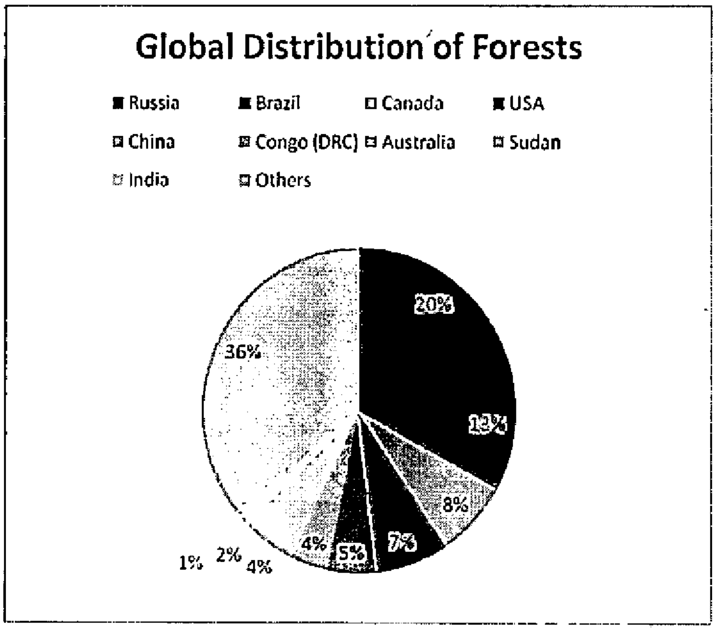
It is in this background that we should examine the forest situation in the country. We also need to consider where we stand in relation to the rest of the world. Section 1 outlines the overall situation with regard to forests in India and where India stands in the global context. Section 2 outlines the path forestry has pursued, assessing the key developments and the challenges that forestry has faced. Section 3 then looks into what is in store for us in the coming decades. The larger implications and options available to deal with the emerging challenges are outlined in Section 4.

FORESTS AND FORESTRY IN INDIA AND THE WORLD

Forest area changes - A global perspective:



Much of human history is characterised by deforestation, especially to accommodate the growing demand for food, fibre and energy. In fact this has been the story in almost all countries and often our ability to stop this is limited. All the more so due to the uneven distribution of forests and the significant differences as regards population and relative availability of forests. In 2010 the extent of forests in the world is estimated at about 4000 million ha or about 31 percent of the world's land area (FAO 2010). However, this is very unevenly distributed with 9 large countries accounting for about 64% of the world's forests.



Just considering the total extent of forests is meaningless and to understand the reality better we need to consider the demographic situation. After all the pressure on forests – leading to deforestation and degradation - is very much dependent on the human population. In this regard India is in an extremely precarious situation, having one of the lowest per capita forest area, just about 0.058 ha, less than one-tenth of the world per capita forest area (see Table 1 – FAO 2011).

Table 1: Per capita forest area

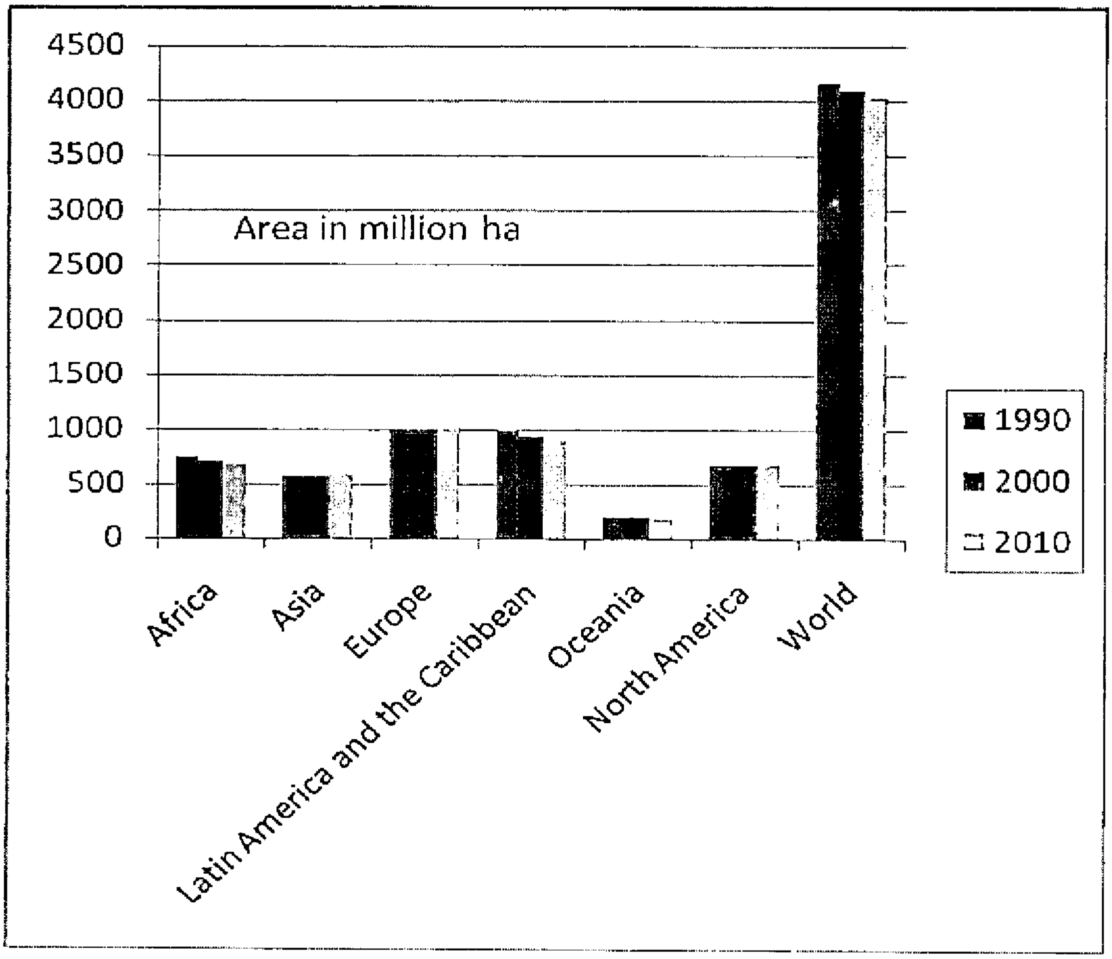
Country	Per capita forest area (in ha)
Australia	7.085
Brazil	2.706
Canada	9.325
China	0.154
Congo (DRC)	2.399
India	**0.058**
Indonesia	0.415
Russia	5.722
Japan	0.196
Sudan	1.692
USA	0.975
World	**0.597**

Obviously the pressure on Indian forests is very high in India and many developing countries and this is reflected in the rate of deforestation and degradation.

Forest area change

FAO undertakes periodic assessment of forest area changes and invariably the world has been losing forests, with most of deforestation taking place in the tropical belt. Even during the last decade (2000-2010) annual forest loss has been about 5.2 million hectares, while during 1990 – 2000 it was 8.3 million hectares (FAO 2010).

There is however considerable regional and country differences in the change in forest area, which is stable in Europe and North America while Africa, Latin America and Oceania have seen significant declines (see **Figure 3**). Inter-country differences in forest area change are particularly notable in the case of Asia. The overall improvement in Asia is primarily due to China's massive afforestation efforts, adding some 30 million ha during 2000-2010. Once this is excluded, the rest of Asia is in the red, with countries like Indonesia, Myanmar and Cambodia suffering from high levels of deforestation.



The forest area in India seems to be increasing at least as per the FAO statistics. As per the FAO assessment the forest area in India in 2010 was 68.4 million ha, while it was 63.9 million, 65.4 million, 67.7 million in 1990, 2000 and 2005 respectively. As per the assessment made by the Forest Survey of India, in 2011 the forest cover in India was 69.2 million ha, or about 21 percent of the land area. In addition, the tree cover outside forests is about 9.1 million ha, bringing the total as 78.3 million ha. In spite of all the technological developments, challenges persist in the assessment of forest cover and definitional differences add to the complexity of making comparisons between divergent sources of information.

Some of the conclusions emerging from long term monitoring of forests in the world are:

- *Forest area is stable or recovering in developed countries*

In Europe, North America and some of the developed countries in Asia (for example Japan, Republic of Korea) forest area is relatively stable. Primarily this is an outcome of the collective impact of demographic transition (stable population and urbanization) and economic factors, especially a significant reduction in the dependence on land as a source of income on account of the growth of industrial and services sectors.

- *Deforestation continues in most developing countries*

Deforestation remains a major problem in most developing countries in Africa, Asia, Latin America and the Caribbean and Oceania and the causes are both endogenous and exogenous.
The first wave of forest clearance stems from population growth and expansion of agriculture, in particular subsistence farming. Industrialisation has unleashed the second wave of deforestation on account of the increasing demand for minerals, energy, timber, food, etc. Currently India is in the second wave of deforestation as forests are cleared for extraction of coal and minerals and infrastructure development, which many in the government consider as essential to sustain economic growth. This has also led private appropriation of public resources.
In many countries deforestation is externally driven on account of the increasing global demand for food, timber, biofuels, industrial raw materials, cattle feed, etc. Tropical forests in countries with relatively low population densities (for example Brazil, Congo, Indonesia, Myanmar, Cambodia) are highly prone to this. "International land grabbing" has recently become a major issue in the context of increasing food prices and the escalating demand for biofuel (Schoneveld, 2011).

- *Forest degradation is a serious problem in India and many other countries*

Forest degradation which results in a significant decline in the quality of forests, including a decline in biological diversity and biomass stock, remains a major, but not easily measurable problem. Degradation is particularly severe when the per capita forest area is very low. In fact largely due to severe degradation, the extent of dense forests is only 12.1 percent, while open forests with a canopy cover account for almost 42 percent of the forests (see **Table 2** – Forest Survey of India, 2011).

Table 2: State of forest cover in India

Forest cover grouping	**Area in million ha**	**Percentage**
Very dense forest (with a canopy cover exceeding 70 percent)	8.35	12.1
Moderately dense forest (canopy cover varying from 40 to 70 percent)	32.07	46.3
Open forest (less than 40 percent canopy cover)	28.78	41.6
Total forest cover	**69.20**	**100.0**

Source: Forest Survey of India, 2011.

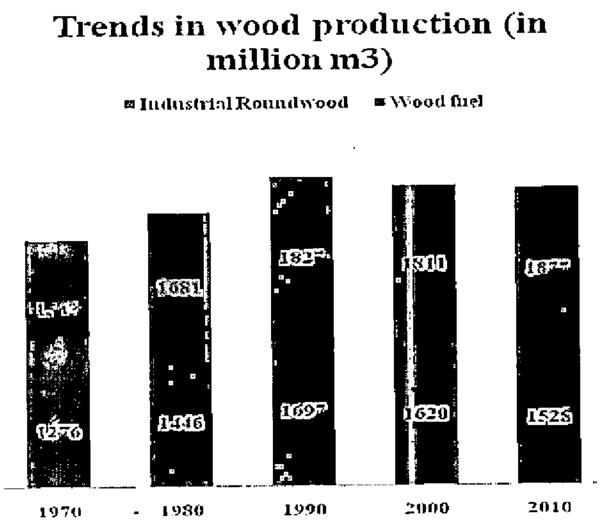
In the Indian situation, degradation is largely an outcome of the intensive grazing and the widespread collection of wood fuel, as also some of the misdirected afforestation/reforestation efforts, including the choice of unsuitable species and management failures. In fact the productivity of our forests, including plantations, is far below the site potential.

Tree growing: Shifting to the farms

While we continue to face the problems of deforestation and degradation of public forests, a positive development is the expansion of tree growing in farms. The country's farm tree resources got a boost on account of the social forestry programmes implemented in the 1970s and 1980s. As per the Forest Survey of India, trees outside forests (manly farm forests) accounted for about 1.5 billion m3, about one-third of the wood stock in the forests. Trees in farms can be grouped into two broad categories (FAO 2012).

- The first includes mixed tree crops found in home gardens, for example in Kerala. In most cases such tree growth is incidental, largely stemming from the less intensive use of land. Many tree species grow naturally when land use is less intensive. The major challenge facing traditional home gardens is their fragmentation and clearance, especially in the context of increasing population and urbanization.

- The second category of farm forestry consists of intensively managed tree crops in blocks, strips and lines in farms primarily aimed to produce wood. Some of the most successful examples of farm tree growing are in Punjab, Haryana, Gujarat and western Uttar Pradesh. In fact farm forestry has changed the landscape in the rural areas in these states and provides a substantial quantity of industrial wood.



Several factors have contributed to the expansion of such farm tree planting. Foremost is in increasing demand as reflected in wood price escalation. Declining profitability of agriculture, increasing cost of labour and absentee ownership have also encouraged farm tree planting. Declining wood supplies from forests have encouraged industries to source their wood supplies from farms and there are several examples of industry-farmer partnerships supporting farm tree planting.

Benefits from forests and trees

This brings us to one of the key issues, namely what for and how we are using our forests, in particular, whether it is sustainable or not. Forests provide three broad ranges of products and services, namely wood (wood fuel and timber), non-wood forest products and ecological services. Use of forests is largely determined by the social and economic conditions, in particular demography, economy, state of science and technology and, more important, the political environment which determines the policies and institutions. Some of the broad trends and issues in this regard are outlined below

Wood production – Some general trends

While wood remains the most important product from forests, at least during the last couple of decades the global production has remained stable at about 3400 million m3, with industrial round wood registering some decline. (see Figure 4-). While many challenges exist in obtaining reliable statistics, a number of conclusions can be drawn from available information:

- Wood production and consumption is unlikely to increase in most of the developed countries, while most of the increase in consumption is expected to take place in the rapidly growing economies. To some extent this has partly resulted in the relocation of forest industries to Asia, especially China, Indonesia and Vietnam.
- Technological changes are to some extent reducing the demand for wood raw material. The most notable in this is increased recycling, especially in the case of pulp and paper. Development of information technology is another major factor influencing the use of wood, a typical example being the significant reduction in the use of newsprint in the context of the growth of electronic media. Similarly the widespread use of high energy efficiency stoves could have a significant impact on the volume of wood fuel use.

But are we going to see this trend to persist in the long term? A major uncertainty relates to the impact of what may happen to the use of wood in the context of climate change policies. Policies and regulations that aim to reduce the use of energy intensive products (especially building materials like steel, cement, glass, etc.) could significantly enhance the use of wood as a more environment-friendly material. If this happens, we may see a trend very different from the past and demand for wood could significantly increase.

In this context it is important to consider the pattern of consumption of wood products in a country like India and what may happen if production of wood has to be increased significantly.

Table 3: Wood stock and consumption in selected countries

Country/ region	Wood stock per person/ in m3	Wood consumption/ person in m3	Timber m3/person	Firewood m3/ person	Consumption as a proportion of the growing stock (in %)
India	4.9	0.216	0.039	0.177	4.4
China	10.00	0.244	0.100	0.144	1.4
Japan	33.2	0.193	0.189	0.004	0.6
Asia	12.32	0.257	0.072	0.185	2.1
World	58.2	0.505	0.229	0.276	0.9

Compiled from FAO 2010 and FAO 2012

Table 3 provides a comparison of per capita wood stock in the country and the per capita consumption. Obviously, as in the case of forest area, India has one of the lowest stock of wood on a per capita basis (including taking into account the stock of wood outside the forests), just about 4.9 m3 per person. While India's per capita consumption is low in comparison with the global and Asian consumption, in relation to the wood stock the consumption is very high. Obviously sustaining even the current low level of consumption would require:

- A significant increase in the productivity and the stock of wood far from the current level; or
- Increase wood and wood product imports, which is already escalating considerably.

With liberalised imports as also overseas investments in plantations (as has been done by some industries), we seem to be neglecting the scope for enhancing productivity of our forests and plantations. In this regard we should be aware of the potential volatility of import dependence in addition to the outflow of foreign exchange contributing the current account deficit.

Plantations and productivity

This brings us to the issue of forest management, especially as regards forest plantations, which India has a very long history. Globally the extent of plantations is about 264 million ha and Asia as a whole tops the list with some 123 million ha and India having an area of over 10.2 million ha in 2010 (FAO 2011). However, our productivity is extremely low (see Table 4); if all the 10 million ha are managed to their full potential, there will be no need to import any wood.

Table 4: A comparison of wood production in selected countries

Country	Area of Plantations (in million ha)	Industrial Wood Production (in million m3)
India	10.0	23.2
South Africa	1.5	19.0
Chile	2.3	40.0
New Zealand	1.8	20.0

Table 4 gives an indication of the problem of very low productivity from forest plantations in India. Even if we assume that all the industrial round wood being produced in India is from plantations (and of course giving an allowance of unrecorded removals), the overall plantation productivity is extremely low. As demonstrated by the high levels of productivity reached in some of the countries like South Africa, Chile, Brazil, New Zealand, etc., India could easily meet all the industrial wood needs for a long time if productivity is increased to the full potential.

The current status of teak plantations in the country is illustrative of the problem of low productivity. Despite the very long history and the fact that India accounts for close to one-third of the teak plantations in the world, as far as productivity is concerned we are behind other major teak growing countries like Indonesia and Thailand, and certainly far behind some of the countries in Central and South America (FAO 2012). Interestingly many of these countries are exporting teak wood to India. According to a recent FAO study, India is the major destination of teak wood exports with eleven of the 14 reporting countries indicating that 70 to 100 percent of their teak wood exports to India. This is paradoxical that with all its long history and knowledge about teak, India is importing teak wood (most often small dimensioned grown on shorter rotations) from far away countries like Guatemala, Ivory Coast, Nigeria and closer ones like Myanmar.

Forests and non-wood products

The historical pre-occupation of colonial forest management with wood production has led to the grouping of all others as "minor forest products", although these play vital roles in the livelihood of local people, in particular forest dwelling tribal communities. Realising the social and economic significance of these, the term "minor" has been replaced by "non-wood" and this broad group includes a wide array of products, including food, medicines, gums, resins, essential oils and cultural artefacts. Many of these along with the underlying traditional knowledge have led a boom in the production of a wide variety of health and beauty products, pharmaceuticals and nutrition supplements.

Increasing commercial importance as also declining supplies from the wild have led to domestication and more organized cultivation of several non-wood forest products. Rubber, cardamom, pepper and several medicinal plants are such examples. Yet a large number of non-wood products continue to be collected from the wild with inadequate efforts to ensure sustainability and to enhance benefits to local communities. Those that have been commercialised have moved out of the forests to become horticultural/agricultural crops. And in at least a few instances globalisation has undennined competitiveness of traditional producers. A typical example of this is sandalwood, and already Australia is becoming a major supplier to the global perfume industry, undermining India's dominance.

Forests and ecological services

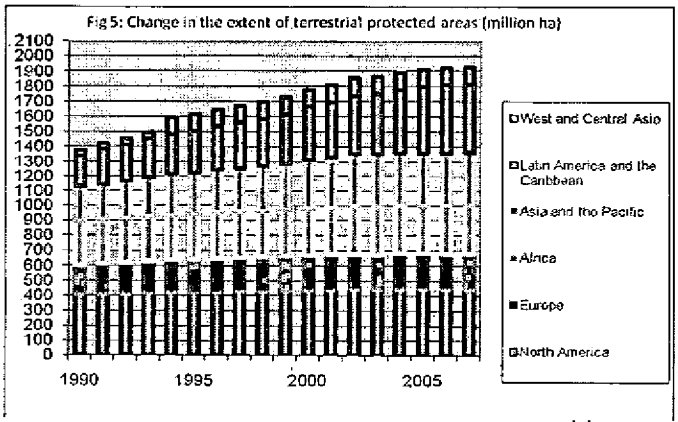
In a situation where forests were abundant ecological services provided by them were taken for granted. However as the extent of forests shrank and the knowledge about ecological services improved, forest policies have increasingly given priority to the provision of such services. Protection of watersheds, in particular to improve stability of stream flow, conservation of biological diversity, carbon sequestration, arresting land degradation and desertification and provision of amenity values have become major thrust areas of forest policies all over the world. Vast tracts of forests have been excluded from timber extraction with the objective of managing them for provision of ecological services. Yet the track record of improving the provision of ecological services is far from satisfactory.

Protected areas

An important strategy in this regard to set aside forests as protected areas. The extent of terrestrial protected areas in the world is estimated at about 1900 million ha or about 14.5 percent of the land area (UN, 2008). Between 1990 and 2000 there has been a rapid growth in the extent of protected areas, especially in the context of various national and international conservation efforts. However, this has tapered off since 2005 (see Fig 5). In the case of India the extent of protected area (IUCN category I to IV) is about 14.7 million ha or about 5.0 percent of the land area (or about 21.5 percent of the forest area). There are several challenges in managing protected areas as indicated below:

1. Although governments have been enthusiastic in constituting protected areas, the commitments get diluted as and when new opportunities for resource exploitation arise. Mining, oil exploration, development of infrastructure, expansion of cash crop cultivation all have affected the extent of protected areas. There is little willingness to forego short term income earning opportunities in

Fig 5: Change in the extent of terrestrial protected areas (million ha)



favour of protecting nature for long term societal welfare. This is all the more so when governments are wedded to the idea of achieving high growth rates of income and conservation is seen as antagonistic to such growth.

2. Organised poaching often supported by international criminal gangs is a major problem, especially for flagship species like tiger, rhino and elephant and many less known but commercially important flora and fauna.

3. Creation of protected areas has often triggered local conflicts when people are not involved in the process and are kept out of management of such areas. This has led to considerable local antagonism, especially in the context of increasing human- wildlife conflicts. Human-wildlife conflicts have intensified in the recent years and we are yet to develop and nurture a culture of co-existence. Increasingly there are efforts to involve local communities through various institutional arrangements like forest protection committees. Ultimately effectiveness of protected areas depends on how conservation efforts are integrated into all human activities and how society is able to determine trade off between conflicting objectives. Benefit sharing is a key for enhancing local participation.

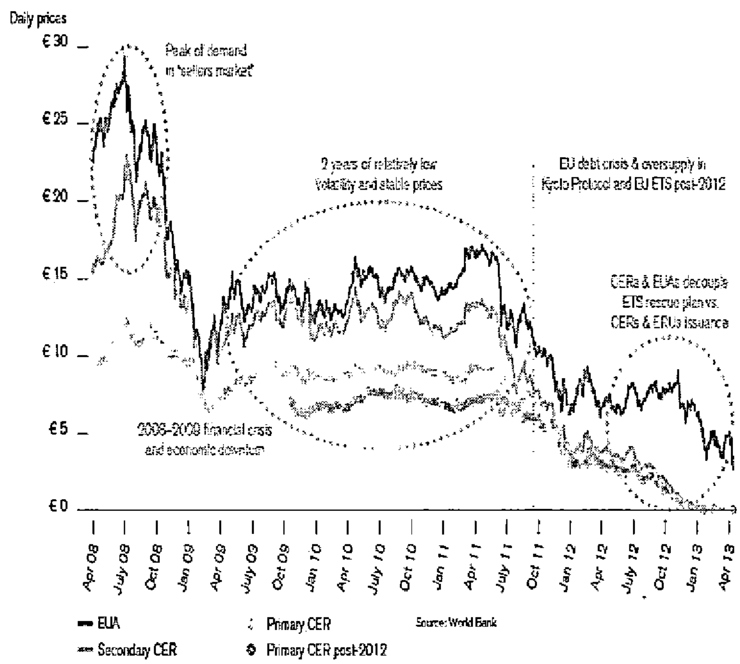
Protecting the "protected areas" remains a major challenge and in the absence of adequate resources and the absence of support from local communities, many are protected "in paper" only. "Conservation (and development) through exclusion" has been ineffective and increasingly there are efforts to involve local communities in managing protected areas. Success of such efforts has been at best mixed. Expanding illegal trade, often controlled by highly organized criminal gangs is affecting flagship species like tiger, rhino, elephant and several other unique plant and animal species.

Markets and ecological services

A major challenge as regards environmental conservation is the classical externality problem and the inability of markets to put a price tag on ecological services. Although there have been efforts to value ecological services such efforts are beset with a number of problems:

- The technical relationship especially as regards the flow of environmental benefits (watershed protection, biodiversity conservation, arresting desertification, etc.) are context specific, and values from one area cannot be used elsewhere. In many cases there is a tendency towards extrapolation that may not reflect the actual site specific values.

- Even when values are estimated, this may not be taken into account in the actual decision making process. In a market driven environment individuals and governments have a strong tendency to focus on immediate benefits; long term environmental issues are more likely to be overlooked in favour of short term gains.



Rewarding those who protect the environment through payment for environmental services has gained considerable attention. This is particularly so as regards watershed protection and carbon sequestration (FAO, 2012). Especially in the case of carbon sequestration, much hope was pinned on the cap and trade system and the development of carbon markets. However, failure to reach tangible outcomes as regards the post-Kyoto climate change framework to regulate emissions has affected the development of carbon markets. Further the global economic crisis since 2008 has affected the willingness and ability to address environmental problems like climate change and carbon prices have virtually crashed during the last one year (see Fig 6 – Source World Bank 2013).

One of the much publicised initiative in this regard is Reduced Emission from Deforestation and Forest Degradation (REDD) agreed during the UN Climate Change conference in December 2007 largely focused on paying people to protect forests and desist from clearance to maintain and improve stability of forest carbon stocks. The scope of this has been broadened to cover activities leading to sustainable forest management (REDD+). There are several international initiatives to build necessary REDD+ capacity. However many challenges persist in making

REDD+ operational and effective. Declining interest in developed economies to provide financial assistance and the lacklustre state of carbon markets would suggest a less optimistic future for initiatives like REDD+.

History of Forest Management in India

Developments in any area – whether it is that of an individual, society or sector – are a historical continuum. For ease of analysis, long periods could be divided into convenient segments. As regards forestry in India, three periods could be identified: (a) The era of classical forestry, mostly up to India's independence, (b) the period of uncertainty and turbulence, spanning for about 4 to 5 decades starting from independence and (c) the period of accelerated globalisation, beginning with the implementation of economic liberalisation policies and opening up of the economy in 1991. The key characteristics of each of these periods are outlined below:

The era of classical forestry:

The first half of the 20th century faced a series of challenges, including the two world wars and their consequences, the severe economic depression between the two wars, the end of colonial rule, the emergence of independent India and of course the upheavals and pains of partition. Notwithstanding all the problems, forestry in India witnessed important developments, including substantial work in developing silvicultural systems for management of natural forests, expansion of plantations, especially of valuable species like teak.

In comparison with the situation now, population pressure on the forests was very limited. Even as 1951, the population in India was only some 361million, less than one-third of the population in 2011. Notwithstanding the multitude of problems, considerable attention could be paid to the scientific and technical aspects of forestry during this period. Pioneering work was done in several key areas like silvicultural systems, ecology, botany, entomology and more importantly the enormous work done in the area of utilization including assessing wood properties, pulp and paper, chemistry of forest products, etc. Even now Indian forestry continues to rely on the monumental scientific work done during this period.

The period of uncertainty and turbulence

While the first half of 20th century witnessed important political and social upheavals, their adverse impact on forests was relatively less significant than the post 1950 period. Economic, social and political transformation that accompanied independence had substantial impact on the forests. This was a period when the forestry profession was adopting a reactive approach and in many cases responding, or, more appropriately, succumbing to pressures from diverse sources. Some of the specific drivers of change and their impact are outlined below:

Agriculture expansion and forest clearance

Undoubtedly, one of the major drivers of change was the rapid growth of population, which increased the pressure on land, especially for expansion of agriculture, and to produce more wood and wood products. While green revolution did help to transform agriculture, still the spread of improved agriculture technology was uneven and throughout the country, expansion of agriculture through land clearance became the norm. A multitude of converging interests – need to increase income to the exchequer, demand for agricultural land, expansion of mining, development of infrastructure (roads, reservoirs, etc,) all brought forests and foresters in the line of fire. Although the 1952 Forest Policy stipulated that we should have one-third of the land under forests, relentless incursion continued accentuated by programmes encouraging food production by permitting forest clearance and periodic regularisation of encroachments. Allocating public forest land to satisfy the multitude of demands was a soft and very convenient option. This battle between the short term options and long term sustainable management of natural resources persist even today.

Forests and industrial development

The next wave of change that affected forests was the thrust on industrial development with forests becoming a source of raw material. This was also a period of rapid increase in the demand for wood products, especially construction timber and more importantly pulp and paper. The self-sufficiency policy led to increased private and public sector investment in developing pulp and paper capacity with the attendant increase in raw material demand. Under the garb of self sufficiency and industrialisation industries were provided with highly subsidised raw material, leaving little incentives to invest in wood production.

The increasing demand for industrial raw material led to large scale expansion of plantations, especially of fast growing exotics like Eucalyptus. To some extent the industrial focus was accentuated with the 1976 report of the National Commission on Agriculture, which emphasized the role of forests in producing wood to cater to the industrial demand. New institutional arrangements like State Forest Development Corporations gave a boost to these efforts. Narrow economic focus often led to indiscriminate clearance of natural forests (as no value was assigned to natural forests other than what could be obtained from the sale of timber) and in many cases the shallow knowledge base has led to disastrous outcomes of failed/ low productivity plantations.

Shift in emphasis and increasing thrust on social and environmental aspects

The criticism of industrial focus, especially on the social and environmental fronts, led to some corrective action as evident from the 1988 National Forest Policy, which underpinned ecological security as the main concern and emphasized the need for securing industrial wood supply from non-forest resources. Social considerations, in particular poverty alleviation of forest dependent communities, have underscored the need for participatory approaches to forest management, especially the adoption of joint forest management. However, we are still in the "learning mode" and there are series of issues that needs resolution to enhance the social and environmental contribution of forests. While there are success stories, several issues relating to the effectiveness of initiatives like joint forest management needs answers.

This period also witnessed the abandonment of many traditional systems of management evolved during the first half of the twentieth century. While long term planning and long rotations have been the hall mark of classical forestry, the profession was in a way forced to relegate these in responding to short term political, social and economic compulsions. While a large extent of natural forests were converted into agriculture, the remaining accessible forests were replaced by short rotation plantations, either to enhance industrial wood supply or sometimes even to prevent encroachment. During the subsequent periods more of the natural forests moved out of production as conservation became an important objective. On the whole classical forestry, as exemplified by systematic observations and well crafted working plans, has largely been neglected, and increasingly what should have been done as routine part of management have been left to be enforced by judicial intervention.

Increasingly, failure to address fundamental developmental issues is affecting forests and forestry adversely. Some of the most forested areas are in fact the most underdeveloped in the country, and social and economic deprivation has led to the emergence of extremism, which has further undermined forest management. In fact some of the forests that have had a long history of scientific management have become go areas for foresters. And some of the solutions that are being attempted – in the form of giving forest land – to deprived sections of society are again a short-sighted soft solution.

The era of globalisation and increasing uncertainties:

As we started moving to the 21st century, in addition to all the traditional social, economic and political problems, forests and forestry had also to cope up with the challenges posed by increasing pace of globalisation. Globalisation is nothing new to Indian forestry as its early stages of development is a product of globalisation and most of the management of valuable forests were geared to produce high quality timber for distant markets. What we are facing now is a qualitatively different and certainly a very rapid pace of globalisation, which impacts forestry in a variety of ways. Some of the implications of this are outlined below:

- Trade of forest products has increased rapidly and the concept of self reliance that formed the foundation of forestry in many countries during the first half of 20th century is almost forgotten and so is the concept of sustained yield. Management of individual forest units on the basis of sustained yield principles has become irrelevant as more of the wood supply is obtained from distant continents and countries. During the period of 1990 to 2005 itself, export of forest products increased from about US$ 164 billion to US$ 351 billion and what we see is a phenomenal growth in the trade of processed products, especially paper and paper products and secondary wood products, in particular furniture. As regards India, imports of forest products increased from US$ 753 million in 1990 to US$ 1,600 million in 2000 and US$ 3,114 million in 2005.

- Changing competitiveness is altering the investment pattern in forestry. As markets and demand shift, many of the traditional producers are finding forest management economically less viable. This is particularly the case with most European producers, as wages increase, domestic demand declines and markets shift to the new growth areas, especially in Asia.
- While globalisation does have a number of positive impacts, it also has its share of negative consequences. In the forest sector, illegal logging and trade has become globalised undermining long term sustainability of production and in a way undermining investment in sustainable forest management. The spurt in demand in many countries coupled with very weak institutional capacity has led to substantial increase in illegal logging. For example the Interpol has estimated the value of global trade of illegal timber as between USD 30 billion to USD 100 billion.
- Globalisation is not just confined to investments, trade and technology transfer, and increasingly there is greater understanding of global environmental issues. Especially after the 1992 UNCED and the multitude of initiatives dealing with environmental issues – in particular combating climate change, biodiversity conservation, arresting desertification, conservation of wetlands – global environmental issues are significantly impacting forests and forestry at the national level.

While historically foresters are accustomed to planning for a stable environment (permitting long rotations, stable markets, etc.) this is no more the situation. Gone are the days when every unit of forests is to be managed following the principle of sustained yield. Wood and wood products are shipped over long distances: for example we may get our wood supply from Brazil or Papua New Guinea, process it as furniture and other products and ship to the markets in Europe and USA. While the growth of global value chains has some advantages, there are also disadvantages.

What will be the future?

Having considered where we are, it is important to examine how the future is likely to unfold and what kind of society-forest relationship is expected to emerge. Like all other resources and other human pursuits, what happens to forests and forestry will be largely decided by what happens outside forests, a sum total of individual and collective behaviour of people driven by their objectives, perceptions, priorities and specific circumstances. But trying to visualise how the future is going to be is an extremely challenging task. Even with the most sophisticated models, the most renowned futurologist may not be able to give a clear picture of how the future is going to be. Yet, we all still indulge in crystal-ball gazing at least to give some broad indication of what is in store for us.

Drivers of change and societal transition

A key issue that will have a significant impact on forests and forestry is how the Indian society with all its diversity will evolve in the coming decades. Forests and forestry for a pre-agrarian and agrarian society are very different from what they are to an industrial or a post-industrial society. The challenge as regards India is that we have all societal segments – tribals who are totally dependent on forests for their livelihood, agrarian societies who are more concerned about land and thus often see forests as a source of land supply, industrial segments that see forests as a source of raw material (or to be cleared to make way for energy, minerals and expansion of infrastructure), or a post-industrial society who often better appreciate the amenity values and thus clamour for conservation. Of course everyone needs environmental services, especially water conservation, climate change mitigation and adaptation and arresting land degradation. So what are the factors that determine societal transition?

Obviously population numbers matter and certainly demographic changes form a key driver that impacts forests and forestry both directly and indirectly. We have seen that between 1911 and 1951 population in India increased from 315 million to 361 million, but shot up to 1210 million by 2011. All the indications are that our population will reach about 1690 million by 2050. Obviously this will place enormous pressure on resources – land, forests, water, energy, etc. Urbanisation, migration and changing age structure are some of the demographic changes that will affect the demand on natural resources. While there may be some uncertainties, one thing is certain: the demand for critical resources – food, fibre, fuel – and a host of ecological services will increase significantly.

Another critical driver is the rate of growth of income. India's growth has been quite remarkable during the last decade, and is only second to China; however clouds of uncertainty are in the horizon, largely due to internal and external factors. Annual growth estimated for 2012-13 by CSO is just 5%, while the Finance Ministry puts this as about 5.5%. As already evident higher growth rates of income is no more certain. Changes in income impact forests and forestry in several ways, on account of the increase in demand for a wide array of goods and services. Other aspects related to income that affects forests and forestry are:

- Increasing inequality in the distribution of income and persistent poverty: This is a major concern that the rich are becoming richer and appropriating more resources, while poor are remaining poor and their access to resources are being curtailed in the name of development. In particular poverty implies increased dependence on public resources including forests – especially for fodder, firewood, land for cultivation, etc. and if investments are inadequate to manage the resources, degradation is bound to accelerate.
- Structural changes in the economy: The share of agriculture in the GDP is declining rapidly on account of the faster growth rate of industrial and services sector. In fact it has declined from about 32% in 1990 to 14% in 2011. Yet close to 50% of the population depend on agriculture for employment. A major concern is that India's growth is not driven by manufacturing, but by services sector. While agriculture growth is lack-lustre, land dependency persists and so is low income. This adds to the pressure on common resources like forests. Preponderance of informal sector activities – which also includes illegal collection of timber and other products – will continue to negatively affect sustainable forest management.
- While the last two decades witnessed an acceleration of the pace of globalization, its pace may change and probably slow down if its negative impacts encourage protectionist measures. Neo-liberal economic policies that contributed to rapid globalisation are facing increasing criticism nationally and globally. Trade barriers could re-emerge and this may impact access to products markets and raw material supplies.

A third driver that has impacted forests and forestry is the rapid advancement of technologies, in particular ICT, including remote sensing and improvement in communications and transportation technologies. Mobile communications and GPS have made major impacts on forestry. New technologies in the horizon – for example LiDAR, Nanotechnology, biofuels and 3-D printing could have significant impacts. More important, technology could have unanticipated impacts on institutions – including forestry departments. Conventional institutional structure could face considerable instability.

Another set of drivers that are already having a major impact is environmental changes and the response of society to deal with problems like climate change, loss of biodiversity, declining water supplies and worsening land degradation. Certainly the responses to these problems will have direct implications on forests and forestry. While there are indications that forests are getting increased public attention, challenges may persist, especially on account of the inability of institutions and policies to respond effectively taking advantage of the greater environmental concerns of the public.

The most uncertain and probably difficult to predict are the changes in politics, policies and institutions. As such we have an extremely mixed situation with very divergent trends. While we can be very proud of having a solid democratic foundation, there are worrying tendencies of the pursuit of non-democratic approaches. Increasing role of private sector and community organizations, pro-active interventions by civil society organizations and decentralization of governance through Panchayati Raj institutions/Gram Sabhas all have impacted forests and forestry directly and indirectly. Certainly initiatives like Joint Forest Management and community forestry are major institutional innovations, although there are still lessons to be learnt from their successes and failures. Adapting our policies and institutions to the larger changes and ensuring that such adaptation helps people to fulfil their aspirations remains a major challenge.

So where will we be in the coming decades?

At the end it is important to visualise what kind of society is likely to emerge in the next couple of decades and how this will impact forests and forestry. While India will become more industrialised (including the industrialisation of agriculture), and the service sector activities could expand (a post-industrial society) provided there are favourable external environment, it could still be largely an agrarian society, highly dependent on traditional agriculture. Emerging problems like climate change and water scarcity will add to the problems. Divergent needs of the different segments in society in a situation of severe resource constraints could only add to the severity of resource use conflicts and the tasks of future foresters will be much more challenging than what it is now. In particular, it will be imperative to address several of the lingering old problems and at the same time address new ones.

- Very rapid rate of urbanization and expanding middle class along with changing aspirations.
- Persistence of poverty and deprivation, especially in rural areas.
- Increasing conflicts as regards the use of forests (as also other natural resources)
- A high level of environmental awareness. But the willingness to pay for environmental services may not increase significantly.
- Climate change mitigation and adaptation becoming a major concerns and carbon foot-print/energy efficiency rating becoming widespread. Yet international procrastination and reluctance to address the problems may elude meaningful solutions.

Implications on forestry and what needs to be done

We live in an unpredictable environment and often we may be swimming against the current, especially when political compulsions ignore concepts of sustainability. Yet the society will move forward and we still have to persist with our efforts towards sustainable forest management. Some of the implications on forestry will be:

- Sustainability and ecosystem carrying capacity becoming extremely critical. In fact we have already exceeded our bio-capacity, and we are depleting the natural capital at a very rapid rate.
- All the indications are that demand for wood will increase significantly, especially as it becomes a preferred energy efficient and ecologically friendly raw material. Obviously we will have to reinvent production forestry that has become less acceptable in the last couple of decades.
- At the same time water conservation and carbon sequestration will emerge as the most important functions of forests. Eventually society will have to address global warming

and forests will have critical roles in the strategies for combating and mitigating climate change.

- Sectoral boundaries will become more blurred, especially as more wood and other products are produced in farms. Adopting a landscape approach will become inevitable and this would require redrafting policies and legislations.

Options available

Certainly embracing change and spearheading change is the most critical, if forests and forestry have to remain relevant. Three areas that require change are:

- Improving our policy framework, making sure that it is really forward looking;
- Continuously adapting our institutions to ensure that they are able to understand the environment in which they operate;
- Systematically upgrading technologies to enhance efficiency and to ensure that the best available knowledge appropriate to the context applied.

There are several areas requiring improvements in the policy and institutional realms. Most often policies tend to have a narrow sectoral perspective and fail to see the larger picture of emerging changes. Consequently, policies become outdated soon after they are formulated. A related area that requires considerable strengthening is the strategic planning capability. We need to get a better picture of developments in closely related sectors within the state, the country and even other countries, how competitive advantage is changing and how we may take action to grab opportunities or ward off threats as they unfold. Most often actions are driven by short term thinking of the more vocal players, be it politicians, bureaucrats, business interests or civil society organizations and often no objective assessment is undertaken before launching such initiatives. Consequently, many are abandoned half-way through, when the problems – economic, social, and ecological - start surfacing. Systematic analysis could avoid many follies that have created graveyards of failed programmes and projects.

A key to chalking out a better society-forest linkage is the reform of our institutions – forest departments, education and training institutions and more important research and technology development organizations. Some of the key areas requiring change are:

1. Enhancing accountability and transparency as regards the delivery of services.
2. Most forest departments have become top-heavy and probably require major restructuring at the top, enabling the shifting of resources to strengthen field level capacity.
3. Separating the policy/regulatory functions from the management functions.
4. A shift from the "Command and Control" approach to "coordinate, connect and facilitate" framework and adopting a much flatter structure for the department.

Reforming education and training will be unavoidable if we have to bring about fundamental changes in the forest sector. As pointed out at the beginning, dealing with societal complexities is much more difficult than dealing with the biological complexity of forests. Yet forestry professionals seldom get the required expertise in social sciences and thus fail badly in dealing with social issues. A related area that requires significant improvement is communication skills. In fact a lot of the problems confronting the sector could have been easily resolved if we had better communication skills.

Another key area that requires significant improvement is science and technology. Especially in a situation of limited resources and competing demands, enhancing efficiency primarily depends on technological improvements. Certainly there have been some efforts, more in the sphere of application of ICT, but at the end what is important is better delivery of high quality products and services, ensuring that scarce resources are conserved. In developing a technology road map for the next two decades particular attention needs to be paid to the following:

- Real time monitoring of changes in forest conditions.
- Reinventing forest management through precision forestry.
- New technologies for value addition and new products and processes.
- Better understanding of managing forests for ecological services.

In improving the R&D system, it is important to address the persistent problems of fragmentation of research, mediocre outputs, leadership deficit and poor track record of inter-institutional collaboration.

References

FAO, 2010. Global Forest Resource Assessment 2010, Main Report, FAO Forestry Paper 163, Food and Agriculture Organization of the United Nations, Rome.

FAO, 2011. State of the World's Forests 2011, Food and Agriculture Organization of the United Nations, Rome

FAO, 2012. State of the World's Forests 2012, Food and Agriculture Organization of the United Nations, Rome.

FAO, 2012. South Asian Forests and Forestry to 2020, Sub-regional report of the Second Asia-Pacific Forestry Sector Outlook Study, RAP Publication 2012/10, Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific, Bangkok.

Forest Survey of India, 2011. India State of the Forest Report 2011, Forest Survey of India, Dehra Dun.

Nair CTS, C. Brown, P. Durst and J. Broadhead, 2011. Forests and forestry in South Asia: the challenges of sustainable management in a changing society, Journal of Resources, Energy and Development, Vol: 8 No 2, pp 113 -130

Schoneveld,G.C. 2011. The anatomy of large scale farm land acquisitions in sub-Saharan Africa, Working Paper 85, Centre for International Forestry Research, Bogor

United Nations, 2008. Millennium Development Goals Indicators database series: Terrestrial areas protected (available at mdgs.un.org/unsd/mdg)

World Bank 2013. Mapping carbon pricing initiatives: Developments and prospects, ECOFYS – Carbon Finance at the World Bank, Washington DC

Forests Outside The Forest Ecosytems – Home Gardens, Mangroves, Sacred Groves

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Home gardens

A home garden (syn. homestead farm) represents an operational farm unit which integrates trees with field crops, livestock, poultry and/or fish. It is having the basic objective of ensuring sustained availability of multiple products such as food, vegetables, fruits, fodder, fuel, timber, medicines and/or ornamentals. It also generates employment and cash income. Homestead agroforestry forms a dominant and promising land use system in many parts of the tropics and maintains high levels of productivity, stability, sustainability and equitability. Incidentally, home gardens represent a symbol of social status in West Java. They are believed to have evolved from tropical forests. In the peninsular Indian state of Kerala too, despite the 'coconut and rubber boom', homestead agroforestry forms a predominant land use pattern. Home gardens constitute an important land use activity in Kerala viz., 4180900 operational holdings with an average size: of 0.43 ha. However, no precise estimates are available on the extent of land area under home gardens.

Species diversity of the tropical home gardens is very high. Home gardens reach high levels of development in terms of plant diversity, labour input and percent income derived from garden in regions where population densities are high. They create a forest-like multi-storey canopy structure. The forest-like structure is derived from either the lack of a discernible planting pattern, or alternatively, the result of deliberate planning to mimic the forest. Moreover, species diversity, size, shape and plant density also vary from place to place depending on cultural, ecological and socioeconomic factors. The farmers and land owners integrate a variety of woody perennials in their crop and livestock enterprises; most of these practices are highly location-specific.

Introduction of rubber *(Hevea brasiliensis)* into the home gardens of Thiruvananthapuram resulted in a reduction of species diversity. Sample survey of 30 villages in Kerala revealed that just 10 species accounted for 74% of the total homestead growing stock and 85% of the total wood volume.

There is a tremendous degree of variability both in the number of arboreal taxa present and their density in the selected homesteads of Kerala. In total 127 woody species (GBH ~ 15 cm) were encountered. This includes the 124 tree species listed in Appendix I, besides, coconut, arecanut and para rubber. The number of woody species per homestead range from 3 to 17 in the small, 3 to 24 in the medium and 4 to 25 in the large holdings. Coconut and arecanut by far, constitute the most dominant components of the home gardens of the entire state, regardless of the holding size categories. The coconut based farming system represents a cropping system capable of providing the primary needs of the farmer, besides helping to conserve soil fertility. Other important arboreal components of the home gardens include: *Ailanthus triphysa, Mangifera indica, Artocarpus heterophyllus, Tectona grandis, Anacardium occidentale, Artocarpus hirsutus, Tamarindus indicus, Erythrina indica, Macaranga peltata. Thespesia populnea, Bombax ceiba, Gliricidia sepium* and *Psidium guajava.*

Although the list of 127 woody species is substantially greater than the earlier inventories, it is perhaps much smaller than the inventories of arboreal species available from other parts of the world. For instance, 301 trees and shrubs were reported from the Mayan home gardens of Yucatan, Mexico, 168 species from Santa Rosa in the Peruvian Amazon and 179 species in the West Javan home gardens. The present list of woody perennials in the home gardens of Kerala makes a near-total inventory. While most of the 127 tree and shrub species encountered are native to the different forest types of peninsular India, thirty two of them including cash crops such as cashew, rubber, cacao, tamarind and the like are exotics. Furthermore, if the herbaceous components are also included, the species richness would be even greater. Home gardens have the potential to serve as repositories of genetic diversity, besides acting as insurance against pests and disease outbreaks, which may be very severe in monocultural stands.

In general, smaller holdings have a higher density of trees per unit area. Mean density of multipurpose trees in the small farms equaled to 116 trees per hectare, while that of medium and large gardens are 46 and 32 respectively. Increased tree and plant density as well as diversity may be strategies particularly of the smaller farmers to ensure higher availability of multiple products on the farm itself. Overall high tree density and species diversity may indicate the tendency of homegarden owners to grow a wide spectrum of trees, which in turn may form complementary associations and also ensure more efficient utilization of the vertical and horizontal space.

Physiognomically also, home gardens exhibit a multi-tiered canopy structure somewhat similar to the tropical evergreen forests. From the ground layer comprising of herbaceous food crops, forage, medicinal and other crops to the upper canopy of fast growing multi-purpose trees, the gradient of light and relative humidity creates different niches enabling various species groups to exploit them. The medium holders might be concentrating more on cash crops like coconut, rubber, cacao and spices. Small holdings and the owners of large gardens tend to grow trees capable of meeting fuel and timber requirements, besides generating cash income. Poor people, having smaller holdings, grew more staple crops, vegetables and fruit crops, while the rich farmers preferred ornamentals and high value cash crops. Commercialization may thus reduce species diversity and hence the 'teak boom' which Kerala experiences now may perhaps reduce species diversity of its home gardens eventually.

Floristic diversity of the home gardens of Kerala is relatively low compared to a value over 0.90 for the species-rich evergreen forests of the Western Ghats.

Species Preferences of the Home garden Owners

In general, farmers tend to prefer timber trees such as ailanthus and teak besides multipurpose trees like mango. The main use of the homestead tree species are listed along with their relative frequencies in Appendix I. A new species may be included in the home gardens on account of its timber, fodder, fuel wood, medicinal and/or ornamental values. Planting of trees may also depend on the space available and/or edaphic characters. Laterite outcrops in the northern Kerala are generally dominated by cashew.

Kerala falls under a single broad eco-climate zone of humid tropics. Therefore, many of the home garden species have a cosmopolitan distribution. Ailanthus recorded the highest percentage frequency on farm borders (11.2% of all trees enumerated as against 2% of scattered trees) and mango trees recorded the highest frequency as scattered trees on the farm lands (7%

vs. 5% of boundary planted mango trees).

Potential for timber and firewood production in the homesteads

Average standing stock of commercial timber from homesteads ranged from 6.6 to 50.8 m^3 ha^{-1}. Moreover, palms, mostly coconut, constituted the principal component of commercial timber production. A substantial proportion of the society's timber demands are met with from the homesteads. Homesteads provided for 74.4 to 83.6% of the total wood requirement of the state. The remainder is derived from estates of cardamom, rubber, tea and coffee (9.3 to 11.8%), imports (2.4%) and wood from forests (4.7 to 11.4%).

Appendix- I. Utilization classes and important uses of tree species (other than palms and rubber) recorded from sampled homesteads in Kerala

Species	Utilization classes
Ailanthus triphysa (Dennst.) Alston	T2
Mangifera indica L.	M3
Artocarpus heterophyllus Lamk.	M2
Tectona grandis L. f.	T1
Anacardium occidentale L.*	M4
Artocarpus hirsutus Lamk.	T2
Tamarindus indica L.*	M3
Erythrina indica Lamk.*	M3
Macaranga peltata (Roxb.) Muell.-Arg.	M4
Thespesia populnea (L.) Soland. ex Correa	T2
Bombax ceiba L.	T4
Gliricidia sepium (Jack.) Kunth. ex Walp.*	M3
Psidium guajava L.	M4
Swietenia macrophylla King*	T2
Emblica officinalis Gaertn.	M3

Casuarina equisetifolia J.R. & Frost.*	T3
Delonix regia (Boj.) Rafin.*	M4
Leucaena leucocephala (Lamk.) de Wit	M3
Paraserianthes falcataria (L.) Fosberg*	T3
Terminalia paniculata Roth.	T2
Azadirachta indica A. Juss.*	M3
Ceiba pentandra (L) Gaertn.	T4
Annona squamosa L.	M4
Artocarpus communis J.R. & G. Frost.*	M4
Murraya koenigi Spreng.	M4
Syzigium cumini (l.) Skeels	T2
Strychnos nux-vomica L.	T3
Polyalthia longifolia (Sonner,) Thw.*	M4
Bridelia roxburghiana (Muell,-Arg,) Gehm.	T2
Hydnocarpus pentandra (Buch.-Ham.) Oken.	M3
Alstonia scholaris (L.) R.Br.	T4
Carica papaya L.	X
Lannea coromandelica (Houtt.) Merr.	T3
Morinda coreia Buch.-Ham.	T3
Cinnamomum malabatrum (Burm.f.) Bl.	X
Schleichera oleosa (Lour.) Oken	T2
Garcinia gummi-gutta (L.) Rob.	
Citrus spp.	
Dalbergia latifolia Roxb.	T1
Cerbera odollam Gaertn.	T4
Mimusops elengi L.	T2

Achras sapota L.*	X
Coffea arabica L.*	M4
Moringa oleifera Lamk.	X
Myristica frgrans Houtt.*	X
Terminalia crenulata Roth.	T2
Pterocarpus marsupium Roxb.	T2
Garuga pinnata Roxb.	T4
Hibiscus tiliaceus L.	T3
Samadera indica Gaertn.	X
Caryota urens L.	PL
Vatica chinensis L.	T3
Adenanthera pavonina L.*	T3
Spondias pinnata (L.f.) Kurz.	M4
Borassus flabellifer L.	PL
Artocarpus gomezianus Wall. Ex Trec.	T2
Albizia procera (Roxb.) Benth.	T3
Acacia auriculiformis A. Cunn. ex Benth.	M3
Cassia fistula L.	T2
Polyalthia spp	X
Santalum album L.	T1
Terminalia catappa L.	M3
Albizia odoratissima (L.f.) Benth.	T2
Averrhoa bilimbi L.*	X
Morus alba L.	M3
Bauhinia purpurea L.	X
Pongamia pinnata (L.) Pierre.	T4
Terminalia bellirica (Gaertn.) Roxb.	T3
Albizia lebbeck Wild.	T2
Excoecaria agalocha L.	T4
Aegle marmelos (L.) Corr.*	M3

Michelia champaca L.	T3
Xylia xylocarpa (Roxb.) Taub.	T2
Saraca asoca (Roxb.) de Wilde	X
Melia azadirach L.	T2
Elaeocarpus tectorius (Lour.) Poir	T2
Samanea saman (Jacq.) Merr.	T4
Careya arborea Roxb.	T2
Carallia brachiata (Lour.) Merr.	T4
Hibiscus rosa-sinensis L.	X
Euodia lunu-ankaenda (Gaertn.) Merr.	T4
Ficus exasperata Vahl.	T4
Theobroma cacao L.	M3
Syzigium sp.	X
Grewia tiliifolia Vahl.	T2
Eucalyptus tereticornis Sm.	T3
Ficus sp.	
Cycas circinalis L	PL
Pajanelia rheedi DC	T4
Sterculia guttata Roxb. ex DC	T4
Holigarna arnottiana Hk. f.	T3
Calophyllum inophyllum L.	T2
Dipterocarpus bourdilloni Brand.	T3
Lagerstroemia reginae Roxb.	T2
Rhizophora mucronata Poir.	T3
Wrightia tinctoria (Roxb.) R. Brown	X
Trema orientalis L. Bl.	T1
Butea monosperma (Lamk.) Taub.	M3
Stereospermum chelenoides (L.f) DC	T3
Miliusa tomentosa (Roxb.) Sinclair	?
Bixa orellana L.	X
Holarhena pubescens (Buch.-Ham.)	T3

Wall. Ex Don.	
Terminalia chebula Retz.	T3
Peltaphorum pterocarpum (DC) Baker ex Heyne.*	T3
Semecarpus anacardium L.	T4
Diospyros ebenum Koenig.	T3
Hydnocarpus alpina Wight.	M3
Sapindus laurifolia Vahl.	X
Ficus elastica (Roxb.) King*	X
Lagerstromia microcarpa Wt.	T3
Memecylon molestum (Cl.) Cogn.	T3
Chrysophyllum cainito L.*	X
Vitex altissima L.	T2
Lawsonia alba Lamb.	X
Syzigium aromaticum (L.) Merr. & Perry*	X
Oroxylum indicum (L.) Vent.	T2
Persea macrantha (Nees.) Kosterm.	T3
Gmelina arborea Roxb.	T3
Toona ciliata Roem.	T3
Cullenia exarillata Robyns.	T4
Cassia siamea Lamk.	M2
Trewia polycarpa Benth.	T4

* exotics

[1]**Use codes:** 1. timber, 2. food and beverages, 3. fodder, 4. fuel/charcoal, 5. green manure, 6, nitrogen fixer, 7. fiber/flosses, 8. glues/resins, 9. latex, 10. dyes, 11, spices, 12. Apiculture/sericulture/lac culture, 13. Essential oils/fatty acids, 14. Cleaning/polishing agents, 15. Religious, 16. Medicinal,17. Poisons/repellents, 18. Paper/pulp, 19. Matchwood, 20. Tannins, 21. Waxes, 22. Uses other than those listed above.

Utilization classes: T= primary timber yielding species, M= multiple use species, PL= palms, X= uses other than those listed above (1,2,3,4 = classification based on durability: 1= perishable, 2= moderately durable, 3= durable, and 4= very durable).

Mangrove Ecosystem: Threat and Conservation

Mangroves are one of the unique plant communities growing in tropical and subtropical estuarine environment, where there is constant intertidal exchange of seawater and fresh water. They usually occur between 32° N and 38° S latitude along the border of the continent. The five environmental factors namely, tropical temperature, fine grained alluvial soil, shores free of tidal action and strong wave, brackish water and large tidal range influence the occurrence of the mangroves. Species composition, zonation, other structural characteristics and the functions of these ecosystems are also decided by these factors.

The world has over 16 million ha of mangroves, out of which India has 681 976 ha (6 740 sq. km) constituting about 7% of the mangrove area of the world or 0.15% of the forest cover of India. Different types of mangrove formations such as deltaic, estuarine, backwater and sheltered insular bay type can be found on the East and West Coast of India. The distribution of mangroves in India is given in Table 1.

Mangrove areas are depleting at an enormous rate. India has lost nearly 40% of its mangrove area in just 10 years, i.e., 674,000 ha in 1987 was reduced to 483,000 ha in 1997. Even though Kerala was found to have 25 km^2 of scattered area under mangrove, the table says that it was sparse during 1987 and nil during 1997. One has to be concerned that from the point of policy or decision making and flow of funds from external agencies for various research and conservation activities connected with mangroves, Kerala may not be considered.

Uses of Mangroves

The local people consider these mangroves to be mere wastelands, even though they have been depending on these ecosystems from time immemorial. The mangroves provide a variety of benefits. They serve as unique nurseries to aquatic life by nutrient trapping and protection. Various studies have found a positive correlation coefficient between fish yield and mangrove area; in one such case, it was 0.92 between brown shrimps and mangrove area (Table 2).

Table 1. Distribution of mangroves in India

State/Union territory	Year 1987	1997
	(thousand ha)	(thousand ha)
West Bengal (Sundarbans)	420	212.3
Andaman and Nicobar Islands	119	96.6
Maharashtra	33	12.4
Gujarat	26	99.1
Andhra Pradesh	20	38.3
Tamil Nadu	15	2.1
Orissa	15	21.1
Karnataka	6	0.3
Goa	20	0.5
Kerala	Sparse	Nil
Total	**674**	**482.7**

Source: GOI, 1987 &1997.

The available trophic resources, water turbidity and structural diversity of mangroves make them efficient nurseries to young ones of the fishes and shrimps. Firstly, the concentration of nutrients is high due to fresh water inflow, nutrient trapping, tidal mixing and environmental modulation resulting in higher primary productivity. This is the base of a food web where zooplankton, mysids and shrimps provide abundant and diversified tropic resources to fish, post-larvae and juveniles.

Table 2. Relationship between mangrove area and fish yield

Reference	Formula	X	Y	R^2	N
Staples, *et al.*	Y=1.074X+218.3	Mangrove shoreline	Banana prawn catch	0.58	6
Turner, 1977	Y=1096X-4.39	Percentage of saline vegetation in an hydrological unit	Percentage of brown shrimps	0.92	7
Paw and Chua, 1989	Y= 0.8648+0.0991	Log_{10} of mangrove area	Log_{10} of penaeid shrimp catch (tons)	0.66	17

Source: Baran and Hambery, 1998

Secondly, the turbidity reduces the perception distance of the predators and increases the escape rate, thus increasing the survival rate of young fishes. Thirdly, the diversity, structural complexity and shallowness of the estuarine habitats provide multiple spatial and tropic niches favorable to fish, post-larvae and juveniles. They also support a unique biodiversity, comprising of animals ranging from small crabs and gastropods to huge reptiles and mammals.

Mangrove tree species are also used as charcoal, timber and fuel wood. Other benefits are also derived in the form of tannins, wood distillate and medicines. Mangroves act as a shelterbelt, providing barrier against cyclones and storms by reducing wind velocity and consequently mitigating the intensity of damage caused to crops and property. The cyclone prone states of Orissa, Gujarat, Maharastra, Tamil Nadu and Andhra Pradesh can take steps to control cyclone by enhancing mangrove restoration activities. Mangroves act as biogeochemical barriers to pollutants generated in solid waste disposal sites through different mechanisms occurring in the root zone. They can retain and stabilize sediments, avoiding the pollutant remobilization by physical disturbance.

Threat

Wetlands all over the world are amongst the most threatened ecosystems because of a mixture of social, economic and political factors. Mangroves have also been subjected to intense threat due to degradation of the ecosystem in the past few decades. As they form a part of the protected area network, they have been assigned national and international status under various conventions such as Ramsar and World Heritage Sites.

There are many reasons for overuse, misuse and destruction of these wetlands. We shall look into the various agencies through which these mangroves are destroyed. Firstly, the over exploitation of these wetlands by excessive removal of trees for fuel wood, charcoal, etc., by traditional users. The wood chip industry for instance has an ever-increasing demand. Secondly, activities requiring maintenance of mangrove ecosystem, which involve rotational felling and replanting of mangrove stands for wood production, are not undertaken scientifically. The whole mangrove area is converted into monospecific plantations like *Avicennia sp.* and *Excoecaria sp.* wituhout considering the zonation attributes. Thirdly, natural resource activities that require little or no inputs for it like coastal agriculture, salt production, extensive shrimp culture, etc, cause further destruction. It was noticed in the gulf of Thailand that mangrove areas were cleared for salt production. In some African countries, dual use was made of the cleared mangroves by undertaking agriculture during floods and salt production during dry periods. It so happens that these mangrove areas are first converted into agriculture lands. As time passes, the agricultural production decreases due to the increase in the concentration of acid sulphates in the soil, after which the land may be abandoned or converted into shrimp culture ponds. For economic reasons people usually shift totally to shrimp farming. This is the most deleterious among all the factors leading to drastic reduction in mangrove area. These shrimp culture techniques have expanded very rapidly during the last 15 years and large sectors of mangroves have been brought under this. Fourthly, activities like offshore dredging, coastal pollution, and construction of dam and diversion of upstream fresh water resources for irrigation, even though are unrelated to mangrove ecosystem are detrimental to it.

The ecological and related socioeconomic effects of the construction of major dams are well known. Though they are constructed hundreds of miles away from these forests, they do have a detrimental effect by dramatic reduction of fish yield, increasing saline intrusion, nutrient depletion and in some areas, sediment accretion due to marine sand deposition in estuaries along with increased coastal erosion. It was also observed that the construction of dam raises the sea level due to high tidal amplitude and low river gradient in the estuary. Estimates based on tidal records show 0.3 to 3.6 $mm.yr^{-1}$ increase in tidal propagation into rivers, maximized by numerous dams constructed during the last decade.

The recent coastal industrialization and urbanization also had a great impact on these ecosystems. These areas are cleared for housing, industry, refineries, tourism development, roads, railways, airports and waste disposal. One of the severe impacts of global warming being the increase in sea level, the mangroves will be the first to be exposed to the current estimated rise of 6 cm per decade (WS 09). This may also increase the salinity level leading to disruption of the zonation pattern and succession process. The extreme case may be soil erosion, as clay particles are highly susceptible to the erosive forces.

These deleterious factors may have a long lasting impact on the mangrove ecosystem. In Sunderbans, there was low species and generic biodiversity in these forests, indicating its high probability to extinction of the vegetation complex of the region in general. In the Andamans, natural regeneration was unsuccessful and only weeds like *Acrostichum aureum* and *Acanthus sp.* invaded the area. This also brings about an alteration in number, stratification, composition, diversity, dominance and regeneration process of the mangrove forest. Even functional aspects like rate of matter export, import and storage efficiency of mangroves are substantially affected. There was also disturbance in the succession patterns of the forests. The rise in the sea level affects the distribution of the biomass. In the case of *Rhizophora mucronata,* it was found that up to 65% of the plant wet weight biomass consisted of prop roots only resulting in the decrease of the biomass accumulating in the stem.

Conservation

Mangroves, as a plant community, have the lowest number of species, with about 80 species of recognized true mangrove trees or shrubs. Around 50-60 species make a significant contribution to the structure of mangrove forests.

Conservation of the mangroves being the need of the hour can be undertaken by implementing proper rehabilitation and restoration measures. The pressures from environmental activists for more effective conservation, sustainable use and protection of the biodiversity have been unremitting and have exerted profound influence on governments around the world. Various departments are involved in the management of mangroves, chief among which are the forest, fisheries and agricultural departments. For a concerted and integrated approach in the management, all the existing mangroves should be brought under one department.

Rehabilitation and restoration measures can ensure better conservation. Rehabilitation can be defined as the act of partially or more rarely, fully replacing the structural and functional characteristics of an ecosystem that has been diminished or lost. It also implies the substitution of alternative characteristics than those originally present with the proviso that they will have more social, economic or ecological value than existed in the disturbed or degraded state. Restoration is the special case of rehabilitation. Here, the rehabilitated ecosystem is the photocopy of the original ecosystem that was depleted. The success of the rehabilitation programme is guided by various factors like genetic changes in the populations, natural variability of the mangrove ecosystem, topographical and hydrological changes to the site, local climatic changes, changes to the neighbouring ecosystems and goals of the rehabilitation programme. Since these factors vary from place to place, the rehabilitated ecosystem may not resemble the original ecosystem (which was disturbed). Whether the mangrove stand reaches an old growth stage depends on the dynamics of the coastal ecosystem under which it grows i.e., biotic and abiotic factors. The success of the mangrove rehabilitation programme can be judged by evaluating the effectiveness of the planting, closeness to which the new mangrove ecosystem meets the original goals of rehabilitation programme, the rate of recruitment of the flora and fauna and the resources like labour and material that were used. In the case of mangrove ecosystem rehabilitation, the effectiveness and efficiency are only sometimes quantified and the long-term sustainability awaits determination.

Mangroves have been rehabilitated for recreation purpose or as a landscaped area or merely for conservation as in the United States of America where this is conducted in a legal context for ecological reasons relating to fisheries and wildlife. In UAE, landscaping of arid coastal regions using *Avicennia marina* has also been done. Here, mangrove planting following damage from an oil spill has also been done. In this sort of mangrove rehabilitation, the assessment of the growth of the trees and subsequent level of practical management is very low. Therefore, quantification of the success of rehabilitation may not be foolproof. The most common method of conserving mangrove ecosystems is by declaring these ecosystems as protected areas in undisturbed sites. Secondly, we can manage the mangrove ecosystems for high and sustained yield for ensuring sustained production of timber, charcoal and shrimp. Reduction of the environmental stress by adding inputs and changing the site condition may increase the primary productivity. The planting of mangroves along the coastlines damaged by cyclones and tidal waves has been highly successful in protecting and stabilizing the coastal areas and in providing substantial timber production. In Bangladesh, 120 000 ha of mangroves have been planted since 1976 to 1993. This is an example of large scale planting of mangrove in the world. But little attempt has been made to study their ecology. Such types of works require the involvement of local people. The Department of Environment and Natural Resources (DENR) in Philippines encouraged planting and conservation of mangrove species by providing local residents with 25 year private leases to small plots of land. Over more than 200 such leases on inter-tidal land were issued to coastal households in the biosphere area to encourage mangrove stewardship. Decline in agriculture and fish yield within the estuary reduces the income of the local community. In order to supplement the income, an increase in mangrove felling, principally for firewood and for fish smoking is noticed. A study conducted in Pichavaram mangrove forest of Tamil Nadu by M S Swaminathan Research Foundation, Chennai (MSSRF) found that the coastal people were deprived of agricultural land and better crop varieties; they were not left with any sustainable source of income and were virtually dependent on natural resources for their livelihood. Here, 40%- 60% people were dependent on the mangroves. A similar case was recorded in the Sunderbans. One of the efficient ways of conserving the mangroves is by providing these local people with a better alternative, which may pave the way for their social and economic upliftment.

Mangrove ecosystem rehabilitation activities are progressing worldwide. Out of the 90 or so countries having mangrove forests, only 20 have attempted programs of mangrove replanting. Only nine out of these 20 countries have planted more than 10 km^2 of area since 1970. Even though the objectives of conservation varied the motive behind was one i.e., conservation. Bangladesh, Indonesia, India, Philippines and Vietnam have put a greater effort in this context.

The narrow range of B:C (Benefit : Coast) ratios for increasing discount rates illustrated that most of the cost and benefits of rehabilitation occur in a relatively short time frame and the maintenance cost reduced within a few years. In general, greater the mangrove area, greater will be the benefits in terms of avoided maintenance cost. Thus, the argument presented over here, on direct and indirect benefits of mangrove, strengthens the case for mangrove conservation where the ecosystem presently exists.

Impact of Shrimp culture

Shrimp culture is one of the main factors for the decline of mangroves. Shrimp culture is classified into extensive, semi intensive and intensive types based on the level of intensity or productivity per unit land area. Out of this, extensive culture accounts for only 22% of world farmed shrimp production but occupies as much as 67% of all pond area. This is the most hazardous one. These types of ponds require a maximum tidal range of –0.4 m to +1.4m below and above the MSL.

Table 3 General information on mangrove rehabilitation projects

Country	Main mangrove species planted	Aim(s) of planting programme	Area of mangrove planted (km^2)	Area of natural mangrove (km^2)
Australia	*Avicennia marina, Aegiceras corniculatum.*	Enhancement of natural regeneration	<1	9695
Bangladesh	*Sonneratia apetala, Avecennia officinalis, Heritiera fomes.*	Sustained yield, Coastal protection	>1200	5767
India	*Avicennia sp., Sonneratia caseolaris, Rhizophora sp.*	Rehabilitation of degraded land	>100	6700
Indonesia	*Bruguiera sp. Rhizophora sp.*	Rehabilitation of degraded areas; timber production	>400	45,421
Pakistan	*A. marina,*	Rehabilitation of	>20	1683

	Ceriops tagal, Rhizophora sp.	degraded land & timber production		
USA	*Rhizophora sp., A . germinana, Laguncularia . recemosa, Conocarpus . erectus*	Rehabilitation of natural areas	<0.4	1990
Vietnam	*Rhizophora sp., Kandelia . caandel, A . alba, C. decandra, S . caseolaris, Nypa fruticans*	Rehabilitation of degraded areas, sea dike protection and mixed shrimp farming-mangrove areas	>530	2525
U.A.E	*A . marina*	Landscaping	<0.1	30

Source: Field, 1998

Table 4. Coast and benefit of direct and indirect use values of mangrove restoration compared

Discount Rate %	Direct benefits (PV mill VND ha^{-1})	Indirect benefits (PV mill VND ha^{-1})	Costs (PV mill VND ha^{-1})	Overall B/C ratio
3	18.26	1.4	3.45	5.69
6	12.08	1.04	2.51	5.22
10	7.72	0.75	1.82	4.65

Source: Niel Adger et al., 1997 PV= Present value1 US$= VND 11 000 (VND= Vietnamese Dong),

Table 5: World shrimp culture areas and annual production by each culture system, based on 1992-1993

Culture systems	Pond areas		Annual shrimp production	
	Hectares	% Of total	Metric Tons	% of total
Extensive	726 900	67%	459 900	22%
Semi-Intensive	304 000	28%	304 000	42%
Intensive	52 000	5%	258 000	36%

Source: Menavesta and Fast, 1998

Semi intensive culture constitutes 42% of all the world shrimp production. This is practiced on 28% of all shrimp pond culture area, with an annual production of 500-600 kg $ha^{-1}yr^{-1}$, which involves a greater control of seed stocking. The intensive shrimp culture on the other hand accounts for 36% of all farmed shrimp. This is produced on only 5% of the shrimp culture area; here ponds are established in areas having an elevation of +2 m above MSL constituting the non-mangrove area. Therefore, intensive shrimp culture techniques involving mechanization and greater control over stocking can conserve the mangrove to a greater extent.

Aquasilviculture can be another way of conserving mangroves. This can be practiced in two ways. Firstly, mangroves are planted at the center of the pond (70 - 80% of the area) and 20-30% of the area around is excavated where the fish gather during low tide giving optimum productivity. Secondly, as followed in Indonesia, the *Rhizophora sp.* is planted towards the seaward side of the pond on a 7 years rotation. During this period, it traps the silt and adds land to the farm area. Later, it is cut for fuel wood and replanted.

For the protection, conservation and sustainable use, establishment of Mangrove Genetic Garden was proposed by the local conservation agencies in Philippines. These gardens protect the germplasm and gene pool of plants, animals and microorganisms. Besides, they may also serve as the reference site for breeding program, scientific research and provide environmental baseline for studying the extent of man's impact on mangrove ecosystems.

Governmental and non-governmental organizations are taking steps to meet the conservation guidelines. Ministry of Environment and Forest (GOI) in 1989 had established a National Mangrove Committee (NATMANCOM) to advise the government on its conservation programs. This commission has recognized 15 mangrove sites in India that requires conservation. This committee helps in the management of these mangroves by preparing management plans, promoting research and adopting a multidisciplinary approach towards better conservation.

Environmental Protection Act (1986) restricts the developmental activities across the coastal line by declaring it as a Coastal Regulation Zone (CRZ). In this zone new shrimp/aquaculture farms must not be established. A Supreme Court judgment in 1996, prohibits setting up of new shrimp farms in the CRZ and only those set up earlier and with the traditional method of farming be allowed.

The International Society of Mangrove Ecosystem (ISME) in association with International Tropical Timber Organisation (ITTO) started a five year project to produce a Global Mangrove Database and Information System (GLOMIS) with its headquarters at Okinawa, Japan. It helps in providing information for research, conservation and management of mangroves all over the world. Many NGOs are also working in this direction; one of the pioneers in this is the Mangrove Action Project (MAP), an internationally renowned organisation known for its activities to meet the cause of conservation.

Conclusion

The world has come to know in the recent past that without managing the ecosystem sustainably we cannot progress. With the world economies coming together to find a solution for the ecological crisis around the globe and trying to restore and conserve the threatened ecosystems, we can expect a better approach towards managing these ecosystems. The international organizations and conventions, bind a particular country for sustainably managing their ecosystems. Since conservation cannot be a one-man action, it is the concerted and committed action of the society as a whole that has to be developed. This requires a proper dissemination of knowledge and information regarding the need of conservation. This applies in the case of mangroves also.

Sacred groves

India is a country that resembles an intricately woven fabric of culture, tradition and diversity. Sacred groves are perhaps the unique ecological entity that epitomizes the cultural, traditional and floral diversity of this vast country. Sacred groves are the relics of once vast tracts of forests, which are obviously maintained intact by the society for social, religious and ecological reasons. Sacred groves are associated with temple deities, ancestral spirits or Gods and Goddesses related to forests and woods.

Since time immemorial, conservation of natural resources has been an integral part of several indigenous communities. Nature worship has been a key force in determining human attitudes towards conservation and sustainable utilization of biodiversity. Various indigenous communities all over the world lived in harmony with nature and thus conserved biodiversity. In the course of time, science and technology developed and industries were established and expanded to meet the increasing demands of people and to take care of various developmental activities.

Furthermore, habitat alteration, over-exploitation, pollution and introduction of exotic species also threatened the global biological resources. This has led to the fast depletion of biodiversity in different ecosystems and adversely affected the ecological balance and socio economic status of the people. These directly or indirectly contribute to the welfare and stability of the environment and society. Therefore, for the conservation of biodiversity, many laws were enacted from time to time.

Many traditional conservation practices of indigenous people in many parts of the world such as protection of small forest patches by dedicating them to the local deity, also contributed to the conservation and protection of biodiversity. Same as the Indian population, flora of India is also tremendously diverse and many are considered sacred. These sacred groves, which are dedicated to local deities or ancestral spirits, are protected by local communities through social traditions and taboos that incorporate spiritual and ecological values. Preserved over the course of many generations, sacred groves represent native vegetation in a natural or near-natural state and thus are rich in biodiversity and harbour many rare species of plants and animals.

Sacred groves are unique and distributed all over India. They are all known by different names in different regions of India. In Kerala, sacred groves are mainly known as Kavu, Sarppakkavu or Valarthukadu. However, it is believed that the number of groves is declining as social values and religious beliefs are changing due to modernization, urbanization and expansion of population and associated market economy. Concretization of the temple makes a good way to the destruction of the sacred groves. Habitat destruction is on rise in these once socially guarded ecosystems. However, no concrete steps are being initiated to protect and conserve these groves, mainly due to lack of accurate and adequate information. Therefore, in-depth assessment of these natural resource pockets can be an excellent tool for any regional biodiversity planning.

Due to high disturbance and conversion many sacred groves have changed to playground or agricultural fields. Threats from several heads have been steadily eating up the spread and distribution of sacred groves. The ever-increasing population pressure has manifested itself into several forms that turn up as the root cause for the destruction of sacred groves. Also the changing social and cultural values have contributed their might to the disappearance of the *kavus*.

Conservation of sacred groves is very significant owing to its ecological, economic and cultural functions. A strategy should be evolved to adopt measures for conserving these relics of the past. Prioritization of the groves is important for directing any conservation measure. This is possible only by analyzing the vegetation structure and composition of the individual sacred groves. The floral wealth of a sacred grove is an indicator to its conservation value.

Sacred groves have an enchanting entity whereby religion, culture and diversity dominate the unique patch of vegetation. Organised ecological studies on sacred groves have yet to be conducted comprehensively over the entire country. Though several floristic and vegetation studies have been conducted, most of them fail to present holistic picture on a landscape basis.

Definition of sacred groves

A sacred grove is a type of vegetation having diversity – cultural and floral – as the main feature. Sacred groves have been defined in different ways by different authors. Sacred grove is a primitive holy place that may have an image and may gradually become an elaborate temple. Sacred groves are scattered forest tracts, which have remained immune from human interference because of religious beliefs. Sacred grove is an age-old tradition where a patch of forest is dedicated to local deities and none is allowed to cut plants or harm animals or any form of life.

Sacred groves are the patch of vegetation or a group of trees protected by the local people through religious and cultural practices evolved to minimize the destruction. They are small patches of natural or near natural vegetation dedicated by local communities to the ancestral spirit or deities. Thus, sacred groves are obviously related to religion, social and ecological parameters of human society.

Origin of sacred groves

When man started to believe in nature, he set the natural things to be sacred. Sacred groves were identified from very early days. In our great epic Mahabharata, divine forest and 'Upavanas' are mentioned at many instances. Similarly, great poet Kalidhasa's creation 'Vikramorvasheeyam' specifically points out the presence of divine forest. Believing trees to be the abode of groves and ancestral spirits, many communities set aside sanctified areas of forest and established rules and customs to ensure their protection. These rules varied from grove to grove but often prohibited felling of trees, the collection of any material from forest floor and the killing of animals. There were many sacred groves all over India adored with worship. The institution of sacred groves dates back to the pre-agrarian hunting-gathering phase of human civilization. They can be considered as one way of expressing the gratitude of man towards the vegetation which sustained and supported life under respective agro-ecological condition. In India, the practice of worshipping plants dates back to 3000 to 4000 BC. World Conservation Monitoring Center (1988) states that the sacred grove is a very old institution that is thought to date back several thousand years, at least the pre-agrarian of hunter-gatherer societies. Woods have become the focal centers for tribal ritual enclosures; these rituals instill courage and confidence in them to encounter the nature. No trace of temples was present in pre-Buddhist period. Buddha is believed to have born in a sacred grove, Lumbinivana which was full of Sal trees. Many sacred groves are 'swayambhoo' and the deities are represented by a stone or stone slab in rural and tribal areas. People in the high ranges of Kerala worshipped the divine "Devi" who was the presiding power of the forests known as Vanadurga. Devi appeared when the sickle of a "Pulayi" hit a stone hidden among the bushes in the forest. In context to this event Devi was consecrated in the forests in the form of an idol. Since then, sacred groves became dominion of a particular community. Subsequently, sacred groves were relied upon by the community for protection and satisfying genuine and bare minimum needs. In Mizoram, even today, the system of sacred groves or safety forests and community woodlots or supply forests persists in various parts.

Sacred groves of India

India is a country with lot of customs and beliefs and has a large number of sacred groves. The number of sacred groves in the country may be as high as 1,00,000 to 1,50,000. The numbers of sacred groves present in the states of Madhya Pradesh, Andhra Pradesh, Karnataka (Coorg), Himachal Pradesh, Maharashtra, Meghalaya, Orissa, Uttar Pradesh and West Bengal are 275, 800, 1214, 11, 953, 79, 322, 6 and 7 respectively. The four important regions for sacred groves are all highlands. They are the Khasi and Jaintia Hills of the Northeast, the Western Ghats, Aravalli Hills of Rajasthan and the Sarguja, Chanda and Bastar areas of Central India. Sacred groves have been found all along the Himalayas from Northwest to Northeast. Kan forests covered once substantial area of central Western Ghats of Karnataka, during the pre and early British periods. A forest working plan for Sirsi and Siddapur taluks of Uttara Kannada also included 73 Kans having total area of 4121 ha.

Sacred groves of Kerala

Kerala state falls in the Western Ghats - one among 25 biodiversity hot spots in the world along with Sri Lanka. The state harbours a plethora of flora and fauna in its pristine natural forests extending over 9400 km. Apart from this contiguous stretches of forests, the state also is a home to numerous sacred groves. The presence of about 15,000 sacred groves has been reported from Travancore and Cochin regions, whereas Rajendraprasad (1995) reported that Kerala has only 2000 sacred groves. The biological spectrum of groves in Kerala closely resembles the typical spectrum of tropical forest biodiversity. 79 per cent of the sacred groves in Kerala are small i.e., below 0.02 ha in extent; hence even the smallest grove should not be neglected from the network of conservation efforts. In Kerala, based on management systems, sacred groves can be categorised into three groups namely those managed by individual families, by groups of families and by the statutory agencies for temple management i.e., Devaswom Board. Many sacred groves are conserved by the family trusts also. Sacred groves of Kerala are rich in biodiversity. Botanical Survey of India discovered a new species of a leguminous climber, *Kunstleria keralensis* from a sacred grove of Kerala Iringole Kavu near Perumbavoor town of Ernakulam district is one of the last remnants of virgin forest in south India and have an area of about 20 ha.

Vegetation

Species diversity and richness

Species diversity is an indication of the richness of a forest ecosystem and many studies regarding the sacred groves end with enlistment of the floral wealth. The vegetation of 'Koil Kaadugal' (Sacred groves) is of different types – evergreen, semi-evergreen or deciduous, depending upon the climatic factors. Analysis of floristic wealth of the 364 sacred groves (> 200 m^2) covering an area of 1.44 km^2 in Kerala comprises about 720 species of angiosperms belonging to 472 genera and 126 families. This is a very high level of species richness and diversity as compared to Silent Valley National Park known for species richness. Silent Valley with an area of 90 sq.km has only 760 species of flowering plants. Similarly, a baseline floristic survey in various sacred groups of Meghalaya revealed that as many as 514 species representing 340 genera and 131 families were present in these forests. Structurally, the vegetation of the sacred groves in South Kerala is typically of tropical evergreen forest in general, with several tiers or types of trees, climbers, shrub and undergrowth. Floristic diversity indices of the sacred groves of Kerala are equal or nearly equal to the forests of the Western Ghats (Tropical Botanical Garden and Research Institute, undated).

Endemism and red listed plants

Endemism means the presence of an organism in a restricted area, and hence, invariably endemism is associated with phytogeography. Sacred groves are islands of vegetation with the man-made ecosystems serving as barriers all around. Western Ghats is one of the hottest centers of endemism. Sacred groves are often the last refuge for endemic and endangered plant and animal species. They are storehouses of medicinal plants valuable to village communities as well as modem pharmacopoeia. Analysis of phytogeographical elements of sacred groves of Kerala indicated that out of 721 species recorded from sacred groves, 154 are endemic to Western Ghats and 33 per cent of them are trees (Induchoodan, 1998). *Myristica malabarica, Nothopegia beddomei, Antiaris toxicaria* are some of the rare and threatened species while *Aporusa bourdillonii* is a vulnerable species recorded from sacred groves of Kerala. Four threatened species, *Blepharistemma membranifolia, Buchnania lanceolata, Pterospermum reticulatum* and *Syzygium travancoricum are* from the sacred groves of Quilon. *Semecarpus kathlekanensis* has been described from sacred grove known as Kathlekan, means dark forests, in Siddapur region in Uttara Kannada district of Karnataka on the banks of the river Sharavathi. 38 species of endangered endemic plants have been enumerated from 12 selected sacred groves of Western Maharashtra falling in the Western Ghats. Sacred grove at Kallabbe in Uttara Kannada district, has 33 per cent of endemic trees, while in the adjacent secondary forests, endemism is only 15 per cent. The sacred groves in the Kanyakumari district harbour many of the rare endemic plants of the Western Ghats such as *Antiaris toxicaria, Diospyros malabarica, Diospyros ebenum, Feronia elephantum, Butea frondosa, Garcinia cambogia, Sterculia foetida, Gnetum ula* and *Cycas circinalis*. The presence of about 50 rare and endangered plant species has been reported from Meghalaya. Out of 329 plant species from 110 families in some sacred groves of Kanyakumari district of Tamil Nadu, 60 species from 40 families are under the rare, endangered and threatened classes. A study conducted in Kerala has elucidated that among the plants growing in the Kavus of North Kerala, at least 50 are endemic to Western Ghats and folk practitioners utilize most of them as raw drug source.

Wild relatives of cultivars

Wild relative of a cultivated crop is a part of the gene pool of that crop. The Indian subcontinent has 152 economic species. Sacred groves protect several plant and animal species valuable for food, medicinal and other uses. Sacred groves shelter many plant and animal species which might have vanished elsewhere in the surrounding environment, often including wild crop relatives and endemic and endangered species. 145 important wild crop relatives belonging to 66 genera have been enlisted from Western Peninsular region. Sacred groves often include wild turmeric (*Curcuma* spp.), wild ginger (*Zingiber* spp.) and cardamom (*Elettaria cardamom*). As many as 63 species have been enlisted from sacred groves of Kerala, which are wild relatives of cultivars.

Sacred groves for conservation

Sacred groves are the treasure house of important flora and fauna. The role of sacred groves as gene pool for *in-situ* conservation of genetic resources has been appreciated by many workers.

Apart from being gene banks and biodiversity enclosures, the authors have highlighted the significance of conserving sacred groves since the trees in them being shade tolerant, can be used for augmenting degraded evergreen and semi-evergreen forests. Many plant species that are absent from the entire ecological region are found in the sacred groves located in that specific region. The sacred groves may harbour genotypes of possible significance in future programmes of forest tree breeding or fruit tree breeding. Sacred groves are the islands of conservation because they stand out mighty from their surroundings. Two magnificent specimens of *Canarium strictum,* which are otherwise present at a distance of about 200 km far off south, were spotted in a scared grove of Western Ghats of Pune. Sacred groves situated in a hill top in the Honavar taluk could form effective nuclei for the regeneration of *Dipterocarpus indicus* which is seen nowhere in this taluk out side. Presence of a new woody climber, *Kunstleria keralensis* has been reported from a sacred grove. *Dalbergia benthami* was located for the first time in Kerala from a sacred grove. A detailed study conducted on sacred groves in Kerala found out that of the 500 sacred groves about 80 are rattan bearing ones and most of these are concentrated in Haripad, Muthukulam, Karunagappally and Mavelikkara villages.

Apart from the biodiversity and breeding values sacred groves withhold, they have yet another role in soil nutrient enhancement that demands conservation of sacred groves. Studies in the Mawsmai sacred forests at Cherrapunjee in the East Khasi Hills show that the trees with fine root systems in the surface layer of soil facilitate rapid uptake of nutrients released by decomposing forest litter. In addition, the roots also intercept nutrients from rainfall wash-offs. The presence of fine root biomass of up to a maximum of 14,000 kg/ha in the soil to a depth of 30 cm is therefore crucial in mopping up the nutrients and keeping the soil alive. It is even suggested that some undisturbed vegetation patches can be formulated as sacred groves, which in turn will be protected by villagers themselves. All these values of sacred groves make it inevitable to spread the network of conservation activities on them.

Threats and disturbances

The rapid march of modernization over the past century has depleted all our sacred groves. Ward and Conner (1927) reported about 15,000 sacred groves in Travancore and Cochin regions of Kerala. Pillai (1940) also reported that the number of sacred groves in the erstwhile province of Travancore to be around 15,000. However, the changing social values and religious beliefs have resulted in dwindling of these valuable resources. The slow but steady vanishing of these islands of biodiversity is evident. Only 2000 well preserved sacred groves are present in the whole state. Similarly out of 361 sacred groves studied in Kerala, a vast majority of them remain fragmented (< 0.5 ha). The values for RISQ (Ramakrishnan index of site quality) obtained for all the three tree layers (i.e. mature trees, saplings and seedlings) in the sacred grove at Ollur, Kerala was between 2.265 and 2.731 against the expected value of 1 for a relatively undisturbed humid tropical forest. This indicates the dominance of light demanding species in population by replacing the species characteristic to the low land evergreen forest as a consequence of disturbance. Invasion of exotic weeds such as *Chromalina odorata, Mikania micrantha, Lantana camara,* etc. and consequent arrested succession adds to further degradation of sacred groves. The number of *Devara kadus* has reduced from 755 to 346 during the period 1900 to 1992 in Karnataka. The area has reduced by about 60 per cent. The process of sanskritization is already happening in the Western Ghats, and such elevation of woodland deities is often followed by construction of temples, causing the decline of the groves.

Mangroves of Kerala: Current Status and its Distribution

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Abstract

The economic and ecological importance of mangroves was seriously discussed since the tsunami of 2004, when they acted as buffers, preventing loss to life and property of coastal population. This paper discusses the spread and socioeconomic dimensions of mangroves across the globe, based on reported studies. Mangroves are seen in 124 countries (tropical and subtropical). Mangroves of Asia form the world's most extensive and diverse ones accommodating 41.4% of global mangroves and in India mangroves are spread in 4450 km^2 occupying about 3% of global mangroves. Kerala has a fabulous history of mangroves of around 70,000 hectares. The mangrove wealth throughout the world has experienced drastic decline over the years. However post tsunami efforts have helped to sustain/improve the status, at least in certain countries.

There are no scientific estimates of mangrove area in Kerala. Despite large scale mangrove depletion in the state, because of anthropogenic pressures, there are rural communities who still depend on the system for their livelihood. More than 85% of mangrove area in Kerala is under the private ownership. The conservation-development debate causes serious damage to these ecosystems.

1. Introduction

Globally wetlands are considered as one of the most prolific and life supporting ecosystems. The significance and value of wetlands was first brought to the notice of the world through a Convention on Wetlands held at the Iranian city of Ramsar, in the year

1971. Mangroves, a part of wetlands, are invaluable treasure of our biodiversity with immense ecological and economic significance. The importance of mangroves was seriously discussed since the tsunami of 2004, when they acted as buffers, preventing loss to life and property of coastal population. Mangroves are proven to be highly productive ecosystem with multiple socio-economic and environmental functions. However, this ecosystem is under threat of depletion, mainly due to anthropogenic interventions. This paper analyses the current state of mangroves in the world relying on reported information.

Mangrove forests are seen in about one quarter of world's tropical coastline from 200 N to 20 0S latitudes (Walsh, 1974). Geological history and evidences show that mangroves appeared between Eocene and Oligocene period (30- 40 million years ago) (CED, 2003). The word "Mangrove" is a combination of two words, "Mangue" (Portuguese, meaning tree bush) and "grove" (English). MacNae (1968) coined the name 'mangal' for mangrove community or habitat and retained the term 'mangrove' for individual species. The term mangrove might have derived from a combination of the Malay word 'mangii - mangii'. However Vanucci (1989) opined that the word 'mangrove' may be of African origin which was used by the Portuguese in the West African coast in the early 15th century and spread throughout the world.

Mangrove ecosystem is a multiple use biodiverse wetland system in the ecotone between sea and land. Mangrove forests are known by different names as coastal woodland, tidal forest and coastal bioshield (FAO, 1994) and occupy less than 1% of the world's surface (Saenger, 2002). These are the rainforests by the sea, and are characteristic littoral plant formations found in 124 tropical and subtropical countries and areas, mainly growing in soft substrates.

The term mangroves, is used to categorize trees and shrubs that have grown in and have developed morphological adaptations (e.g. aerial roots, salt excretion glands and vivipary of seeds) to the inter tidal environment and to the ecosystem. Mangroves have various root adaptations to survive in the anaerobic conditions. Prop roots for *Rhizophora* (red mangrove) and pneumatophores for *Avicennia* (black mangrove) are typical cases. Mangroves form a distinctive ecosystem composed of peculiar plants, animals and micro flora and fauna commonly found along sheltered coastlines, shallow-water lagoons, estuaries, rivers or deltas in the tropics and sub-tropics where they perform important socio-economic and environmental functions.

Among the plant species seen in the intertidal regions, only few are categorized as true mangroves and others are grouped as mangrove associates. Plant families like *Rhizophoraceae, Avicenniaceae* and *Combretaceae* have good physiological and structural adaptations to the brackish water habitat and are called as true mangroves. True mangroves are mainly restricted to intertidal areas between the high water levels of neap and spring tides. Globally, 50-70 mangroves species are reported (Lugo and Snedaker, 1975; Saenger *et al.*, 1983; Tomlinson, 1986) with the highest species diversity in Asia, followed by Eastern Africa. Of these, there are about 69 true mangroves. The important true mangrove species are *Acanthus ebracteatus, Acanthus ilicifolius, Acrostichum aureum, Heritiera minor, Rhizophora sp., Avicennia sp., Sonneratia sp., Ceriops sp., Xylocarpus sp. and Lumnitzera sp.* Plant like *Caesalpinia, Mora, Thespesia* are mangrove associates (FAO, 2007), which are seen along the river banks without possessing the specific features of true mangroves.

2. Mangrove ecosystem- the support to life and livelihoods

Mangroves are considered as one of the most productive terrestrial ecosystem which can produce 29-75t/ha of biomass (Palot and Jayarajan, 2007). Traditionally local communities in mangrove ecosystems collect fuelwood, fodder, honey, medicinal plants, timber and other products (Pattanaik *et al.*, 2008). One ton of mangrove fuelwood is equivalent to 5 tons of Indian coal, generating heat without smoke (Kathiresan, 2010). The local people around Sunderbans (both India and Bangladesh) used to extract honey from mangroves. Mangroves especially *Avicennia* and *Sonneratia* are cheap nutritive feed for cattle.

The fish yield and presence of mangroves have positive relationship. Kapetsky (1985) reported that the average yield of fish and shellfish in mangrove areas as about 90 kg/ha, with maximum yield up to 225 kg/ha (FAO, 1994). The destruction of mangrove area leads to the decline in fish catch to the tune of about 480 kg/ha/year (MacKinnon and MacKinnon, 1986). The local fishermen in Thailand had suffered substantial loss in coastal fish stock and yield which was attributed to destruction of mangroves (Aksornkoae *et al.*, 1992; Sathirathai and Barbier, 2001).

The mangrove ecosystem is generally renowned as providers of various kinds of services such as storm abatement, sediment trapping, nutrient uptake and transformation. There are reports that 29.5% of net primary production of a mangrove forest is exported to the marine ecosystem (Duarte and Cebria`n, 1996). The microbes in the mangrove mudflats fix 20g nitrogen/m^2 (1250kg/ha) (Ahmad *et al.*, 2003). The local people in the coastal area of Kerala collect the nutrient rich mud from the marshy mud flats of mangroves for manuring the coconut plantation with the belief that it will promote better yield for the palms (Nambiar and Raveendran, 2009). The total organic carbon stock in mangrove ecosystem on a ground area basis is 62 Mg/ha/year (Khan *et al.*, 2007). It is capable of removing excessive nutrients in the shrimp farms up to 70 per cent for NO3-N and $NH4^{+}$-N, reducing PO4 + -P fluctuation and producing bio active compounds (Ahmad *et al.*, 2003). Mangroves have the capacity to metabolize organic wastes and can be considered as natural sewage treatment plant (Upadhyay *et al.*, 2002). UNEP in 2011 reported the value of mangroves as $ 3.5 million/km^2/year (www. mangrovesforthefuture.org).

As mangrove ecosystem represents substantial connection between coastal habitat and terrestrial system, their degradation affect the ecological stability of coastal zone. Evidences suggested that coastal area with dense and thick mangrove shield has suffered fewer losses and less damage to property than those areas in which mangroves had been degraded or converted to other alternate uses (Dahdouh- Gurban *et al.*, 2005; Harakunarak and Aksornkoae, 2005; Kathiresan and Rajendran, 2005; Wetlands International, 2005). The sacrificial belt or coastal bioshield gave protection to lives of thousands of people in Bangladesh during Chakaria Sunderbans in 1960, Super cyclone of Orissa, 1999 (Das, 2011) and Wukong typhoon in Vietnam, 2000. After Asian tsunami, 2004 there has been a mounting call for re-establishing protective greenbelts along coastlines. Understanding the importance of mangroves in dissipating the storm surge/Tsunami impact the government of Sri Lanka and Thailand had initiated rehabilitation and replanting of mangroves trees (Harakunarak and Aksornkoae, 2005; UNEP, 2005).

Scientists have also highlighted the role of mangroves in sequestering carbon from the atmosphere and serving both as source and repository of nutrients and sediments for other inshore marine habitats, such as sea grass beds and coral reefs. Mangroves are one among the most carbon rich forests in the tropics, containing on an average 1.023 Mg carbon per hectare (Donato *et al.*, 2011). Among the mangrove species, *Rhizophora* sp. has the greatest ability of carbon sequestration (Fujimoto, 2004). In the estuarine region, mangroves play a pivotal role in moderating monsoonal tidal floods and in coastal protection. It supports numerous forms of wildlife and avifauna as well as estuarine and near-shore fisheries. Continuous depletion and degradation of these vital coastal resources leads to the serious impairment of the environmental stability of coastal forests that provide protection to inland agricultural crops and villages.

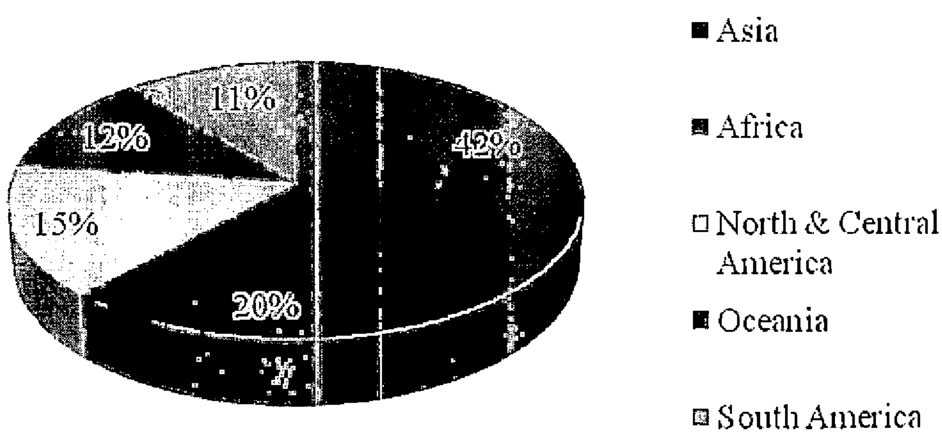
3. Global- Distribution

Two zones of mangrove distribution had been identified across the world viz. the eastern zone consisting of the East Africa, Thailand, Philippines, Southern Japan, Australia, New Zealand and the western zone consisting of the Atlantic coast of Africa and the America (Chapman, 1970; 1975). The first attempt on estimating the total mangrove area in the world was undertaken as part of the FAO/UNEP Tropical Forest Resources Assessment in 1980, where the area was estimated at 15.60 M ha spread in 51 countries (FAO/UNEP, 1981) (Table 1). Later, Tomlinson (1986) reported the presence of mangroves in almost 124 countries. FAO (2006) furnished an account of the area and distribution of mangroves globally. Asia accommodates largest mangrove area of the world with 42% (5.79 M ha) followed by Africa (20%). The rest of the area is located in North and Central America, Oceania and South America (Fig. 1). Palot and Jayarajan (2007) reported nearly 14 M ha of mangroves distributed in about 80 countries. However Giri *et al.* (2010) using earth observation satellite reported that mangroves are seen in 118 countries with an area of 13.78 Mha. Five countries (Indonesia, Brazil, Nigeria, Australia and Mexico) together account for about 48% of all mangrove area and 75% of the total mangrove area is found in just fifteen countries. The total mangrove area represents 0.7% of the total tropical forest of the world. The area estimate from these countries was based on ground surveys, remote sensing data and expert estimates.

Table 1: Global distribution of mangroves

Sl No.	Source of information	Year	No. of countries	Area (M ha)
1	FAO/UNEP Tropical Forest Resources A ssessment	1981	51	15.60
2	Fisher and Spalding	1993	91	19.80
3	Aizpuru *et al.*	2000	112	17.00
4	FAO	2006	-	13.79
5	Palot and Jayarajan	2007	80	14.00
6	Giri *et al.*	2010	118	13.78

Fig 1: Worldwide status of mangroves



Source: Adapted from FAO (2006).

Mangroves of South and South East Asia form the world's most extensive and diverse mangroves accommodating 41.4% of global mangroves i.e. nearly 6 M/ha (GEC, 2011; ITTO,

2012) (Table 2). Mangroves are present in almost all coastal nations of the Asian continent. The continent is an abode of species diversity of mangroves and more than 56 species were reported (FAO, 2007). Mangroves offer livelihood for numerous rural communities in Indonesia, Malaysia, Bangladesh and India.

Indonesia, Malaysia, Myanmar, Bangladesh and India together house more than 80% of total Asian mangroves (Fig. 2). Indonesia occupies the largest area with 50% share (20% of world mangrove) followed by Malaysia and Myanmar. India with 4.66 lakh ha occupies fifth position in mangrove area among the Asian countries. Sunderbans, the largest mangrove ecosystem in the world (covers about 2.84 % of global mangroves) is jointly shared by India and Bangladesh. Bangladesh also has equal mangrove area as in India. The rest of the Asian mangroves are located in West Asian countries such as Bahrain, Oman, Saudi Arabia and United Arab Emirates.

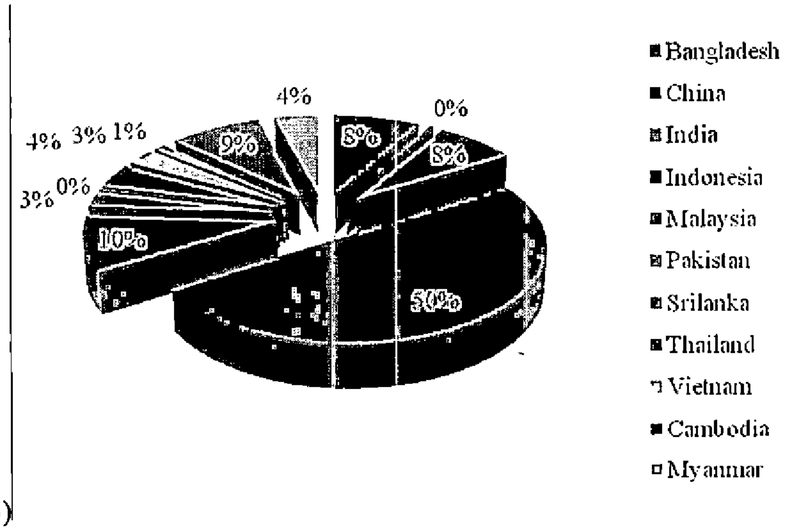
Table 2: Distribution of mangroves in Asia

Sl No.	Country	Year	Area (ha)	Area (ha) (2005)
1	Bangladesh	1995	476215 (8)	476000 (8)
2	China	2001	22480 (0.4)	22480 (0.4)
3	India	2003	446100 (7)	448000 (8)
4	Indonesia	2003	3062300 (51)	2900000 (50)
5	Malaysia	2005	564971 (9)	565000 (10)
6.	Pakistan	2001	158000 (3)	157000 (3)
7	Srilanka	1996	9530 (0.2)	8800 (0.2)

8	Thailand	2000	244085 (4)	240000 (4)
9	Vietnam	2000	157500 (3)	157500 (3)
10	Cambodia	1997	72835 (1)	69200 (1)
11	Myanmar	1999	518646 (9)	507000 (9)
12	Philippines	2003	247362 (4)	240000 (4)
	Asia	**2002**	**60,47,798** (100)	**58,57,575** (100)

Source: Developed from FAO (2006). Figures in parentheses represent percentage to total. The estimates are from different years. However percentage is calculated based on area estimate of Asia in 2002 and 2005.

Fig. 2: Distribution of mangroves in Asia



(2005)

Source: Adapted from FAO (2006).

4. Mangroves: the shrinking resource

Estuarine and coastal ecosystems are one among the most threatened natural systems in the world (Lotze *et al.,* 2006; Worm, 2006; Halpern *et al.,* 2008). World's mangroves are under pressure from both human and nature's furies. Regardless of the numerous services and benefits provided by mangroves, these coastal bio shields are repeatedly undervalued and viewed as wastelands, nuisance or unhealthy environments. To enhance food security, boost national economies, alleviate poverty and improve living standards, many countries have encouraged the development of shrimp and fish farming, agriculture and salt production in mangrove areas. In addition, high population pressure in coastal areas has also led to the conversion of many mangrove areas to alternate uses such as tourism, industrial uses and urban development.

It was reported that 35% of the world mangroves are lost in between 1980 and 2000 (M EA, 2005). Duke *et al.* (2007) predicted the complete loss of mangroves by 2100 mainly due to the destruction in Asian countries. Mathew *et al.* later in 2010 feared it to occur at an earlier date i.e. by 2050. FAO attributed high population pressure, the large-scale conversion of mangrove areas for shrimp and fish farming, agriculture, infrastructure and tourism, as well as pollution and natural disasters as the major causes for the destruction of mangroves.

The rate of loss of mangroves exceeds the loss of the rainforest at 2.1% c per annum. A whopping 36% of Asian mangroves have been deforested at the rate of 1.52% per year (Valiela *et al.,* 2001; MEA, 2005; FAO, 2007). The change in the status of mangrove ecosystem across the globe is compiled and presented in Table 3. The loss in total mangrove area around the globe was around 3.6 M ha since 1980, equivalent to an alarming 20%. The worst affected area is Oceania, where 28% of mangroves were lost between 1980 and 2010. The continent with largest mangrove area, Asia, lost 1.6 M ha of mangroves mainly due to changes in land use. Indonesia, Mexico, Papua New Guinea, Vietnam, Malaysia and Madagascar are reported to be the countries which have lost major area, between 1990s and 2000-2005 (FAO, 2007).

Table 4 details the rate of change in mangrove area over the years. The slowdown has occurred in the rate of mangrove depletion in the world from 1.88 M ha in the 1980 to 1.69 M ha in 1990 and later to 1.52 M ha during 2010. It is relieving to note that, the rate of decline has slowed down from 1.04 to 0.32% over the three decades. The progressive afforestation and rehabilitation measures and conservation of the existing mangrove ecosystem have been attributed as the reasons for the improved global growth rate. The change reflects an increased awareness of the value of mangrove ecosystems and it is clearly visible in case of the Sunderbans in Bangladesh and Ecuador. A significant reduction in the scale of destruction of mangroves occurred in South America with an impressive growth rate of 1.81% per year during the period 2000-10. Nearly one M ha of mangroves was planted between 1980 and 2010 due to adoption of sound conservation strategies.

The pattern is similar in Asian region too. North and Central American region is also slowly showing improving situation, even though the rate of decline still continues. An impressive growth rate in the area (2.86%) has taken place in African countries during 1990-2000 compared to the previous decade (-4.05%). But they lost the momentum in the next decade and ended up with a negative growth rate of 1.40 per cent in 2000-2010. Oceania, however exhibits increase in the rate of mangrove destruction. The recent rate of decline has reached a level of 2.33 per cent per annum.

In relative terms, countries with high deforestation rates include Singapore, Benin, Dominica, Brazil and Côte d'Ivoire in the 1980s and Côte d'Ivoire, Honduras, China, Congo and Barbados in the 1990s. Conversely, a number of countries have registered a positive change over time, including Bangladesh, where the world largest mangrove area (The Sundarbans Reserved Forest) is well protected and substantive and successful efforts have been made in coastal afforestation. The relatively large mangrove deforestation rates in Asia, the Caribbean and Latin America in the 1980s reflect large scale conversion of mangroves for aquaculture and tourism infrastructure.

The major cause of global mangrove loss has been the coastal economic development especially the aquaculture expansion (Barbier and Cox, 2003). Aquaculture contributes 58% to mangrove loss with shrimp farming alone accounting for 41% of total deforestation (Valiela *et al.,* 2001). The extraction of forest products from mangroves causes 26% of global mangrove loss and 16% in Asia, fresh water diversion accounts for 11% of loss globally and 14% in Asia and reclamation of land for other uses cause 5% and 7% of loss globally and in Asia respectively (Barbier, 2006). Apart from these, herbicide impacts, agriculture, salt ponds and other coastal developments also resulted in mangrove deforestation. The unsustainable levels of grazing and fishing activities, land reclamation and waste disposal are also the reasons for the large scale destruction and depletion of the mangrove areas. The widespread depletion of these coastal bioshield has occurred mainly in Asian countries like Thailand, Vietnam, Malaysia and Indonesia.

The Asian region has lost almost 20% of mangroves in the period of 1980–2010 and the 90% of the loss occurred in Indonesia, Pakistan, Vietnam, Malaysia and India. It is a positive sign that growth rate in Asia has improved between 1980 (-1.44%) and 2010 (0.10%). The rural masses of Asia depend on mangroves for timber, fish, fodder, fuelwood, thatching materials, medicine and honey. The main reason for the over exploitation and depletion of mangrove area in Indonesia and Thailand was a large scale development of shrimp farms. Owing to the lucrative economic return, shrimp farming has been promoted by the governments to boost national economies, as a latent source of earnings for local communities and as a method of poverty alleviation. In later years, realizing the negative impact on the ecosystem, the government of these countries has initiated corrective measures to restore the lost mangroves in the last few years.

The self-sufficient food production drive in India and Myanmar led to the conversion of mangrove lands to rice fields. Mangrove areas in China, Indonesia, Philippines and Vietnam have been used for salt production. While in Singapore and Pakistan, construction of dams and diversion of water for irrigation increased soil salinity, which damaged the surrounding mangroves (FAO, 2007). Anthropogenic pressure and subsequent urbanization drive cause damage to the mangroves, throughout the world, currently. Besides these human factors, natural hazards such as cyclones, storms, tsunamis and floods frequently occur in this region, threatening several coastal ecosystems, including mangroves. However, different Asian countries have initiated conservation of mangroves through rehabilitation and management and the decade 2000-10 witnessed a small improvement in mangrove area to 6.2 M ha.

Table 3: Global distribution of mangroves over the decades (Mha)

Region	1980	1990	2000	2010
Africa	3.67 (20)	2.42 (15)	3.21 (20)	2.79 (18)
Asia	7.79 (41)	6.74 (42)	6.16 (39)	6.22 (41)
North & Central America	2.95 (16)	2.59 (15)	2.35 (15)	2.24 (15)
Oceania	2.18 (11)	2.09 (14)	2.01 (13)	1.58 (10)
South America	2.22 (12)	2.07 (14)	1.99 (13)	2.38(16)
World	18.79 (100)	16.9 (100)	15.74 (100)	15.23 (100)

Figures in parentheses represent percentage to total Source: FAO, 2007; ITTO, 2012

Table 4: Average annual growth rate of global decline of mangroves (%)

Region	Compound growth rate (%)		
	1980-90	**1990-00**	**2000-10**
Africa	-4.05	2.86	-1.40
Asia	-1.44	-0.89	0.10
North & Central America	-1.29	-0.97	-0.49
Oceania	-0.43	-0.38	-2.33
South America	-0.69	-0.38	1.81
World	-1.04	-0.72	-0.32

5. Mangroves in India

Globally, one of the rarest and the richest mangrove ecosystems are seen in India which is located in 69–89.5^0 E longitude and 7–23^0 N latitude. The Indo- Malayasian region is considered to be the cradle of the evolutionary process of mangrove vegetation (Upadhyay *et al.*, 2002). The Indian mangroves comprise approximately 59 species in 41 genera and

29 families (Singh *et al.*, 2012). In India, major mangrove species diversity is reported in the Sunderbans (West Bengal) and Bitherkanika (Orissa) followed by Godhavari coast of Andhra Pradesh and Andaman & Nicobar Islands. The mangrove families viz. *Rhizophoraceae, Avicenniaceae, Acanthaceae* and *Meliacea* are reported from India (Thothathri, 1981). Three diverse types of mangroves are seen in India, the first being *deltaic mangroves* located on the east coast, Gulf of Kuchh and Khambhat Gulf on the west coast, covering more than 50% of the total Indian mangroves. The second type is *coastal mangroves*, which are found along the intertidal coastal lines, minor river mouths, sheltered bays and backwaters of the west coast. The *island mangroves* are found along shallow protected intertidal zones of bay islands such as Lakshadweep and Andamans (Ingole, 2005).

India has a long coastal belt of more than 7,500 km including Andaman & Nicobar Islands. Mangroves in India are spread over an area of 4.66 lakh hectares along the 5700 km coastal line (FSI, 2011) occupying 0.14% of the geographical area of the country with 3.1% of the global and 8% of Asian mangrove coverage. (FAO, 2007; FSI, 2011; Kathiresan, 2010; Singh *et al.*, 2012). The distribution of mangroves in India is presented in Table 4.5.

Mangrove cover in India has been categorized according to canopy density of more than 70% as very dense, between 40-70% as moderately dense and between 10-40% as open mangroves. Twenty six per cent of mangroves belong to the very dense category whereas moderately dense and open mangroves constitute 36 and 38%, respectively in India. West Bengal and Andaman & Nicobar Islands are the places where very dense mangroves are seen whereas moderately dense and open mangroves exist in other states. In Union territories of Daman & Diu and Pondicherry open mangroves only are seen (Singh *et al.*, 2012).

About 52% of the total Indian mangroves are located along the east coast of the country, primarily in West Bengal and Orissa. The rest is distributed along west coast (34 %) and the Andaman & Nicobar Islands (14%) (Fig 3). Sunderban mangroves, the largest mangrove delta of the world is located in India and Bangladesh. It occupies 30% of mangroves in India. The Sunderbans got its name from a mangrove species *Heriteira fomes* called Sundari in local language. Over 1,600 plant and 3,700 animal species have been identified in Indian mangrove ecosystem. West Bengal occupies maximum mangrove area (47.65%) followed by Gujarat (21

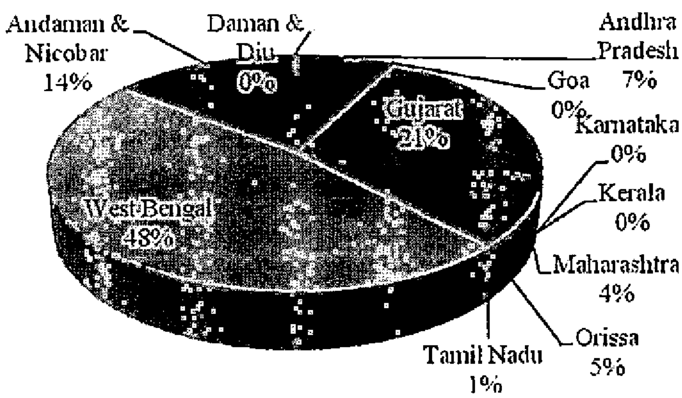
.06%) and the Union Territory of Andaman & Nicobar Islands (14.33%). The rest of the mangroves of the country are scattered in other coastal states like Andhra Pradesh, Orissa, Maharashtra, Tamilnadu, Goa, Kerala and Karnataka and in two Union Territories.

Table 5: Mangrove distribution in India (Area in ha)

Sl No.	State/UT	Very dense mangrove	Moderately dense mangrove	Open mangrove	Total	% to total area
1	Andhra Pradesh	0	1500	31400	32900	7.40
2	Goa	0	1400	200	1600	0.40
3	Gujarat	0	19500	74100	93600	21.06
4	Karnataka	0	300	0	300	0.07
5	Kerala	0	300	500	800	0.18
6	Maharashtra	0	5800	10000	15800	3.56
7	Orissa	0	15600	4700	20300	4.57
8	Tamil Nadu	0	1800	1700	3500	0.78
9	West Bengal	89200	89500	33100	211800	47.65
10	Andaman & Nicobar	25500	27200	11000	63700	14.33
11	Daman & Diu	0	0	100	100	0.12
12	Pondicherry	0	0	100	100	0.02
	Total	1,14700	1,62,900	1,66,900	4,44,500	100

Source:TNAU, 2012.

Fig. 3: Distribution of mangroves in India



Similar to the situation elsewhere, mangroves in India is also under threat. The National Remote Sensing Agency report showed 40 per cent of mangroves in India as destroyed. The destruction was to the tune of 7,000 hectares between 1975 and 1981 (Madhusoodhanan and Vidyasagar, 2012). Anthropogenic pressures, expansion of agricultural and salt making lands, development of industries and ports and the expansion of coastal aquaculture are the critical factors for the depletion and destruction of mangroves in India. The economic and ecological significance of mangroves are not properly perceived by the public. Hence the conservation approach was generally absent, though the legal protection is there. For sustainable use and conservation of mangrove areas the Supreme Court of India has included mangrove environment under the Coastal Zone Regulation-1(CRZ-1). Mangroves have been declared as ecologically sensitive areas under the Environmental Protection Act, 1986 as well.

6. Mangroves in Kerala

Kerala with a coastal line of about 590 km, 35 to 120 km in width and 41 rivers emptying into the Arabian Sea, was once very rich in mangrove formations, perhaps next only to the Sunderbans. Kerala has more than 900 km2 of interconnected waterways, rivers, lakes and inlets that together constitute the Kerala backwaters. In the state, mangroves are seen as narrow strips confined to the mud flats of delta, on the leeward faces of estuaries and also the embankments of the coast. The mangrove ecosystem of Kerala is nested within the upper reaches of estuaries, lagoon, backwaters and creeks along the coastal belt. This interlinked network of waterways forms an excellent matrix for the dispersal of mangrove propagules and the regulation of soil salinity, the two crucial factors determining mangrove presence and long term persistence in a landscape. From time immemorial these rich wetlands have been providing livelihood to thousands of people especially in the coastal areas in the form of fish, fuelwood, fodder and other key ecological services. The first report of existence of mangrove vegetation along Kerala coast was given in the illustrious work *Hortus Indicus Malabaricus* (Van Rheede, 1678-1703).

Kerala coast, covering 10% of the country's coastal line has only less than one per cent of India's total mangrove ecosystem. All along the coast, occurrence of small mangrove is seen in isolated patches along the fringes of estuaries and backwaters (especially in South Kerala) and also along the river lines in the coastal areas. Mangroves of the state are less complex in terms of tidal creek networks compared to the dense complex networks of mangrove ecosystems along the east coast of the country (Naskar and Mandal, 1999).

The scientific estimates of the area under mangroves in Kerala are scanty. An estimate based on authentic record (Blasco, 1975) indicated that there were about 70,000 ha of mangroves in the state, have now reduced to few hundred hectares and observed that only the remnants or vestigial stock of mangroves existed in many parts of the state largely confined to some estuaries and creeks. A compilation of reports on the area by different authors is presented in Table 4.6. Ramachandran and Mohanan (1987) reported that until a few centuries ago, backwaters of Kerala were fringed with extensive mangrove vegetation and it was based on discussion with the older people and local enquires. The mangrove area estimate based on observations and local enquiry by Basha, (1991) reported that it was 1,671 ha. The estimate of Kurien *et al.* (1994) is in conformity with this report. Mohanan (1997) estimated the mangrove spread as 4,200 ha which showed significant improvement. This might be due to the methodological differences in estimation.

In 2003, the Forest Survey of India reported it as 800 ha. But, Unni in the same year reported double the area.which is similar to 1991 study. Later in 2006, Radhakrishnan *et al.* reported the area as 4,118 ha. However area estimate using remote sensing by FSI (2009, 2011) reported only 500-600 ha. Based on the latest field investigation by the Kerala Sasthra Sahitya Parishad (KSSP), Madhusoodhanan and V idyasagar (2012) reported about 2,502 hectares of mangroves in the state. But the estimates are based on visual judgments and lack scientific basis. The most authentic report on the area under mangroves in Kerala is by FSI (2003, 2005, 2009 and 2011) based on remote sensing data. However this needs to be validated through ground level survey. Thus, realistic scientific estimation of mangroves in the state is highly warranted.

Table 6: Area under mangroves in Kerala

Sl No.	Authors	Area (ha)
1	Basha, 1991	1671
2	Kurien, 1994	1095
3	Mohanan,1997	4200
4	FSI, 2003	800
5	Unni, 2003	1650
6	Radhakrishnan *et al.*, 2006	4118
7	FSI, 2009	500
8	FSI, 2011	600
9	Madhusoodhanan and Vidyasagar, 2012	2502

A journey particularly in train from Thiruvanathapuram to Kasargode along the coastal belt provides ample evidence for the presence of mangroves along the coast and in some pockets mangroves have still not lost their natural regeneration capacity. Mangroves are present in all the ten coastal districts of Kerala. Majority of mangroves in Kerala are mainly seen in Kannur (44%) followed by Ernakulam (24%) (Table 4.7). The four northern districts of Malappuram, Kozhikode, Kannur and Kasargode account for more than 60% of the mangrove area of the state, imparting higher heterogeneity in the ecosystem than the Southern part (Fig. 4.4). After comparing the two studies, Basha (1991) and Madhusoodhanan and Vidyasagar (2012), a sizeable area reduction has noticed in Kozhikkode district (17.5% to 5.6%). However, overall mangrove area seems to have increased. But both of these studies are not based on scientific methods of area estimation.

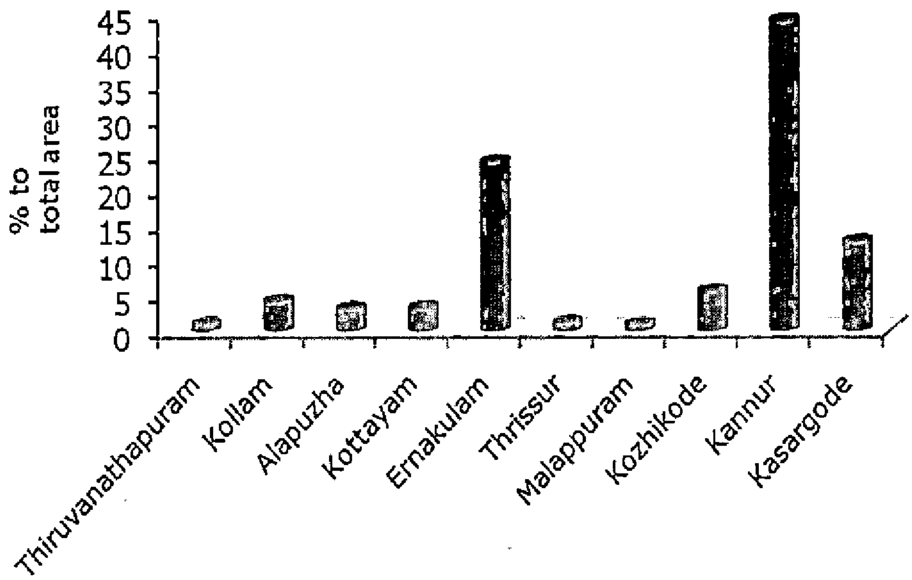
Mangroves in Kerala are spread mainly in the districts of Kannur, Ernakulam and Kasargode. Even scanty presence of mangroves in the other districts plays important ecological functions and economic role in the local economics. Mangroves of Kollam (Ashramam) and Kottayam (Kumarakom) has prominent place in the tourism map of Kerala. Mangroves of Kumarakom, Mangalavanam (Cochin) and Kadalundi (Kozhikode) are the hot spots of birds, especially migratory birds. The first Community Reserve for Mangroves in South India was established in Kadalundi (Hema and Devi, 2012). Mangroves there acted as protective shield in the area during Asian tsunami of the year 2004. The local communities depend on this ecosystem for livelihood activities.

Table 7: District wise area distributions of mangrove vegetation along Kerala coast (ha)

Sl No.	Districts	1991	1994	1997	2003	2012	% to total area (2012)
1	Thiruvanathapurm	23	-	15	23	28	1.1
2	Kollam	58	-	15	58	105	4.2
3	Alapuzha	90	-	25	90	78	3.1
4	Kottayam	80	-	20	80	80	3.2
5	Ernakulam	260	89	250	260	600	24.0
6	Thrissur	21	41	25	-	30	1.2
7	Malappuram	12	-	100	12	26	1.0
8	Kozhikode	293	23	200	293	140	5.6
9	Kannur	755	939	3500	755	1100	44.0
10	Kasargode	79	-	50	79	315	12.6
	Total	1671	1095	4200	1650	2502	100

Source: Basha,1991; Kurien *et al.*, 1994; Mohanan, 1997; Unni, 2003; Madhusoodhanan and Vidyasagar, 2012

Fig. 4: Distribution of mangroves in Kerala, 2012



The species diversity of mangrove vegetation in the state is considered to be high. Unni (2004) and Khaleel (2009) reported 18 true mangrove species and 23 associates from the state. Anupama and Sivadasan (2004) reported only 15 true mangroves. But the mangrove associates were nearly three times, i.e. 49 in number belonging to nine genera and seven families. Madhusoodhanan and Vidyasagar (2012) also found 15 species but could locate only 33 associates. Table 9 furnishes the common mangrove species in Kerala and its major uses. The important mangrove families commonly seen in Keral are *Rhizophoraceae, Avicenniaceae* and *Sonneratiaceae*. *Avicennia oficinalis, Avicennia marina, Bruguiera cylindrica, Excoecaria agallocha, Kandelia candel, Rhizophora mucronata* and *Sonneratia caseolaris* are the commonly seen mangrove species in Kerala. *Sonneratia alba* is the species very rarely seen in the state and it is reported from Tirur (Malappuram) in the year 2012. Two species *Derris trifoliate* and *Acrostichum* are also reported from the state, but scientific community is yet to make conclusions on these two.

Table 9: Major species of mangroves in Kerala

Sl No.	Scientific name	Family	Local name & distribution	Uses
1	*Acanthus illicifolius*	Acanthaceae	Chulli, C*	Medicinal
2	*Aegiceras corniculata*	Myrsinaceae	River mangrove, Pookandal, M*	Fuelwood
3	*Avicennia oficinalis*	Avicenniaceae	White mangrove, Uppatti, C*	Fuelwood, Fodder, Medicinal,
4	*Avicennia marina*	Avicenniaceae	Cheru upputti, C*	Fodder
5	*Bruguiera cylindrica*	Rhizophoraceae	Kuttikandal, C*	Timber, Cork making, Medicinal,
6	*Bruguiera gymnorrhiza*	Rhizophoraceae	Kara kandal O*	Timber, Medicinal, Live fence
7	*Bruguiera parviflora*	Rhizophoraceae	O*	Fuelwood
8	*Bruguiera sexangula*	Rhizophoraceae	R*	Fuelwood, Timber
9	*Excoecaria agallocha*	Euphobiaceae	Kanambhotti, Komatti, C*	Cork making, Medicinal
10	*Excoecaria indica* / *Shi rakiopsis indica* (new name)	Euphobiaceae	R*	M edici nal
11	*Kandelia candel*	Rhizophoraceae	Cherukandal, Ezhuthanni kandal, C*	Fuelwood, Medicinal
12	*Lumnitzera racemosa*	Combretaceae	Black mangrove, Kada kandal, O*	Timber

13	*Rhizophora mucronata*	Rhizophoraceae	Peekandal/Prathan kandal, C*	Timber, Medicinal
14	*Rhizophora apiculata*	Rhizophoraceae	Vallikandal, O*	Fuelwood, Medicinal
15	*Sonneratia caseolaris*	Sonneratiaceae	M angrove apple, Blathi kandal, C*	Fuelwood, Medicinal
16	*Sonneratia alba*	Sonneratiaceae	Nakshathra kandal, R*	Fodder, Fuelwood, Timber

Source: Anupama and Sivadasan, 2004; Radhakrishnan *et al.*, 2006; Pattanaik *et al.*, 2008; Khaleel, 2009; Madhusoodhanan and Vidyasagar, 2012.

M*- Malabar Coast, C*-Common, R*-Rare, O*- Occasional

Majority of these mangrove species are either used for fuelwood or timber. The most preferred species for the fuel wood is *Rhizophora* sp. especially its stilt roots. Local communities prefer mangrove species for their fuel wood requirement owing to its easy accessibility, high fuel efficiency and easy drying nature. Mangrove species in Kerala have medicinal properties as well. *Avicennia oficinalis, Bruguiera cylindrica, Excoecaria agallocha* and *Excoecaria indica* are generally used in home remedies. The fruit of *Avicennia* sp. are used in the treatment for rheumatism. The wood of *Bruguiera cylindrica* and *Excoecaria agallocha* are used for cork making. However the younger generation among the local communities has only limited knowledge.

7. Mangroves in Kerala: The conservation- Development debate

The backwaters of Kerala are playing a significant role in the growth of mangroves along the coast especially in Kollam, Alappuzha, Kottayam and Ernakulam districts. The scanty and patchy distribution of mangroves in Kerala could be attributed to the microtidal nature of estuaries and limited intertidal mud flats along the banks (Jagtap *et al.*, 2004). However major development initiatives of the state are concentrated in these coastal belts leading to the large scale destruction of mangroves. The demographic pressure on land in the state is very high due to the high population density (859/km^2). The economic development strides also exert great pressure on the scarce land resources of the state.

Kerala is the only state in India where mangrove area is not under the control of state forest department. The mangroves patches in the state are owned by Government departments (Fisheries, Revenue, local self governments, Forest and Tourism), quasi-government agencies (Kerala Agricultural University), Central government (Railways) and major share under private ownership. More than 85% of mangrove area in Kerala is under the private holdings/ownership (Lakshmi, 2002; Unni, 2003). Rough estimates show only 200 hectares as under government or quasi-government ownership. The government of India has notified mangrove ecosystems under CRZ-I category. Hence, clearance or utilization of mangroves for alternate purpose is forbidden. But because of the surging land prices, the private owners, especially in urban areas prefer to clear off the mangroves to fetch better price in the land market. (Mangrove ecosystems are generally considered as waste lands and hence low priced). The local community's dependence on mangroves for livelihood are slowly declining as the younger generation is migrating, both occupational and geographic.

During early periods 90% of mangroves in Kerala were destroyed either for paddy cultivation, coconut orchard or for land reclamation (Ramachandran *et al.*, 2005). The demographic pressure along with industrial needs has resulted in large scale reclamation of many productive wetlands like paddy fields and the marshy tracts along the coastal line.

Destruction of mangroves is more visible in Southern part of Kerala especially in and around Cochin backwaters compared to Northern part of Kerala. The presence of environmental activist groups SEEK (Society for Environmental Education, Kannur), Kerala Sastra Sahitya Parishad, Malabar Natural History Society to cite a few in north Kerala restrict the chances of destruction. Further the CRZ rules (1991) and Kerala Conservation of Paddy land and Wetland act (2008) also limits the conversion process.

Mangroves in Ernakulam districts are mostly grown along the Cochin backwaters under the strong influence of Vembanad Lake (Ramsar site). Being the commercial hub of the state, all the developmental activities in Kochi is concentrated along the backwaters. The mangroves along the Cochin backwaters are incessantly subjected to large scale destruction for different developmental projects such as International Container Transshipment Terminal (ICTT) Vallarpadam, LNG Petronet Terminal, residential projects in Maradu and neighbouring areas. More than 100 hectares of the Government's land (those of the Fisheries Research Station, of erstwhile Kerala Agricultural University) was cleared for the establishment of LNG Petronet Terminal. There are reports of regular conflicts between local fishermen and the security personnel of CISF (Central Industrial Security Force). Fishing and fishermen were not even allowed to travel through the nearby creeks to their fishing grounds which severely affected their livelihood. The situation is similar to that of ban imposed by the Government of Orissa around the marine wildlife sanctuary in the mangrove zone of Paradeep (Venkatesh, 2006).

Mangroves were also cleared for the construction of roads and bridges while implementing Goshree Island development project in Ernakulam. An International cricket stadium was proposed by Kerala Cricket Association (KCA) at Edakochi, in the outskirts of Cochin Corporation in 9.3 hectares of land. The site is a wetland (Pokkali lands with mangroves in the fringes of the field). The region is also part of Vembanad Lake, a Ramsar site. KCA has initiated the preliminary works with clearing mangrove habitats in the field. However, with the intervention of environmental groups and other activists, the court intervened in the issue and later the work has been withheld after an order from Union Ministry of Environment and Forests (MoEF). This conflict is yet to be resolved.

More importantly, the area is a rich pool of *Avicennia*, a variety of mangroves which separates salt content from saline water and deposits it on its leaves reducing the salinity in water. The scientific studies need to be initiated in this regard to elicit the particular gene of *Avicennia* which enables this separation and inculcate it into crops to make them saline water resistant. The research on development of saline water resistant crops can be gained through this gene. About 20 acres of mangrove land was recently acquired from the Fisheries Research Station, Puthuvypu for the establishment of National Oceanarium. The State Fisheries Resource Management Society (FIRMA), implementing agency of the project has offered to plant, nurture and maintain mangroves either at Vypeen or Valanthakadu Island in lieu of the mangroves that would be lost or disturbed while the project is being implemented. Kerala State Coastal Zone Management

Authority (KSCZMA) decided to give in-principle approval for the project. The actual extent of destruction of mangroves can be estimated only after Environment Impact Assessment (EIA).

Similar instances of massive mangrove destruction are also reported from North Kerala, though on a lower scale. A mangrove theme park was opened up by the Pappinnisserri Ecotourism Society in an area of 4.85 hectares in ecologically fragile mangrove area in Kannur district. Later the park was closed following the directions of the Honorable Supreme Court of India, due to social and ecological reasons.

The maximum genetic diversity of mangroves in the state is reported from Kunhimangalam in Kannur where large scale deforestation of mangroves are reported in lieu of shrimp farming and other developmental activities (Khaleel, 2009 and local opinion). The mangrove lands are effortlessly reclaimed after purposeful human inflicted damages to the stem and subsequent drying up of trees.

Mangrove vegetation along the coast especially in the riverside had been cleared from early period for agriculture and human settlements and currently the vestiges of mangrove bushes are seen along the coast. Unplanned and unscientific bund construction in the mangrove areas has resulted in great toll of organisms dependent on mangroves. These bunds affect the natural habitat and affect the fish wealth. In Kerala, railway lines are mostly passing through coastal areas. There was large scale destruction of mangroves in Kozhikode, Kannur and Kasargode districts for the doubling works of Mangalore- Shornur railway line.

The coastal Kerala has been harboring luxuriant growth of mangroves in the past which is being depleted in extent and quality due to various biotic interferences. The various reasons attributed for the drastic loss of mangrove areas in Kerala are illegal cutting of mangrove trees for fuel wood, over grazing for fodder, fish and shrimp culture, indiscriminate encroachment of land for developmental activities, conversion of mangrove lands into coconut plantations and sand mining. The change in the land use pattern consequently led to the degradation of all wetlands including mangroves. Apart from the erratic and insufficient runoff to the coastal area, excessive sand mining from the river bed especially in the coastal tracts of Malappuram and Kozhikode district had heavily threatened the very existence of the unique mangrove ecosystem. (Radhakrishan *et al.*, 2006).

The important reason for the large scale land filling in the coastal area of sea, river or lake or small canals in Kerala is the absence of clear cut boundary line. Nearly 80% of the mangroves are owned by the private people, the absence of marked boundary in the marshy mangrove area aggravate the reclamation activity. When water recedes in the summer months exposing the mud flats the reclamation is easy.

The mangrove flora which has high natural regenerative capacity has remained stunted in many pockets in the coastal area. This is primarily due to pollution from urban and rural areas. The mangrove depletion in the state has reached to the extent that the functional role of the mangrove ecosystem in both hydrological and biotic terms has been narrowed down. Many wetlands are over loaded with heavy metals, other toxic substance, plastic and degradable and non degradable substances. In many places eutrophication has inhibited the growth of the biota in the natural habitat.

V. Conclusion

Mangroves are invaluable treasure of our biodiversity with immense ecological and economic significance. They are proven to be highly productive wetland ecosystems with multiple socio-economic, environment and ecosystem functions. However, this ecosystem is largely threatened and is being degraded in most countries owing to anthropogenic activities and unsustainable exploitation. Scientific attention on mangrove ecosystem was prominent during the post tsunami period. Studies, later on confirmed the storm protection function of the ecosystem. Consequently, there have been global efforts for restoration and conservation of these ecosystems. Though the global mangrove area has declined over years, the rate of decline is slowing down. The pattern is similar in India too. Restoration and conservation of existing mangrove assumes significance in view of the ecosystem functions than the direct benefits. The legal, social and political efforts are to be pooled towards achieving the goal.

References

Ahmad, I., Tjaronge, M. and Suryati, E. (2003) Performances of Tiger shrimp culture in environmentally friendly ponds. *Indonesian Journal of Agricultural Science,* 42(2): 48-55.

Aizpuru, M., A chard, F. and B lasco, F. (2000) *Global assessment of cover change of the mangrove forests using satellite imagery at medium to high resolution.* In: EEC Research project n 15017-1999-05 FIED ISP FR – Joint Research Centre, Ispra.

Aksornkoae, S., Maxwell, G.S., Havanond, S. and Panichsuko, S. (1992) *Plants in mangroves.* Bangkok:I UCN Asian Regional Office.

Anupama C. and Sivadasan, M. (2004) Mangroves of Kerala, India. *Rheedea,* 14(1): 9-46.

Barbier, E.B. (2006) Natural barriers to natural disasters: replanting mangroves after the tsunami. *Frontiers in Ecology and the Environ*ment, 4(3): 124-131.

Barbier, E.B. and Cox, M. (2003) Does economic development lead to mangrove loss? A cross-country analysis. *Contemporary Economic Policy,* 21(4): 418-432.

Basha, C.S. (1991) Distribution of mangroves in Kerala. *Indian Forester,* 117: 439- 448.

Blasco, F. (1984) *Taxonomic considerations of the mangrove species.* In: The mangrove ecosystem: research methods. Paris: UNESCO, pp: 81 - 90.

CED [Centre for Environment and Development]. (2003) *Survey and Inventory of wetlands of Kerala for conservation and sustainable management of resources.* Project Report, Kerala Forest Department, Thiruvananthapuram, Kerala.

Chapman, V.J. (1970) Mangrove phytosociology. *Tropical Ecology,* 11: 1-9.

Chapman, V.J. (1975) *Mangrove vegetation.* Lehre: J. Cramer publishing company.

Dahdouh-Guebas F., Jayatissa L.P., DiNitto, D. (2005) How effective were mangroves as a defence against the recent tsunami? *Current Biology*, 15: 443–47.

Donato, D.C., Kauffman, B., Murdiyarso, D., Kurnianto, S., Stidham, M. and Kanninen, M. (2011) Mangroves among the most carbon rich forests in the tropics. *Nature Geoscience*, 4: 293-297.

Duke, N.C., Meynecke, J.O., Dittmann, S., Ellison, A.M., Anger, K., Berger, U., Cannicci, S., Diele, K., Ewel, K.C., Field, C.D., Koedam, N., Lee, S.Y., Marchand, C., Nordhaus, I. and Dahdouh-Guebas, F. (2007) A world without mangroves? *Science*, 317: 41–42.

Duarte, C.M. and Cebria´n, J. (1996) The fate of marine autotrophic production. *Limnology and Oceanogaphy*, 41: 1758- 1766.

FAO [Food and Agricultural Organization, UNEP [United Nations Environmental Programme]. (1981) *Tropical Forest Resourcess Assesment Project, Forest Resources of Tropical Asia.* FA O, UNEP, 475 pp.

FA O [Food and Agricultural Organization]. (1994) *Mangrove forest management guidelines.* FA O Forestry Paper 117, Rome: Food and Agricultural Organization.

FAO [Food and Agricultural Organization]. (2006) *Global Forest Resources Assessment 2005 – progress towards sustainable forest management.* FA O Forestry Paper 147, Rome: Food and Agricultural Organization.

FAO [Food and Agricultural Organization]. (2007) *The worl d's mangroves 1980-2005.* FAO Forestry Paper 153, Rome: Food and Agricultural Organization.

Fisher, P. and Spalding, M.D. (1993) *Protected areas with mangrove habitat.* Cambridge, UK: UN EP-World Conservation Monitoring Centre.

FSI [Forest Survey of India]. (2003) *State of Forest Report.* Dehradun, India: Forest Survey of India.

FSI [Forest Survey of India]. (2009) *State of Forest Report.* Dehradun, India: Forest Survey of India.

Fujimoto, K. (2004) Below ground carbon sequestration of mangrove forest in the Asian-Pacific region. In: *Mangrove management and conservation: Present and future,* Ed: Vannucci, M. Japan: United Nations University Press, pp. 138-146.

GEC [Gujarat Ecology Commission]. (2011) *Socio- economic and ecological benefits of mangrove plantation.* Ahmedabad, Gujarat: Gujarat Institute of Development Research (GIDR), 164p.

Giri, C., Ochieng, E., Tiesszen, L.L., Zhu, Z., Singh, A., Loveland, T., Masek, J. and Duke, N. (2010) Status and distribution of mangrove forests of the world using earth observation satellite data. *Global Ecology and Biogeography,* 20(1): 154-159.

Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., lenihan, H.S., Madin, E.M.P., Perry, M .T., Selig, E.R., Spalding, M., Steneck, R. and Watson, R. (2008) A global map of human impacts on marine ecosystems. *Science,* 319: 948–952.

Harakunarak, A. and Aksornkoae, S. (2005) Life saving belts: Post tsunami reassessment of mangroves ecosystem values and management in Thailand. *Tropical Coasts,* 7: 48-55.

Hema, M. and Devi, P.I. (2012.) Socioeconomic impacts of the community based managements of the mangrove reserve in Kerala, India. *Journal of Environment Professionals Sri Lanka,* 1*(2):* 30-45.

Ingole, B. (2005) Indian Ocean coastal ecology. *Encyclopedia of Coastal Science,* pp. 446 -554.

International Tropical Timber Organization [ITTO]. (2012) *Tropical Forest Update,* 21(2): 20-24. [Online]: Available http://www.itto.in//tfu/. Accessed on [11th Dec. 2012].

Jagtap. T.G., Ansari, Z.A., Coutinho, F B., Charulata, S. and Gaidhane, D.M. (2004) Impact of climate change on mangrove forests along the South west coast: A case study from Kasargode, Kerala, India. In: Proceedings of the workshop on Vulnerability Assessment and Adaptation due to climate change on Indian Agriculture, Forestry and Natural Ecosystem, Ed: Ravindranath, N.H., Sharma, S.K., Garge, A. and Bhattacharya, S. and Murthy, I.K. Ministry of Environment and Forest, Government of India. pp:136- 149.

Kapetsky, J.M. (1985) Mangroves, fisheries and aquaculture. Rome: *FAO Fisheries and Aquaculture Report* 338: 17-36.

Kathiresan, K. and Rajendran, N. (2005) Coastal mangroves forests mitigated tsunami. *Estuarine Coastal and Shelf Sciences,* 65: 601-606.

Kathiresan, K. (201 0) Importance of mangroves forest of India. *Journal of Coastal Environment,* 1:1-26.

Khaleel, K. M. (2009) *Study of the ecosystem services and socioeconomic impact of mangrove wetlands of North Malabar.* Research project. Kerala State Council for Science Technology and Environment (KSCSTE), Thiruvanathapuram, 124p.

Khan, M.N.I., Suwa, R. and Hagihara, A. (2007) Carbon and nitrogen pools in a mangrove stand of *Kandelia obovata (S.,* L.) Yong: Vertical distribution in the soil-vegetation system. *Wetlands Ecology and* Management, 15:141-153.

Kurien, J. (2001) The socio-cultural aspects of fisheries: Implications for food and livelihood security: A case study of Kerala state, India. In: *Understanding the cultures of fishing communities: A key to fisheries management and food security,* Ed: Goodwin, J.R.M. FAO Fisheries Technical Paper 401:196-217.

Lakshmi, K. (2002) *Ecological studies on the mangroves of Valapattanam and Thalassery River basins.* Ph.D thesis, University of Calicut, 279p.

Lotze, H.K., Lenihan, H.S., Bourque, B.J., Bradbury, R.H., Cooke, R.G., Kay M.C., Kidwell, S.M., Kirby, M.X., Peterson, C.H. and Jackson, J.B.C. (2006) Depletion, degradation, and recovery potential of estuaries and coastal seas. Science, 312: 1806–1809.

Lugo, A.E. and Snedaker, S.C. 1(975) Properties of a mangrove forest in southern Florida. pp.170–212. *Proceedings of the International Symposium on Biology and Management of Mangroves,* In: EDs.: Walsh, G.E., Snedaker, S.C. and Teas, M .J. Florida, USA: University of Florida.

MacKinnon, J. and MacKinnon, K. (1986) *Review of the protected areas system in the Afrotropical realm.* Gland, Switzerland: UN EP/IUCN.

MacNae, W. (1968) A general account of the fauna and flora of mangrove swamps and forest in the Indo-West pacific region. *Advances in Marine Biology*, 6: 73-270.

Madhusoodhanan, V. K. and Vidyasagar, K. (2012) *Keralathille kandalkkadukkal.*K erala Sasthra Sahithya Parishad, 92p.

Mangroves for the future. (2012) [Online]: Available: http://www.mangrovesforthefuture.org/ Accessed on [12th Dec.2012].

Mathew, G., Jeyabaskaran, R. and Prema, D. (2010) Mangrove Ecosystems in India and their Conservation. In: *Coastal Fishery Resources of India - Conservation and sustainable utilization,* Eds: Meenakumari, B., Boopendranath, M. R., Edwin, L., Sankar, T.V., Gopal, N. and Ninan, G. Cochin: Society of Fisheries Technologists, pp. 186-196.

MEA [Millennium Ecosystem Assessment]. (2005) Ecosystems and human well-being: current state and trends. *Coastal systems.* Washington, D.C., USA: Island Press.

Mohanan, C.N. (1997) The Mangroves. In: *Natural Resources of Kerala,* Eds: Tampi, K.B.,Nayar, N.M and Nair, C.S. Thiruvananthapuram, Kerala: WWF- India, pp. 149-158.

Nambiar, G.R. and Raveendran, K. (2009) Exploration of untapped potentiality of coastal paddy fields of Kerala (India) - A case study. *Middle -East Journal of Scientific Reearch,* 4(1): 44-47.

Naskar, K. and Mandal, R. (1999) *Ecology and biodiversity of Indian mangroves. Part-I, Global status,* Delhi: Daya Publishing House, 361p.

Palot, M .J. and Jayarajan, O. (2007) *Kandal kadukal theeradesha nithyaharitha vanam.* District Forestry Extension and Information Centre, Kannur: Kerala Forest Department, 24p.

Pattanaik, C., Reddy, C.S., Dhal, N.K. and Das, R. (2008) Utilization of mangrove forests in Bhittarkanika wildlife sanctuary, Orissa. *Indian Journal of Traditional Knowledge,* 7 (4): 598-603.

Radhakrishnan, C., Gopi, K.C. and Palot, M.J. (2006) Mangrove and their faunal associates in Kerala, with special references to Northern Kerala, India. *Records of the Zoological Survey of India,* 246:1-81.

Ramachandran, K.K., Mohanan, C.N., Balasubramanian, G., Kurian, J. and Thomas, J. (1987) *The mangrove Ecosystem of Kerala: Its Mapping Inventory and Some Environment Aspects.* Trivandrum, Kerala: Centre for Earth Science Studies, 38pp.

Saenger, P., Hegerl, E.J. and Davie, J.D.S. (1983) *Global status of mangrove ecosystems.* Commission on Ecology Papers No. 3. World Conservation Union (IUCN): Gland, Switzerland,

Saenger, P. (2002) *Mangrove ecology, silviculture and conservation.* D ordrecht: K luwer Academic Publishers, 360pp.

Sathirathai, S. and Barbier E.B. (2001) Valuing mangrove conservation in southern Thailand. *Contemporary Economic Policy,* 19: 109–22.

Singh, A.K., Ansari, A., Kumar, D. and Sarkar, U.K. (2012) Status, biodiversity and distribution of mangroves in India: An overview. In: *Seminar on Marine Biodiversity,* Utter Pradesh State Biodiversity Board, Lucknow, 22 May.

Thothathri, K. (1981) Studies on the mangroves of peninsular India versus the Andaman and Nicobar Islands. *Bulletin of Botanical Survey of India,* 23 (3&4): 151-154.

TNAU [TamilNadu Agricultural University]. (2012) Mangroves of India [Online]:Available:http://agritech.tnau.ac.in/forestry/forest_mangrove_index.html Accessed on [10th Sept. 2012].

Tomlinson, P.B. (1986) *The botany of mangroves.* Cambridge, UK: Cambridge University Press.

Unni, P.N. (2003) Conservation of mangroves in Kerala. pp. 16-27. In: *Prospects and problems of Environment: Across the millennium,* Eds: Madhyastha, M.N., Sridhar, K.R. and Lakshmi, A. Delhi: Daya Publishing House, 323p.

Unni, P.N. (2004) Mangrove biodiversity of Kerala and its management. In: Proceedings of the *Training Workshop on Conservation of Mangrove Ecosystem.* MoEF, Govt. of India, Forests and Wildlife Department, Govt. of Kerala & OISCA International South India Chapter, Kannur, Kerala, India, 25-27 June.

Upadhya, V.P., Ranjan. R. and Singh, J.S. (2002) Human- mangrove conflicts: The way out. *Current Science* 82(11): 1328-1336.

UNEP (United Nations Environment Programme). (2005) After the Tsunami: Rapid environmental assessment. UNEP Report, Nairobi, [Online]: Available:http://www.unep.org//tsunami/reports Accessed on [12th Feb. 2011].

UNEP [United Nations Environment Programme)]. (2011) *Economic analysis of mangrove forest: A case study in Gazi Bay, Kenya.* United Nation Environment Programme [UNEP] iii, 42p.

Valiela, I., Bowen, J.L. and York, J.K. (2001) Mangrove forests: One of the world's threatened major tropical environments. *BioSicence,* 51:807–815.

Van Rheede, H .A. (1 678-1703) *Hortus Indicus Malabaricus,* Vol.1-12, Ámsterdam.

Vannucci, M. (1989) *The mangrove and us- A synthesis of insights.* New Delhi: Indian Association for the Advancement of Science.

Walsh, G.E. (1974) *Mangroves in: Ecology of halophytes.* New York: Academic Press, 51-174.

Wetland International. (2005) *Wetland International Annual Review.* [Online]: Available: http://www.wetlands.org. Accessed on [11th Jan. 2013].

Worm, B. (2006) Impacts of biodiversity loss on ocean ecosystem services. *Science,* 314: 787–790. www.mangrovesforthefuture.org

Homegardens– Sustainable Models For Small Farms

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Homegarden is one of the major farming systems in the uplands of Kerala, a state which is characterised by a predominance of small holdings. Known by various names such as mixed garden horticulture (Terra, 1954), compound farms (Lagemann, 1977), mixed garden/ house garden (Stoler, 1978), homestead agroforestry (Nair and Sreedharan, 1986; Leuschner and Khalique, 1987) and several others homegardening is practised in various parts of the world by resource poor farmers mainly as a survival strategy.

The integrated system of farming practised by the farmer in the land surrounding his dwelling place has been defined differently by various authors. Ninez (1984) considered homestead as a sub system which aims at the production of household consumption items. Soemarwoto and Soemarwoto (1984) defined homegarden as an agroforestry system which ideally combines the ecological functions of forests with those of providing the socio-economic needs of the people. Hanman (1986) referred homestead to the home and its adjoining land owned and occupied by the dwelling unit of the household, including the immediate area surrounding the dweller's unit and the space used for cultivation of trees and vegetables. Soemarwoto (1987) described homestead as a system for the production of subsistence crops for the farmer and his family which may or may not have the additional production of cash crops. Jacob (1997) defined home garden/homestead as a functional/operative and self sustaining farm unit which consists of a collection/assembly/conglomeration of crops and multipurpose trees, planted arbitrarily, with or without animals/poultry/apiculture, owned and primarily managed by the dwelling farm family, with the objectives of satisfying the basic family needs (food, fuel, timber) and producing marketable surplus for the purchase of nonproducible items. Homestead farms have been defined as an operational unit which is adjacent to or surrounds the farmer's home and is generally occupied by a wide array of crops along with or without livestock and other subsidiary income generating activities for subsistence and for generation of cash income (Regeena *et al.*, 2003)

Traditional homegardens of Kerala revisited

Traditional homegardens of Kerala were coconut and arecanut based systems which lent themselves for all sorts of experimentation by farmers on intercropping, mixed cropping as well as mixed farming by virtue of its very liberal growth habits. Thus a wide range of trees, shrubs, herbs and creepers could be seen in the interspaces of the main crop of coconut/arecanut. Fruit and timber yielding trees like mango, jack, guava, cashew, bullock's heart, wild jack, teak, mahogany and portia were common components. Trees like rosewood, sandalwood, were also occasionally planted. Exotic species like Acacia and Mangium are relatively new introductions. Local shade tolerant varieties of black pepper (*Piper nigrum*) were trailed on all trees and served mainly as a source of cash income to the farmer. Shade tolerant varieties of banana, tuber crops like cassava, yam, dioscorea, spices like ginger and turmeric and a variety of vegetables were grown efficiently utilising the space and sunlight available in the limited area. The weed species growing in the interspaces of all these crops formed fodder for the livestock activity.

Just as the system permitted sharing of resources among the components, to a large extent it also it promoted love and sharing mentality among the owners. Most of the vegetables which were in excess were often shared among neighbours and the barter system of exchange effectively added to the diversity of the food basket in each household. The staggered planting of annual and seasonal crops ensured the distribution of production throughout the year.

Homegardens however small in size are noticed to accommodate a wide array of crops, including annuals and perennials along with or without animals, birds and other agri-related subsidiary enterprises. Many a time they also assume the status of agroforestry systems as a wide variety of timber and fuel yielding trees form a component of the system. Trees are often valued as a fixed source of income and at any point of time trees and animals form the major assets of the small farmer which can be readily encashed in case of an emergency.

Coconut and arecanut based homesteads provided for biodiversity conservation by default. The deliberate planting of more and more trees and plants add to the diversity. Homegardens have been acknowledged to be sites for insitu conservation of plant diversity (Gajaseni and Gajaseni, 1999). Kamtuo *et al.,* 1985 reported 100 species in kitchen gardens and 77 species in hut gardens of North East Thailand. Thaman (1985) reported 85,114 and 79 distinct species from random surveys of homegardens in Papua New Guinea, Fiji, and Tongra. Nair and Sreedharan, 1986 and Jose and Shanmugaratnam, 1994 reported 66 and 130 species from single homesteads in Kerala.

High plant diversity in homegardens is also evidenced by reports of 68 tree species from Karnataka (Shastri *et al.,* 2002), 122 from Assam (Das and Das, 2005) and 127 from Kerala (Kumar *et al.,* 1994). After an extensive survey of over 1000 homestead farms of Kerala Regeena *et al.,* (2003) reported as high as 180 species from a garden of 0.4 ha size. It is also observed that the total number of cultivated and wild species of plants in the homesteads varied greatly with the crops cultivated and the intensity of management. The number of agroforestry components also were limited in farms which were intensively cropped (Regeena, 2007).

A polycropped homegarden with livestock component is depicted in Fig 1. The crop sequence progressing from creepers through different canopy layers of vegetables, tubers, banana, minor fruit plants and big trees give the homegarden a structure and appearance similar to the tropical rain forests (Jose and Shanmugharatnam, 1992). This intensive integrated farming is perhaps the best option for the small farmer to tap maximum out of the limited land resource in hand.

Homegardens also tend to be more eco-friendly in the sense that they rely very little on purchased chemical inputs for pest and disease management. Pest and diseases are often managed on their own through inter and mixed cropping and crop rotation. Very little effort at chemical control is taken by the farmers in case of the crops grown for home use and for crops grown in the homesteads.

The multi-storeyed structure and the wide range of species ensures almost complete coverage of the soil by plant residues while refuse obtained from household and from domestic animals are also used in maintaining the soil fertility. The trees and shrubs use their extensive root systems to absorb substantial quantities of nutrients from lower horizons and enrich top soil through leaf fall. They also serve in replenishing the soil nutrients by conveying up minerals from the subsoil and releasing them on the soil surface in the form of litter. The process is enhanced by tree canopy cover which moderates the microclimate and enhances organic matter accumulation, microbial activity and mineralisation. The soil quality and its productive capacity is preserved and improved by preventing soil erosion, promoting high biological activity of the soil fauna, improving soil organic matter content, and by continuously replacing the nutrients removed in the harvested produce through judicious application of manures and effective recycling mechanisms.

The traditional homegardener was also a very industrious and hardworking fellow who started his day at the small hours in the morning with a walk around his garden critically examining his crops and tending to his animals. The extent of physical labour he put into his farm depended on the economic status as well as other activities carried out by him. Other activities included mostly trading in agricultural commodities, processing of agricultural commodities like copra which formed a major source of income to the farm family. However strict supervision and management of the farm ensured a healthy farm which provided for a healthy family. Owners of smaller farms used to sell their labour for cash income.

Animals like cow and goat were common in all homesteads mainly as a source of organic manure for the farm. Milk though valuable was secondary in importance. While the farmers with relatively larger holdings reared cows small holders often preferred goats. Backyard poultry units with 15–20 birds also were common in all homesteads. These animals and birds not only ensured nutrition security to the household through providing unadulterated milk, meat and eggs, but also provided for efficient recycling of bio-wastes generated in the farm.

Traditional homegardens thus have several attributes of sustainable agriculture which may be summarised as below.

They conserve natural resources, thrive on minimum agro-chemicals, enable risk spreading, give staggered production spread over the entire year, ensure gender equity and ensure intra as well as inter generational equity.

Moreover they also cater to the varying needs of the farmer and farm family like:

- Ensuring food and nutrition security

- Providing food and fodder to farm animals and fuel to the farm household
- Seeds for the ensuing season
- Gainful employment to family members
- Ensure resource recycling through crop rotation as well as livestock rearing
- Provides for the aesthetic and religious needs of the farm family.

It is also claimed that the dense vegetative cover created by the homestead agro-forestry system around the dwelling place is an ecological necessity in the context of the high rainfall in the region.

Kerala Homegardens–The present situation

The typical homegarden as described above is almost a myth and is very rarely seen in Kerala now. The socio economic scenario of Kerala has undergone such tremendous changes over the last 20-30 years that it has also affected the homegardens.

The size of the homegardens of Kerala ranges from 0.1 ha to 0.8 ha with an average of 0.3 ha, falling well within the range of global inventory of tropical homegardens given by Fernandes and Nair (1986).

An analysis of the Kerala homegardens of today presents a very disheartening picture. Most of them are very rapidly becoming uneconomic units due to the smallness in size. Rapid expansion of population, spread of nuclear families and subdivision of ancestral property among offspring render the farms even smaller and make them unfit to be categorised as a farm. Coupled with this the changes that have happened in the socioeconomic scenario have resulted in gross neglect of the farms, irrespective of their size and they seem prone to extinction.

Regeena et al (2004) after an extensive survey of homegardens reported that the Kerala homegardens fall into six major categories, viz.,

1. Coconut based
2. Arecanut based
3. Spice based
4. Rubber based

5. Coffee based and

6. Livestock based.

However the agricultural sector of Kerala is undergoing vast changes and it is in all likelihood possible that the first two categories may soon be replaced by the fourth. While how a rubber based system can be grouped under homegarden system which traditionally is supposed to cater to the subsistence needs of the farmer remains a debatable issue, the speed with which even very small holdings are converting to rubber, (mainly under the impact of the soaring rubber prices and also because of the difficulty in managing coconut and arecanut palms (pests and diseases, labour problem, low prices) warrants such a fear.

This has to be further examined in the context of the general status of agriculture in Kerala today which is characterised by the following features.

1. Shift to perennial monocrop plantations most prominently natural rubber (*Hevea brasiliensis*).

2. Absentee landlordism.

3. Absence of skilled manpower and very high cost of labour.

4. Absence as well as reluctance of family members to work on family farms.

5. Absence of appropriate machine to work small farms.

6. Lack of appropriate research output suited to the homestead farming system with the result that the crop mix, management etc are decided by the farmers themselves.

7. Uneconomical nature of agriculture particularly in the context of the tedious nature of work and the time involved.

8. A general apathy among the younger generation towards agriculture.

It has often been argued that traditional sustainable agricultural systems like homegardens should be protected and preserved. However with a general shift in emphasis from subsistence orientation to commercial orientation, shift to perennial monocrop plantations cannot be avoided.

Small farmers world over are known to be risk averse and slow in adapting to innovations. However they are also noticed to be quick in adapting to changes which they perceive to be beneficial to them. Arecanut and Coconut palms of Kerala are affected by a very wide array of pests and diseases, management of which is highly impractical in view of scarcity and high cost of labour though effective technologies are available. Old problems like root (wilt) still persist without any effective remedy and new maladies like yellowing crop up. Except for an occasional rise, prices of coconut and areacanut tend to be unfavourable to the farmers. It is no wonder that the farmers then shift to a crop which is highly remunerative at the same time present lesser problems at least for the present.

This shift cannot be prevented by law for the burden of protecting and preserving a sustainable system cannot be forced upon the shoulders of farmers but should be borne by the society. The only feasible way is to make the system more profitable through cost saving methods as well as through enhancement of profitability.

In this background it will be appropriate to look into the economic analysis of a well managed homestead farm depicted in Table I.

Table I: Economic analysis of a homestead farm

Sl. No	Particulars	Details
1	Age of the farmer	56
2	Main occupation	Agriculture
3	Area owned and operated	0.4 ha
4	Crops cultivated	1. Coconut – 28 Nos 2. Banana – 500 3. BLack pepper -100 4. Garcinia -2 5. Nutmeg – 2 6. Arecanut – 50 7. Glyricidia – 100 8. Jack – 4

		9. Mango – 4 10. Vegetables like bitter gourd, brinjal, cowpea, 11. Cassava – 400 sq ft 12. Other tubers- 400 sq ft 13. Ginger -160 sq ft 14. Turmeric – 160 sq ft 15. Teak – 4 16. Wild jack -1
5	Other activities	17. Poultry -100 nos (in separate enclosure) 18. Japanese quail- 300 19. Goat – 4 20. Ornamental poultry – 25 pairs 21. Ornamental fish – 300 pairs 22. Vermicomposting 23. Sales of planting materials – banana suckers, seedlings of vegetables

It was found that the system could generate a gross farm income of Rs. 309920 and a net farm income of Rs. 144710. The cropping intensity was 168 and benefit cost ratio was 1.91. It could also generate 110 man days of gainful employment to the family members. The returns it can be seen, almost compares with the returns from 0.4 ha of rubber under average management which will come to approximately Rs. 168,800/-. While this entire amount is received as cash earnings, major part of the earnings from homesteads is just imputed value of produce used for home consumption. An added attraction to the small grower is the possibility for ready encashment of rubber at frequent intervals.

It is obvious from the table that the major cash earnings to the farmer come from subsidiary and allied activities while most of the produce from annuals and perennials are used for consumption and other subsistence needs. Another point worth mentioning is that the produce from crops which are marketed goes to the market with very little processing or value addition which if promoted can provide for a substantial increase in farm income.

It is noticed that majority of the perennial crops (coconut, arecanut, black pepper) in homegardens are senile and unproductive. This undermines the overall productivity and profitability of the system. A complete rejuvenation of the system with new improved varieties and better management practices can go a long way in improving productivity.

Kerala with a very severe land constraint has no alternative but to increase the productivity of the land already under cultivation. In order to achieve this, sustainable integrated model of farming as practised in homegardens should be protected and popularised – neither of which is happening in Kerala today. Integration of activities like apiary in areas where rubber cultivation is prevalent, ornamental fish culture and fish cultivation in homesteads with facilities for the same, ornamental floriculture in urban centres with proper linkage with traders, rearing of layer poultry and quails, small scale nursery and agri based small scale enterprises can all be linked to the homestead farm without eroding the basic tenets of sustainability and eco friendliness. Technical skill in the new enterprises should be given to the farmers and proper market linkages have to be established. In the present era of Information Technology our farmers also should be made computer savvy so that they can reap the benefits of the World Market.

A concerted effort towards generating technology suited for the small farm sector as well as for the integrated system is of utmost priority. Research in this line has been pathetically low mainly due to the practical difficulties in conducting research in homesteads which are highly complex entities. The adoption of a farming system perspective to research needs for the small farm sector is likely to identify suitable new and cost effective technologies for increasing production and productivity of small farms. Improved cultivars suited for the shade situations prevailing in small gardens , better farm management practices and machinery suited for the varied requirements of small farms (like harvesting coconuts, pest management in coconut, harvesting of mango, jack and also small garden tillers which can be operated even by farm women or children) are urgently required. This can also mitigate the drudgery associated with hard annual labour in farms and can attract youth to agriculture. Shortage of farm labour can also be addressed through mechanisation.

Market intelligence is another area which needs utmost attention and priority. Collection and dissemination of correct market information and intelligence based on it should be done and farmers should be enabled to access the correct information so that they can plan their crops according to market trends.

Small farmers are reportedly risk averse and laggards in adapting to innovations. However they have also proved to be very quick to adopt something which has proved beneficial to them. It is up to the researchers to provide them with innovative technologies.

Absentee landlordism is another hindrance to development of agriculture in Kerala. Though there is no feasible way to lease out the homesteads government can possibly think of legally enforcing proper cultivation in all pieces of land owned by any person whatever be his main occupation, considering the severe limitation of land available for cultivation and the huge unsatiated demand for food and dietary supplements.

Small holders especially homegardeners are low cost producers. Their yields generally are low and of poor quality due to low inputs, traditional technology of cultivation and low standards in post harvest processing. This results in inefficiency and consequent low farm income. Ways and means to make them efficient have to be urgently evolved. Appropriate technology, small affordable machinery, easy and timely credit support and market linkage have to be ensured to make the system profitable and there by sustain the farmers' interest in them.

References

Das T and Das A K. (2005). Inventorying plant biodiversity in homegardens: A case study in Barak Valley, Assam, North East India. Curr. Sci. 89(1): 155-163.

Fernandes E C M and Nair, P K R (1986).An evaluation of the structure and function of tropical homegardens. Agric. Syst., 31: 279-310.

Gajaseni, J. And Gajaseni, N. (1999). Ecological rationalities of the Traditional home garden system in the Chao Phraya Basin, Thailand. Agro Forestry Systems 46: 3-23

Hanman, F.M. 1986 Alternative ways of incorporating women concerns in Farming Systems Research. In: report of the Asia Rice Farming Systems working group meeting, IRRI, Manila, Philiplines p. 222.

Jacob, J. 1997. Structure analysis and system dynamics of Agro Forestry Home Gardens of Southern Kerala. Ph.D thesis, College of Agriculture, Vellayani, KAU, Kerala, India

Jose, D. And Shunmugharatnam, N. 1993. Traditional home gardens of Kerala: A sustainable human eco system. Agro Forestry Systems 24: 203-213

L agemann, J. 1977. Traditional farming systems in Eastern Nigeria. Weltforum Verlag, Munich, Germany

Leushner, W.A. and Khalique, K. 1987 Homestead Agro Forestry in Bangladesh. Agro Forestry Systems. 5: 139-151

Nair, M.A. and Sreedharan C. 1986 Agro Forestry Farming Systems in the homesteads of Kerala, Southern India. Agro Forestry Systems 4: 339-363

Ninez, V.K. 1984. Household gardens: theoretical considerations on an old survival strategy. Research series No. 1. International Potato Centre, Lima, Peru

Regeena, S. , Jacob John, S.Ravi, V. Krishnakumar and K. Geetha 2003. Homestead farms-Agricultural heritage systems of Kerala. KAU.

Regeena, S., Jacob John, V. Krishnakumar, K. Geetha and A. Venkatesh. 2004. Final report of NATP "Analysis and Development of homestead farms of Kerala and Andaman and Nicobar-A farmer participatory approach. "KAU. Thrissur.

Regeena, S. 2007 Plant Biodiversity in the Home Gardens of South Kerala. International Journal of Plant Sciences. 2 (1: 31-38)

Soemarwoto, O. 1987. Home Gardens: A Traditional Agro Forestry Syst ems with a promising future in: Agro Forestry a decade of development (Eds.) Stepppler, H.A. and Nair, P.K.R. ICRAF, Nairobi, pp. 157-170

Stoler, A. 1975 Garden use and household consumption pattern in a Javanese Village. Ph.D thesis, Columbia University, Dept. of Anthropology, Newyork.

Terra. G.T.A. 1954 Mixed garden horticulture in Java. Malaysian J. Trop. Geography 4: 33-43

Impact of Mining on Environment

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Mining is the process of extracting mineral deposits from the Earth. There are different types of mining like open cast mining, underground mining, etc. The mining industry in India is a major economic activity which contributes significantly to the economy of India. The GDP contribution of the mining industry varies from 2.2% to 2.3% only, but going by the GDP of the total industrial section it contributes around 10%. India is the largest producer of sheet mica, the third largest producer of iron ore and fifth largest producer of bauxite in the world. However, mining in India is also famous for human rights violation and environmental pollution.

Impact on land

Any mining activity reshapes the natural landscape and in most cases requires large scale deforestation of the area. Such anthropogenic activities will have adverse impact on the faunal and floral diversity, sometimes leading to the extinction of an entire community itself. This may affect the ecological stability of the area. A disturbance to the natural topography affects the natural slope patterns and drainages in the area. Mining activity produces large amounts of materials in the form of overburden and wastes from the ores that are produced in the processing and are concentrations of the ore. Some of them may be toxic and contaminate the water and air in the vicinity of the mine which affects the health of man and animal equally. Disposal of waste is a serious problem in any mining operation. Dumping of the mine waste in the nearby areas and the deforestation will enhance the rate of soil erosion.

Impact on water

Acid mine drainage is the metal rich water formed from the chemical reaction between water and rock containing sulphur bearing minerals. The run off formed is usually acidic and frequently comes from areas where mining activities has exposed rocks containing pyrite. However, metal rich drainage can also occur in mineralized areas that have not been mined... AMD is formed when pyrite reacts with air and water to form sulphuric acid and dissolved iron. This acids runoff dissolves heavy metals such as copper and lead into ground and surface water.

Mining sites may also release high amount of toxic metals like arsenic, copper, lead, iron, Cadmium, Nickel and other trace elements. All these metals if added to the water table will have serious impact on the quality of groundwater. Open cut mines sometime intersect local aquifers and contaminate the water table. Mine sites near the river disturbs the river channels by discharging the mine waste into the river causing a siltation. This may lead to rise in the river bed causing flooding and sediment deposition on the flood plain, sometimes smothering the vegetation. Mining, if carried out in the upstream areas of the river will have serious effect on the flow regime of the river leading to braiding and other natural adjustments.

Impact on air

Mining releases lot of dust and fine suspended particles. Movements of vehicles in the site where normally the tracks are unsealed blow out all the dust and finer particles to the air causing air pollution. Mine workers usually succumb to several mine dust-related diseases like silicosis, asbestosis etc. In the coal mines coal bed methane which is a greenhouse gas is sometimes released to the atmosphere. Burning of the fossil fuels and release of such greenhouse gases all will affect the ozone layer.

Mining requires lot of detonations, explosions, drilling and crushing operations, etc. which cause noise pollution affecting not only the mine workers and nearby inhabitants but also the animals and scares the animals inhabiting in the nearby area. This may lead to the migration of animals and birds again disturbing the local ecosystem.

Other effects

Due to the drastic changes to the topography and deforestation mining activities normally trigger natural calamities like land slide and subsidence. Explosion along the fault planes may trigger minor earthquakes also.

Social consequences of mining

Mining normally is done in the forested and hilly areas where the inhabitants are more attached to the environment than the urban population. Mining activity sometime displaces these lesser privileged masses from the places where they are born and brought up and that disturbs them psychologically and culturally. Those who are living in the nearby areas may have serious mining related diseases like asbestosis, silicosis and even carcinogenic diseases.

Sand mining

Sand mining is posing a serious threat to the environment. Indiscriminate mining from the traditional sources like riverbed, sand dunes etc is degrading the respective environments and destroying the ecosystem. In the village and towns around the river where sand mining takes place ground water level has fallen drastically and wells are almost perennially dry. Excessive sand mining depletes the riverbed and the absence of sand on the riverbed affects the velocity of the water flow making it violent during monsoon. The lowering of water table helps the saline water intrude into river as the case has been reported in many coastal areas. Uncontrolled sand mining without considering the sediment budget disturbs the hydrodynamics of the river. Exposure of the riverbed to the solar radiation dries up the river. Depletion of the sand in the stream bed and along the coastal areas causes deepening of rivers and estuaries and enlargement of river mouths and coastal inlets. This may give an impetus to the saline intrusion and tidal effects. Also the area may become more vulnerable to storm surges and cyclones. Changes in the channel morphology enhance degradation of riverine environment and may trigger disasters like river bank erosion, drought, and destruction of agricultural land etc. Excessive sand mining also threatens engineering structures like bridges constructed in the river. Disappearance of sand dunes may expose the interior land vulnerable to storms and cyclones.

Sand mining destroys the aquatic and riparian habitat and leads to the loss of fishing production. Many hectares of fertile stream side land as well as valuable timber resources and wildlife are lost in the riparian area manually. Also fish breeding and their migration have been affected because of sand mining. Rivers are a source of food for many bird species and sand mining puts a question mark on their survival. People living in the areas suffer from lung related diseases due to dust emanating from the sand laden lorries.

Off late sand mining is creating social unrest in the sand mining areas. Whenever people protest against illegal sand mining, mining lobby threatens the villagers with dire consequences and even exploiting the communal and cast sentiments for their advantage.

Act and rules governing minerals

The Mines and Minerals (Development and Regulation Act, 1957, ('MMDR') and the Mines Act,1952, together with the rules and regulations framed under them, constitute the basic laws governing the mining sector in India.

The relevant rules in force under the MMDR Act are the Mineral Concession Rules, 1960, and the Mineral Conservation and Development Rules, 1988. The health and safety of the workers is governed by the Mines Rules, 1955 created under the jurisdiction of the Mines Act, 1952.
The Mineral Concession Rules, 1960 outline the procedures and conditions for obtaining a Prospecting License or Mining Lease. The Mineral Conservation and Development Rules, 1988 lays down guidelines for ensuring Mining on a scientific basis at the same time, conserving the environment. The provisions of Mineral Concession Rules and Mineral Conservation and Development Rules are, however, not applicable to coal, atomic minerals and minor minerals. The minor minerals are separately notified and come under the purview of the state Governments. The State Governments have for this purpose formulated the Minor Mineral Concession Rules. Common minor minerals mined from state of Kerala are granite, laterite, ordinary clay, ordinary sand, sea shells, dimension stone etc.

Conclusion

No doubt mining poses potential threat to the environment, but it should be stressed, however, that mining affects only a very small percentage of the land. Since mining is so important for the survival of the modern civilization we cannot do away with it just because of its environmental impact, as it is rightly said "if it can't be grown it has to be mined". However, since environment is equally important proper impact assessment should be carried out before mining starts and measure should be taken to minimize its effect on the environment. Mine reclamation activities like reshaping and contouring of spoil piles, replacement of top soil, afforestation, etc helps to improve the environment of the mined area. Reclaimed land can be used for agriculture, forestry, wildlife habitation and recreation.

Coastal Zone Management in the Backdrop of Global Warming

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Introduction

Coastal zone is a transitional region between the land and the ocean where the terrestrial and marine environments influence each other. Coastal zone consists of the coast, beach/shore and near-shore zone. It is an abode of resources and sensitive ecosystems which is subject to intensive human activities and economic development. Vulnerability to coastal hazards such as coastal erosion, storm surges, high and steep monsoon waves, coastal flooding and tsunami is characteristic to the coastal zone. The impact of coastal hazards on economic, ecological and social assets of the coastal areas and the effects that ocean and coastal uses as well as activities farther upland can have on ocean and coastal environment exemplifies the need for Coastal Zone Management (CZM) to address and mitigate the consequences of conflicts arising out of multiple uses. Global warming and resultant climate change have added an additional dimension to CZM to plan appropriate adaptation strategies.

The concept of CZM was rarely used in coastal area management till 1991 when the Coastal Regulation Zone (CRZ) Notification was issued in 1991, under the Environment Protection Act (1986). It remains the most important and the only coast specific legislative instrument for CZM in the country. Specific scientific observations on coastal processes, coastal erosion and near-shore waves for enabling to propose scientific interventions as part of CZM was lacking in the country, including Kerala till the early eighties. The Centre for Earth Science Studies (CESS) was one among the pioneering institutes which generated an exhaustive field data on near-shore waves, coastal morphology, sediment transport and shoreline changes to form the baseline data for CZM. The Ministry of Earth Sciences has now major programmes through its organizations like INCOIS, NIOT and ICMAM to generate baseline data like ocean waves, currents, bathymetry, shoreline, etc for the entire coastal zone of the country. The Coastal Management Plan prepared for the implementation of CRZ notification provided a base for planned coastal development in the State. The Integrated Coastal Zone Management Plan for facilitating heavy mineral utilization in Alappad panchayat is one of the earliest issue-based coastal management plans. The ICMAM, Chennai under the Ministry of Earth Sciences has various programmes on CZM including Shoreline Management for different regions of the country.

Climate change and Coastal Zone Management

Global warming and resultant climate change are realities. The world today is hotter than it has been in the last few thousands of years. The IPCC has reported that by the end of the century, if current trends continue, the global temperature is likely to climb higher than at any time in the past two million years.

Coastal areas are vulnerable to global warming, which drives climate change. The impacts are mainly with respect to accelerated sea level rise and backwater/estuary level changes, shoreline erosion, increased storm frequency or intensity, changes in rainfall and related flooding. Other impacts include changes in chemical characteristics, like ocean acidification and physical characteristics like thermal stratification of marine systems, saltwater intrusion into groundwater aquifers, increased harmful algal blooms, spread of invasive species, habitat loss (especially coastal wetlands), species migrations and changes in population dynamics among marine and coastal species. As state and local governments consider future climate change policies and strategies, coastal zone management programs will play an important role in identifying vulnerabilities and fostering adaptation to climate change.

Assuming that no adaptation programmes are in place, IPCC has estimated potential land loss resulting from sea-level rise and the number of people exposed as 5763 km^2 and 7.1 million respectively for a sea level rise of 1 m for India. At the same time, adaptation strategies through CZM will alter the nature of the risk and change the socially differentiated nature of the vulnerability of populations. Response strategies that are based solely on tackling the physical parameters of risks from sea-level rise and tropical cyclones have been shown in some circumstances to enhance the vulnerability of certain parts of the population which could also be addressed through CZM approach.

Sea Lever Rise and Impacts

Since Sea Level Rise (SLR) due to global warming could lead to a series of connected impacts, the impacts due to SLR have become the major concern for coastal zone managers. The sea surface is a very dynamic system which never remains constant. The most evident sea level fluctuations are due to waves and tides. Sea level fluctuations caused by waves are short term changes happening in every few seconds. The change is of the order of a few centimetres to a few metres. Waves are mostly wind driven. Tides cause sea level changes of the order of a few metres and the period of fluctuation is 12 to 24 hours. Tides are caused by the gravitational pull of the moon and the sun. Storm surges and tsunamis cause extreme sea level fluctuations which again have a period of maximum of a few minutes. The former occurs due to cyclones and the latter due to submarine earthquakes. Quite apart from tides, waves, storm surges and tsunamis, long term sea level changes occur because of the process of 'eustasy and isostasy'.

Eustasy is the rise or fall of sea level relative to the land. It is usually associated with glaciation and interglacial period of warming. During glaciation, large quantity of water gets stored as ice caps/glaciers resulting in a drop in the water level. During interglacial period, ice in the Antarctic and Arctic melts and sea level rises. Isostasy is the rise and fall of land which causes a relative change in the sea level. This vertical movement of land can be global or regional.

Isostasy is the tendency of the earth's crust to maintain equilibrium. When the crust is pressed down at one area, another part of the crust will rise to compensate and attain equilibrium or when the force pressing down the crust is released, it rises to its previous level. The main reason for isostatic changes is again glaciation and interglacial period of warming. During ice ages, the ice accumulates to thousands of metres thick on the continental areas. The weight of the overburden depresses the land surface, causing glacial isostasy. When the ice melts during interglacial warming periods the surface rises to its former position. Tectonic land movements like earthquakes can also have an effect on sea level, though for a particular region.

When eustatic changes are faster than isostatic changes, the coastlines are submerged. When the reverse occurs, coastal emergence is the result. It may be noted that processes like local subsidence can overtake the sea level changes due to eustatic and isostatic process.

Past sea level changes

During the past 3 million years, water has periodically been locked up within large continental glaciers and then released, producing cycles in the level of the sea. Researchers generally agree that about 15,000 to 20,000 years ago, the sea was approximately 100 m lower than at present. The increase in sea level since then has not been uniform. Based on geological data the global average sea level may have risen at an average rate of 0.5 mm/yr over the last 6000 years and at an average rate of 0.1 to 0.2 mm/yr over the last 3000 years.

Global warming and sea level rise

The increasing global temperature that is observed to be happening during the present and last centuries has added a new dimension to sea level rise. During the last century the worldwide temperature rose by a little over half a degree above the earth's temperature of 15 degrees Celsius. According to some estimates this could be a 2 degree increase by AD 2100. Majority of the scientists are of the view that the rise is mostly attributable to human activities such as burning of fossil fuels that release large quantities of CO_2. Release into the atmosphere of other greenhouse gases like methane and chlorofluorocarbons are also in the increase. There is also a group of scientists who hold the view that the present global warming is mostly part of a natural climatic cycle and that only a small part of the rise is attributable to human activities. The presence of greenhouse gases, water vapour and ozone in the atmosphere is very important for maintaining the temperature of the earth to the level required for the sustenance of life on earth. Without the natural insulation provided by the above, the average temperature of the earth would have been minus 15 degree Celsius. But when the greenhouse gases are increased, the earth's temperature increases, resulting in global warming leading to thermal expansion of the oceans.

Present changes in sea level

The present sea level rise could be attributed to thermal expansion of the oceans, melting of glaciers and ice caps in mountains and melting of Antarctic and Greenland glaciers. Changes in terrestrial storage of water are also contributing to sea level changes. The sea level changes of the 20th century are based on tidal data analysis.

The warming and the resultant thermal expansion of the oceans contribute to about half of the sea level rise. As the oceans get warmed, their density decreases and water volume increases. The oceans expand and the sea level rises. It is estimated that the contribution of thermal expansion to sea level rise is about 1 mm/yr. Glaciers and ice caps at the terminus of mountains are found to be melting at an increasing rate during the last 150 years. The exchange of water with glaciers and ice caps changes the mass of the oceans and thus sea level. Its contribution to sea level rise is 0.2 to 0.4 mm/yr over the 20th century. The melting of glaciers in Antarctica and Greenland is contributing about 0.5 mm/yr over the 20th century as a result of long term adjustment to past climatic changes. The contribution to sea level rise due to changes in terrestrial storage of water over the period 1910 to 1990 is estimated to be – 1.1 to 0.4 mm/yr. The global average sea level rise during the 20th century based on the above components is estimated to be 1 to 2 mm/yr.

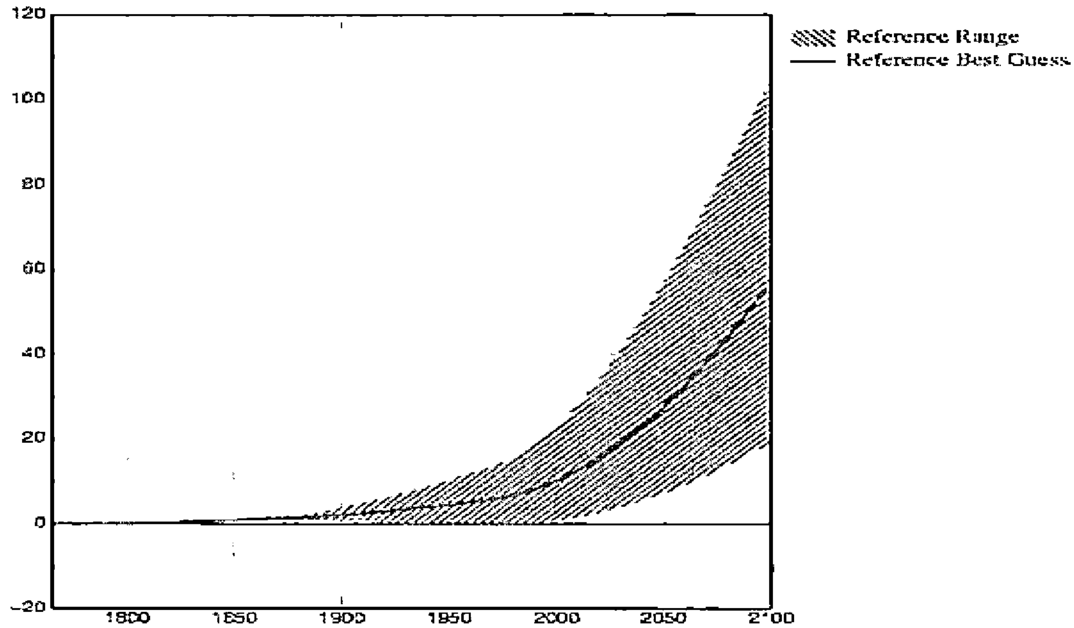
Projected sea level rise from 1990 to 2100

The Inter-governmental Panel on Climate Change (IPCC) has projected a sea level rise of 0.11 to 0.77 m by 2100. The various components are given as:

- Thermal expansion contribution of 0.11 to 0.43 m, which may accelerate through 21st century
- Melting of glaciers and ice caps of mountains contribution of 0.01 to 0.23 m
- Antarctica contribution of -0.17 to 0.02 m
- Greenland contribution of -0.02 to 0.09

There is an apprehension among scientists that the dynamic instability of the West Antarctic Ice Sheet (WAIS) could accelerate the melting of glaciers and further increase the projected sea level rise. Also the increasing trend in the emission of greenhouse gases and the resultant increase in global warming could make changes in the above projection. It has been projected by some researchers that a continued growth of green house gas emissions and

Fig.1: Future projections of sea level (after IPCC, 2001)



(Reference: IPCC emissions scenario 92a)

associated global warming could well enhance sea level variations to 1-3 m by 2100 and an unexpectedly rapid melting of WAIS could push it to 5 m (Dasgupta, et al. 2007). It may be noted that even if the greenhouse gas emission is stabilized, thermal expansion and melting of glaciers could continue to raise the sea level for many more years.

Sea level rise along the Indian coast

The present rate of sea level changes along the Indian coasts has been computed from long term tide data (Unnikrishnan and Shankar, 2007). Fairly long reliable tide data is available for Mumbai, Kochi, Chennai, Vishakhapatnam and Diamond Harbour (Kolkata). It is seen that the rate of sea level rise is consistent with global estimates of 1 to 2 mm/yr. The rate of sea level rise is found to be higher in Kochi of about 1.75 mm/year (Table 1). Sea level is falling in Chennai with a rate of -0.65 mm/yr (Unnikrishnan, et al. 2006). The position of the tide gauge being in Hooghly estuary on the delta of River Ganga with a subsidence rate of 4 mm/yr could be the reason for the high value in Diamond Harbour (Table 1).

Table 1: Sea level rise along the Indian coast

Location	Period of analysis	Sea level rise (mm/yr)
Mumbai	1878 - 1993	1.20
Kochi	1939 - 2003	1.75
Vishakhapatnam	1939 - 200	1.09
Diamond Harbour (Kolkata)	1948 - 2004	5.74

Impacts of sea level rise on the coast

Whatever be the reasons for global warming, the accompanying sea level rise would cause impacts on the coastal zone. Coastal zones are particularly vulnerable to sea level rise and resultant modifications to coastal processes. In a country like India where the major cities like Mumbai, Kochi, Chennai and Kolkata are situated in the coastal zone, the impacts would be very significant since large populations and economic activities are concentrated there. The coastal systems and processes respond to sea level rise by migrating onshore/inland. Rising sea level inundates wetlands and other low-lying lands, erodes beaches, modifies morphology, intensifies flooding, and increases the salinity of rivers, bays, and groundwater tables. Some of these effects may be further compounded by other effects of changing climate such as increased frequency of maritime storms and resultant storm surges and flooding. Additionally, the coastal protection structures to be constructed to protect property from rising sea level may have adverse effects on the environment.

Inundation of wetlands and low lying areas

Coastal wetlands provide habitat for many species, play a key role in nutrient uptake, serve as the basis for many communities' economic livelihoods, provide recreational opportunities and protect local areas from flooding. Being low lying, these wetlands are particularly vulnerable to sea level rise. As the sea rises, the outer boundary of these wetlands will erode and new wetlands will form inland as previously dry areas are flooded by the higher water levels. Coastal vegetation like mangroves and the wild habitats it supports could get affected. The amount of newly created wetlands, however, could be much smaller than the lost area of wetlands since existing structures could prevent formation of new wetlands inland. An IPCC estimate suggests that during the next century, sea level rise could convert as much as 22% of the world's coastal wetlands to open water. In the process vast areas of mangroves and salt marshes will be destroyed.

Tidal wetlands in areas with small tidal range are the most vulnerable since the increase in sea level could be more than the tidal range. This is particularly important for Kerala with a tidal range of about 1 m. The impact of sea level rise on filtration ponds and other low lying areas adjacent to backwaters and estuaries of Kerala would be significant. The existing bunds and tidal barriers would require strengthening. More flood plains would be required to accommodate the increased inflow of sea water into the backwater system. The ongoing reclamation of coastal wetlands is reducing the availability of the existing flood plains instead of increasing its coverage. This may be compared with the fate of the city of Venice where reclamations of the adjoining wetlands have resulted in the flooding of the entire city during every spring tide.

Coastal erosion and modification of morphology

The sea levels are already rising and many of the shorelines of the world have become erosion prone. The reach of the sea and waves into the land increases which would increase coastal erosion. There will be a landward migration of barrier beaches and barrier islands and a parallel retreat of the shoreline. Sand dunes would be eroded. There will be enhanced scouring at the foot of earth cliffs which would lead to increased slumping of the cliffs. The damage to coastal morphologies such as beaches, dunes and cliffs that would otherwise protect coastal property from storm waves could increase vulnerability of hinterlands to waves and storm surges. The shoreline recession due to sea level rise would cause a 'coastal squeeze' of the many barrier beach systems along the Kerala coast such as those between Neendakara and Ponnani and those north of Ezhimala. The risk to buildings and other structures situated close to the present shoreline will necessitate increased efforts for coastal protection. Another impact will be on the pocket beaches in the bays between headlands. There is a possibility that these would disappear, affecting coastal tourism. It may be noted that sufficient sediment supply to the beach could offset shoreline regression and cause beach progradation even with an increasing sea level rise.

Weakening of coastal protection structures

The increasing sea level and retreating shoreline could weaken the existing coastal protection measures. Increased wave overtopping of the seawall could cause its slumping. In the case of groins on the beaches, wherever present between the groins could disappear increasing the stress on the groins. Larger waves could pass over submerged breakwaters and submerged reefs causing them to break close to the beach. The infrastructure and properties being protected would be exposed to increased risk. It may need more expenditure to maintain the effectiveness of the existing shore protection structures.

Increase in salinity of rivers, bays and groundwater tables

Rising sea level increases the salinity of both surface water and ground water through saltwater intrusion. Saltwater would penetrate farther inland and upstream. Many urban and rural areas in the State pump required freshwater from portions of rivers that are slightly upstream from the point where water is salty during summer season. If sea level rise pushes salty water upstream, then these fresh water intakes might draw salty water during dry periods. Shallow coastal aquifers are also at risk. As rising water levels submerge low-lying portions of the coastal zone, portions of the aquifer would become saline. Increase in salinity in estuaries can harm aquatic plants and animals that do not tolerate high salinity. Agriculture in low lying areas like those adjacent to Vembanad backwater could be affected by increased salinity intrusion

Increase in storm surges

Bay of Bengal is the hotbed of cyclone generations in India. A study by Unnikrishnan et al 2006, has found that there would be an increase in the frequency of tropical cyclones, particularly intense events during post-monsoon season. A recent study conducted in Australia also indicates the possibility of an increase in the frequency of occurrence of storms and accompanying storm surges. A small increase in sea level can significantly magnify the impact of storms urges and coastal flooding.

Inundation of land

An increased sea level can inundate low lying areas such as deltas, mudflats and banks of estuaries and backwaters more or less permanently. Episodic inundation due to storm surges will be more frequent in low lying areas.

Other impacts

Sea level rise also increases coastal flooding from rains, because low areas drain more slowly as sea level rises. Other impacts of climate change may further enhance coastal flooding. Flooding from rains may become worse if higher temperatures lead to increasing rainfall intensity during severe storms. Sub-optimal functioning of the sewage systems of coastal cities with resulting health impacts could grow into a major problem with increasing sea levels.

A dissenting note

There is a group of scientists, technocrats and administrators who hold the opinion that the impact of sea level rise would not be as serious as being projected. They feel that rising sea level is a natural phenomenon that happens during interglacial periods. The sea level has risen by about 100 m since the earth emerged from the last Ice Age some 20,000 years ago. The earth got itself adjusted to this change in sea level. It is their view that earth will get itself adjusted to sea level rise during the 21st century also. The forecasts of future sea level rise are also questioned. These forecasts fluctuate widely depending on the method used. The assumptions used in the models for prediction have many inaccuracies leading to larger inaccuracies in the projected values. Also, sea levels do not rise uniformly the world over. They warn against spending huge amounts of funds and efforts for a 'speculative' disaster.

Management of sea level rise

Containing the emission of greenhouse gases and controlling global warming are important for managing sea level rise. International efforts have been strengthened through the Kyoto Protocol which sets legally binding targets and timetables for cutting the greenhouse gas emission of industrialized countries. Countries have already started preparing National Adaptation Programmes of Action following the guidelines of the United Nations Framework Convention on Climate Change (UNFCCC), to tackle the probable impacts of sea level rise. Strengthening coastal protection measures, increased protection for important and vital infrastructures, relocating people from low lying areas, locating new constructions and developments in safe areas, sustaining existing flood plains and strengthening tidal barrages are some of the actions required. Conservation of coastal wetlands such as mangroves, tidal flats and beaches are considered to be vital for accommodating the rising sea water and thus reducing the adverse impacts of sea level rise. Equally important is conservation of coastal morphologies such as sand dunes and cliffs which would act as the nature's defense mechanism to rising sea level and increasing coastal erosion.

Indian initiative

One of the important Indian initiatives to manage the possible impacts of sea level rise is the Coastal Regulation Zone (CRZ) notification which regulates activities in the coastal zone (MoEF, 2011; 1991). In addition to the sea coast, banks of estuaries, backwaters and rivers with tidal influence are also brought under the provisions of this regulatory framework. The CRZ provides a buffer zone close to the shoreline to accommodate the impacts of sea level rise. Establishment of industries and new construction activities have been prohibited/regulated in the defined coastal regulation zone, thus reducing the possible loss of life and properties from coastal hazards.

References

Church, J.A., Gregory, J.M., Huybrechts, Kuhn, M., Lambeck, K., Nhuan, M.T., Qin, D. and Woodworth, P.L., 2001. Changes in sea level. In Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Inter-govemmental Panel on Climate Change, Cabridge University Press, Cambridge, U.K., 2001, pp. 639-690.

MoEF, 1991. Notifiction No. S. 0114 dated 19th February, 1991, Ministry of Environment and Forest, Government of India, New Delhi.

Unnikrishnan, A.S. and Shankar, D., 2007. Are sea-level-changes along the coasts of North Indian Ocean consistent with global estimates? Global Planet. Change, 2007, Vol.57, No.3-4, pp.301-307.

Unnikrishnan, A.S., Kumar, K.R.., Fernandes, S.E., Michael, G.S. and Patwardhan, S.K., 2006. Sea level changes along the Indian coast: Observations and projections. Current Science, 2006, Vol.90, No.3, pp.362-368.

Environment and Human Health – in the Context of Climate Change.

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Introduction:

The environment consist of any or all physical, chemical, biological ,social and cultural factors which can influence health status of populations. Most of the diseases are not random occurrences but rather are related to environmental factors (1). The relationship between the environment and its impact on human health is highly complex and each of effect is associated with a variety of economic and social aspects. Globally 24% of the estimated burden of disease is attributed to environment (WHO). The relation between the environment and human health has been observed for centuries. Hippocrates (BC 460-377) made a connection between disease and environmental conditions especially in relation to water and seasons (1). Along with emerging and reemerging communicable diseases, 37 new pathogens with epidemic potential identified globally during last 3 Decades.

The world's climate system is an integral part of the complex of life supporting process and environment. Climate and weather have always had a powerful impact on human health and well being. But like other large natural systems, the global climate system is under pressure from human activities. Over the ages the human societies have altered local ecosystem and modified regional climates. Global climate change is there for a newer challenge to ongoing efforts to protect human health (2). Impacts of climate change and increase surface temperature, frequent floods and draughts, changes in natural ecosystem, earlier flowering of plants and pole ward shifts in the distribution of several species – all are linked to health of humans. Climate changes like climatic extremes have direct physical effects on humans and transmission of many infectious disease agents, alteration of regional food productivity have indirect effects which are likely to have greater magnitude.(3) ENSO events cause physical effects such as draughts and floods. They interact with suitable ecological and socioeconomic conditions which may cause disease out breaks. The WHO World Health Day theme for the year 2008 was "protect health from climate change."

According to IPCC (Inter governmental Panel on Climate Change) during the 20th century average surface temperature increased by 0.6^{0}C and this mainly occurred during the last 50 years. IPCC predicted that during 21st century the temperature increase will be estimated to be 1.4 to 5.8^{0}C (2). Since 1750 the atmospheric carbon dioxide level increased up to 31%. From 1950 onwards there is 0.5% increase of carbon dioxide per year. 75% cause is due to fossil burning and the rest due to deforestation. Now the global average level is 370 ppm; it will reach to 490 to 1260 ppm by 2100. Atmospheric methane has increased 151% since 1750 and nitrous oxide by 16% and ozone by 35%. By 1990 to 2100 the mean sea level rise is predicted to be 0-09 to 0.88 meters along with increase of biotoxins and algal blooms. (4)

The health impacts are different in different countries and populations. The vulnerability depends on various conditions like population density, age distribution, level of economic development, food availability, income level and distribution, local environmental conditions, preexisting health status and quality and availability of public health services. Poor and very young and old among them are at a higher risk. (5) In Asia the main health concerns under climate change are vector borne disease like malaria, water borne disease like cholera and diarrhoeal diseases, thermal stress and air pollution related illnesses.(2) The main effects of climate change in tropical countries are above and below rain falls. Above rainfall and health impact are:

a) Increased mosquito abundance or decreased if breeding sites are washed away.
b) Changes in mosquito abundance contamination of surface water.
c) Contamination of water with faecal matter and rat urine.
d) Increase risk of respiratory and diarrhoeal diseases deaths.
e) Drowning, injuries associated with population displacement.
f) Loss of food supply, psychosocial impacts (6)

On the other side the below rainfall health impacts are:

a) Draught- Changes in vector abundance if vector breeds in dried up river bed.
b) Increased risk of disease associated with lack of water for hygiene.
c) Agricultural: food shortage, illness, malnutrition.
d) Starvation death, malnutrition and increased risk of infection.
e) Health impact associated with displacement (5).

Draught related malnutrition may increase the individual susceptibility to illness. Warmer temperature produces smaller adult mosquitoes which may require multiple blood meals in order to reproduce.

Environment of Kerala:

Kerala provides a geographical and ecologically circumscribed complex mosaic of land where the development –environment link is getting neglected and disrupted. Due to the inherent nature of geography, climatic conditions and ecological characteristics the environment system is very fragile here (8). The state occupies 1.27% of India's land area and 3% of population with a density of 859/sq km compared to 382 per square km of India. The decadal growth of Kerala during 2001 to 2011 was 4.86 %, compared to 17.6% of India and 12.9% of world. During the last ten years the population living in urban area increased from 25% to 48% (7): The phenomenon of urbanization was rampant in Kerala not due to migration or increased birth rate but due to extension/growth of urban areas to neighboring rural areas. The high density of population along with rapid urbanization, unregulated construction activities, unhealthy life styles, and land use patterns disrupted the environment. Along with the human factors the tropical climatic conditions with heavy rain fall and stagnant water bodies become fertile breeding ground for water borne and vector born diseases. As per the available data Kerala has got Forest area of 11309 sq km, of this only 77% consists natural forest. The fact that 92% of the income generated by the Forest Department in 2011 was by selling forest wood give us an idea of deforestation in the state. Unregulated sand and clay mining not only caused ecological lose but also loss of many a human life. Construction boom not considering the real needs is also destructing our hills and rocks at a fast pace.(8) Due to climate change we have to expect more water borne disease in the future years. According to the reliable mathematical modeling - 4X4 assessment sectorial, regional analysis following were predicted (9). With respect to 1970s the temperature is likely to rise by 1-3 degree centigrade. In coastal areas of the Arabian Sea the net sea level rise trends is 1.75 mm/year with inundation area 4.2km^2 for 1m rise. There will be reduction in water yield of water resources up to 10%. Large scale flooding and soil erosion leading to morbidity and mortality was also predicted (9).

With the rapid urbanization, the solid waste management in most of the cities in Kerala is posing a major environmental problem now days. Now the understanding of the kick backs experienced by "Kerala model of health" as emerging and reemerging diseases which were attributed to environmental problems like poor waste management. Due to the peculiar consumption pattern in the state the per capita solid waste generation is high. Segregation of waste at the source is poor and the practice of house hold level composting which was very common earlier has now fallen in to disuse (10). The per capita waste generated in urban areas was 400 grams/day and it was 250 grams /day in the rural areas. Thus a five member family produces 1.5 to 2.5kg solid waste daily (11). The increase in the quantity of waste and the increased non biodegradable components has become a challenge. Plastic and E waste are now on increase (11). The problem got worsened by high consumption pattern of Keralites and low per capita availability of land (12).

Following part of the article will give a description of diseases, changing epidemiology due to either environmental disruption or/and climate change, recent time trends of their incidence in India and Kerala.

1. Water borne diseases: **Diarrhoel disease**

The incidences of water borne diseases are increased during draught and rainy season. The first one is due to due to contamination of the water sources by flooding and the second one is scarcity and concentration of the pathogens. Major diseases are ADD, Cholera, Typhoid and hepatitis. Transmission of enteric disease may be increased in high temperature by promoting their growth (2). Floods and draughts are associated with increased risk of diarrhoeal disease. Heavy rain wash contaminants to water supply, flood may disrupt water purification system and draught can reduce the availability of fresh water. A time series analysis had shown that for one degree rise in temperature there was 8% increase in admission due to ADD. Sea surface temperature increase and increase number of chòlera incidence was documented from Bangladesh.(13) A study in US from 1948 to 1994 show statistically significant association between heavy rain fall and water borne disease; over 50% of outbreaks were preceded by upper 10^{th} percentile of rain fall record (14). In India, the figures for estimated disability adjusted life years (DALY) lost due to diarrhoeal diseases were 23,801,447 in 2006 and by 2016, 21,486,636 DALYs are projected.

In case of hepatitis, now Kerala is in the phase of intermediate endemicity. Thus hepatitis is a "development paradox". All the areas of the world undergoing rapid epidemiological transition have to pass through this phase. Most of the adult cases were reported from lower/upper middle class families which were earlier reported by ICMR from Indian cities (15).

The reported cholera has been linked to monsoon pattern of the state. Cholera outbreaks were reported from Aleppy 2000, Palakkad 2005, 2006, Wynad 2011. Most of the cases were reported from tribal belts in Nilambur, Attapady and Wynad areas were sanitation practices are poor. During the coming years we expect more cholera cases due to global warming. The cholera bacteria will survive for months in the estuaries in coastal areas which are more in Kerala. Cholera is greatly linked to social, economical and political change. (15)

2.Rodent borne disease: **Leptospirosis.**

Due to rapid ecological changes in the region during the past decade many zoonoses have emerged and resulted into epidemics causing significant morbidity and mortality in human beings in different parts of the country. (16) Rodents act as a reservoir of many diseases like leptospirosis, plague. Increase in rain fall may increase rodent population thereby increase contact between human and rodents. The flooding of burrows displace them towards human habitations. Draught conditions may reduce rodent's natural predators thus increase the number of rodents. The 1994 plague outbreak in India was followed by flooding and in Orissa in 1996, and in 2004 Bombay leptospirosis was reported following heavy rains. In Kerala the incidence of leptospirosis was reported to be increased following rainy days. (Aravindan 2004).

Leptospirosis is one of the diseases which predominantly occur in coastal region. The Andaman Islands have been known to be an endemic focus of leptospirosis since the 1920s. The outbreaks of leptospirosis are increasingly being reported from other states such as Kerala, Gujarat, Tamil Nadu and Karnataka. The outbreaks of leptospirosis, an emerging zoonotic disease, are increasingly been reported from many States/UTs such as A&N Islands, Kerala, Gujarat, Tamil Nadu, Karnataka, Maharashtra and Orissa. In addition, sporadic cases have also been reported from Goa, Andhra Pradesh and Assam. (16)

Leptospirosis outbreaks were reported in Kerala from 1997 onwards and during the following years there was an increasing trend of incidence. During the last 10 years 2000 cases and 100 deaths were reported annually and the situation worsened in 2011. (15)

The place/person distribution showed that during the early years in Ernakulam district pineapple workers, Aleppy paddy field workers, Calicut agricultural workers are getting more infection. Studies have shown that in Kottayam district people residing in the canal banks are more affected. A disease mapping prepared in Kozhikode according to the cases reported at Calicut medical college had shown that there is clustering of cases on both sides of Canoly canal (Suresh Babu 1998). Now leptospirosis is reported from all districts of Kerala. Though cases were reported from all months majority of cases occurred in late Monsoon. The change in the distribution and incidence rate of leptospirosis has occurred proportionate to the alterations in the eco-system. Reclamation of wastelands, afforestation, and irrigation changes in crops and agricultural technology have been important factors. All over Kerala natural drainage of rain water to canals or small rivers and stream is blocked by human activities. This drainage congestion and water logging is an important factor for spread of the disease (15). The NICD team suggested that the manmade ecoenvironmental disturbances like creation of bunds, construction of houses in a continuous fashion, construction of roads with inadequate drainage system, water logging, etc contributed to the increase of leptospira in the state.(8)

3. **Vector borne diseases:**

3.1 Dengue

Dengue is the most important arboviral disease of humans, occurring in tropical and subtropical regions of the world. In recent decades dengue has become an increasing urban health problem in tropical countries. Between 1970 and 1975 the annual number of epidemics of dengue was positively correlated with southern Oscillation Index (SOI). A study on dengue in Vietnam found that the number of cases have increased during the El Niño years. (2)

Dengue is an ecological disease and the transmission is related to rainfall and temperature. Every year during the period of July-Nov there is an upsurge in the cases of Dengue/DHF. However, in the peninsular states and western parts of the country the disease has become perennial. The risk of dengue has shown an increase in the recent years due to rapid urbanization, lifestyle changes and improper water storage practices in urban, peri-urban and rural areas, out of 35 States/Union Territories in the country, 31 have dengue cases during last two decades from 1991 to 2010. (16). In a preliminary study using A1B scenario of PRECIS model, transmission windows for dengue transmission (20–32°C temperature and >55% RH) were projected by the year 2030 which show increase in transmission months open for dengue transmission in northern areas and reduction in western part of southern India.

Kerala: Dengue was 1st reported from Thrissur in 1973 among school children and serologically confirmed from NIV Pune. The recent epidemic started in Kottayam in 1997. Then cases have been regularly reported from all districts and the whole state become endemic. The dengue cases were more reported from Ernakulam, Idukki and Kottayam and spread to other districts by 2003. Now it is being reported from all districts of Kerala. The state with 3% of the Indian population is contributing more than 8% of dengue cases during the early years of 21st century. (8) Research studies from Kerala have shown that dengue is associated with rubber plantations where water gets stagnated in the containers attached to rubber plants for latex collection. Another study from Ernakulam concluded that improper disposal of plastic cups provides suitable breeding places for Aedes mosquitoes. In Trivandrum Corporation area the dengue outbreak was attributed to unregulated construction activities added by improper solid waste management and early rain falls (15).

3.2 Chikungunya

Reports of large scale outbreaks of fever caused by chikungunya virus infection in several parts of southern India during 2006 have confirmed the re-emergence of this virus after a quiescence of three decades. A total of 13,90,322 clinically suspected cases have been reported by 16 states/UTs (190 districts) in 2006. Chikungunya cases start appearing in post monsoon period that is May onwards with a in July, August and September as during this period vector density is very high and decline thereafter. *Aedes aegypti* plays the major role in transmitting the disease in all the states except Kerala, where *Ae. Albopictus* plays the major role. (16)

Since May June 2006, Kerala has reported out breaks of chikungunya in some localities of Kozhikode (Olavanna), Alapuzha (Cherthala), Ernakulam and Trivandrum (Vizhijam) districts. These four districts have highest population density ranging from 1050 to 1498 per square km. The places were sea shore and low lying areas and the primary causes were water scarcity and wrong storage practices. The aedes indices: house index ranges from 21.7% to 57.8%, which means that about 20-58% of the premises have got presence of aedes breeding containers. (15) In 2007 central southern districts were affected - it was a multifocal epidemic, where wider areas were affected. The places were hilly with rubber and pineapple estates. The primary causes were multiple environmental factors again. In Kottayam and Pathanamthitta districts the aedes breeding was associated with rubber plantations while in Calicut it was with coconut shells and arecanut and cocoa plantations. During the years of the formation of the state the habitats of Asian tiger mosquitoes (Aedes albopictus) were confined to dense forests of Western Ghats. In the subsequent years due to increased deforestation and invasion of forest area by people the mosquito became a peridomestic breeder thus increasing man mosquito contact. This is facilitated by the increased house density, plenty presence of containers in and around the houses.

Peculiarities of Kerala favoring Aedes breeding chikungunya spread are listed below: geographical situation in the equatorial belt - 25°N to 25°S latitude with tropical climate and increased rain fall, increased breeding, biting, and longevity of mosquitoes. Atmospheric temperature ranges from 16 to 40°C in all seasons and relative humidity ranges from 60 to 70% which favors longevity and increased biting habit of mosquitoes. Plenty of water with inappropriate supply and storage practices favor breeding. Various drinking water schemes (Eg: Japan drinking water, Jalanidhi, etc) works related to which like laying pipes and digging canals are widespread in the state and alter the natural drainage and facilitate water collections.

Increased population density and population mobility increase the chances of bringing the chikugunya virus to "receptive area" along with mosquitos. The health seeking behavior of people to specialist centers mostly situated in urban areas which were far away from their rural residential areas and high mobility of population facilitate the spread. (15) Breeding habitats of Aedes are artificial accumulation of water in: Broken bottles discarded tins, fire brackets, flowerpots, coconut shells, earthen pots, tree holes, rubber containers, plastic containers which are widely distributed in Kerala. A study published in 2011 by the author revealed that compared to plastics and pots the physicochemical characteristics of coconut shells favour mosquito breeding (17). Due to widespread coconut cultivation, discarded unused coconut shells around the cultivation and housing areas act as a potential breeding ground for mosquitoes.

3.3. Malaria

The world's most important vector borne disease. Over 2.5 billion people are at risk and an estimated 0-5 billion cases and more than 1 million deaths occur per year. Historical data have shown that following EL Nino in 1877 there was an epidemic of malaria in India; the proximate cause were found to be the draught, breaking rains leading to vector abundance (6). Statistically significant relationship was found between EL Nino and malaria epidemics in Colombia, Peru, Venezuela recently. (2) Malaria varies seasonally in highly endemic areas. Early in 20th century Punjab experienced periodic epidemic of malaria which is attributed to excessive monsoon rainfall and high humidity. (18) Strong correlation was found between incidence of malaria and annual rain fall, number of rainy days in Rajasthan and Gujarat (Bouma 1996).

The country-wide resurgence of malaria was again experienced in 1994. The malaria situation in India has steadily improved during the past decade with the number of reported cases being around 1.5 million with about thousand deaths annually at present. Development project activities without health impact assessment have resulted in malaria outbreaks in short terms and endemic malaria with foci of *P.falciparum* resistance strains in long term. Certain cities contribute large proportion of Malaria in the state like Chennai in Tamil Nadu and cities like Mumbai had shown an increase. (16)

Malaria was almost eliminated from Kerala in 1970s. But during the last 2 decades it seems to be coming back, mainly due to manmade changes in the ecosystem for developmental activities known as "Project malaria." Major construction activities leads to disturbance in ecosystem prolific increase in breeding sites, increased man-mosquito contact and bringing people carrying parasites from endemic to non endemic area and mixing population with different immune status thus favoring spread of malaria. Examples are Construction work of ACME pariyaram 1996, Vismaya park 2008-09 in Kannur, (19) Jubilee, Daya hospitals in Thrissur.

3.4 Japanese Encephalitis (JE)

Around the world, the incidence has gone up from 44,000 in 2004 to 58,000 in 2009; with deaths ranging from 14,000 -16,000 in the last five years. Japanese encephalitis is a major problem in Uttar Pradesh, Assam, Andhra Pradesh, Goa, Karnataka, Kerala, Manipur, Tamilnadu, Maharashtra, Bihar and West Bengal. The disease is presently reported as Acute Encephalitis Syndrome (AES). During 2010, 5149 AES cases and 677 deaths were reported in 15 states. Outbreaks of JE usually coincide with the monsoon and post monsoon period when the density of mosquitoes increase. (16) Incidence of JE in India has increased in eastern Uttar Pradesh in the last five years. The knowledge about lower and upper thresholds of temperature, rainfall and RH required for JE endemicity is still lacking.

First time during the year 1996, 96 cases of Japanese encephalitis and 6 deaths from it were reported from Aleppy district. It continued in 1997. The cases were mainly reported from Kuttanad region which stretches between Alapuzha, Kottayam and Pathanamthitta districts. Most cases were reported during the months of January and February following northeast monsoon (20). As the part of agricultural development project regulator was constructed in vembanad backwater which prevented the saline water entry in the area and washing away of water plants and algae. Decrease in fish and other predator leads to the increased breeding of Culex tritaenorhyncus mosquito which is the vector of JE. Due to economic reasons many people have shifted their occupation from agriculture to poultry /cattle, pig farming The increase in cattle, pig and poultry population has added in maintaining the domestic cycle of the virus. The 42 kms long Alapuzha - chenganassery road cutting across the heart of Kuttanad paddy fields have prevented water flowing from one side to other resulting in water stagnation thereby aiding the growth hyacinth, pistia, African payal etc This is an ideal breeding place for mosqutoes(20). After the construction of vembanad bund the tide disappeared leading to accumulation of wastes, pesticides and loss of salinity resulting in epidemics. The fish production reduced from 16000 tons to 7000 tons (21). In other districts the uncultivated rice fields with decaying vegetations following monsoon became a good fertile ground for breeding of Culex mosquito.

Conclusion:

"Human beings are the centre of concerns for sustainable development and they are entitled to a healthy and productive life, in harmony with nature. The goals of sustainable development can only be achieved in the absence of a high prevalence of debilitating diseases, while obtaining health gains for the whole population requires poverty eradication. There is an urgent need to address the causes of ill health including environmental causes and their impact on development...." The Rio Declaration on Environment and development. Due to large number of "developmental" activities not considering sustainability and the attitude of policy makers as well as people the environmental health problems are worsening in India especially in our state Kerala. The descriptions in this article try to give a glimpse of only the tip of the iceberg.

Table 1 .Time trend of incidence of water and vector borne disease reported in Kerala.

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Malaria- cases	2940	2289	2986	2575	2790	2554	1121	1675	1804	2046	2299
Dengue- cases	0	74	163	3866	839	1047	1087	550	733	1425	2597
Leptospirosis- cases	1174	2582	2928	2162	1455	1716	1708	1106	1305	1237	1016
Hepatitis - cases	5488	4632	5333	7433	6992	8265	6515	6231	6963	7844	1016
Typhoid -cases	10393	7521	8408	12996	9451	7383	6385	4261	1890	2632	2529

(Sources: DHS, IDSP-Govt of Kerala)

Table 2: Relative risk and DALY attributable to climate change.

Out come	Relative Risk South east Asian region	Relative Risk Developed Countries	DALY/Million Population World
Cardiovascular disease	**1. 0– 1.013**	**0.999 – 1.000**	**Not done**
Diarrhea	**0.99 – 1.17**	**0.94 – 1.06**	**1460**
Malnutrition	**1.0 -1.27**	**1.0 – 1.0**	**2847**
Flood deaths	**1.0 – 1.75**	**1 .0– 8.75**	**192**
Malaria	**1.0 – 1.02**	**1.0 -1.27**	**1018**

Estimation of disease burden and relative risk due to climate change by 2030 AD

This Estimation was done using HadCM2 Global climate model (GCM) which is approved by IPCC, verified by back casting (10)which is given in the table 2.

References:

Ray M.Meril Environmental Epidemiology, Principles and Methods. Jones and Bartlett publishers 2010.

McMichael, Campbell-lendrum, Corvalan, Ebi et al; Climate change and human health–Risk and responses. World health Organization Geneva 2003

Epstein PR; Climate and health Science (285), 347-48. 1999

Technical summary; Climate change 2001; The scientific basis-IPCC. Cambridge University press 2001.

Wood ward AJ; protecting human health in a climate changing world: Role of social and economic development. Bulletin of World Health Organization (78) 1148-55.2000.

Kovats R; El Nino and health: World health Organization Geneva 1999.

Report -India Census 2011. Registrar General of India. New Delhi.

Kerala State Environment policy draft. Government of Kerala (2007).

Climate change in India. A 4X4 assessment sectorial, regional analysis 2030s. Ministry of Environment and forests, GOI, November 2010.

Malinya mukta Keralam Action Plan. Local Self Government Department; Government of Kerala 2007.

Dileep Kumar. Household solid waste generation. Janapatham; Jan 2010:28-30.

Economic Review 2008 available from http://www.keralaplanning board.org.

Ckeckly W; Effects of El Nino and ambient temperature on hospital admission for diarrhoeal disease. Lancet (355) .2000.

Curriero FC; The association between extreme precipitation and water borne disease out breaks in United States, 1948-1994. American journal Of public health (8) 1194-99 .2001.

Dr JayakrishnanT., Environmental Epidemiology and Health transition in Kerala. Study Paper 2012.p25

Report of the working group on Communicable disease 12th five year plan. Ministry of Health and Family welfare .Government of India. 2012.

Rao Bhaskar, JayakrishnanT, Biju: .Characteristcs of aedes albopictus breeding sites. South East Asian journal of Tropical medicine and public health .2011.1077-79

Christophers SR; Epidemic of malaria of the Punjab, with a note on predicting epidemic years. Paludism2. 17-26. 1911

Jayakrishnan Control of project malaria in Northern Kerala – Community Health forum Kerala 2003: 66-69.

Joy Elamon .Agricultural development and Japanese encephalitis . A case study from from Kerala . medico friend circle bullettine Nov-Dec 1997.

Gopakumar M, Sanu N Kuttanad Package. Sasthragathi (47) : 20011 December 6-15

Pollution from Agriculture: Sources, Impacts and Threats

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Food security, after drinking water availability is of greatest priority in a society. Hence, agriculture is a dominant component of the global economy. While mechanization of farming in many countries has resulted in a dramatic fall in the proportion of population working in agriculture, the pressure to produce enough food has had a worldwide impact on agricultural practices. In many countries, this pressure has resulted in expansion into marginal lands and is usually associated with subsistence farming. In other countries, food requirements have required expansion of irrigation and steadily increasing use of fertilizers and pesticides to achieve and sustain higher yields.

Agricultural pollution refers to biotic and abiotic byproducts of farming practices that results in contamination or degradation of the environment and surrounding ecosystems (land, water and air), and cause injury to humans and their economic interests. The pollution may come from a variety of sources, ranging from point source pollution (from a single discharge point) to more diffuse, landscape-level causes, also known as non-point source pollution. Management practices play a crucial role in the amount and impact of these pollutants. Management techniques range from land management, animal management and housing to the spread of pesticides and fertilizers in global agricultural practices.

Non-point source pollution, once known as "diffuse" source pollution, arises from a broad group of human activities for which the pollutants have no obvious point of entry into receiving ecosystems. In contrast, **point source** pollution represents those activities where wastewater is routed directly into receiving water bodies by, for example, discharge pipes, where they can be easily measured and controlled. Non-point source pollution is much more difficult to identify measure and control than point sources. Non-point source pollutants, irrespective of source, are transported overland and through the soil by rainwater and melting snow. These pollutants ultimately find their way into groundwater, wetlands, rivers and lakes and, finally, to oceans in the form of sediment and chemical loads carried by rivers. **All types of agricultural practices and land use, including animal feeding operations (feed lots), are treated as a non-point sources.** The main characteristics of non-point sources are that they **respond to hydrological conditions,** are **not easily measured or controlled directly** (and therefore are difficult to regulate), and **focus on land and related management practices.**

Sources

The major sources of pollution from agriculture are as follows

1. **Agro chemicals**

1.1 Pesticides.

Pesticides are applied to agricultural land to control pests that disrupt crop production. Soil contamination can occur when they persist and accumulate in soils, which can increase plant uptake of the chemicals, alter microbial processes, and also cause toxicity to soil organisms. The extent to which the pesticides and herbicides persist depends on the compound's unique chemistry, which affects sorption dynamics and resulting fate and transport in the soil environment. Pesticides can also accumulate in animals that eat contaminated pests and soil organisms. In addition, pesticides can be more harmful to beneficial insects, such as pollinators, and to natural enemies of pests (i.e. insects that prey on or parasitize pests) than they are to the target pests themselves.

Pesticide leaching

Pesticide leaching occurs when pesticides mix with water and move through the soil, ultimately contaminating groundwater. The amount of leaching is correlated with particular soil and pesticide characteristics and the degree of rainfall and irrigation. Leaching is most likely to happen if using a water-soluble pesticide, when the soil tends to be sandy in texture, if excessive watering occurs just after pesticide application, or if the adsorption ability of the pesticide to the soil is low. Leaching may not only originate from treated fields, but also from pesticide mixing areas, pesticide application machinery washing sites, or disposal areas.

Problems associated with the use of pesticides

- Most of them are hazardous. Non target organisms are also affected by their toxicity – some of which may be beneficial organisms.
- It is difficult to prevent the circulation of these chemicals in the environment. Air and water carries them to far off places.
- Most of them are synthetic organics or their decomposition products persist in toxic state in the environment for long durations. They are bio accumulated and bio magnified which cause problems at higher tropic levels in an ecosystem.

Ecological effects of pesticide pollution

Differential toxic action of pesticides on different species results in an unbalanced biotic community. Species susceptible to the toxic action of the pesticide are eliminated while the resistant ones multiply without competition. Organisms on which the eliminated species depended for its food requirement are also affected. Absence of predation causes these forms to multiply in numbers. Thus a chain of events is initiated which alters the species composition of the ecosystem beyond recognition. Insignificant pest may become so numerous as to cause another pestilence.

Persistence of pesticides in the environment

Pesticide persistence depends on the rate of disintegration per unit time it takes to naturally break down to non toxic compounds under ideal soil conditions. This is often expressed as a half-life of the pesticide which is the time taken by the pesticide for decomposition of half of the original quantity. Pesticide persistence can be divided into three categories including:

1. Non persistent: half-life less than 30 days.
2. Moderate: half-life of 30 to 100 days.
3. Persistent: half-life of more than 100 days (Vogue *et al.*, 1994),

The persistence of pesticides in the environment depends up on their chemical and physical properties, dose and formulations, type of soil, soil moisture content, temperature, physical properties of the soil, composition of the microflora and the plant species present. Under favourable conditions of decomposition, the degradation may be brought about rather quickly while adverse conditions may delay it for considerable period.

Bio accumulation and biomagnifications of pesticides

Pesticides even though present in exceedingly low concentration in the soil or surrounding water are taken up by various plants and animals which may accumulate and concentrate them several thousand times. The concentration of 0.00001 ppm of DDT may be magnified to almost 70000 times in oysters within a period of 40 days. One kg of soil may contain only 0.0001 mg of an organo chlorine pesticide whereas carrots grown on this soil may contain as much 2 to 6 mg per kg and the rabbits feeding on these carrots may contain as much as 22 to 35 mg kg^{-1} of the toxicant. Similar bio accumulation and bio magnification have been recorded for a number of other pesticides also (Gruzdyev, 1988).

The process of bioaccumulation and bio magnification makes exceedingly low quantities of pesticides or their toxic residues available to the living organism in a highly concentrated state. The worst effects are on the animals at higher tropic level.

i.Herbicides

Herbicides are chemicals which are used to suppress unwanted plants. The use of these chemicals has increased markedly during the last twenty five years. Most of the herbicides have very little toxicity to vertebrates. But, some of them show extreme toxicity to higher animals including man.

A great deal of public attention towards the application of about 44 M lbs of **Agent Orange** on about 1.4 M ha of rich fertile land and forests in Vietnam War by USA during 1960's. Agent orange consisted of mixture of 2-4-D and 2-4-5-T with contamination by tetrachloro dibenzo-p-dioxan(TCDD) which is formed when the temperature increases during manufacture of 2-4-5-T). TCDD is an extremely toxic compound, had been shown to be carcinogenic as well as teratogenic to the people who were exposed to the mixture (Young *et al.*, 1978). The entire area where Agent Orange was applied was rendered barren.

ii. Fungicides

Though many of these compounds have little toxicity to vertebrates, there are a few notable exceptions. Compounds containing mercury cause great concern. Consumption of grains treated with these has resulted in many deaths and permanent neurological disability in human in Pakistan and Iraq (Haq, 1963).

iii. Fertilizers

Fertilizer applications that supply nutrients in quantities far in excess of those taken up by plants, results in contamination of both surface and ground water. Nitrates and phosphates are often involved. Nitrate contamination occur in both surface run off and drainage waters, while excessive levels of phosphates generally occur only in surface run off. Excess N supplied by both synthetic fertilizers (as highly soluble nitrate) and organic sources such as manures (whose organic N is mineralized to nitrate by soil microorganisms) can lead to groundwater contamination of nitrate.

Impact of agricultural activities on groundwater nitrate pollution

Nitrogen contamination may come from a variety of sources: municipal sewage, animal manure, atmospheric deposition, biological N fixation, soil organic N, and/or nitrogen fertilizers. The consequences of contamination in a specific water body will depend upon the amount of contamination from all sources and characteristics of the receiving waters. Nitrogen fertilizers or manure applied to farmlands can be considered as non-point sources of nitrate (Ray and Member, 1999). Nitrogen compounds in these sources are oxidized in aerated soils to soluble nitrate. With sufficient surface-water infiltration, soluble nitrate can leach below the root zone to underlying groundwater. Unconfined aquifers with shallow water tables overlain by permeable soils are especially vulnerable to nitrate contamination.

The effect of excessive nitrate in drinking water is linked to methemoglobinemia (or blue baby syndrome) which affects the foetus and young children and non-Hodgkin's lymphoma (WHO 1995 and Hudak 1999). Often nitrate concentrations in agricultural areas are associated with pesticide and microbial contaminations.

Other possible associations between nitrate in drinking water and chronic health problems include·

1. Hyperthyroidism (goiter) linked to exposure to nitrate in drinking water (Seffner 1995; Van Maanen *et al.* 1994)
2. Increased risk for central nervous system malformations in newborns whose mothers had consumed private well water equal to or greater than 26 ppm NO_3-N (Arbuckle *et al.* 1988)
3. Genotoxic effects at the chromosomal level reported in persons consuming water with very high nitrate levels (Van Maanen *et al.* 1996 and Tsezou *et al.* 1996),
4. Increased risk of developing insulin-dependent diabetes associated with 2 to 8 ppm NO_3-N in water supplies (Kostraba *et al.*, 1992).

Eutrophication

The term eutrophication means nutrient enrichment. Due to addition of domestic wastes, phosphates and nitrates to water bodies makes it rich in nutrients and become highly productive and this process is called eutrophication. The nutrient deficient (oligotrophic) water bodies slowly turn to mesotrophic (intermediate or moderate nutrient status) and further to eutrophic stage. Natural eutrophication is a slow process. But human activity speeds up the natural eutrophication and accelerated eutrophication occurs. Huge amount of organic matter, fertilizers and sewage effluents are added to water bodies through run off and promote the luxurious growth of algae and other water plants. The development of dense population of planktonic algae within a short span of time in water reservoirs is called algal blooms. The water body which could have served as a reservoir of fresh water becomes useless within a short span of time (Smith *et al.*, 1999).

Creation of oxygen deficit in aquatic ecosystems and Algal blooms (water blooms)

Organic matter serves as a source of energy to microbial life in aquatic ecosystems. Over abundance causes rapid rise in microbial activity resulting in oxygen deficit for the macrofauna. The aerobic activity is replaced by anaerobic activity and various organic acids, phenols, alcohols and inorganic gases like ammonia, nitrous oxide, methane, hydrogen sulphide etc. accumulate in the system, which harm the aquatic life (Massive fish kill in Gomati river in 1975 in U. P). The water body becomes congenial for many pathogenic organisms also.

Nitrate-contaminated drinking water can cause blue baby syndrome. Together with excess P from the same fertilizer sources, eutrophication can occur downstream due to excess nutrient supply, leading to anoxic areas called dead zones.

Fertilizers and Pesticides as sources of air pollution

The various gases released from fertilizer industries as well as agricultural fields *viz.* various oxides of sulphur and nitrogen, NH_3, H_2S, methane as well as phosphene from marshy lands (under continuous submergence for a long period of peat and muck soils), hydrocarbons and particulate matter cause air pollution. Some of the gases like oxides of sulphur and nitrogen may contribute to acid rains also.

The problem of abundance of infectious microbes

Organic wastes, sewage effluents, excreta exudates and fecal matter support a rich population of microbes which include numerous bacteria, viruses, protozoans, larval stage of different insects, etc. which cause dangerous diseases to plants, animals and humans.

g) Heavy metals and trace elements

Toxic trace elements and heavy metals come under the category of non degradable pollutants. They present in the environment in bio available form. The major sources of heavy metals and trace elements to the environment are through combustion of fossil fuel, industrial activity and mining and processing of wastes. Heavy metals enter soils through addition of sludge, composts, or fertilizers. The major ones which cause health problems are arsenic, cadmium, nickel, mercury and lead.

Problems associated with trace element pollution are

1. Higher levels of trace elements are injurious to plants, animals and microbes.
2. Many of them are lipophillic: provides free access to biological system.
3. Their persistence in the environment and subsequent transformation into more toxic state are distinct possibilities.
4. Bio concentration and magnification in the biosphere may substantially damage our food supplies, water resources and land.
5. Synergistic effects when two or more than such elements are involved greatly enhance the trace element toxicity

6. Carcinogenic, teratogenic and mutagenic effects may occur even at low concentrations which often evade detection.

i. Arsenic

Arsenic (As) is ubiquities in distribution. In lime stones and siliceous deposits, its concentration ranges from 0.5 to 2.0 ppm while in volcanic ash as much as 20 ppm of As is found. The total daily intake of as from all sources in India by humans ranges from 0.2 to 0.35 mg day^{-}. Trivalent compounds of As are known to be the main toxic forms of this metal. Arsenic minerals exist in the environment principally as sulfides, oxides, and phosphates. In igneous rocks, only those of volcanic origin are implicated in high aqueous arsenic concentrations. Sedimentary rocks tend not to bear high arsenic loads, and common matrices such as sands and sandstones contain lower concentrations owing to the dominance of quartz and feldspars. Groundwater contamination by arsenic arises from sources of arsenopyrite, base metal sulfides, realgar and orpiment and iron oxyhydroxides. Mechanisms by which arsenic is released from minerals are varied and are accounted for by many (bio) geochemical processes: oxidation of arsenic-bearing sulfides, desorption from oxides and hydroxides, reductive dissolution, evaporative concentration, leaching from sulfides by carbonate, and microbial mobilization.

Generally, in unpolluted environments, ordinary crops do not accumulate enough arsenic to be toxic to man. However, in arsenic contaminated soil, the uptake of arsenic by the plant tissue is significantly elevated, particularly in vegetables and edible crops (Larsen *et al.*, 1992). Arsenic contamination in the groundwater is causing significant global human health problems. It has been estimated that 60 to 100 million people in India and Bangladesh are currently at risk of arsenic related disease as a result of drinking arsenic contaminated groundwater (Anawar et al., 2002). Chronic arsenic poisoning can cause serious health effects including cancers, melanosis (hyperpigmentation or dark spots and hypopigmentation or white spots), hyperkeratosis (hardened skin), restrictive lung disease, peripheral vascular disease (blackfoot disease), gangrene, diabetes mellitus, hypertension, and ischaemic heart disease (Chen et al., 1995; Guha-Mazumder et al., 2000)

ii. Cadmium

Cadmium (Cd) is a heavy metal that is of great concern in the environment, because of its toxicity to animals and humans. Concentrations of Cd can accumulate in plants that are not toxic to them, yet are toxic to the animals eating the plants. Cadmium toxicity especially affects humans rather than animals, because of their longevity and the accumulation of Cd in their organs by eating Cd-contaminated food (Tudoreanu and Phillips, 2004). Anthropogenic pathways by which Cd enters the environment are through industrial waste from processes such as electroplating, manufacturing of plastics, mining, paint pigments, alloy preparation, and batteries that contain cadmium (Adriano, 2001; Cordero *et al.*, 2004). Household appliances, automobiles and trucks, agricultural implements, airplane parts, industrial tools, hand tools, and fasteners of all kinds (e.g., nuts, bolts, screws, nails) are commonly Cd coated. Cadmium is also used for luminescent dials, in photography, rubber curing, and as fungicides (Adriano, 2001). Cadmium contamination of groundwater may come from agricultural inputs like phosphate fertilizers. The most likely origin of the excess Cd is from heavy applications of cheap, contaminated phosphate fertilizers (Booth, 2005; Stephens and Calder, 2005).

Cadmium accumulates in animals, especially in the kidney, liver, and reproductive organs. Respiratory absorption of cadmium is about 15 to 20% whereas up to 5% of cadmium is ingested orally is absorbed from gastro-intestinal tract. About 50 to 70% cadmium content of the body is present in liver and kidneys.

Low level exposures spread over long durations produce chronic pulmonary and renal tubular diseases. Obstructive lung diseases result from chronic bronchitis, progressive fibrosis in lower portions of the lungs leading to emphysema. Elevated levels of Cd in humans can cause kidney damage. The notorious Itai–Itai ("ouch–ouch") disease is associated with Cd exposure (Yeung and Hsu, 2005). It results in painful bone demineralization (osteoporosis) and softening of bones because Cd replaces calcium in the bones.

iii. Mercury

Mercury (Hg) is one of the most toxic heavy metals commonly found in the global environment including lithosphere, hydrosphere, atmosphere and biosphere. A series of complex chemical transformations allows the three-oxidation states of Hg to cycle in the environment (Barbosa *et* *al.*, 2001). Its zero oxidation state Hg^0 exists as vapor or as liquid metal, its mercurous state Hg_2^{2+} exists as inorganic salts, and its mercuric state Hg^{2+} may form either inorganic salts or organo mercury (insecticide and fungicide) compounds. Mercury (Hg) has been used for millennia in many applications, primarily in artisanal mining and as an electrode in the chlor–alkali industry. Its unique chemical characteristics enable global atmospheric transport and it is deposited after various processes, ultimately ending up in one of its final sinks, such as incorporated into deep sediment or bio accumulated, primarily in the marine environment. Most of the Hg encountered in all environmental media (water/soil/sediments/ biota) is in the form of inorganic mercuric salts and organomercurics, with the sole exception of atmosphere. The mercuric salts $HgCl_2$, $Hg(OH)_2$ and HgS are the prevalent forms existing in the environment and CH_3HgCl and CH_3HgOH are main forms of organic compounds, together with other organomercurics (i.e., dimethylmercury and phenylmercury) existing in small fractions (USEPA, 1997). Natural, anthropogenic and re-emitted sources are the three major sources of Hg emissions (USEPA, 1997), whereas the most important anthropogenic sources of Hg pollution in the environment are urban discharges, agricultural materials, mining and combustion and industrial discharges. Atmospheric deposition is an important pathway for Hg deposition into the environment. The amount of Hg in the atmosphere is estimated to have increased as much as ten-fold since the beginning of the industrial revolution (USEPA, 2003). Emission inventories indicate that Asian Hg sources account for more than 50% of the global anthropogenic total Hg (Jaffe *et al.*, 2005).

Impact of mercury poisoning

The earliest effects of methyl mercury poisoning in adults are non-specific symptoms such as paresthesia, malaise, and blurred vision. It can cause nausea, lack of appetite, weight loss, abdominal pain, diarrhoea, skin burns and irritation, swollen gums and mouth sores, as well as drooling. With increased exposure, more severe symptoms appear such as numbness and tingling in the lips, mouth, tongue, hands and feet, tremors and lack of coordination, vision and hearing loss, memory loss, personality changes, respiratory distress and kidney failure. Acute exposure to elemental mercury and vapour can result in acrodynia or "pink disease", which is characterized by bright pink peeling palms, fingers, and soles of the feet, excessive perspiration, itchiness, rashes, joint pain and weakness, elevated blood pressure and heart palpitations. Methyl mercury readily crosses the placenta from mother to baby, and also the blood-brain barrier. Methyl mercury can also cause mental impairments and learning disabilities, cerebral palsy, seizures, spasticity, tremors, and lack of coordination, along with eye and hearing damage in the unborn baby as a result of the mother's exposure. In addition, methyl mercury can also pass into the mother's breast milk, further exposing the newborn baby.

The largest epidemic of methyl mercury poisoning took place in Iraq during 1971-1972 when people ate the wheat grains treated with methyl mercury fungicides. The average methyl mercury content of these grains was about 4.8 to 14.6 mg kg^{-1}. About 600 people were affected and about 500 deaths were occurred.

Minamata disease

Major episode of mercury poisoning had occurred in Japan because of industrial discharge of mercury compounds. Minamata disease was first discovered in Minamata city in Kumamoto prefecture, Japan, in 1956. It was caused by the release of methyl mercury in the industrial wastewater from the Chisso Corporation's chemical factory, which continued from 1932 to 1968. This highly toxic chemical bio accumulated in shellfish and fish in Minamata bay and the Shiranui Sea, which, when eaten by the local populace, resulted in mercury poisoning. The animal effects were severe enough in cats that they came to be called "dancing cat fever."

Minamata disease is a neurological syndrome caused by severe mercury poisoning. Symptoms include ataxia, numbness in the hands and feet, general muscle weakness, narrowing of the field of vision, and damage to hearing and speech. In extreme cases, insanity, paralysis, coma, and death follow within weeks of the onset of symptoms. A congenital form of the disease can also affect foetuses in the womb.

iv. Nickel

Nickel (Ni) is the 24th most abundant element in the Earth's crust, comprising about 3% of the composition of the earth. It is the 5th most abundant element by weight after iron, oxygen, magnesium and silicon. It is a member of the transition series and belongs to group VIII B of the periodic table along with iron, cobalt, palladium, platinum and five other elements. Nickel is a nutritionally essential trace metal for at least several animal species, micro-organisms and plants, and therefore either deficiency or toxicity symptoms can occur when too little or too much Ni is taken up respectively. Nickel is one of many trace metals widely distributed in the environment, being released from both natural sources and anthropogenic activity. Natural sources of atmospheric nickel levels include wind-blown dust, derived from the weathering of rocks and soils, volcanic emissions, forest fires and vegetation. Nickel finds its way into the ambient air as a result of the combustion of coal, diesel oil and fuel oil, the incineration of waste and sewage.

Human nickel exposure originates from a variety of sources and is highly variable. Nickel is normally present in human tissues and, under conditions of high exposure, these levels may increase significantly. The metabolism of nickel involves conversion to various chemical forms and binding to various ligands. The organ distribution of nickel has been documented by a number of investigators. Although differences in distribution occur as a function of route of exposure, the solubility of the nickel compounds and time after exposure, the primary target organs for nickel-induced systemic toxicity are the lungs and the upper respiratory tract for inhalation exposure and the kidney for oral exposure. Other target organs include the cardiovascular system, the immune system and blood.

Human exposure to highly nickel-polluted environments has the potential to produce a variety of pathological effects. Among them are skin allergies, lung fibrosis, cancer of the respiratory tract and iatrogenic nickel poisoning. Nephrotoxicity has been noted and aminoaciduria and proteinuria were the indices of nickel toxicity. Nickel exposure has been reported to produce haematological effects in both animals and humans.

Many harmful effects of nickel are due to the interference with the metabolism of essential metals, such as Fe (II), Mn (II), Ca (II), Zn (II), Cu (II) or Mg (II), which can suppress or modify the toxic and carcinogenic effects of nickel. The toxic functions of nickel probably result primarily from its ability to replace other metal ions in enzymes and proteins or to bind to cellular compounds containing O-, S-, and N-atoms, such as enzymes and nucleic acids, which are then inhibited. Nickel has been shown to be immunotoxic, altering the activity of all specific types involved in the immunological response, resulting in contact dermatitis or asthma.[Coogan et al., 1989].

v. Lead

Lead sulphide or galena is the main source of lead. It is the ubiquitous toxic metal and can be detected practically in all components of the environment as well as of the biosphere. Lead is toxic to most of the living organisms but has known function within a biological system. Lead finds wide applications in industries and effluents from these units contain a good quantity of this element. It may also come from combustion of fossil fuels, exhausts of automobiles run on petrol containing lead compounds which are added as anti knock agents.

Plants growing near busy water ways are regularly exposed to fumes and smoke discharged from auto mobiles containing plenty of lead. Routes of exposure to lead include contaminated air, water, soil, food, and consumer products.

Lead poisoning

Lead poisoning (also known as plumbism, colica Pictonum, saturnism, Devon colic, or painter's colic) is a medical condition in humans and other vertebrates caused by increased levels of the heavy metal lead in the body is one of the oldest known environmental hazards. Lead interferes with a variety of body processes and is toxic to many organs and tissues including the heart, bones, intestines, kidneys, and reproductive and nervous systems. It interferes with the development of the nervous system and is therefore particularly toxic to children, causing potentially permanent learning and behavior disorders. Symptoms include abdominal pain, confusion, headache, anemia, irritability, and in severe cases seizures, coma, and death.

One of the largest threats to children is lead paint that exists in many homes, especially older ones; thus children in older housing with chipping paint or lead dust from moveable window frames with lead paint are at greater risk.

h) Soil erosion and sedimentation

Agriculture contributes greatly to soil erosion and sediment deposition through intensive management or inefficient land cover. It is estimated that agricultural land degradation is leading to an irreversible decline in fertility on about 6 million ha of fertile land each year. The accumulation of sediments (i.e. sedimentation) in runoff water affects water quality in various ways. Sedimentation can decrease the transport capacity of ditches, streams, rivers, and navigation channels. It can also limit the amount of light penetrating the water, which affects aquatic biota. The resulting turbidity from sedimentation can interfere with feeding habits of fishes, affecting population dynamics. Sedimentation also affects the transport and accumulation of pollutants, including phosphorus and various pesticides.

As discussed below, the ecological impact of these pollutants range from simple nuisance substances to severe ecological impacts involving fish, birds and mammals, and on human health.

Table 1. Agricultural impacts on water quality

Agricultural activity	**Impacts**	
	Surface water	**Groundwater**
Tillage ploughing	**Sediment/turbidity**: sediments carry phosphorus and pesticides adsorbed to sediment particles; **Siltation** of river beds and loss of habitat, spawning ground, etc.	
Fertilizing	Runoff of nutrients, especially P, leads to eutrophication causing bad taste and odour in public water supply, Excess algae growth leading to deoxygenation of water and fishkills.	Leaching of nitrate to groundwater; excessive levels are a threat to public health.
Manure spreading	Carried out as a fertilizer activity; spreading on frozen ground results in high levels of contamination of receiving waters by pathogens, metals, phosphorus and nitrogen leading to eutrophication and potential contamination.	Contamination of ground-water, especially by nitrogen
Pesticides	Runoff of pesticides leads to contamination of surface water and biota; dysfunction of ecological system in	Pesticides leach into groundwater causing human health problems from contaminated wells.

	surface waters by loss of top predators due to growth inhibition and reproductive failure; public health impacts from eating contaminated fish. Pesticides are carried as dust by wind over very long distances and contaminate aquatic systems 1000s of miles away (e.g. tropical/subtropical pesticides found in Arctic mammals).	
Feedlots/animal corrals	Contamination of surface water with many pathogens (bacteria, viruses, etc.) leading to chronic public health problems. Also contamination by metals contained in urine and faeces.	Potential leaching of nitrogen, metals, etc. to groundwater.
Clear cutting	Erosion of land, leading to high levels of turbidity in rivers, siltation of bottom habitat, etc. Disruption and change of hydrologic regime, often with loss of perennial streams; causes public health problems due to loss of potable water.	Disruption of hydrologic regime, often with increased surface runoff and decreased groundwater recharge; affects surface water by decreasing flow in dry periods and concentrating nutrients and contaminants in surface water.
Silviculture	Broad range of effects: pesticide runoff and contamination of surface water and fish; erosion and sedimentation problems.	
Aquaculture	Release of pesticides (e.g. TBT[1]) and high levels of nutrients to surface water and groundwater through feed and faeces, leading to serious eutrophication.	

Pollution Control

I. Waste water treatment

Water pollution control generally involves the removal of impurities from waste water before it reaches the point of discharge. Waste water must be purified or treated to some degree in order to protect public health and to prevent deterioration of existing water quality. Some of the parameters to be controlled are turbidity, dissolved oxygen, BOD, coliforms, acidity and toxic substances. General waste water treatment processes are given in table 2.

Table 2. General waste water treatment processes

Process	Application	Quality improvement
Coagulation and sedimentation	Primary treatment(physical method) Removal of P-lime soda application	Reduction in turbidity Reduces P Reduces hardness (Ca^{2+}& Mg^{2+}
Gravity filtration	Primary treatment	Reduction in suspended particles; low turbidity
Filtration and chlorination	Municipal water supplies treatment	Reduction in turbidity and bacteria
Fine screening	Removal of raw sewage	Reduction in BOD
Microstraining	Clarification prior to filtering	Reduction in microscopic particles
Carbon filters	Adsorption	Removal of odour & taste
Ion exchange	Deminaralisation	Removal of ions
Electrochemical desalting	Reverse osmosis	Reclamation of water from salinity and alkalinity

(Narayanan, 2007)

II. Solid waste management

Solid waste is the unwanted or useless solid materials generated from combined residential, industrial and commercial activities in a given area. It may be categorised according to its origin (domestic, industrial, commercial, construction or institutional); according to its contents (organic material, glass, metal, plastic paper etc); or according to hazard potential (toxic, non-toxin, flammable, radioactive, infectious etc). Management of solid waste reduces or eliminates adverse impacts on the environment and human health and supports economic development and improved quality of life. A number of processes are involved in effectively managing solid waste from polluted area. These include monitoring, collection, transport, processing, recycling and disposal. General solid waste disposal methods are given in table 3.

Table 3. General solid waste disposal methods

Process	Purpose	Waste disposal
Filtration	Dewatering	Sludge
Chemical addition	Precipitation	Sludge
Land fill	Storage and disposal	Inert and radioactive materials
Submerged combustion	Dewatering	Liquids
Incineration	Volume reduction	Most organic materials
Biological degradation (compost)	Dilution	Biodegradable organics
Recycling	Reuse	Metals

(Narayanan, 2007)

Biodegradation and Bioremediation

Biodegradation, bioremediation and bioaugmentation are strategies to keep the concentration of environmental pollutants at very low levels.

Biodegradation refers to any biologically mediated structural alteration (by microbes) of a compound viz. biodegradation of chemicals, cotton and wool wastes by various chemical transformations like hydrolysis, dehalogenation, dealkylation etc.

Bioremediation is the use of living organisms to clean up pollutants from soil, water and waste water. Controlled application of micro organisms for destruction of chemical pollutants is common in waste water treatment, toxic waste disposal by bioreactors and biofilters.

Phytoremediation is the cultivation of specialized plants that absorb specific contaminants from soil through their roots or foliage. Processes and mechanisms of contaminant removal in Phytoremediation are given in table 4. Phytoremediation can and has been used to clean up heavy metals, pesticides, solvents, explosives, crude oil, polyaromatic hydrocarbons, land fill leachates, agricultural runoff, acid mine drainage, and radioactive contamination. Pollutant bioavailability is obviously a critical factor for the success of phytoremediation.

Table 4. Processes and mechanisms of contaminant removal in Phytoremediation

Process 1.	Mechanism	Contaminant
Rhizofiltration	Rhizosphere accumulation	Organics/Inorganics
Phytostabilisation	Complexation	Inorganics
Phytoextraction	Hyper-accumulation	Inorganics
Phytovolatilization	Volatilisation by leaves	Organics/Inorganics
Phytotransformation	Degradation in plant	Organics

(Ghosh and Singh, 2005)

Conclusions

Soil is a great geochemical reservoir for contaminant as well as a natural buffer for transportation of chemical materials and elements in the atmosphere, hydrosphere, and biomass. For this reason, it is the most important component of the human biosphere. As soil is an important constituent of the human biosphere, any harmful change to this segment of the environment seriously affects the overall quality of human life. Human activities to increase the crop productivity for food security with unbalanced use of agrochemicals like fertilizers and pesticides has lead to contamination of the lithosphere, hydrosphere and atmosphere. Further, this has lead to public health problems also. Balanced use and timely application of fertilizers along with controlled use of agrochemicals is necessary to reduce the pollution of biosphere from agriculture. Solid and liquid waste management along with different methods of bioremediation should be undertaken at farm level so that the contamination of biosphere can be reduced at source level itself.

References

Adriano, D.C., 2001. *Trace Elements in Terrestrial Environments. Biogeochemistry, Bioavailability, and Risks of Metals*. Springer-Verlag, New York. 867 p.

Anawar, H. M, Akai, J., Mostofa, K. M., Safiullah, S., and Tareq, S. M. 2002. Arsenic poisoning in groundwater: health risk and geochemical sources in Bangladesh. *Environ Int.* 27:597–604.

Arbuckle, T. E., Sherman, G.J. Corey, P.N. Walters, D., and Lo, B. 1988. Water nitrates and CNS birth defects: A population-based case-control study. *Arch. Environ. Health. 43(2):162-167.*

Barbosa, A. C., Jardim, W., Dórea J. G., Fosberg, B., and Souza, J. H. 2001. Mercury speciation as a function of gender, age, and body mass index in inhabitants of the Negro River Basin, Amazon, Brazil. *Arch Environ Contam Toxicol.* 40:439–44.

Booth, B. 2005. The added danger of counterfeit cigarettes. Environmental Science and Technology 39, 34A (one page only).

Chen, C. J., Hsueh, Y. M., Lai, M. S., Shyu, M. P., Chen, S.Y., and Wu, M. M. 1995. Increased prevalence of hypertension and long-term arsenic exposure. *Hypertension.* 25:53–60.

Coogan, T. P., Latta, D. M., Snow, E. T., and Costa, M. 1989. Toxicity and carcinogenicity of nickel compounds. *Crit. Rev. Toxicol.* **19** (4) 341-345.

Cordero, B., Lodeiro, P., Herrero, R., Esteban Sastre de Vicente, M., 2004. Biosorption of cadmium by Fucus spiralis. Environ. Chem. 1:180–187.

Ghosh, M and – Singh, S. P.2005. A review on phytoremediation of heavy metals and utilization of its byproducts . *Appl Ecol. Environ Res* 3(1): 1-18.

Guha-Mazumder, D. N, Haque, R., Ghose, N., De, B. K., Santra, A., and Chakraborty, D.2000. Arsenic in drinking water and the prevalence of respiratory effects in West Bengal, India. *Int J Epidemiol.* 29:1047– 52.

Grudyev, G. S. 1988. *Chemical Protection of Plants*. Mir publications Moscow.

Haq, I. U. 1963. Agrosan poisoning in man. *British med. J.* 1: 1579-82.

Hudak, P. F.1999. Regional trends in nitrate content of Texas groundwater. *J. Hydro. 228:37-47.*

Jaffe, D. Prestbo, E., Swartzendruber, P., Weiss-Penzias, P., Kato, S., and Takami, A. 2005. Export of atmospheric mercury from Asia. *Atmos Environ.* 39:3029–38.

Kostraba, J. N., Gay, E. C., Rewers, M., and Hamman. R. F. 1992. Nitrate levels in community drinking waters and risk of IDDM: An ecological analysis. *Diabetes Care 15(11):1505-1508.*

Larsen, E. H., Mosheim, L. and Nielsen, M. M. 1992. Atmospheric elements around point sources and human health risk assessment: II. Uptake of arsenic and chromium by vegetables grown near a wood preservation factory. *Sci Total Environ.* 126: 263– 75.

Narayanan, P. 2007. *Environmental Pollution: Principles, Analysis and Control* .Publ. India Binding House, Noida, 671p.

Ray, C. and Member P. E., 1999. Management nitrate problems for domestic wells in irrigated alluvial aquifers. *J. Irrig. and Drain. Eng., 127: 49-53.*

Seffner, W. 1995. Natural water contents and endemic goiter - a review. *Zantralblatt fur Hygiene und Umweltmedizin 196(5):381-98.*

Smith, V. H. Tilman, G. D. and Nekola, J. C. 1999. Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems Environ Pollution 100:179- 196.

Stephens, W. E. and Calder, A. 2005. Source and health implications of high toxic metal concentrations in illicit tobacco products. Environ Sci. Technol. 39: 479–488.

Tsezou, A., Kitsiou-Tzeli, S., Galla, A., Gourgiotis, D., Papageorgiou, J., Mitrou, S., Molybdas, P. A. and Sinaniotis, C. 1996. High nitrate content in drinking water: Cytogenetic effects in exposed children. *Arch. Environ Health 51(6):458-61.*

Tudoreanu, L. and Phillips, C. J. C., 2004. Modelling cadmium uptake and accumulation in plants. *Adv Agron.* 84: 121–157.

Van Maanen, J. M., Van Dijk, A. Mulder, K. de Baets, M. H. Menheere, P. C. van der Heide, O. Mertens, P. L. and Kleinjans, J. C. 1994. Consumption of drinking water with high nitrate levels causes hypertrophy of the thyroid. *Toxicol Letters 72(1):365-74.*

Van Maanen, J. M., Welle, I. J., Hageman, G., Dallinga, J. W., Mertens, P. L., and Kleinjans, J. C. 1996. Nitrate contamination of drinking water: Relationship with HPRT variant frequency in lymphocyte DNA and urinary excretion of N-nitrosamines. *Environ Health Perspectives 104(5):522-8.*

USEPA (United States Environmental Protection Agency).1997. Mercury Study Report to Congress. EPA-452/R-97-004.

USEPA (United States Environmental Protection Agency). 2003. National Estuary Program. Coastlines 13.5.

Vogue, P. A. Kerle, E. A. and Jenkins. J. J. 1994. Pesticide Properties Database. 1994. National Pesticide Information Center. http://npic.orst.edu/ppdmove.htm

*WHO (*World Health Organization), *Guidelines for drinking water quality, 2nd. Ed., 1995*

Yeung, A.T. and Hsu, C. 2005. Electrokinetic remediation of cadmium contaminated clay. J. Environ Eng. 131: 298–304.

Young, A. L., Calcagni, J. A., Thalken, C. E., and Tremblay J. W. 1978. The toxicology, environmental fate, and human risk of Herbicide Orange and its associated dioxin. USAF Occupational and Environmental Health Laboratory, *Brooks AFB, Texas Technical reports* 78-92.

Agricultural Production Vulnerability: Evidence from Tamil Nadu

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1. Introduction

During the past five decades of planned development, India has achieved a spectacular increase in food grain production. Development of major and minor irrigation projects had gone up. Green revolution enabled India to enter into a new era in input use. The use of HYV seeds, plant protection chemicals and fertilizers have increased manifold. But, the farming community had not yet equitably shared the overall gains.

During the course of development, significant changes have taken place in the agrarian structure of India as indicated by the changes in the pattern of landholdings. The landholding pattern reveals that it is dominated by the marginal and small holdings (81.8% of total holdings). The latest available figures however suggest that these small and marginal farmers, now own only 36% of agriculture land in the country (19% and 17% respectively). Further, the land area cultivated in the small and marginal holdings is progressively increasing. These changes in agrarian structure are the outcome of institutional, technological and demographic factors. **Land as an input in agricultural production therefore declines in importance and the non-land inputs acquire greater importance.**The share of the purchased inputs in crop cultivation has increased significantly over the period indicating modernization of Indian agriculture.

There has also been a consistent decline in the rate of growth of the agriculture sector in 1990s as compared to 1980s. It was 4% per annum during the 1980s on an average, which came down to 3.2% during 1990s and 2% in the last five years. Growth in real value of foodgrain production has been an abysmal -3% during the 1990s and -5% during 1999-2000 to 2002-03, with minor improvements estimated during 2003-04 (Mathur*et al,* 2006). While there has been a decline in overall rate of agricultural growth, there are considerable inter-regional variations across the country. With regard to the period from 1993 to 2003, the state-wise analysis shows wide variations in growth from 28% to –19% between the triennium ending 1996 and 2003 respectively.

The agriculture sector in India is also undergoing major structural changes in terms of the share of allied sectors in agriculture, mainly dairying, fishery and poultry which are gaining greater importance. In fact, the share of livestock products in gross value of agricultural product (i.e. crop production *plus* livestock rearing) is progressively increasing. It had increased from being, less than 16% in 1970-71 to 26% 1995-96. In addition, three major changes have taken place in crop composition. In the first place, the share of non-food crops has increased in terms of area devoted to these crops. For instance, during the triennium ending 1971-72, nearly 25.7% of the cultivated area was devoted to non-food grains. Their share increased to 35.1 by 1999-2000. Second noteworthy development is that food crops such as sugarcane, oil seeds, spices and condiments, fruits, vegetables, etc., are acquiring greater importance. The third important change is that the share of superior cereals like rice and wheat in the total food grains production has been increasing.

The agricultural economy in Tamil Nadu state has also witnessed the same kind of transformation over the years. Performance of Tamil Nadu's Agricultural Sector had been impressive since 1960's when improved crop varieties were introduced. After the introduction of improved varieties, a phenomenal breakthrough in productivity of crops was achieved resulting in higher production of most of the crops. Tamil Nadu has done extremely well in irrigated agriculture particularly in rice, sugarcane and groundnut, the major crops of the state. Agricultural growth enhanced overall economic growth of the state during 1980s but agriculture's share has declined during 1990s.

While it is increasingly accepted that the vulnerability of farming community to different sources of risk cannot be solely understood through the quantification of biophysical impacts, no previous formal study in the state has explored the socio-economic aspects of vulnerability to different sources of risk with an in depth examination of the underlying socio-economic and farm level factors that determine how farmers respond to and cope with different sources of risk.

The degree to which the different sources of risk affect agricultural production depends on a wide variety of factors, including household level, farm level and supra household level. Vulnerability is also mediated by institutional factors, including the rules, norms and policies that govern land tenure, the availability of markets, financial capital, insurance and support programs, and the degree of technology development and distribution.In this context it is of our major interest to understand the extent of vulnerability to agricultural production in Tamil Nadu state. This paper analyzes the vulnerability of Tamil Nadu farmers to different sources of risk and variability in yield by developing a vulnerability index.

2. Theoretical Review of the concept of vulnerability

Though the term "vulnerability" is not a new concept among the Environmental and development economists, the concept of vulnerability has gainedincreasing importance within the global change research community in recent years (Gbetibouo and Ringler, 2009). The word 'vulnerability' is usually associated with natural hazards like flood, droughts, and social hazards like poverty etc. Of late it is extensively used in climate change literature to denote the extent of damage a region is expected to be affected by various factors affected by climate change. In the context of climate change there are many studies on vulnerability and its definitions vary according to the perception of the researchers.Vulnerability isconceptualized in different ways across different disciplines. Liverman (1990) noted that vulnerability hasbeen equated to concepts such as resilience, risk, marginality, adaptability, and exposure. This diversity ofconceptualization is due to the fact that the term "vulnerability" has been used in different policycontexts, referring to different systems exposed to different hazards.

Chamber (1983) defined that vulnerability has two sides. One is an external side of risks, shocks to which an individual or household is subject to climate change and an internal side which is defenselessness, meaning a lack of means to cope without damaging loss. Blaikie*et al.*, (1994) defined vulnerability as the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impacts of natural hazards and states that vulnerability can be viewed along a continuum from resilience to susceptibility. According to Adger (1999) vulnerability is the extent to which a natural or social system is susceptible to sustaining damage from climate change. It is generally perceived to be a function of two components. The effect that an event may have on humans, referred to as capacity or social vulnerability and the risk that such an event may occur, often referred to as exposure. Watson *et al.,* (1996) defined vulnerability as the extent to which climate change may damage or harm a system, depending not only on a system's sensitivity but also on its ability to adapt to new climatic conditions. Kasperson*et al.,* (2000) defined vulnerability as the degree to which an exposure unit is susceptible to harm due to exposure to a perturbation or stress and the ability or lack of the exposure unit to cope, recover or fundamentally adapt to become a new system or to become extinct.

In general climate change is expected to lead to more precipitation, but much of this increased wetness may not end up where it is most needed. Arid and semi-arid regions are likely to suffer even more reduced rainfall and increased evaporation. In this respect, climate change is an added risk to these regions which have already been undergoing a process of increased desertification and land degradation, caused both by overexploitation and inappropriate land-use as well as general climatic variations(McGuigan*et al*, 2002).Blaikie (1994) describes vulnerability as the characteristics of a person or a group to anticipate, cope, resist and recover from the impact of a natural hazard. For Chambers (1989), vulnerability represents the ability or not to modify the impacts of disaster and the means to cushion risks. On a national level, vulnerability manifests itself in poorer countries due to a lack of resources and capacity to respond. At the community level class, caste, gender, ethnicity, age, level of education and access to resources all determine vulnerability (Blaike, 1994; IPCC, 2001; Warrick and Rahman, 1992, Adger and Kelly, 2001).Vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed as well as the system's sensitivity and adaptive capacity (IPCC, 2001).The 2007 Human Development Report of the UN Development Programme (UNDP) described "vulnerability" in the context of climate change as "an inability to manage risk without being forced to make choices that compromise human well-being over time (http://southasia.oneworld.net/globalheadlines/developing-a-vulnerability-index-for-climate-change).

In the first stage Climate Variability Vulnerability Index (CVVI) will be developed at community levels across production environments. Following Eriyagama, et al, (2010), vulnerability index will be constructed. The vulnerability can be expressed as a function of exposure, sensitivity and adaptive capacity. Thus, the model will be -

Climate Variability Vulnerability Index = f (Exposure, Sensitivity, Adaptive capacity)

IPCC (2001) defines exposure as "the nature and degree to which a system is exposed to significant climatic variations". Thus, exposure relates to climate stress upon a particular unit of analysis (Gbetibouo and Ringler 2009). The Exposure Index will use frequency of exposure to historical climate hazards as a proxy for future climate hazard exposure, and computes Exposure Indices for droughts, floods, cyclones and multihazards (considering combined frequency of droughts, floods and cyclones) for each environment such as canal, tank, well and rainfed conditions.

Sensitivity is defined as "the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli" (IPCC 2001). It describes the human-environmental conditions that can either worsen the climate hazard or trigger an impact (Gbetibouo and Ringler 2009). The proposed study considers sensitivity to be twofold in the context of those employed in agriculture, namely, Human Sensitivity and Livelihood Sensitivity. Human Sensitivity is represented by rural population density. Livelihood Sensitivity is characterized by a number of proxies such as: percentage of the population employed in agriculture, and agricultural diversity (crop diversity and degree of engagement in off-farm and non-farm income activities).

Adaptive capacity is "the ability of a system to adjust to climate change, including climate variability and extremes, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (IPCC 2001). It is considered to be "a function of wealth, technology, education, information, skills, infrastructure, access to resources, stability and management capabilities" (IPCC 2001). This assessment considers adaptive capacity to be a function of Socioeconomicasset ownership as well as Infrastructural asset ownership.

The procedure of constructing the index is similar to that of the Human Development Index (UNDP 2006), in which the values of each component indicator is normalized to the range of values in the dataset. Each component indicator and the final climate variability Vulnerability Index will have a value of 0-100 with 100 implying maximum vulnerability. The climate variability Vulnerability Index is the average of the three sub indices: the Exposure Index, the Sensitivity Index and the Adaptive Capacity Index. Although this index does not represent absolute damage risk and is only a comparison of the level of risk between districts, it does indicate where to prioritize strategic planning and investment in climate variability adaptation. Such prioritization is essential for policymakers to base their decisions on investment.

The literature suggests that there are two main distinct epistemological approaches to conceptualizing vulnerability. One approach views vulnerability as the "end point," in terms of the amount of (potential) damage caused to a system by a particular climate-related event or hazard. The second approach considers vulnerability as the "starting point," i.e. as a state that exists within a system before it encounters a hazard event (Kelly and Adger 2000; Brooks 2003).

Chambers (1989) defines vulnerability as exposure to contingencies and stress, and the difficulty ofcoping with these exposures. Adger (1996) also identifies two components of vulnerability: the effectsthat an event may have on humans (referred to as capacity or social vulnerability), and the risk that suchan event may occur (referred to as exposure). Thus, vulnerability refers to both internal and externaldimensions. The internal dimension relates to defenselessness and insecurity, as well as the capacity toanticipate, cope with, resist, and recover from the impacts of a hazard. The external dimension involvesexposure to risks and shocks. Furthermore, Bohle (2001) developed a conceptual framework ofvulnerability named the "double structure of vulnerability," which comprises exposure and coping. Here,the external perspective refers mainly to the structural dimensions of vulnerability and risk, while theinternal dimension of vulnerability focuses on coping and actions taken to overcome or at least mitigatethe negative effects of economic and ecological change.

The Intergovernmental Panel on Climate Change (IPCC) Second Assessment Report (SAR) andMoser (1998) change the focus of vulnerability from emphasizing internal/coping and external/exposure,and examine two similar but different factors: sensitivity and adaptive capacity (or resilience). The SARdefines vulnerability as the extent to which climate change may damage or harm a system; vulnerabilitytherefore depends not only on the system's sensitivity, but also on its ability to adapt to new climaticconditions (Watson et al. 1996). According to Moser (1998), any definition of vulnerability requires theidentification of two components: sensitivity and resilience. Sensitivity refers to the responsiveness of asystem to climatic influences, and the degree to which this responsiveness might be affected by climatechanges.

The IPCC Third Assessment Report (TAR) reconciles both sides by adding a third component tovulnerability, defining it as: "The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a functionof the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, andits adaptive capacity" (McCarthy et al. 2001). According to this definition, vulnerability includes anexternal dimension that is represented by the exposure of a system to climate variations, as well as a morecomplex internal dimension comprising its sensitivity and adaptive capacity to these stressors (Füssel andKlein 2006). The IPCC Fourth Assessment Report (AR4), which reports recent advances in ourunderstanding of climate change, contains a vulnerability definition consistent with that of the TAR(IPCC 2007). Under this framework, a highly vulnerable system would be one that is very sensitive tomodest changes in climate, where the sensitivity includes the potential for substantial harmful effects, andfor which the ability to adapt is severely constrained.Downing etal. (2001) distinguish three domains of vulnerability: present criticality, adaptive capacity, and climatechange hazard. Luers et al. (2003) propose a method for quantifying vulnerability (given the system,outcome variable, and stressor of concern) based on its three components: exposure, sensitivity, andadaptive capacity. Turner et al. (2003) recognize that vulnerability is determined not by exposure tohazards (perturbations and stresses) alone, but also depends on the sensitivity and resilience of the systemthat is experiencing such hazards. These authors develop an integrated conceptual framework ofvulnerability built on these three major dimensions of vulnerability, namely exposure, sensitivity andadaptation/resilience.Thus, vulnerability is understood as a function of three components: exposure, sensitivity andadaptive capacity, which are influenced by a range of biophysical and socio-economic factors (TERI2003).

3. Methodology

For the purpose of our understanding, we follow the IPCC Third Assessment Report according to which vulnerability is defined as "The degree, to which a system is susceptible to or unable to cope with adverse effects of climate change including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity" (McCarthy et al. 2001). Thus as per this definition, vulnerability has three components: exposure, sensitivity and adaptive capacity. These three components are described as follows:

- Exposure can be interpreted as the direct danger (i.e., the stressor), and the nature and extent of changes to a region's climate variables (e.g., temperature, precipitation, extreme weather events).

- Sensitivity describes the human–environmental conditions that can worsen the hazard, ameliorate the hazard, or trigger an impact.

- Adaptive capacity represents the potential to implement adaptation measures that help avert potential impacts.

The first two components together represent the potential impact and adaptive capacity is the extent to which these impacts can be averted. Thus vulnerability is potential impact I *less* the adaptive capacity *(AC)*. This leads to the following mathematical equation for vulnerability:

$$V = (I - AC)$$

3.1. Data:

Data on different indicators were drawn from data collected from 600 households covering 27 districts of Tamil Nadu state.

Table.1. Vulnerability indicators, variables and data sources

Determinants of vulnerability	Vulnerability indicator	Unit of measurement	A priori functional relationship between the indicator and vulnerability
Exposure	Annual Rainfall	Mm	(-)
	Number of risk occurred in last 10 years	Number of times	(+)
Sensitivity	Area under irrigation	Hectares	(-)
	Sources of irrigation	Scores: Rainfed:0; tanks :1; canal :2; wells : 3; Tank+well :4; Canal+well : 5	(-)
	Percent of GIA to GCA	Percent	(-)
Adaptive capacity	Percent of earning members	Percent	(-)
	Educational level of the farmer	Score: Illiterate: 0 Primary:1 Secondary:2 Higher secondary:3 Collegiate:4	(-)
	Experience	Number of years	(-)
	Farm size	Hectares	(-)
	Membership in	Yes:1	(-)

	organizations	No : 0	
	Proportion of farm income to total household income	Percent	(-)
	Adoption of crop insurance	YES : 1 NO : 0	(-)
	Loan obtained	Rs.	(-)
	Paddy yield	Tonnes per ha	(-)

Note:

Exposure relates to the degree of climate stress upon a particular unit of analysis; it may be represented by either long-term changes in climate conditions or changes in climate variability, including the magnitude and frequency of extreme events

Sensitivity describes the human–environmental conditions that can either worsen the hazard or trigger an impact

Adaptive capacity is a significant factor in characterizing vulnerability. In the climate change literature, adaptive capacity is similar or closely related to a host of other commonly used concepts such as adaptability, coping ability, management capacity, stability, robustness, flexibility, and resilience.

3.2. Construction of vulnerability index

Following Gbetibouo and Ringler, 2009, the vulnerability index was constructed as follows: Thus vulnerability is potential impact I *less* the adaptive capacity *(AC)*. This leads to the following mathematical equation for vulnerability:

$$V = (I - AC)$$

Where V is vulnerability, I is potential impact, and AC is adaptive capacity. A higher adaptive capacity is associated with a lower vulnerability, while a higher impact is associated with a higher vulnerability. Given the above equation, vulnerability is defined as a function of a range of biophysical and socio-economic factors, commonly aggregated into three components that estimate the adaptive capacity, sensitivity, and exposure to different risk factors.

Construction of vulnerability index consists of several steps. First is the selection of study area which consists of several regions. In each region a set of indicators are selected for each of the three component of vulnerability. A list of possible indicators is provided in the Table.1. For each component of vulnerability, the collected data are then arranged in the form of a rectangular matrix with rows representing regions and columns representing indicators. Let there be M regions/districts and let us say we have collected K indicators. Let *Xij*be the value of the indicator *j* corresponding to region *i*.

Normalization of indicators using functional relationship: Obviously the indicators are in different units and scales. The methodology used in UNDP's Human Development Index (HDI) (UNDP, 2006) is followed to normalize them. That is, in order to obtain figures which are free from the units and also to standardize their values, first they are normalized so that they all lie between 0 and 1. Before doing this, it is important to identify the functional relationship between the indicators and vulnerability. Two types of functional relationship are possible: vulnerability increases with increase (decrease) in the value of the indicator. Assume that higher the value of the indicator more is the vulnerability. For example, area under irrigation, higher the valuesless will be the vulnerability of the farmers to agricultural production vulnerability.

$$X_{ij} = \frac{X_{ij} - \mathrm{Min}(XL)}{\mathrm{Max}(X_{ij}) - \mathrm{Min}(X_{ij})}$$

It is clear that all these scores will lie between 0 and 1. The value 1 will correspond to that region with maximum value and 0 will correspond to the region with minimum value.The other formula is also used if the indicator has negative relationship:

$$X_{ij} = \frac{\mathrm{Max}(X_{ij}) - X_{ij}}{\mathrm{Max}(X_{ij}) - \mathrm{Min}(X_{ij})}$$

After standardizing the data, we next attach weights to the vulnerability indicators. A review of the literature indicates that three methods are used to assign weights to indicators: (1) expert judgment(Brooks et al. 2005; Moss et al. 2001); (2) arbitrary choice of equal weight (Lucas and Hilderink 2004;O'Brien et al. 2004; Patnaik and Narayanan 2005) and (3) statistical methods such as principalcomponent analysis or factor analysis (Cutter et al. 2003; Thornton et al. 2006). We do not assign equalweights because this strategy is too subjective, and the literature shows that indicators do not equallyaffect vulnerability (Hebb and Mortsch 2007). The development of weights via expert judgment is oftenconstrained by the availability of expert knowledge in smaller communities and difficulties in reaching aconsensus on the weights among expert panel members (Lowry et al. 1995). Therefore, we herein useprincipal component analysis (PCA) to generate weights for the indicators.PCA is a technique for extracting from a set of variables those few orthogonal linearcombinations of variables that most successfully capture the common information. Following Filmer andPritchett (2001) and Gbetibouo and Ringler, 2009, we define the first principal component of a set of variables as the linear index of all thevariables that captures the largest amount of information common to all the variables.

PCA is a multivariate technique for finding patterns in data of high dimension. Once the patterns hidden in data are identified, PCA helps to compress the data by reducing the number of dimensions without much loss of information. In the language of Linear Algebra it is a linear transformation of the original variables. PCA allows us to compute a linear transformation that maps data from a high dimensional space to a lower dimensional space. In original data variables may be correlated and PCA help to transform them into uncorrelated variables. The essential steps in the computation of Principal components are as follows:

1. Arrange the data in the form of a matrix, rows representing regions (M) and columns are indicators (K). Let us call this matrix as X. Then X has dimension $M \times K$.

2. For each variable, compute its mean across all observations and subtract the mean from each observation. This produces a new matrix , $X - \overline{X}$ in which sum of all elements in each column is zero.

3. Compute the covariance matrix using the formula $(X-\overline{X})^T (X-\overline{X})/m$. In this matrix, the diagonal elements are the variances of the respective variables and off diagonal elements are the co-variances between variables.

4. Compute the Eigen values[1] and Eigen vectors of the covariance matrix.

5. Arrange the eigen values in the descending order of magnitude. The eigen vector corresponding to the highest eigen value is the first principal component of the data set. The eigen vectors of the second, third etceigen values are the second, third,etc principal components. In other words the principal components are now arranged in the order of significance. We can retain eigen vectors up to a desired level of significance and leave the remaining ones which are insignificant. This is because each eigen value represents a portion of variance and we keep the first 'm' eigen vectors such that

$$\frac{\sum_{i=1}^{m} \lambda i}{\sum_{i=1}^{k} \lambda i} > \text{Threshold level (normally 90 or 95 \%)}$$

A criterion usually followed is MINEIGEN criterion according to which we retain all the components with eigen value > 1.

6. The eigen vectors retained can be used to recalculate the values for eachobservation.

In determining the weights for the indicators, theweights are determined by the factors loadings of the first principal component.

[1] The eigen value is a measure of standardized variance, with a mean of 0 and standard deviation of 1. Each standardized variable (here, each of the 19 indicators) contributes at least the variance of 1 to the principal component extraction. The Kaiser criterion states that unless a principal component extracts at least as much as one of the original variables (i.e. has a standardized variance equal to or greater than 1), it should be dropped from further analysis (Filmer and Pritchett 2001).

To quantitatively assess the vulnerability index, we run a Principal Component Analysis. The principal component is used to construct the vulnerability index. Each variable is normalized to take a value between 0 and 1.The assigned weights are then used to construct overall vulnerability index.

4. Results and Discussion

In order to study the efficacy of the insurance products, the performance of insurance products viz., NAIS was studied. This section presents the results from the household survey conducted in Tamil Nadu state. Also the results from a case study of farmers where the NAIS is being adopted by the farmers. The present study was taken up with a view to critically examine how the farmers perceive about the risk mitigation measures provided by the government and about their awareness and adoption of crop insurance programmes as a toll to minimize their farm risk. The study is conducted throughout the state of Tamil Nadu by interviewing 600 farmers spreading over 27 out of 32 districts of the state. For the purpose, the farmers covered under the Cost of Cultivation for Principal Crops scheme were interviewed to collect the information. The survey covers all categories of farmers such as, marginal to large farms cultivating all important crops in one or two seasons and all types of production environments like tank irrigation, groundwater irrigation, canal irrigation and rainfed farming. Data were collected during January – March, 2009

4.1. General characteristics of farmers

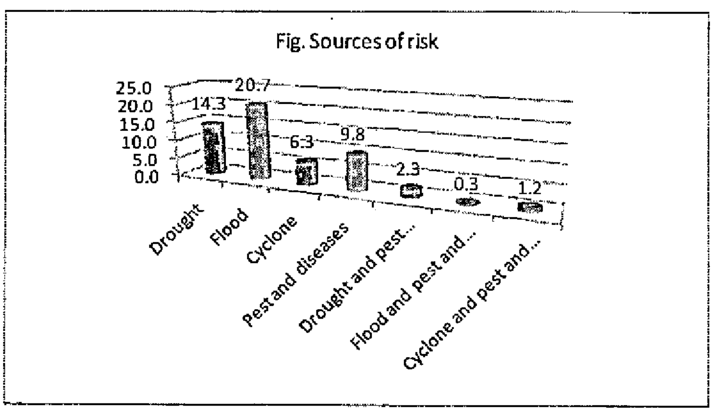
Among the 600 sample farmers contacted for interview, more than 82% were in the age category of above 40. There were sizeable respondents at the age of above sixty. This implies that the farming nowadays is no longer the business of youth in the state. Only age olds and less educated are involved in farming activities. About 50 per cent of the farmers are illiterate or primary educated.

The average size of the families of the farmers in Tamil Nadu is 4.5 having 1.85 earning members on an average. About 86% of the families are possessing members of less than six while more than 55 of the families have members less than the state average. These results can be visualized in two views. One is that the government policy of one or two children per family has been well received by the farming community of the state. The other is that the joint family system is lost its ground in the state. The table further revealed that about 60% of the families have more than one earning member (almost 99% of the families have 1 to 4 earning members). About 45% of the families have two earning members while 38% of the farm families have at least one earning member. The results show that the members of the farm families are looking for viable alternate sources of income.

Fragmented land holdings and sub optimal productivity are the important characteristics of the holdings of Indian farmers. The same trend is reflected in the present study also. Small and marginal farmers account around 42% of the total holdings. The cropping intensity and irrigation intensity were worked out to be slightly higher than 100 at 115.46% and 126.87% respectively. Mainly crop insurance is been practiced by paddy and sugarcane farmers. This might be the reason behind the slightly better position of irrigation intensity (127%) than the cropping intensity (115%). They were contacted for survey in expectation that irrigated land farmers will go in large for crop insurance.

4.2. Sources of risk

Farmers in Tamil Nadu face various sources of production risk like drought, flood, cyclone, pest and diseases and so on. It is critical that these sources of risk be identified and managed timely by various risk management strategies. The experience in Tamil Nadu state shows that the sources like flood and drought are the two extremes



assume important risks affect agricultural production. These followed by pest and diseases and cyclone. Sometimes, farmers affected by two risks simultaneously. Under these situations, farmers incur huge loss when compared to the normal conditions.

4.3.Descriptive statistics

The agricultural production vulnerability index is worked out and the descriptive statistics are presented in Table.2. It is seen that the mean is worked out to 0 and the standard deviation is 5.14. The minimum value is worked out to -25.81 and the maximum is 10.23.

Table.2 Descriptive statistics of the Agricultural production Vulnerability index

Particulars	Value
Mean	0.0000
Median	0.8350
Standard Deviation	5.1437
Sample Variance	26.4580
Minimum	-25.8100
Maximum	10.2374

The computed vulnerability indicates that it assumes both positive and negative values. The distribution of vulnerability index suggests to have five classes of vulnerability viz., less vulnerable, moderately vulnerable, vulnerable, highly vulnerable and very high vulnerable. This class is mainly based on the percentiles i.e. 20%, 40%, 60%, and 80%.

Fig.1. Agricultural production vulnerability index

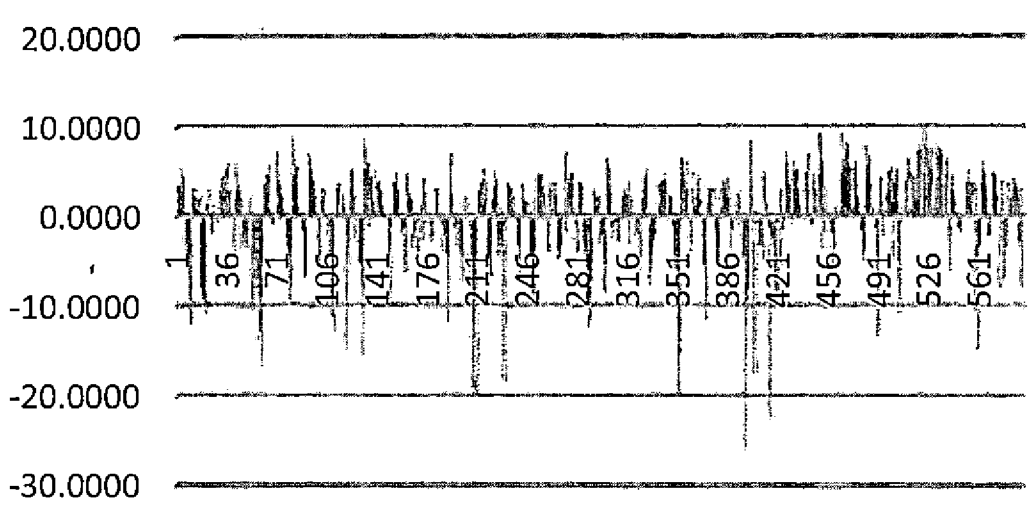


Table.3 Frequency and proportion of farmers under different class of vulnerability

Class of vulnerability	Number of farmers	Percentage
Less vulnerable	102	17
Moderately vulnerable	81	14
Vulnerable	132	22
Highly vulnerable	172	29
Very high vulnerable	103	17

It could be seen that 17% of the farmers fall under less vulnerable, 14% of the farmers are moderately vulnerable, 22% are highly vulnerable and 17% are very high vulnerable.

Our interest here is to find out whether there is any significant relation between the farm size and vulnerability. It is seen that all category of farmers are vulnerable to agricultural production in varying degrees. For instance, 6 large farmers are highly vulnerable, 78 are less vulnerable, 48 are moderately vulnerable, 2 are very high vulnerable and 32 are vulnerable. Of the total number of farmers vulnerable to agricultural production, 19% are marginal farmers, 21% are small, 30 % are medium and 28% are large farmers.

Table.4. Farm size category wise the vulnerability index

		Vindex					Total
		HighlyV	LessV	ModerateV	VeryHighV	Vulnerable	
CatyF							
Large	Frequency	6	78	48	2	32	166
	Row Pct	3.61	46.99	28.92	1.20	19.28	
	Col Pct	3.49	76.47	59.26	1.94	24.24	
Marginal	Frequency	61	1	0	48	7	117
	Row Pct	52.14	0.85	0.00	41.03	5.98	
	Col Pct	35.47	0.98	0.00	46.60	5.30	
Medium	Frequency	54	19	25	16	65	179
	Row Pct	30.17	10.61	13.97	8.94	36.31	
	Col Pct	31.40	18.63	30.86	15.53	49.24	
Small	Frequency	51	4	8	37	28	128
	Row Pct	39.84	3.13	6.25	28.91	21.88	
	Col Pct	29.65	3.92	9.88	35.92	21.21	
Total	Frequency	172	102	81	103	132	590
Chi-square						344.75	(<0.0001)

The statistical test confirms that the vulnerability significantly varies across size groups.

Our interest here is also to identify the factors which are responsible for vulnerability. The results from Principal Component Analysis are used to identity factors which are closely related to the vulnerability. It is seen that the factors viz., area under irrigation, farm size, and sources of irrigation are highly correlated with the vulnerability.

Table 5. Factors determining the farm level agricultural production vulnerability

Variable	First eigen vector	Component Loadings
Rainfall (mm)	0.1463	-0.2229
Percentage of earning members	-0.0154	0.0235
Educational level of the farmer	0.2958	-0.4506
Experience in years	0.0286	-0.0436
Farm size in ha	0.4868	-0.7416
Area under irrigation NIA) in ha	0.5601	-0.8532
Membership in various organization	-0.0333	0.0508
Proportion of farm income to total household income	0.0215	0.0328
Crop insurance adopted (YES=1; No=0)	0.2791	-0.4252
Source of irrigation	0.4211	-0.6415
Loan obtained (Rs.)	-0.1583	-0.2412
Number of time risk occurred in last 10 years	-0.099	-0.1517
Paddy yield (ton/ha)	0.2178	-0.3318

Hence, adequate intervention in irrigation would enable the farming community to improve the adaptive capacity against the different sources of risk in agricultural production.

5. Conclusion

The quantitative operationalization of agricultural production vulnerability across regions and size group of farmers were computed for the state of Tamil Nadu.Principal component analysis was used to generate weights for the different indicators, and an overallvulnerability index is calculated.Our results show that the vulnerability varies across regions and farm size category.

The factors such as area under irrigation and sources of irrigation are the important factors highly correlated with the agricultural production vulnerability. General policy recommendations can be drawn from the above results.As there are inter-regional variations, policy makers should tailor policies to local conditions An effective way toaddress the impacts of different sources of risk would be to integrate adaptation measures into sustainabledevelopment strategies, thereby reducing the pressure on natural resources, improving environmental riskmanagement, and increasing the social wellbeing of the poor. Finally, policy makers should invest in the development ofinfrastructure in rural areas, while in high exposure regions, priority shouldbe given to the development of more accurate systems for early warning of extreme climatic events (e.g.,drought or floods), as well as appropriate relief programs and agricultural insurance.

References

Adger, W.N. 1996. *Approaches to vulnerability to climate change*. Centre for Social and Economic Research on the Global Environment Working Paper GEC 96–05. Norwich, U.K.: University of East Anglia.

Adger, W.N., 1999. "Social Vulnerability to Climate Change and Extremes in Coastal Vietnam",World Development, 2: 249-269.

Adger, W. and Kelly, P., (2001) *Living with environmental change: social vulnerability, adaptation and resilience in Vietnam,* Routledge, London

Bohle, H.G. 2001. Vulnerability and Criticality: Perspectives from social geography. *IHDP Update, Newsletter of the International Human Dimension Programme on Global Environmental Change* (IHDP) 2:1–4.

Blaikie, P. (1994), *At risk : natural hazards, people's vulnerability, and disasters,*Routledge, London.

Brooks, N., 2003. Vulnerability, risk and adaptation: A conceptual framework. Working paper 38. Norwich, U.K.: Tydall Centre for Climate change Research, University of East Anglia.

Brooks, N., W.N. Adger and P.M. Kelly, 2005.The determinants of vulnerability and adaptive capacity at the national and the implications for adaptation.*Global Environmental Change* 15 (2005): 151–162.

Chamber, R., 1983. Rural Development: Putting the Last First, Essex: Longman

Chambers, R. 1989. Editorial introduction: Vulnerability, coping and policy. *IDS Bulletin* 20 (2): 7.

Cutter, S.L., B.J. Boruff and W.L. Shirley. 2003. Social vulnerability to environmental hazards. *Social Science Quarterly* 84 (2): 242–261.

Downing, T.E., Butterfield, R., Cohen, S., Huq, S., Moss, R., Rahman, A., Sokona, Y. and L. Stephen. 2001. *Vulnerability indices: Climate change impacts and adaptation*. United Nations Environment Programme, Policy Series 3. New York: United Nations.

Eriyagama, N.; Smakhtin, V.; Chandrapala, L.; Fernando, K. 2010. Impacts of climate change on water resources and agriculture in Sri Lanka: a review and preliminary vulnerability mapping. Colombo, Sri Lanka: International Water Management Institute. 51p. (IWMI Research Report 135). doi:10.3910/2010.211

Filmer, D. and L.H. Pritchett, 2001. Estimating wealth effects without expenditure data—or tears: An application to
educational enrolments in States of India. *Demography* 38 (1): 115–131.

Füssel, H.M. and R.J.T. Klein. 2006. Climate change vulnerability assessments: An evolution of conceptual thinking. *Climatic Change* 75 (3): 301–329.

GbetibouoGlwadysAymone and Claudia Ringler. (2009). Mapping South African Farming Sector Vulnerability to Climate Change and Variability: A Subnational Assessment, IFPRI

Discussion Paper 00885, Environment and Production Technology Division, International Food Policy Research Institute, Washington.D.C.

Hebb, A. and L. Mortsch. 2007. *Floods: Mapping vulnerability in the Upper Thames watershed under a changing climate.* Final Report of the Canadian Foundation for Climate and Atmospheric Sciences (CFCAS) Project: Assessment of Water Resources Risk and Vulnerability to Changing Climatic Conditions.

http://southasia.oneworld.net/globalheadlines/developing-a-vulnerability-index-for-climatechange

IPCC.(2001).Intergovernmental Panel on Climate Change, Third Assessment Report, http://www.ipcc.ch.

IPCC (2001) Working Group II, *Climate Change 2001: Impacts, Adaptation and Vulnerability, contribution of Working Group II to the third assessment report of the IPCC,* Cambridge University Press, New York.

IPCC (Intergovernmental Panel on Climate change). 2007. *Climate Change 2007: Impacts, adaptation and vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, eds. Cambridge, UK: Cambridge University Press.

Kasperson, J.X., R.E.Kasperson, B.L.Turner, W.Hsieh, and A.Schiller, 2000. "Vulnerability to Global Environmental Change", *The Human Dimensions of Global Environmental Change,* Cambridge, MIT Press.

Kelly, P.M., and W.N. Adger. 2000. Theory and practice in assessing vulnerability to climate change and facilitating adaptation. *Climatic Change* 47: 325–352.

Liverman, D.M., 1990. Vulnerability to global environmental change. In Understanding global environmentalchange: The contributions of risk analysis and management, R.E. Kasperson, K. Dow, D. Golding, and J.X.Kasperson, eds. Worcester, MA: Clark University.

Lowry, J., H. Miller and G. Hepner. 1995. A GIS-based sensitivity analysis of community vulnerability to hazardous contaminants on the Mexico/U.S. Border. *Photogrammetric Engineering &Remote Sensing* 61 (11): 1347– 1359.

Lucas, P.L., and H.B.M Hilderink. 2004. *The vulnerability concept and its application to food security*. Report
550015004/2004. Netherlands: National Institute for Public Health and the Environment (RIVM).

Luers, A.L., D.B. Lobell, L.S. Skar, C.L. Addams and P.A. Matson. 2003. A method for quantifying vulnerability, applied to the agricultural system of the Yaqui Valley, Mexico. *Global Environmental Change* 13: 255– 267.

McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J. and White, K.S., eds. 2001. *Climate change 2001: Impacts, adaptation and vulnerability*. Cambridge, UK: Cambridge University Press.

McGuigan Claire, Rebecca Reynolds, and Daniel Wiedmer (2002). Poverty and climate change:assessing impacts in developing countries and the initiatives of the international community, London School of Economics Consultancy Project for The Overseas Development Institute.

Moss, R.H., A.L. Brenkert and E.L. Malone. 2001. *Vulnerability to climate change: a quantitative approach*.
Research report Prepared for the U.S. Department of Energy.

Moser, C.O.N. 1998. The asset vulnerability framework: Reassessing urban poverty reduction strategies. *World Development* 26 (1): 1–19.

O'Brien, K.L., R.M. Leichenko, U. Kelkar, H.M. Venema, G. Aandahl, H. Tompkins, A. Javed, S. Bhadwal, S. Barg, L. Nygaard and J. West. 2004b. Mapping vulnerability to multiple stressors: climate change and globalization in India. *Global Environmental Change* 14: 303–313.

Patnaik U. and K. Narayanan. 2005. Vulnerability and climate change: An analysis of the eastern coastal districts of India. Paper presented at the "Human Security and Climate Change International Workshop," Asker, Norway, June 21–23.

TERI (The Energy Research Institute). 2003. Coping with global change: Vulnerability and adaptation in Indian agriculture. Delhi, India: The Energy and Resource Institute.

Thornton P.K., Jones P.G., Owiyo T., Kruska R.L., Herrero M., Kristjanson P., Notenbaert A., Bekele N. and Omolo A., with contributions from Orindi V., Otiende B., Ochieng A., Bhadwal S., Anantram K., Nair S., Kumar V. and U. Kulkar. 2006. *Mapping climate vulnerability and poverty in Africa.* Report to the Department for International Development (ILRI) Nairobi, Kenya.

Turner B.L., R.E. Kasperson, P.A. Matson, J.J. McCarthy, R.W. Corell, L. Christensen, N. Eckley, J.X. Kasperson, A. Luers, M.L. Martello, C. Polsky, A. Pulsipher and A. Schiller. 2003a. Framework for vulnerability analysis in sustainability science.Proceedings of the National Academy of Sciences, USA. PNAS 100:8074–8079.

UNDP (United Nations Development Programme). 2006. Calculating the Human Development Indices, Technical Note 1 in Human Development Report, 2006.

Warrick, R. and Rahman, R (1992) "Future Sea Level Rise: Environmental and Socio-Political Consideration" in Mintzer& Stockholm Environment Institute, *Confronting climate change : risks, implications and responses*, Cambridge University Press, Cambridge

Watson, R.T., M.C.Zinyowera and R.H.Moss, 1996. "Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses", Cambridge University Press, Cambridge.

Measuring Impact of Climate Change on Agriculture Sector

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Introduction

Over the past two decades the debate on global climate change has moved from scientific circles to policy circles with the world nations more seriously than ever exploring a range of response strategies to deal with this complex phenomenon that is threatening to have significant and far reaching impacts on human society. The Intergovernmental Panel on Climate Change

(IPCC) in its fourth assessment report observed that, 'warming of climate system is now unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global sea level' (Solomon *et al.*, 2007). Policy responses to climate change include mitigation of greenhouse gases (GHG) that contribute to the expected changes in the Earth's climate, and adaptation to potential impacts caused by the changing climate. While GHG mitigation policies have dominated the overall climate policy so far, adaptation strategies are also being emphasized now to form a more comprehensive overall policy response.

The United Nations Framework Convention on Climate Change (UNFCCC) – the international apex body on climate change – refers to adaptation in the context of change in climate only. In other words without greenhouse gas emissions there is no climate change and hence no need for adaptation. Going by this widely accepted interpretation, adaptation is necessary only because mitigation of greenhouse gases may not completely halt climate change.

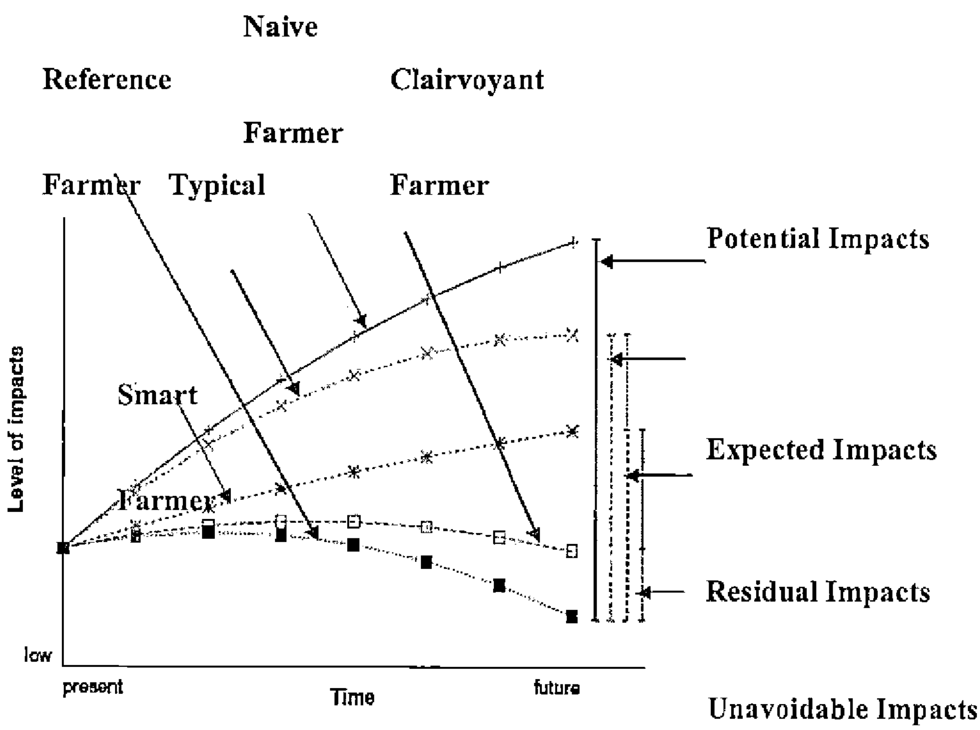
Stern Review summarizes this view: 'adaptation is crucial to deal with the *unavoidable* impacts of climate change to which the world is already committed' (Stern, 2006, emphasis added).

However, the reality is that several millions of people world-over are currently at the risk of climate-related impacts. To say that their sufferings are not the concern of climate change policy could make such policies irrelevant from the point of view of developing countries where most victims of climate-related impacts reside. At the same time, it may not be meaningful to attribute every climate related issue to the climate change policy because it would make an already complex policy issue further complicated. Adaptation in the context of climate change should be discussed taking into account these conflicting perspectives.

For both mitigation and adaptation policy formulation, one of the crucial inputs needed is the potential impacts due to climate change on various climate sensitive sectors. For mitigation, such information would provide the required justification for de-carbonizing the energy systems. On the other hand, in the context of adaptation, knowledge on climate change induced impacts will be helpful in prioritizing the adaptation in the most needed sectors and regions. Further, climate change impacts estimated with proper accounting of adaptation will be helpful in identifying the factors that ameliorate the adverse effects of climate change.

Concern about potential adverse impacts of climate change has triggered what could be named as impact assessment research since early 1990s. Over the past two decades the impact assessment research has gone through a metamorphosis with gradual movement towards vulnerability and adaptation assessment. However, impact assessment studies continue to prosper with interesting innovations in methodology and scope of analysis. Figure 1 shows the conceptual basis for climate change impact assessment studies, with focus on agriculture. The reference case illustrates the future without climate change. The naïve farmer allows the adverse impacts of the climate change to manifest without undertaking any adaptation. The impacts under such scenario are referred as potential impacts. A typical farmer is expected to undertake autonomous (or, unplanned) adaptation and hence avoid impacts to some extent (resultant impacts are referred as expected impacts). With planned (along with autonomous) adaptation, a smart farmer can further reduce the climate change impacts; the resultant impacts referred as residual impacts. A clairvoyant farmer on the other hand in principle can undertake all theoretically possible adaptations and avoid climate change impacts to the maximum extent. The impacts that even the clairvoyant farmer can not avoid are referred as unavoidable impacts of climate change. In the climate change impacts literature the residual impacts (or in some cases, the unavoidable impacts) are referred as 'vulnerability'.

Figure 1. Conceptualization of Climate Change Impacts



(**Source:** Fussel and Klein, 2006)

Climate Change and Indian Agriculture

India is a vast country covering 3.28 million km^2, occupying only 2.4 per cent of the world's geographical area but supporting 16.2 per cent of the global human population. It is endowed with varied climate supporting rich biodiversity and highly diverse ecology. More than sixty percent of its population is dependent on climate sensitive activities such as agriculture. Climate change projections made up to 2100 for India, indicate an overall increase in temperature by 2-4°C with no substantial change in precipitation quantity. The expected changes in climate, especially rainfall, are also marked by significant regional variation, with the Western Ghats, the Central Indian and the North Eastern regions projected to receive more rainfall compared to the other parts of India. Further, an increase in intensity and frequency of extreme events such as droughts, floods, and cyclones is also projected. All these changes are likely to have adverse impacts on India's water resources, agriculture, forests and other ecosystems, coastal zones, energy and infrastructure and on human health. Agricultural impacts due to climate change have received considerable attention in India as they are closely linked to the food security and poverty status of a vast majority of population.

Mall *et al.* (2006) provides an excellent review of climate change impact studies on Indian agriculture mainly from physical impacts perspective. The available evidence shows significant drop in yields of important cereal crops like rice and wheat under climate change conditions. However, biophysical impacts on some of the important crops like sugarcane, cotton and sunflower have not yet been studied adequately.

The economic impacts of climate change on agriculture have been studied extensively world over and it continues to be a hotly debated research problem. There are two broad approaches for assessing economic impacts – agronomic-economic approach and Ricardian approach. In the first approach the physical impacts (in the form of yield changes and/or area changes estimated through crop simulation models) are introduced into an economic model exogenously as Hicks neutral technical changes. In the Indian context Kumar and Parikh (2001a) have estimated the macro level impacts of climate change using such approach. They showed that under doubled carbon dioxide concentration levels in the later half of twenty first century the gross domestic product would decline by 1.4 to 3 percentage points under various climate change scenarios. More significantly they also estimated increase in the proportion of population in the bottom income groups of the society in both rural and urban India under climate change conditions. One of the major limitations of this approach is its treatment of adaptation. Since the physical impacts of agriculture are to be re-estimated under each adaptation strategy, only a limited number of strategies can be analyzed.

Since the scope for incorporating adaptation into the agronomic-economic approach is rather limited, an alternative approach was proposed by Mendeloshn *et al.* (1994). This approach, called Ricardian approach, is similar to Hedonic pricing approach of environmental valuation. The approach is based on the argument that, 'by examining two agricultural areas that are similar in all respects except that one has a climate on average (say) 3°C warmer than the other, one would be able to infer the *willingness to pay* in agriculture to avoid a 3°C temperature rise' (Kolstad, 2000). While all possible adaptations are accounted for in the impact estimation using this approach, the constant relative prices assumption could lead to biases the results of this approach. For India, Kumar and Parikh (2001b) have used a variant of this approach and showed that a 2°C temperature rise and seven percent increase in rainfall would lead to almost 9 percent loss in farm level net revenue (1990 net-revenue expressed in 1999-2000 prices). The regional differences are significantly large with northern and central Indian districts along with coastal districts bearing relatively large impact. Mendelsohn et al. (2001) have compared climate sensitivity of the US, Brazilian and Indian agriculture using the estimates based on the Ricardian approach and have argued that using the US estimates for assessing climate change impacts on Indian agriculture would provide biased results.

The results of the two broad approaches outlined above correspond to what could be termed as 'typical' and 'clairvoyant' farmer, respectively (see Figure 1). While the estimates from agronomic-economic approach account for adaptation only in partial manner, the Ricardian approach treats farmer as though she has perfect foresight. In the Ricardian approach farmers are assumed to identify instantaneously and perfectly any change in climate, evaluate all associated changes in market conditions and then modify their actions to maximize profits. These assumptions also imply that agricultural system is *ergodic* – i.e., space and time are substitutable. *Ergodic* assumption imply, for example, that skills, institutional and financial endowments for responding to say, drought (that are typically refined in arid places) are assumed to be available for use by people in humid areas (where such resources are under-developed) immediately and in essentially cost-less manner. Further there is scope for inter-farmer communication and information diffusion. Both these factors motivate incorporation of spatial features in the Ricaridan analysis. There are other motivations for accounting for spatial autocorrelation in the Ricardian analysis. For instance, Schlenker *et al.* (2006) bring in spatial features to arrive at *efficient* estimators of regression parameters. Recent studies in the US have demonstrated that such refinements are essential to get accurate estimates of climate sensitivity (Polsky, 2004; Schlenker *et al.*, 2006). Similarly, careful analysis of the changing nature of climate sensitivity of Indian agriculture is important to understand the role of technology in ameliorating the climate change impacts.

Any study dealing with climate change impact assessment should be wary about the potential uncertainties associated with the analysis. Uncertainties exist at each step of the impact assessment starting with the climate predictions. The degree of uncertainty increases as the analysis moves towards economic impact assessment. Among the various sources uncertainties, the uncertainty associated with climate predictions perhaps is the most crucial and difficult to deal with. Most studies in the literature have adopted scenario approach to handle the climate uncertainty. Thus, there is no single climate prediction for which the impacts would be assessed, but they are estimated for a range of likely temperature/precipitation combinations. The present study also follows similar approach and as explained at the beginning of section 3, predictions from a number of climate models have been considered while developing India specific climate change scenario. Based on this suite of climate models, by 2070-2099, the average temperatures across seasons are likely to range between 2.5 to 5°C over different regions of India. Winter temperatures are likely to be significantly higher ranging between 3.75 to 4.95°C across the regions. The uncertainty is much higher with regard to the precipitation prediction and by 2070-2099 the South-West monsoon precipitation is likely to increase between 9 to 27% across the regions.

Given this background, the following three papers will provide a comprehensive perspective on the range of issues being studied in the climate change impacts literature with focus on agriculture:

References

Kavi Kumar, K.S.: 'Climate Sensitivity of Indian Agriculture: Do Spatial Effects Matter?' – *Cambridge Journal of Regions, Economy and Society*, 2011

Kavi Kumar, K.S., P. Shyamsundar, and A.A. Nambi: 'Economics of Climate Change Adaptation' – *Economic and Political Weekly*, 2010

Kavi Kumar, K.S. and B. Viswanathan: 'Weather Variability and Agriculture: Implications for Permanent and Temporary Migration in India' – *Climate Change Economics*,forthcoming.

Climate Change Impacts in Animal Agriculture Under the Humid Tropics

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It is commonplace that no situation exists on earth which can offer natural climate in an incessantly optimal level for any living being throughout its existence. In fact, thwarts pave way to advancement, adaptation, evolution and eventual advantage. On the contrary, domestication restricts the freedom of animals and birds to choose the best available spatial and temporal opportunities for their optimum. So, the climatologists, animal scientists and engineers need to synergize their efforts to obtain the fullest potential from the stock on a sustainable basis for a long period of time in order to ensure safe and sufficient output for the benefit of the population to inhabit. It is reckoned that the environment is on a challenging turn, becoming increasingly hostile. Global climate change models project an increasing probability of droughts and floods worldwide (Cline, 2007). Observation goes that: "climate change is the greatest ecological, economic and social challenge of our time" (Sundaresan J, 2011). The International Fund for Agricultural Development (IFAD) acknowledges climate change as one of the challenges that needs to be addressed since it is one of the factors affecting rural poverty (IFAD, 2009). While climate change is a global phenomenon, its negative impacts would smack the developing countries more severely, all the more the poor, who rely heavily on natural resource base for their livelihoods. Well known is that Indian economy is basically agriculture oriented where livestock plays an inevitable role, accounting 4.7% to the Gross Domestic Product (GDP). Kerala, a political state within the Indian Union, atypically belongs to the coastal humid tropical region in the Indian peninsula with atypical features of climatic variants, challenges and opportunities in sustainable agriculture.

The State of Kerala appears to be teaming with greenery due to high monsoon rainfall and thick vegetation. The region presents highly westward slanting landscape ranging from eastern mountains steeply descending to coastal plains. Kerala has tropical monsoon climate, and a fragile and closed eco-system with the presence of Western Ghats and Arabian Sea bordering a narrow strip of land. The landscape is divided into three physical zones namely high ranges, midlands and coastal regions. Most of the parts receive annual showers from south-western monsoon (heavy and longer, during June to August) and north-east monsoon (episodic, lighter, shorter and with thunderbolts, during October to November).

However, many parts of Kerala habitually experience prolonged dry spell from November to May especially when pre-monsoon showers fail. Decimation in wetlands (mainly paddy fields) and forest area, indiscriminate land filling, sand mining, and subsequent groundwater depletion, drying of streams, rivers and surface wells are at the hike, on one side. Floods and droughts, landslides, cloud bursts, rainfall decline, temperature rise and many more have to be accounted. Obviously, the region is moving from wetness to dryness within the humid climates. It is likely to be a threat to the linked sectors such as crop cultivation, animal agriculture, forestry, biodiversity, water resources and human health.

Sea level rise is another important climate change related issue along the Kerala Coast. Based on the recent reports, the sea level rise along the Kerala coast was 1.73 mm/year. The projections in sea level rise are likely to go up since ice in the Polar Regions is melting very fast due to global warming. As per IPCC (2007), the rise in sea level was 12 to 22 cm during the last century and steadily increasing till 2003, but since then, somehow the rise is slower. In the Indian Ocean, higher sea level rise was noticed from 2004 to 2009. So, saline water intrusion and water quality in many parts of Kerala and their impact on the above sectors need to be addressed.

The natural forest utilizes about 686 Giga tonnes of carbon - about 50% more than atmosphere – is being cleared at an average rate of about 13 million hectares per annum over the world. Deforestation is responsible for 20 to25% of global greenhouse gas emissions. As many as 572 fires broke out in the forest of Kerala during 2004 summer and the average loss of forest per year during the last decade (1991-2003) came to about 2,093 ha. Severe droughts, high temperature and low relative humidity are the atmospheric factors responsible for forest fires in addition to human interventions. The economic review, prepared by the State Planning Board, 2003 warns that a third of the State's biodiversity would vanish or would be close to extinction by 2030 unless steps are taken to check extinction of species. Of the 300 rare, endangered or threatened species in the Western Ghats, 159 are in Kerala. Of these, 70 are herbs, 23 climbers, eight epiphytes, 15 shrubs and 43 trees. Besides, 10 species of fresh water fish are identified as most threatened. Kerala has a flora of 10,035 species, which represents 22% of Indian flora. Of these, 3,872 are flowering plants of which 1,272 are endemic. As many as 102 species of mammals, 479 birds, 169 reptiles, 89 amphibians and 262 species of fresh water fish are reported from Kerala. Many of these are endemic. The review recalls that during the 20th century, at least 50 plant species have become extinct in the Country. Three species of birds-Himalayan mountain quail, forest spotted owlet and pink-headed duct-have become extinct. Besides, as many as 69 bird species have been categorised as extinct. The mammals, Indian cheetah and lesser one horned rhinoceros have also perished. The Malabar civet is on the threshold of extinction and 173 species have been listed as threatened. It may be noted that nearly 23% of the total endemic flora species of the Country are in Kerala. Describing a conservation strategy, the review says that ecologically sensitive areas have to be identified with reference to topography, hydrological regimes and this has to be networked with species diversity.

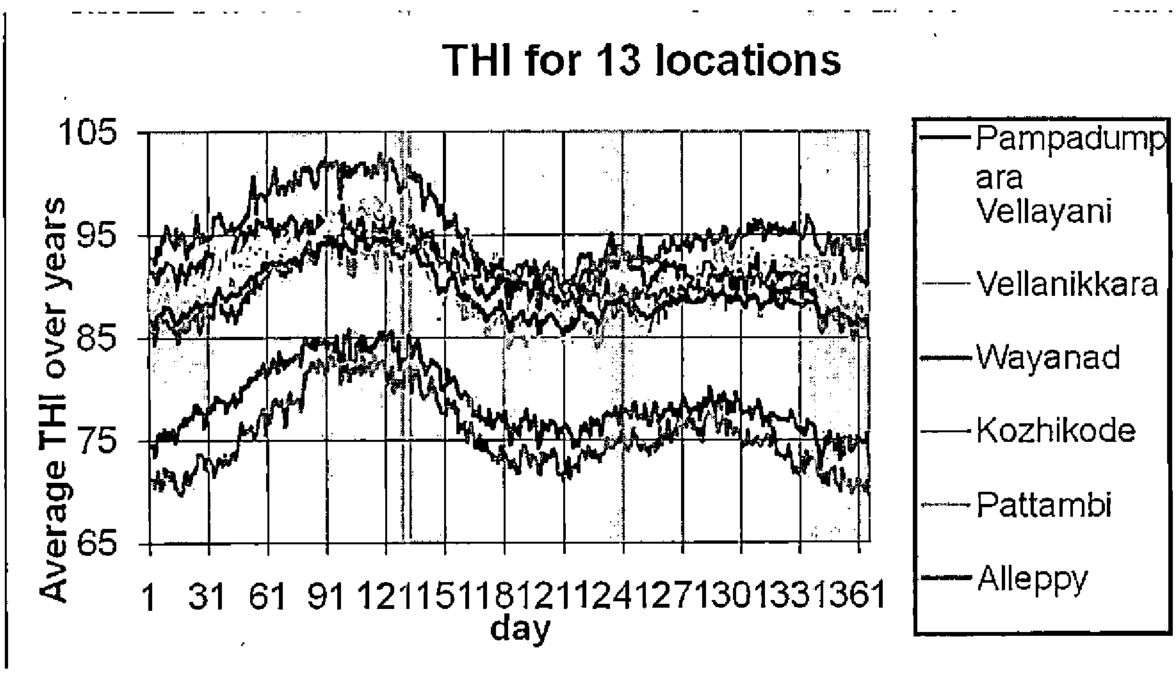
Impacts of droughts and floods

The occurrence of summer droughts and floods during monsoon season is not uncommon across the state of Kerala. Reports indicate that such weather abnormalities are likely to occur and reoccur under the projected climate change scenario. For the first time, the unprecedented summer drought was noticed across the state in 1983. Similar drought was noticed in summer 2004 and 2013. The water levels are very low in major reservoirs wherever drought is prevalent. Surface water resources are dried up. Dairy farming is adversely affected due to lack of fodder and water in several districts during the current summer 2013.

Thermal stress is noticed on cattle, poultry and elephants during summer due to high maximum temperature that prevails between 35 and 40 degree Celsius. The seasonal fluctuations are predominant in fodder availability and milk production. One of the reasons for low milk production during summer in cattle could be due to thermal stress and poor intake. The mortality rate in poultry could be explained, again due to heat load though the rate of mortality is relatively less in Kerala when compared to other states, where heat wave during summer is a threat. In all cases, the egg size, egg number, fertility, hatchability and feed conversion ratio are adversely affected.

Initial studies indicate that installation of sprinklers on roof-top reduces in-house temperature, where the birds are seemingly comfortable during summer and the mortality is minimised in poultry. The disease outbreak (like duck plague, duck cholera, fowl cholera) was noticed during summer 2013 and heavy mortality was noticed up to 50%. Increased salinity concomitant with severe drought cannot be ruled out in case of massive duck plague outbreak (as in Kole water-fields in Thrissur district).

In contrast, high rainfall marking high relative humidity for more number of days during monsoon season leads to occurrence of several other diseases. This issue has to be addressed further.



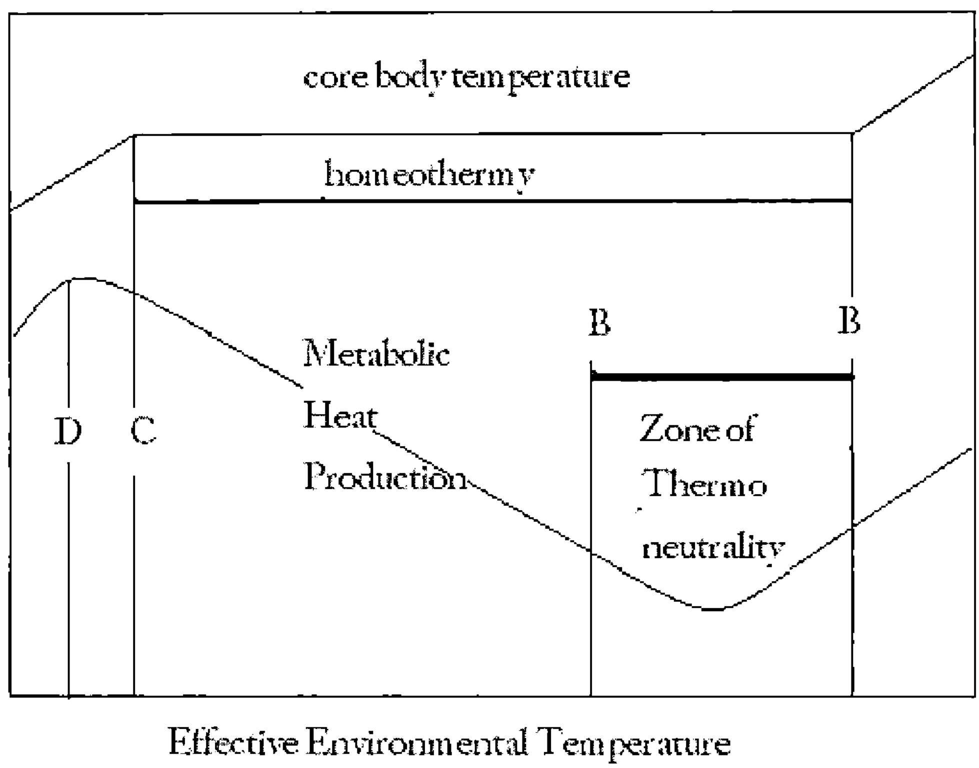
Direct and indirect effects

The effect of animal production in the hot humid climate has global significance in the light of climate change threats. Effects of increasing effective temperature, droughts, increasing salinity of inland water bodies, deforestation and pollution are concerns of subtropical and even temperate regions due to possible fallout of global climate change.

Direct effects

Direct effects include multiple stresses due to temperature, humidity, radiation, low plane of nutrition, heavy rains, pests and diseases. The cyclical phenomenon of drought and floods has additional effects.

Fig.1 Kleiber's law of metabolic heat production and core body temperature as influenced by environment temperature



C = lower critical temperature

D= point of reduction of metabolic heat

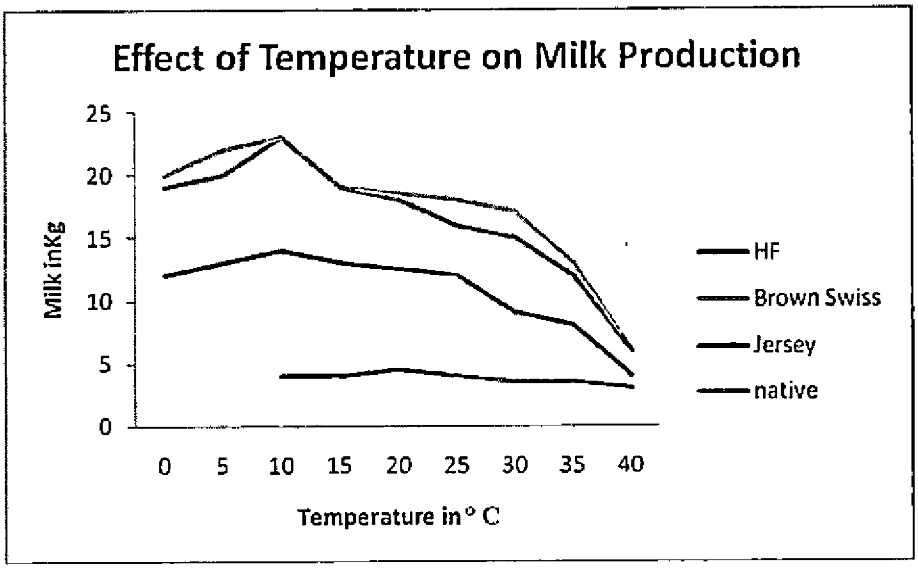
B on the left side = lower point of zone of thermal neutrality below which chemical regulation is needed to maintain homeothermy.

B on the right side = upper critical temperature.

The indirect effect of climate is the reduced availability of quality feed ingredients. Direct and indirect effects cause stress which cause depletion of body reserves and thereby reduced production, growth and reproduction. Among all stresses that the climate offers, the thermal stress due to effective environmental temperature in the most important. Challenge before the scientific community of the tropical world is to find ways to enhance milk production in the prevailing climatic conditions. Historically the traditional livestock production largely depended on heat tolerant native breeds that produced less milk compared to temperate exotic breeds. The dairy sector now largely comprises of extensive and expanding crossbred population in Kerala. For crossbreds, increased air temperature and humidity measured as temperature humidity index (THI) above critical thresholds are related to low dry matter intake (DMI) and to reduce efficiency of milk production.

The zone of thermo-neutrality within which no additional energy above maintenance is expended to heat or cool the body- for livestock is between -0.5 to 20^{0}C and the upper critical temperature (B on the right side) may reach to 25-26^{0}C(West,2003). The ambient temperature of hot humid region is above this critical temperature during several months of each year. Effective environmental temperature is a combined effect of ambient temperature and humidity. The combined effect is quantified as temperature humidity index (THI) $db°C - \{0.31 - 0.31RH)(db°C - 14.4)\}$. The normal THI to maintain production in dairy cattle is 72. In our state, during most days in a year it is hot and humid and hence the THI is high enough to cause significant heat stress.

Heat distress on animals will reduce the rate of animal feed intake and causes poor performance growth (Rowlinson, 2008). Among the direct effects of climate change most significant is the reduced milk production at higher temperatures. The following chart adapted from Esmay 1961 based on studies conducted in psychrometric chamber shows reduction in milk production in breeds which incidentally forms the sires used for crossbreeding activity of Kerala.



Indirect Effects

Earth's climate is undergoing noteworthy changes. The frequency and severity of risks in agriculture particularly in last few decades have increased on account of climate variability. The dependence of Indian agriculture on climate, weather, rainfall and the timeliness of rainfall is substantial. The principal evidence of climatic change has been rising temperatures, erratic rainfall pattern, and increase in the severity of droughts, floods, and cyclones which have caused huge losses in agricultural production and the livestock population.

The climate change, especially global warming is now well documented. The increase in global average temperature is due to the observed increase in anthropogenic greenhouse gas concentrations. The global livestock sector generates directly or indirectly 18% of global greenhouse gas (GHG) emissions as measured in CO_2 equivalent (FAO, 2007). Considering the large population of livestock, most of the developed countries were complaining about the GHG emission from Indian livestock. Commercial livestock farming has not emerged as a successful model in Indian condition due to various reasons. The varying environmental factors and the inability to devise and to popularize cost effective adaptation methodologies contribute to this factor. However, the small holder production system prevailing in the country has the advantage of reduced GHG because of dung distributed in the pasture during grazing.

The projected climate change over India based on various models, suggest steady increase in temperature and at a later stage slight increase of rainfall. Climate change will have far-reaching consequences for dairy, meat and wool production mainly via impacts on grass and range productivity. Changes in rainfall patterns may translate to an increased spread of existing vector-borne diseases and macro parasites of animals as well as humans with the emergence and spread of new diseases. In some areas, climate change may also cause new transmission models; these effects has already experienced in Kerala with the increasing density of mosquito population and a variety of fever outbreaks. In spite of the major impact of climate change on livestock sector and the direct contribution of this sector to climate change not many studies has been undertaken in this area in Kerala.

Increasing temperatures due to climate change has detrimental effect on animal productivity especially on exotic and crossbreds. About 97% of the cattle population in Kerala comprises of Crossbreds and such large crossbred population evolved as result of crossbreeding native cattle and exotic cattle of temperate climate should give us an opportunity to study the adaptation and acclimation aspects of cross breeding.

Earlier research work at Kerala

Indo Swiss Project in 1963 contemplated to involve a new multipurpose breed suitable for the climatic conditions prevailing in Kerala. Integrated Cattle Development Project (ICDP) plan was mooted for the fourth five year plan. Increase in animal population has also been attributed as a cause for climatic change.

A few studies have been reported on the effect of extreme climates on production performance of livestock. Studies on the physiological sturdiness with respect to adaptability of cross bred animals (Sahiwal X Brownswiss crossbreds) in comparison to native zebu cattle indicated that the cross bred could face the thermally adverse climate in tropics successfully and can perform in hot humid areas. Based on this research some simple effective management procedures such as providing shelter during day time, night feeding, feeding roughages in the evening, were recommended for the crossbred cattle under the tropical and sub tropical conditions. The study could evolve a modified tolerance index for tropics. The author has made elaborate studies on the problem of dairying in hot humid climate and developed a formula for temperature humidity sunshine Index (THSI) which is a modification of THI (temperature humidity Index (Thomas C.K. 1969).

In another study by Rajagopalan T G (1975) to evaluate the performance of Jersey cattle in Indian conditions, it was found that Jersey animals are quite suitable for cross breeding programme in view of their high average performance level under local climatic conditions in India.

Thiagarajan M (1989) in his work has attempted to investigate the effects of housing and feeding on growth and production of *Bos taurus* X *Bos indicus* cross bred cattle. He has studied the beneficial effects of open air conditions in hot humid tropical environment and advised loose housing system in hot humid tropical environment in which cattle have continuous access to open paddock shaded by trees. Under the hot humid conditions high wind velocity in the open seems to favour the cows considerably.

Study by Suraj and Sivakumar, (2012) suggests that the environment in which the dairy cattle are reared affects its ability to maintain thermal balance. It was found that the climatic condition of the different zones and the choice of materials played a major role in deciding the comfort level of the animal in the individual housing system.

The analysis based on temperature humidity index of Kerala for the last 10 years has revealed that climatic stress is very high in most parts of the state throughout the year (unpublished data, Prasad, 2013).

Future line of work

Though Kerala has achieved much in crossbreeding of cattle compared to other states of India, the average milk production of the cows is much less than its genetic potential. Improved production potential and sustainability in production in the prevailing climate should be supported by scientific research and this field will be of more importance in the background of climate change. Soil degradation through use of agro-chemicals is a serious issue that needs to be addressed on a priority basis in India during the next five-year plan. Imbalanced use of chemical fertilizer has led to declining fertilizer response in the fertile irrigated regions. Excess use of some nutrients, driven in part by imbalanced subsidies, has led to depletion of other nutrients from the soil leading to deterioration of the soil health. Alarmingly, the drastic decrease in the organic carbon content of the soil and the change in C:N ratio is one of the major reasons for soil degradation and decrease in agricultural productivity. The nature and extent of problem differ in different of parts of the country.

The carbon sequestration potential by cultivatable fodder plots could be used to partly mitigate the greenhouse gas emissions of the livestock sector. This will require avoiding land use changes that reduce ecosystem soil carbon stocks and a cautious management of fodder plots aiming at preserving and restoring soils and their soil organic matter content. Trade-offs between greenhouse gas emissions and animal production need to be better understood at the farm and regional scales, through a continued development of observational, experimental and modeling approaches (Soussana, 2010). Development of appropriate cost effective technologies for climate change mitigation, conservation of natural resources and ensuring the livestock productivity is very important from social and economic point of view.

- to analyze and update the trends in climatic changes and to integrate the information to develop a database
- to forecast extreme weather events which can be detrimental to livestock farming by using computer simulation tools
- to study the impact of climatic change on production and reproduction performance of animals.
- to study the decline in disease resistance as well as emerging new diseases on basis of changing climate of Kerala
- to sort out suitable mitigation measures to the changing climate so that the livestock farming sector of Kerala is not affected by the climatic variation
- assisting the farmers in developing and adopting appropriate measures and management schemes in changing climate scenario

- immediate reasons for climate change should be traced out and effort should be taken to develop measures to mitigate the production of greenhouse gas emissions from livestock

Reference

Esmay ML (1978) Principles of Animal Environment, AVI publishing Company, Connecticut, 351 p

IPCC (Intergovernmental Panel on Climate Change) (2007). Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor & H.L. Miller, eds.]. Cambridge, UK, Cambridge University Press in The Hindu, pp 147-155.

Rajagopalan T G(1974). Study of some aspects of the performance of Jersey cattle. MSc Thesis submitted to Gujarat College of Veterinary Science and Animal Husbandry, Anand

Rowlinson, P. (2008). Adapting livestock production systems to climate change – temperate zones. In: P. Rowlinson, M. Steele & A. Nefzaoui, eds. Livestock and global change.Proceedings of an international conference, Hammamet, Tunisia, 17–20 May 2008. Cambridge, UK, Cambridge University Press. 61-63.

Shashi, K., Pathak and Mason, N.J. 2002. Our shrinking ozone layer: General perspectives and remedial measure. Resonance, December pp.71-80

Soussana, J.F., Tallec, T. & Blanfort, V. (2010) Mitigating the greenhouse gas balance ofruminant production systems through carbon sequestration in grasslands. Animal 4:3, 334-350

Suraj P T (2011) Effect of dairy cattle under different housing pattern in north and western regions of Tamilnadu. PhD thesis submitted to Tamilnadu Veterinary and Animal Sciences University

ThiagarajanM (1989). Effect of environmental heat stress on performance of crossbred dairy cattle. PhD thesis submitted to Kerala Agricultural University.

Thomas C.K. and Sastry , N.S.R 1991. Dairy Bovine Production (first ed.). Kalyani Publishers, New Delhi, pp 106-125

West, J. W. (2003). Effects of heat-stress on production in dairy cattle. *J. Dairy Sci.*, 86, 2131-2144.

Micro Level Planning for Sustainable Management of Land Resources

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Land – the limited natural resource

Land is the most important natural resource for mankind and diversity is the oddity of land. Agriculture production is mainly dependent on natural resources, e.g. land, water, soil, biodiversity, along with air and sunlight. But these natural resources are rapidly shrinking due to demographic and socio-economic pressures, monsoonal disturbances, increasing frequencies of floods and droughts etc. Land is one such natural resource whose supply is very much limited. At the same time, growing population pressure and human activities are increasing the demand on the limited land for both agricultural and other uses. Land use classification based on different type of uses indicate that a little more than half of total land mass of 328.73 million hectare in India is used for agriculture. Measured in terms of acreage of land available for productive use per capita, the availability of land is, in fact declining. The demand for arable land, grazing, vegetation, mining, wildlife and urban development are greater than the land resources available. The per capita availability of arable land has decreased from 0.21 ha in 1981 to 0.13 ha in 2009. Agricultural land accounts to about 56% of the total area (182.46 million ha). During the last decade (1999-2000 to 2009-10), area under nonagricultural uses has increased by 2.57 million ha (11%). During the same period cultivable land has marginally declined by 1.4 million ha (0.8%) and net sown area has declined by 1.04 million ha (0.7%). Since 1970-71 net cultivated area is more or less stable at 140 million ha, where as the cropping intensity has increased from 111% to 137%. Land use classification of India is given in table1.

Land resources of Kerala

Kerala is endowed with a combination of distinct altitudinal variations resulting from the rise of the land mass from 5 meters below sea level in the west to the soaring heights of 2695 meters in the east within the short span of 120 km. The small expanse of land with an area of 38,863 km^2 has a base length of 560 km along the coast and width ranging from 11 km to 124 km. Physiographically, the terrain has three natural regions namely, lowlands, midland, highlands (Figure 1). The state is gifted with ten soil types derived from the laterite base and has 12 distinct agro climatic zones. There are 44 river basins, 1750 sub basins and 4452 mini watersheds providing multitudes of lively micro ecosystems. The environment of these micro watersheds are conducive to varying crop types, such as, coconut and rice in the sultry lowlands, rice, tapioca, banana, arecanut, coconut, pepper, cashew and rubber in hot humid midlands and tea, coffee and cardamom in the cool sub tropic highlands.

Fig 1. Physiographic terrain of Kerala

Physiographic units, altitudes and areas			
Unit	**Altitude (m)**	**Area (Km^2)**	**Area(%)**
Lowland	0 - 7.5	3979.3	10.24
Midland	7.5 - 75	16231.2	41.76
Highland	> 75 m	18653.5	48.00

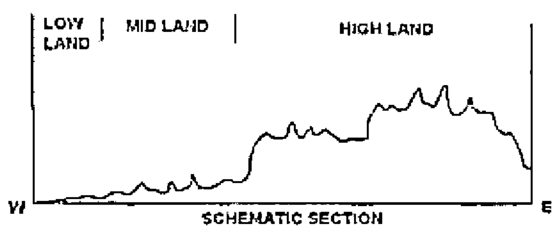

Figure 1

Kerala has a diverse land use and cropping pattern. The land reforms introduced in the State brought in radical and comprehensive institutional changes leading to drastic transformation in the land holding pattern. This has resulted in shift in the land use pattern. Agriculture is the dominant land use type of the State. It accounts for over 55% of the geographical area followed by forest land (including degraded forest) of 28% but area under non-agricultural use is only 11% (Farm Guide, 2010). The land use pattern of Kerala during 2010-11 reveals that out of a total geographical area of 38.86 lakh ha net sown area is about 53%. Forest occupies around 28%. The net sown area has declined slightly by 0.35% over the previous year. The share of total cropped area in the total geographical area is 68%. But it marked a decline of 21217 ha during 2010-11 over the previous year. The share of land under non-agricultural uses out of total geographical area was 9% in 2009-10 and has increased to 10% in 2010-11. There was a decline in the area under current fallow (917 ha) and increase in the area under fallow other than current fallow (6569 ha) during 2010-11 over 2009-10. The area under cultivable waste declined 6349 ha and barren and uncultivated land declined by 2473 ha (Table 2). The state is also endowed with a number of occurrence/deposits of minerals such as heavy mineral sands (Ilmenite, Rutile, Zircon, Monazite, Sillimanite), Gold, Iron Ore, Bauxite, Graphite, China clay, Ball clay, Fire clay, Tile and Brick clay, Silica sand, Lignite, Limestone, Lime shell, Dimension stone (granite), Magnesite, Quartz-Steatite etc.

Agro-Ecological Zones

Four parameters that together evolve distinct agronomic environments wherein a distinct cropping pattern flourishes are altitude, rainfall pattern, soil type and topography. Based on this, the state has been delineated into thirteen agro-climatic zones. The principal characteristics of each zone are summarized (Table 3). Many of them are currently in vogue and are associated with areas having singular agro-climatic features and cropping patterns.

Land use planning

Land use planning is a systematic way of addressing the use of the land resource, focusing on the evaluation of land and the options for land use. The main goal is how we are managing our land resources optimally. In India, land use planning can be applied at 5 broad level; National, regional, district, watershed and block/village level. The earlier approach to planning was 'top to bottom' where in the social and local aspects were not considered fully. Later, the 'micro concept' based on equity, people participation and improvement from 'bottom to top' has been introduced (Gautam, 2002).

Ever since man has learnt crop husbandry he has been constantly trying to enhance the production through improved agricultural practices. Development of appropriate technologies that are adaptable and adoptable to different agro-climatic zones was a strategic step towards providing easier access to new technologies in resource poor situations. Over the years, it has been realized that there is a substantial gap between generated technologies and sensitiveness of agricultural technologies to the agro-ecological situations, social factors, financial factors and preferences of farm families. Information at the micro level are required to design sustainable land use models and technologies that enable optimal utilization of the local resources; both bio physical and economic. The diversity in the physical landscape imposes severe limitations to introduce a plan for the farming system as a whole. A systematic assessment of land and water potential, alternatives for land use and economic and social conditions is needed in order to select and adopt the best land-use options. For this it is important to assess the development potential of the dominant sector of the economy, i.e. agriculture. Attempts to study the agrarian structure and economic development in many instances, have failed to identify the prime reasons behind the dismal performance of the farm sector especially in the micro point of view. Enquiries to assess the suitability of micro climatic and regional specific socio -economic parameters in farming are often staggered and non- comprehensive. Nor were there any concerted efforts to revive the farming or to develop new plans in the light of the results and conclusions of the micro level studies. Moreover, the substantial gap existing between generated technologies and sensitiveness of agricultural technologies to the agro-ecological situations, social factors, economic factors and preferences of farm families are often over looked.

Non availability of accurate and dependable data base below the *taluk* level on agriculture and allied sector has been pinpointed as one of the major constraints impeding resource based planning (GOI, Planning Commission). The Working Group on Decentralized Planning in Agriculture has rightly pointed out the need for initiating comprehensive exercise at state level to delineate the state into various agro ecological/agro climate zones and further classify the district into sub units. In each agro ecological unit, resource based plan including the yield gap should be addressed. The Agro-climatic Regional Planning exercise of the Planning Commission during 8th and 9th plan period was a serious attempt to plan for smaller homogenous regions keeping in view the natural resources and capabilities towards achieving development. At the same time, the basic right of people to be involved in decisions which directly affect them has been supported by the statements contained in the Agenda 21 Document of the Rio Conference, 1992.

Participatory approach in for micro level planning in agriculture

People's participation is very important for the success of any development project. In recent years, participatory tools are frequently made use of for assessing various development issues such as local resources, watershed issues, environmental problems, local needs and gender issues in local communities in a relatively short period.

Participatory approaches in scientific investigations and the technique of Participatory Rural Appraisal (PRA) or Participatory Learning and Action (PLA) were originally propounded and propagated by Chambers (1991). He also opined that data collection in large questionnaire survey could be costly, time consuming and most of the data collected lay idle without being used by anybody. The research findings of Action Aid Nepal (1992), Huddad et. al. (1993) and Rajarathnam etc. al. (1993) suggested that PRA could be applied to a larger scale of enquiry and could be scaled up for larger areas under consideration.

The importance and significance of stake holder participatory analysis in an agro-ecological unit basis is discussed below. The study aimed to identify the constraints and potential and to suggest broad agricultural development plans for the Palakkad district of Kerala. The problems and constraints to farming were assessed along with the strength and opportunities for developing farming into a sustainable activity on the basis of the resource endowments in the respective agro climatic units. Enterprise mixes were suggested for the agro-ecological units based on stakeholder preferences and suitability. The study complemented the delineation of Palakkad district of Kerala into different agro-ecological units based on soil and climatic considerations by NBSS& LUP, Bangalore as part of RSVY. Even though there are 12 agro ecological units as identified by the NBSS &LUP in Palakkad, the study is confined to units VII, VIII, IX, and X, identified as areas with agricultural importance and where farming is a major economic activity. Taking in to consideration the geographical condition and logistic convenience of farmers, 3- 4 PRA sessions were planned in each zone, pooling panchayats. Key informant farmers (KIF) representing rice based cropping system, homestead systems, plantation based systems, dairying, fisheries etc and the representatives of Kudumbasree/Self Help Groups (SHG) as available in the zone were purposively invited. The KIF were identified with the help of Krishibhavan officials, Fisheries department , Rubber Board etc. 10-15 farmers representing each of the enterprises attended the sessions. In addition, elected representatives of panchayats, officials of the departments of Agriculture, Animal Husbandry, Dairy Development, Irrigation, etc also took part. Semi structured schedules and PLA guide lines were prepared for facilitating the sessions. After the initial briefing up and a short inauguration by the respective local body president, the farmers were grouped on the basis of6 enterprises and the information collected as per the objectives. Based on the information collected from each zone, a workshop of all stake holders representing the various units was organized at the district head quarters and the draft report of each zone was placed before them for validation. The data collected were subjected to triangulation among various stakeholders including the elected representatives of the district panchayat administration.

Palakkad- the rice granary of Kerala

Palakkad is located in the east central portion of Kerala state and lies between 10° 19' and 11° 14' north latitudes and 76° 1' and 76° 54' E longitude. The district has humid tropical climate with temperature ranging from 19° c to 42°c and 75% rain is received from the South-west monsoon. The district has a total geographical area of 4457.84 Sq.km which accounts to 11.5% of the total area of the State. Palakkad accounts for about 38% of paddy area and about 34% of the total rice production in the state (Economic Review, 2010). The land utilization pattern of the district is given in Table 2, which indicates diversified units of topography, physiography, climate and soil and land use pattern. The major crops cultivated in the district are paddy, pulses, coconut, sugarcane, banana and plantains, mango, jack and vegetables. Other important crops which are exclusively confined to the district are cotton, groundnut and ragi. The area under mango plantation in the district is estimated at 9991 ha constituting nearly 12% of state share with a production of 95114 tonnes which is higher by 64 % over the state average. All the mango orchards are concentrated in a particular village *Muthalamada* which is now popular as 'mango city'. Irrigation projects play a major role in retaining the agricultural importance of the district. Nearly 33512 hectares of land have been brought under major irrigation schemes. The main source of irrigation is canal and the district accounts for about 46% of the total area irrigated by canals in the State.

Stakeholder preference for Enterprise - mix

With rising population and declining land–man ratio agriculture may not be able to provide adequate income and employment to households. Integration of farm enterprises suitable to different agro-ecological areas and their resource endowments would provide better livelihoods to the farmers. The enterprise suitability of the selected agro ecological units of Palakkad was studied in terms profitability, marketability and resource availability through enterprise preference matrix prepared by the villagers (Table 4). It clearly indicated that the preference for enterprises varied across different units even within the district. To our surprise, in the so called 'rice granary', paddy has been ranked low by the farmers in the enterprise preference matrix. The percentage difference in profit from paddy for the alternative crops varied from Rs. 108 to Rs. 1900 per hectare (Rajalekshmi, 2006).

A comparative analysis of the strengths, weaknesses, opportunities and threats (SWOT) of the selected units indicated that they varied from each other in terms of inherent strengths and weaknesses (Tables 5-8). Favourable climate and fertile soil suited to diverse crops and the presence of irrigation and water sources are the major strengths of all units. Large cattle population and availability of water bodies to sustain an integrated farming system are added advantages. The functional *padasekarasamithis* and *Kudumbasree* units give impetus to agricultural developmental activities in all the four units. The National Rural Employment Guarantee Scheme (NREGS) being operational in the district since 2006 could be effectively harnessed to solve the labour scarcity problems in agriculture.

Apropos weaknesses, it could be seen that even though sufficient water and irrigation sources are present, lack of proper maintenance of irrigation canals, silting of dams and unscientific scheduling of irrigation water have led to the inefficiency of resource use. Capital inadequacy and labour scarcity coupled with non availability of agro machineries suitable to small holdings have increased the cost of cultivation. Even though the units have substantial cattle population, scientific livestock management is not widely known among farmers. The farmers in all the units complained about the insufficiency of financial assistance from the Government for farming (Table 5). The opportunities of these units for enhancing production and productivity and to avail gainful employment are considerably high, provided adequate and specific interventions are made in each unit (Table 6). The prospects of harnessing the opportunity through the established net work of Self Help Groups of *Kudumbasree* and the like are yet to be realized. Specific projects that tap the opportunities have to be formulated covering all the prospective agro ecological units.

However, the major threats identified through the study suggest policy level as well as location specific interventions to create conducive environment for growth and development. Even though the Kerala Land Utilization Act is in force, the loopholes in the Act and the lack of interest in its enforcement still lead to conversion of paddy fields to other crops and non agricultural purposes. The apathy and dying interest of people, particularly youth in farming is yet another serious threat as far as agriculture is concerned. Concerted efforts to retain people in farming through innovative approaches and an assurance of remunerative and stable price are needed. The impact of climate change on farming and farm income are being experienced by farmers of late; and suitable cropping sequence and crop calendar have to be adapted by farmers to combat climate change. At the same time the Government has to offer attractive crop insurance schemes, lest the farmers would be at peril.

Proposed interventions to enhance agricultural production

In the light of inferences drawn out of SWOT Analysis and participatory evaluation of the agro climatic and socio economic characteristics of the units, interventions under the following areas were recommended to be immediately under taken to enhance agricultural production in the units.

•Water conservation and irrigation

Community level organizational mechanism for better management of water involving farmers in the maintenance of canals and scheduling of irrigation water, through Water Users' Associations (WUAs) as envisaged in the "Kerala Irrigation and Water Conservation Act 2003" is suggested.

•Crop Production and management

All the four agro ecological units selected have favourable soil and climatic conditions to sustain diverse crop production systems. The lack luster performance of the crop sector could be attributed partly to the short fall in achieving the basic infrastructure support like irrigation, seeds, manures, fertilizers, mechanization, storage and marketing. A production system wise analysis showed that rice continues as a less remunerative crop in the district when compared with alternative crops like coconut, tapioca and banana. (Rajalekshmi, 2006). At the same time, various schemes implemented so far in agriculture had only short term objectives that could not address the sustainability of production systems. Policy interventions at meaningful micro level planning leading to horizontal and vertical integration among the panchayats and line department schemes for holistic development and infrastructure creation is the need of the hour. Being the rice granary of the state special measures have to be taken for protecting and preserving the paddy fields. Considering the food security and ecological functions met by rice cultivation, a compensatory price mechanism has to be evolved to pay for the opportunity cost of farmers in continuing rice cultivation and conserving the paddy fields.

A Food and Nutrition Security package for Palakkad district high lighting the scope of bringing at least 50% of the summer rice fallows under arid and semi arid crops like pulses and grams could be looked in to. Diversification and value addition of coconut and by products in a commercial line, organized efforts for tapping the potential of horticultural crops and their value addition and capacity building of the 'Kudumbasree' groups for taking up enterprises providing necessary forward and backward linkages including technology transfer are recommended.

c) Livestock production and management

Livestock has been an inevitable component in the integrated farming system followed in traditional farming in all the units. Even under hostile conditions, nearly 50% of the small/marginal farmers maintain at least one or two cattle. Specific interventions to evolve high yielding breeds of cattle suited to the climatic conditions, instituting easier and cheap loan facilities at nominal interest rate for longer period ,establishing decentralized chilling facilities for storage of milk during rainy season and surplus production periods ,establishing facilities for producing value added products of milk and capacity building and training to SHGs and providing the infra structure facilities for processing and marketing and popularizing fodder cultivation and scientific fodder conservation like silaging and encouraging backyard poultry in homesteads have been suggested.

d) Research and Extension Strategies

The research strategy for the agro ecological units under study should be the one addressing specific local problems in addition to research on a wider perspective. The units have reported that the yield of rice has been stagnant over the last few years under the same management level. The problems faced by agriculture in one unit are entirely different from those faced in other parts. The research policy of the agricultural university should be restructured in such a way to facilitate demand driven and location specific research including climate change mitigation studies and strategies.

The indices of technology adoption in major crops and dairying fall in the range of 45- 60 in all the units. This implies that the recommended technologies and scientific management are not being fully adopted at the field level. SAARC Agricultural Vision 2020 has pinpointed the absence or weak Research-Extension-Farmer linkages resulting in large gaps in the farmers' practices and improved technologies. Effective revamping of the Research–Extension interfaces of researchers and extension officials and the reorganization of field level agricultural offices may be fruitful. As the present organization of Krishibhavan, the field level implementing organ of the state Agricultural department seldom give the Agricultural Officers enough time to involve in agricultural extension activities and the field problems, a change of the structural pattern of Krishibhavans creating the post of a clerical position to manage the office would be beneficial.

e) Forward and backward linkages

In order to overcome the constraints with regard to forward and backward linkages in farming like non-availability of quality seeds and planting materials, non-availability of fertilizers during peak cropping season, non-availability of labourers, and insufficiency of agro machineries and lack of marketing facilities for meat and egg in the agro ecological units, establishment of seed villages, bio control labs, decentralized storage and primary processing facilities at the *padasekharam* level, farmers' daily markets for vegetables and fruits in Chittoor town, Labour Banks at panchayat levels, common facility centres may be set up at appropriate locations in the agro ecological units to provide adequate backward linkage and to ensure hygienic production, standardization, packaging and labeling of agro processing enterprises of Kudumbasree/ SHGs.

f) Institutional integration at grass root level

Agricultural production system of any region comprises crop, live stock and dairying, fisheries, irrigation, soil and water conservation etc. It is observed that different agencies are functioning without any effective coordination and integration at the grass roots level. Even though irrigation is a crucial element in agricultural development, there is no mechanism at the grass roots level for scientific irrigation scheduling. In the case of finance and credit, the District Credit Plan is prepared without detailed consultation with stakeholders like farmers, elected representatives and extension officials of the concerned departments. Preparation of the Credit Plans of banks at the gramapanchayat level and its integration with Peoples' Plan Programme would be more meaningful. It could be very well established that it is not the lack of resources and avenues, but the lack of comprehensive planning based on a perspective cutting across the boundaries of the departments that is impeding sustainable growth and development. Integration with major programmes like MGNREGS for development of water sources and irrigation and drainage facilities, water harvesting structures, land development and horticulture development for SC/ST/BPL farmers and undertaking watershed development projects may be done. The unskilled labour force registered under MGNREGS should be organized to form labour banks to address labour scarcity during peak agricultural season and the labour budget and seasonality calendar under NREGs should be designed to suit the cropping season and peak agricultural operations of the panchayat, thus complementing agricultural production. The study strongly points out at the need for further efficient planning and allocation of resources viz., financial, physical and human resources at the grass roots level.

Conclusion

The recommendations of the micro level study goes with the suggestions given in the State of the Agriculture report of Government of India (2013) that for proper management of natural resources and to ensure sustainable agriculture growth in the country, there is need for a land use policy. Land use planning should be integrated with all developmental programmes, especially MGNREGA for holistic rural development, natural resource management and eco-restoration. As per Seventh Schedule of the Constitution of India since Land and Water falls under the purview of State Governments, the States should bring about suitable legislation for regulating conversion of agricultural land for non-agricultural purposes. Moreover, climate change could drastically alter the distribution and quality of natural resources thereby adversely affecting livelihood security of people. Observations of Intergovernmental Panel on Climate Change (IPCC) indicate that adverse impact of climate change due to rising temperatures and extreme weather events on food production system could impact agricultural growth. Several areas have been identified as risk prone due to impact of climate change like coastal areas, Indo-Gangetic plains and the drought and flood prone regions of the country. Micro level planning would become helpful in surviving the unforeseen situational shortages arising due to climate change.

Reference

Acton Aid Nepal (1992) Utilization Survey Report Part 1. Monitoring and Evaluation Unit. Action Aid Nepal, Sindhupal Chowk, Nepal 123 P

Chambers, R (1991) Shortcut and participatory methods for projects. *Putting People First: Sociological variables in rural development* (ed. Cernea,M.M) Oxford University Press, London,pp.31-76.

Economic Review (2008), State Planning Board, Government of Kerala

Gautam, N.C. (2002) *Methodology for land use planning- a systematic approach.* Centre for Land Use Management, Hyderabad. p. 195

Govt. of India. State of Indian agriculture 2012-13.

Huddad, L, Chung, K and Devi Y.P. (1993) Report on Alternative Methods to Locate the Food and Nutritional Insecurity. Andhra Pradesh Agricultural University, Hyderabad, pp. 130-142.

Rajalekhsmi, P (2006) Shifting of paddy cultivation in Palakkad distict- an economic analysis. PhD thesis (unpublished), Dept of Economics, University of Calicut.

Rajarathnam J., Ganesan C., Helen T. and Abel, N.B (1993). "Validating Wealth Ranking of PRA and Formal survey in identifying the Rural Poor' CMC, Vellore, TN 84p

Table 1. Land use classification in India

Year	Geographical Area	Agri. Land/ Cultivable land/ Culturable land/ Arable land	Forests	Not available for cultivation		Other uncultivated land excluding fallow land			Fallow Lands		Total cropped area
				Area under nonagricultural uses	Barren and unculturable land	Permanent pastures & other grazing lands	Land under Misc. tree crops & groves	Culturable waste land	Fallow lands other than current fallows	Curre-nt fallows	
1950-51	328726	189641	40482	9357	38160	6675	19828	22943	17445	10679	131893
1990-91		185177	67805	21087	19389	11404	3818	14995	9662	13703	185742
2000-01		183455	69843	23752	17483	10662	3445	13631	10267	14777	185340
2001-02		183551	69720	23912	17417	10528	3453	13520	10534	15344	188286
2002-03		183449	69821	24118	17520	10450	3443	13651	11967	22337	174108
2003-04		183132	69968	24513	17469	10484	3383	13241	11313	14487	189669
2004-05		182946	69960	24757	17471	10452	3364	13272	10878	14790	191119

2005-06(p)		182685	69994	24989	17334	10444	3391	13225	10696	14211	192756
2006-07(p)		182508	70002	25436	17290	10414	3364	13271	10516	15509	192408
2007-08(p)		182691	70020	25711	16990	10198	3413	13059	10329	14512	195138
2008-09(p)		182514	70034	26064	16798	10177	3356	12752	10286	14191	195357
2009-10(p)		182466	70042	26171	16783	10149	3351	12857	10484	15753	192197

FmenTable 2. Land use pattern of Kerala for the year 2011-12.

Land use Pattern in Kerala						(Area in ha)
Sl. No.	Classification of Land	2010-11	2011-12	Percent of Geographical Area	Change in Area between 2010-11 and 2011-12	
					Actual	Percentage
1	Total Geographical Area	3886287	3886287	100	0	0
2	Forest	1081509	1081509	28	0	0
3	Land put to non agricultural uses	384174	399924	10	15750	4
4	Barren and uncultivated land	19573	17552	0.5	-2021	-10
5	Permanent Pastures and Grazing land	153	85	0	-68	-44
6	Land under miscellaneous tree crops	3690	3369	0.1	-321	-9
7	Cultivable waste	91665	95437	2	3772	4
8	Fallow other than current fallow	51943	57670	1	5727	11
9	Current fallow	76028	77056	2	1028	1
10	Net area sown	2071507	2040132	53	-31375	-1.5
11	Area sown more than once	575954	621025	16	45071	8
12	Total Cropped area	2647461	2661757	69	14296	1
13	Cropping intensity	128	130	0	2	

Source: Directorate of Economics and Statistics

Table 3 Parameters for identifying agro-ecological zones

Parameter	Level	Description
I Altitude	Type I	Altitude Up to 500 m above MSL (Low altitude zone- hot humid tropics, spread over the entire state)
	Type II	More than 500 m above MSL
II Rainfall	Pattern I	Both the southwest and northeast monsoons are active and moderately distributed. Southwest monsoon with June maximum (South of 11°N latitude)
	Pattern II	Poorly distributed rainfall; southwest monsoon with July maximum and concentrated in 3-4 months. Northeast monsoon relatively weak (North of 110 N Latitude).
III Soil Type	1	Alluvial soil (Spread over river banks)
	2	Sandy soil (Coastal areas)
	3	Sandy loam soil (Coastal areas)
	4	Laterite soil with well defined B horizon (Natural midlands)
	5	Laterite soil without B-horizon (Natural highlands).
	6	Red soil (Southern-most Kerala)
	7	Black soil (Chittur taluk of Palakkad district)

	8	Peat (kari) soil (Kuttanad)		
	9	Acid-saline soil (Pokkali and Kaipad areas)		
IV Topology		Vallyes	Hill Tops	Slopes
	Model I	Extensive valleys with level but raised garden lands		
	Model II a	Valleys less extensive	Hills with moderate gradients	Slopes having mild gradients
	Model II b	Valleys less extensive	Hills with moderate gradients and top with egg shaped hump	Steep slopes
	Model II c	Valleys less extensive	Hills with table tops	Steep slopes
	Model IIII	Narrow valleys	Hills with steep gradients	Steep slopes

Table 4 .Crop/Enterprise suitability matrix for palakkad

Sl.No	Crop/Enterprise	Unit VII	Unit VIII	Unit IX	Unit X
1	Paddy	V(23.5)	VII(18)	VIII(12)	III(25)
2	Rubber	-	I (26.5)	I(28)	I(28)
3	Dairying	I(28.5)	I(26.5)	VI(17)	VII(21.5)
4	Vegetables	IV(24)	III(24.5)	-	VIII(20)
5	Poultry	VI(23)	III(24.5)	-	-
6	Tapioca	V(23.5)	II (26)	IV(21.5)	VI(22)
7	Banana	-	III(23)	IV(21.5)	II(26)
8	Goat rearing	-	IV(22)	II(24)	IV(23.5)
9	Agro processing	-	-	III(22.5)	VII(21.5)
10	Apiculture	-	-	III(22.5)	IV(23.5)
11	Sericulture	II(26)	-	-	-
12	Toddy tapping*	I(28.5)	-	-	-
13	Mango cultivation	III(24.5)	-	-	-

Table 5.Comparative analysis of strengths of the selected agro ecological units

Strengths	Unit VII	UnitVIII	Unit Ix	Unit X
Fertile soil & congenial climate	□	□	□	-
Presence of irrigation & water sources	□	□	□	□
Availability of ponds, water bodies etc.	□	-	-	□
Large cattle population	□	-	□	-
Traditional rice mills	□	□	-	-
Majority of farmers are marginal or small farmers	□	-	-	-
Existence of functional padasekharams	□	□	□	-
Access to technology	□	-	-	□
Marketing network of VFPCK	-	□	-	-
Plantation crops dominated farming	-	-	-	□
Underutilized homesteads	-	-	□	□
Functional Kudumbasree/SHG	-	□	□	□
Presence of Functional Farmers Service Cooperative Banks	-	□	-	-
Paddy farming as a major livelihood activity	□	□	-	□
NREGS in operation	□	□	□	□

Table 6. Comparative analysis of weaknesses of the selected agro ecological units

Sl No	Weaknesses	VII	VIII	IX	X
1	Lack of proper maintenance of irrigation canals/ponds	□	□	□	□
2	Unscientific irrigation scheduling	□	□		
3	Scarcity of water	□			□
4	Insufficiency of agromachinaries	□		□	□
5	Delay in supply of paddy seeds	□	□		□
6	Insufficient veterinary care	□		□	
7	Fodder availability is less		□		
8	Insufficient milk collection centres	□		□	
9	Non availability of timely labour	□	□	□	□
10	Lack of awareness on scientific /cattle management	□		□	
12	Milk societies unable to collect surplus production	□			
13	Non functioning mills/factories	□	□		
14	Low adoption of recommended crop/livestock management practices	□		□	
15	Lack of systematic pest &disease control				□
16	Dependence on informal credit	□			
17	Lack of storage and marketing facilities		□	□	□
18	Unstable price of agricultural produces		□		□
19	No marketing support for kudumbasree			□	
20	Poor performance of RSGP		□	□	
21	Insufficient technical support in field			□	□
22	Large variation in land holding size				□
23	Insufficient financial assistance from Government	□	□	□	□

Table 7. Comparative analysis of Opportunities of the selected agro ecological units

SlNo	Opportunities	VII	VIII	IX	X
1	Presence of several agro processing units &traditional mills	□	□		
2	Under utilized coconut gardens and homesteads	□	□	□	□
3	Fallow wetlands for second crop	□		□	□
4	Summer rice fallows		□	□	□
5	Fish farming in ponds.	□		□	□
6	Prospects of dairying		□	□	□
7	Waste lands for fodder cultivation		□		
8	Prospects of Rabbit/goat/Poultry	□	□	□	□
9	Prospects of micro enterprises through groups	□	□	□	□
10	Agroservice centres of youth &custom hire service	□			
11	Functional group farming committees	□	□	□	
12	Integration with MGNREGS	□	□	□	□

Table 8. Comparative analysis of threats for development in the selected units

SlNo	Threat	VII	VIII	IX	X
1	Uncertainity with regard to release of water from Parambikulam- Aliyar project	□	□		
2	Inflow of inferior quality planting materials & agricultural inputs from neighbouring states	□			
3	Short supply of Potash fertilizers	□			
4	Natural calamities , pest & diseases, climate change	□	□	□	□
5	Damage by wild animals& birds	□	□	□	□
6	Undulating topography rendering farm mechanization difficult				□
7	Upper limit of land ceiling for availing benefits	□	□		
8	Loopholes in KLU Act & its non effective enforcement				□
9	Flash bandhs and hartals	□	□	□	□
10	Indebtedness of farmers				□
11	Apathy towards farming in youth	□	□	□	□

Indigenous Technical Knowledge in Natural Resource Management and Social Capital

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Introduction

Indigenous Technical Knowledge (ITK) provides the link between ancient and present human societies. Social capital development, which depends on the collective wisdom, relationships and trust among the members of a social system, is indispensable for participatory development in any sphere of activity. With increasing pressures on the natural resources to meet the growing human needs, it becomes necessary to device ways and means of utilizing these natural resource endowments in a sustainable way. Combining the strengths of ITK and social capital in the conservation of natural resources holds the key for sustainable development. Certain critical concerns in this regard are discussed in the pages that follow:

Indigenous Technical Knowledge

Indigenous Knowledge refers to the unique, traditional, local knowledge existing within and developed around the specific conditions of women and men indigenous to a particular geographic area. Indigenous knowledge is the local knowledge - knowledge that is unique to a given culture or society. IK contrasts with the international knowledge system generated by universities, research institutions and private firms. It is the basis for local-level decision in agriculture, health care, food preparation, education, natural resource management, and a host of their activities in rural communities. Indigenous knowledge is the information base for a society, which facilitates communication and decision-making. Indigenous information systems are dynamic, and are continually influenced by internal creativity and experimentation as well as by contact with external systems.

The term indigenous technical knowledge is often camouflaged with the belief that is associated with forthcoming happenings and the innovations made by the farmers to solve specific problems. Some of the related terms are:

- **Indigenous Knowledge (IK):** is the participants' knowledge of their temporal and social space. Indigenous knowledge as such refers not only to knowledge of indigenous peoples, but to that of any other defined community.
- **Indigenous Knowledge System (IKS):** delineates a cognitive structure in which theories and perceptions of nature and culture are conceptualized. Thus it includes definitions, classifications and concepts of the physical, natural, social, economic and ideational environments. The dynamics of IKS takes place on two different levels, the cognitive and the empirical. On the empirical level, IKS are visible in institutions, artifacts and technologies.
- **Indigenous Technical Knowledge (ITK):** is specifically concerned with actual application of the thinking of the local people in various operations of agriculture and allied areas.
- **Belief:** change in behaviour of insects, animals and vegetation indicating a forthcoming event without any scientific rationale but could be true in happening.
- **Innovation**: outside the arena of ITK, but scientifically based development of practices using the locally available resources to solve specific problems.

The emergence of the concept of sustainable agriculture in late eighties in Indian agricultural scenario has evoked interest on ITK that has the element of use of natural products to solve the problems pertaining to agriculture and allied activities. Indian farmers, over centuries, have learnt to grow food and to survive in difficult environments, where the rich tradition of ITK has been interwoven with the agricultural practices followed by them.

India, a country spreading over 3287.26 thousand sq. km. and inhabited by about 1000 million people has been nurturing a tradition of very rich civilization over a period of five thousand years. India's ancient scriptures consisting of 4 Vedas, 108 Upanishads, 2 epics, Bhagwad Gita, Brahmasutras, 18 Puranas, Manu Smiriti, Kautilya Shastra and Smritis as well as the innumerable sayings, proverbs and teachings of sages contain profound literature of ideas, concepts and practices which are designed to address the process of building harmonious relationship among man, animal and nature. The enhancement of the quality of life of the

Indians who in great majority live in and depend on agricultural production systems would be impossible by keeping this rich tradition of ITK aside. The special features of indigenous knowledge are:

1 **Local** in that it is rooted in a particular community and situated within broader cultural traditions; it is a set of experiences generated by people living in those communities. Separating the technical from the non-technical, the rational from the non-rational could be problematic. Therefore, when transferred to other places, there is a potential risk of dislocating indigenous knowledge.

2 **Tacit** knowledge and, therefore, not easily modifiable

3 **Transmitted** orally, or through imitation and demonstration. Codifying it may lead to the loss of some of its properties.

4 **Experiential rather than theoretical knowledge.** Experience and trial and error, tested in the rigorous laboratory of survival of local communities constantly reinforce indigenous knowledge.

5 **Learned through repetition,** which is a defining characteristic of tradition even when new knowledge is added. Repetition aids is the retention and reinforcement of indigenous knowledge.

6 **Constantly changing,** being produced as well as reproduced, discovered as well as lost; though it is often perceived by external observers as being somewhat static.

Social Capital

Social capital is defined as the sum of the actual and potential resources embedded within, available in, and derived from the network of relationships possessed by an individual or social unit. It is indispensable for connection and co-operation and for successful collective action.

Social Capital: Dimensions

Social capital consists of 3 mutually reinforced dimensions: Structural, Relational and Cognitive social capital:

1. Structural – Social Networks.
2. Relational – Content of Social relationships developed through social interactions – trust, confidence.
3. Cognitive – Resources that provide shared representations, interpretations and systems of meaning among people.

Social Capital Development: Approaches

1. Constructing shared language, vision through which people are able to share knowledge freely.
2. Cultivating trustworthiness to motivate that there is no hoarding of knowledge.
3. Providing opportunities for detecting, communicating and exchange of knowledge through the creation of need and/or reconfiguration of existing network ties both inside and outside the community.

ITK and Social Capital in Indian Agriculture

The ITK system has been developed by the people based on their experiences and continuous improvement through informal experimentation over centuries. These ITKs are interwoven and assimilated in the cultural life of the people. India has one of the largest collections of ancient manuscripts in the world, which includes 14 sastras, 4 vedas, 4 upvedas and 6 branches of vedangas. The advent of the concept of sustainability in Indian agricultural scenario has invoked interest on ITK that has the element of use of natural products to solve problems pertaining to agriculture and allied activities. ITKs are based on experience, often tested over a long period of use, adapted to local culture and environment, dynamic and changing, and lay emphasis on minimizing the risks rather than maximizing the profits. ITK covers a wide range of subjects such as crop production, livestock rearing, natural resource management, food preparation, health care and many other related topics. Various aspects of agriculture and allied activities have been included such as soil, water and nutrient management; crop cultivation; plant protection; farm equipment, farm power, post-harvest preservation and management; pasture and fodder management; agro-forestry; bio-diversity conservation and exploitation; animal rearing and health care; animal products preservation and management; fisheries and fish preservation; and ethnic foods and homestead management encompass ITKs.

Diversity of Indigenous Knowledge

Indigenous knowledge systems are:

- Adaptive skills of local people usually derived from many years of experience that have often been communicated through oral traditions and learned through family members over generations.
- Time-tested agricultural and natural resource management practices, which pave the way for

sustainable agriculture.

- Strategies and techniques developed by local people to cope with the changes in the socio-cultural and environmental conditions.
- Practices that are accumulated by farmers due to constant experimentation and innovation.
- Trial-and-error problem-solving approaches by groups of people with an objective to meet the challenges they face in their local environments.
- Decision-making skills of local people that draw upon the resources they have at hand.

Characteristics of ITK

- ITK is not static but dynamic
- Exogenous knowledge and endogenous creativity brings change to ITK
- ITK is intuitive in its mode of thinking
- ITK is mainly qualitative in nature
- ITK study needs a holistic approach
- ITK, if properly tapped, can provide valuable insights into resources, processes, possibilities and problems in particular area
- ITK is recorded and transferred through oral tradition
- ITK is learned through observation and hands-on experience
- ITK forms an information base for variety
- ITK reflects local tradition

Classes of ITK in agriculture

- Climatology
- Local soil and taxonomy
- Soil fertility
- Primitive cultivar
- Inter cropping
- Agronomic practices
- Irrigation and water management
- Plant protection
- Post -harvest technology and methods.

Roles of ITK

- ITK can aid development efforts
- ITK can facilitate local people's participation
- ITK is a valuable source of developing appropriate technologies

Scope of ITK analysis

- New biological and ecological insight
- Resource management

- Protected areas and conservation education
- Development planning
- Environment assessment

Process and methods of ITK analysis

A. Identification and collection of ITK: methods and techniques

1. Documentation of oral histories
2. The Delphi method
3. Agro-ecosystem analysis
   a) Mapping (ecological, agronomic, seasonal, spatial)
   b) Transect
4. Manual discriminative analysis (ask farmers to discriminate practices and find rationality)
5. Decision tree analysis
6. Use of local resource persons
7. Linguistic and historic analysis of concepts, vocabulary and key words
8. Ethnobotany
9. Critical incident analysis (farmers' seed exchanges and new variety introduction)
10. Analysis of peasants' journals and newspapers
11. Arranging competition
12. Conducting documentation workshops
13. Continuous interactions during on-farm experiments
14. Anthropological methods (investigation into the social, culture and other aspects of rural tradition)
15. Local taxonomy
16. Hear-say method
17. Crop histories
18. Survey method
19. In-depth interview of farmers.

B. Documentation

Types of documentation

1. Documenting large variety of practices without scientific validation
2. Documenting prevalent practices and comparing them with traditional ones
3. Documenting the practices/details of experimentation on a specific aspect and understanding the various linkages
4. Documenting the practices evolved to mitigate specific problems of farming or for sheer survival under conditions of ecological and economic stress
5. Documenting practices that had evolved in response to specific external interventions

Methods and Techniques

- Notes
- Photos

- Audio-recordings
- Video-recordings

B. Testing and Validation: method and techniques

1. Prepare a list of all the collected ITK practices
2. Decide the continuum for rating the rationality of ITK with specific weightages

Continuum	Weightage
Very rational	5
Rational	4
Undecided	3
Irrational	2
Very irrational	1

3. Send the list of ITK practices to experts for their opinion and judgment on each practice.
4. Calculate the weighed mean score of individual practices.
5. Select practices above mean score as rational.

Developing extension programs to validate farmer experiments

Farmers are not passive consumers, but active problem solvers who develop for themselves most of the technology they use. For many hundreds of years before today's national agricultural research systems were set up, farmers did their own research. And, by integrating technology from different sources and continuing to adapt it on their farms, they still do so today. Indigenous knowledge systems form the basis for informal experimentation of farmers. The factors which influence farmer experimentation are:

- **Ecological**: innovations that result due to interaction among crops, soil, and climate
- **Historical**: a major happening such as crop failure or year of glut or scarcity
- **Serendipity**: a practice discovered by farmers accidentally
- **Economic**: Farmers innovate new practices taking advantage of government subsidies for flood and drought relief activities.

Validating farmer experiments is an extension process in which farmers are encouraged to replicate their own experiments in their own environment in order to:

- Understand experiments in the socio-cultural and agro-ecological environments
- Determine the impact of the experiments on productivity, profitability, and sustainability of the agricultural system

The various steps involved in the process of developing the extension programs are:

- Selecting "research minded" village extension workers
- Identifying "research minded" farmers who are already involved in farmer experiments; and
- Establishing programs for validating farmer experiments

The various steps involved during the process of validating farmer experiments are:

- Understand the rationale behind farmer experimentation.
- Recording the mode of conducting experiments.
- Identifying farmers' evaluation criteria.

Understanding, identifying, recording, and evaluating farmer experiments form the various stages of validating farmer experiments. It is important that extension personnel must understand the farmers' criteria when they explore indigenous approaches to experimentation.

Blending of Indigenous and Scientific Knowledge: Issues and Strategies

Agricultural research for the most part has been highly discipline-oriented in our country. Normal science generates packages, whereas resource-poor families engage in farming as a continuous performance. Research station technologies have focused primarily on attaining high yield of target crops. The introduction of modern technologies through the application of chemical fertilizers, agrochemicals, machinery, and modern methods of irrigation in developing countries was a departure from traditional agriculture and has led to pollution and land degradation. In addition, lack of relevance to small farm conditions was found to be one of several constraints in the station research technologies. Therefore, during the process of technology development, farmers' informal experimentation is usually not considered as a source of innovation. In spite of increased coordination between research and extension through periodical extension-scientific workers' conferences, it is found that farmers' innovations are not considered while conducting on-farm research trials. On-farm trials conducted by researchers and extension worker mostly concentrate on crop varietal comparison, fertilizer response, and testing of different packages of practices for different crops. In contrast, farmers experiment on alternative coping strategies to avoid extreme conditions such as droughts and floods, diversified food production techniques such as intercropping and border cropping in order to broaden their food and fodder requirements, and adjusting their sowing and harvesting periods to meet the local market demand are commonly ignored.

In many cases, agricultural researchers and extension functionaries are not aware of local classification systems of farmers regarding soils, crops, livestock, and other natural resources. A case study conducted by the International Crops Research Institute for Semi-Arid Tropics (ICRISAT) in Shirapur, a South Indian village, showed that the indigenous soil categories of farmers were more accurate than the formal system in stratifying the soils into groups for analysis and provided improved bases for indexing variations in land quality. In addition, indigenous soil types are considered better for long term sustainability of the soil structure and soil fertility. Because soil analysts in Soil Testing Laboratories (STLs) are not familiar with the indigenous classification, their fertilizer recommendations may not fit in with the local soil categories. Another case study conducted in Chengalpattu District, Tamil Nadu State showed the indigenous classification of rice varieties is based on criteria such as water source, cropping season, crop duration, and grain quality. The village extension workers disseminate information on the seed varieties recommended by the researchers to the farmers. These extension decisions are reflected in the types of seeds made available through the seed multiplication units. Although several varieties suitable to semi-arid zones of Tamil Nadu are adapted to severe drought conditions, most of the varieties being encouraged through the agricultural extension system are suitable only in resource-rich environments such as those with an assured supply of irrigation. The indigenous, locally adapted varieties of rice are no longer as easily available.
Farmers are mainly seen as the recipients of technical messages but not the originators of either technical knowledge or improved practice. The technical messages concentrate mostly on seed-to-seed packages of practices for different crops grown in the region. Resource conservation strategies such as watershed management, agro-forestry, and soil conservation rarely form part of the technical messages. The reasons can be enumerated as:

1. Lack of understanding of traditional agriculture which further leads to a communication gap between promoters and practitioners giving rise to myths;
2. The accomplishments of farmers often are not recognized, because they are not recorded in writing or made known; and

3. Poor involvement of farmers and their organizations in integrating, consolidating, and disseminating what is already known.

Strategies

Keeping these potential constraints in conventional transfer of technology, a conceptual framework for incorporating indigenous knowledge systems into agricultural research and extension has been developed with the following salient features:

1. Strengthening the capacities of regional research and extension organizations;
2. Building upon local people's knowledge that are acquired through various processes such as farmer-to-farmer communication, and farmer experimentation;
3. Identifying the need for extension scientist/social scientist in an interdisciplinary regional research team;
4. Formation of a sustainable technology development consortium to bring farmers, researchers, NGOs, and extension workers together well ahead of the process of technology development;
5. Generating technological options rather than fixed technical packages;
6. Working with the existing organization and management of research and public sector extension;
7. Bringing research-extension-farmer together at all stages is practically difficult considering the existing bureaucracies and spatial as well as academic distances among the personnel belonging to these organizations. Hence, utilize the academic knowledge gained by some extension personnel (subject matter specialists) during the process of validating farmer experiments;
8. Outlining areas that research and extension organizations need to concentrate on during the process of working with farmers.
9. Understanding that it is impractical to depend entirely on research stations for innovations considering the inadequate human resource capacity of the regional research system.

Conclusion

Indian agriculture is at present confronted with a number of challenges including instability of productivity and diminishing sustainability of natural resources. These issues have evoked growing interest in the study of indigenous knowledge systems that are based upon the local resources. Since, information on ITK is seldom documented, it often happens that such information are lost, if not passed on from generation to generation or protected and practiced by the local people. Hence, in today's concept of IPR regime, it is all the more imperative to document and protect our valuable ITK for posterity. In the context of agricultural sustainability, ITK is also required to be properly documented for the benefit of researchers, planners and development officials. Validation of ITK is a logical step to qualify and quantity effectiveness of the practices. Suitable modifications of the local practices, through research and development will help to develop appropriate and acceptable technologies that are more suited to our farming situations. Considering this, a Mission Mode project on Collection, Documentation and Validation of Indigenous Technical Knowledge was launched in 2000 by Indian Council of Agricultural Research (ICAR) under the National Agricultural Technology Project (NATP) with the following objectives:

- Identify, collect, classify and document ITK and its variants in different agro-climatic regions in respect of production systems, farming systems and situations;
- Catalogue and characterize the information for developing a data base;
- Ascertain the propensity of the extent and level of use of various ITKs by the farmers in the management of various farming systems;
- Validation of ITK though a quick screening method and through formal experimentation, wherever needed; and
- Evolve a mechanism to protect property rights and facilitate the process of sharing the benefit by the farming community.

For the purpose of documentation, information on ITK was collected from various literatures which are available in different forms, and through voluntary disclosure by the users of ITK or through facilitators. The information on ITKs, geographical indications of the plant materials used in the ITKs through quick screening and experimentation has been documented in different volumes. It is understood that the publication have not been able to cover all the published information. Therefore, such efforts need to be made on continuous basis. These are the time tested knowledge and experiences of the peoples' accumulated experience in dealing with situations and problems in varying aspects of life and such knowledge and practices are special to particular culture. Indigenous knowledge are not primitive, left over from the past but on the contrary, are systems of finally tuned and adopted, both biologically and socially, to counter the process of what are often harsh and inimical environment and often represent hundreds, sometimes thousands of years of adaptive evolution in which vagaries of climate, the availability of land, water, the basic need of people and their animals for food, shelter and health have been amalgamated in a system which has allowed society to exist and develop in face-to-face tremendous odds. Various ITKs in agriculture, animal husbandry, fisheries and other and based activities have been in use since the human civilization by the farmers, animal owners and other practitioners. In spite of advancement in scientific knowledge in agriculture, ITK-based practices still remain in use by the vast majority of the farming community particularly in resource poor farming situations, without the knowledge of its scientific rationality. In this context, blending of indigenous knowledge with modem scientific technologies and developing the social capital are inevitable to ensure sustainable development of agriculture and allied sectors.

Peoples Biodiversity Register: A Tool for The Conservation And Management of Biodiversity

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1. Introduction

Conservation and sustainable management of biodiversity have emerged as important human concerns in recent decades. This has triggered a number of international as well as national initiatives. The Convention on Biological Diversity (CBD), in force since 1993, is the most significant of the pertinent international agreements. About 171 countries including ours ratified the provisions of the Convention and subsequently went on with measures to implement them. As a follow-up to this convention, India has enacted the Biological Diversity Act, 2002, which received the assent of the President on the 5th February, 2003. The rules promulgated under this Act, in force as of 15th April, 2004.

India is a country rich in diversity of life and traditional knowledge and wisdom. Such knowledge and wisdom is manifested both in classical systems such as Ayurved and Yunani, as also in folk traditions of health care and folk practices. India is one of the 12 mega diverse countries of the world that sustains largely a bio-mass based civilization as well as 7.8% of the global recorded species. But our country's ecological resource base is under threat, with extensive destruction of natural habitats, widespread degradation of agro-ecosystems and a growing burden of air and water pollution. Simultaneously, India's knowledge base of uses of biodiversity is also being eroded. The recent enactment of the Biological Diversity Act (BD Act) is an important step towards halting this attrition. This Act is especially notable for having created substantial space for involving people at the grass-roots in conserving, sustainably using and sharing in the benefits from biodiversity resources and associated knowledge.

2. Biological Diversity Act, 2002

The Biological Diversity Act, 2002 is a part of the Indian initiative to make some progress and to put into practice these two important provisions of the CBD. With this in view it provides for the establishment of a National Biodiversity Authority (NBA), State Biodiversity Boards (SBB) and Biodiversity Management Committees (BMC) at the level of Panchayats, Municipalities and City Corporations. As passed, however, it only has the status of a complementary act and will have to be operated side by side with a whole range of other acts, including, in particular, those pertaining to forest, wildlife, Panchayati raj institutions, plant varieties and farmers' rights, and patents.

The newly passed Biological Diversity Act 2002 is a response to the many significant concerns emanating from new developments in biotechnology and information technology, and from the ongoing erosion of biodiversity. These developments imply that all organisms, even microbes and worms, from the land and in the waters are potentially resources of considerable economic value, worthy of efforts at conservation, scientific investigation and of securing rights over the associated intellectual property. This has prompted the development of two rather conflicting international agreements, the Trade Related Intellectual Property Rights provisions (TRIPS) of GATT and the Convention on Biological Diversity (CBD). CBD has two notable provisions. One is the sovereign rights of countries of origin over their biodiversity resources. The other is the acceptance of the need to share benefits flowing from commercial utilization of biodiversity resources and associated knowledge with holders of traditional knowledge. In the light on these it is realized that the formidable task of conservation, sustainable use and equitable sharing of benefits of biodiversity can be addressed only as a People's movement. Therefore, the fundamental dynamics of the preparation of Biodiversity Register is the participation of people in the process.

3. Genesis of People's Biodiversity Register

The concept of 'PBR' was evolved gradually from several associated experiments conducted in different parts of our country. The Community Biodiversity Registers experiment initiated by the Foundation for the Revitalization of Local Health Traditions, Bangalore, in 1993 paved the way for recording local heritage by means of Participatory Rural Appraisal exercise. The idea of documenting people's knowledge in the form of PBR has been evolved in the experiments initiated by the Indian Institute of Science, Bangalore, since 1995. The participatory project on People's Biodiversity Register implemented by Ernakulam District Panchayat in Kerala under the People's Plan Campaign during 1997-1999 was the first of its kind in the country. The methodology involved was documenting knowledge and perceptions of local people about Biodiversity and conservation at the Grama Panchayat Level in the form of a People's Biodiversity Register. Later in 2003, the Centre for Ecological Sciences at the Indian Institute of Science, Bangalore was asked by the MOEF, Government of India to bring out a 'Process and Methodology Manual' for PBR in order to manage country wide Programme and also consolidation of the Biodiversity information.

4. People's Biodiversity Register

The preparation of People's Biodiversity Registers (PBR) is thus an important element of the follow up of the Biological Diversity Act (BD Act). PBR exercises have to be fine tuned to the local conditions. In fact, to do this effectively, it may be appropriate to go down below the level of a Panchayat/Municipality and as in the case of Village Forest Committees, sub-committees of BMCs at the level of individual villages/hamlets/town wards and to prepare PBRs at this level. Local community members may not wish to share all of the information recorded in the PBRs with the outside world. At the same time, they would be happy to share this information with others, either unconditionally, or as terms of benefit sharing in case of commercial use.

In accordance with the recent advances in Information and Communication Technology, there are tremendous opportunities to organize such shared information from PBR exercises, along with other pertinent scientific, technological, law or market-related information into a networked biodiversity Information System (BIS). Such a BIS would serve as the knowledge base for the implementation of the BD Act at all scales from the national (NBA) through the states (SBBs) to districts, towns and villages (BMCs). The Biodiversity Information System will have to compile information on a wide range of issues which are summarized as follows

Crop Fields and Orchards

1. Identity of pests and diseases of crop fields and orchards and on effective and environment friendly control measures.

2. Promote biological control measures including local production of biological control agents.
3. Information on nutrient/ micronutrient status of soils.
4. Maintain and locally add value to indigenous crops and varieties.
5. Promote on-field conservation measures of crop varieties and claim.
6. Promote positive role of non-cultivated plants and animals associated with agro-ecosystem.
7. Press for protection of crops against pollution.
8. Develop a database on pests and diseases to fulfill requirements of international conventions.

Forest/Tree Plantations

1. Alternative set of species of fodder, mulch, nectar source, bio-cosmetic, vegetable dyes or other values.
2. Link appropriately with JFM programmes.
3. Maintain, restore and add value to trees associated with Agriculture.
4. Plan Agro-forestry activities.
5. Promote provision of goods and services from forest lands to rural economy.
6. Promote planting of trees yielding fodder, leaf manure, bamboos, other minor forest produce.
7. Work out methods and schedules of sustainable harvests of minor forest produce.
8. Promote value addition to non Timber Forest products.
9. Wild life conflict to devise ways of minimizing them and obtain due compensation.
10. Promote traditional conservation practices like protection to sacred groves, trees and animals

Grazing

1. Promote maintenance of grasslands.
2. Devise methods and schedules of sustainable use of grazing resources.
3. Record and appropriately regulate grazing pressure by outsiders and nomadic herders.
4. Promote maintenance of natural biological communities on hill slopes.

Wetlands

1. Promote maintenance of natural biological communities in wetlands.
2. Promote traditional conservation practices like protection to sacred ponds, fish and heronries.
3. Document and regulate destructive fishing practices such as use of dynamite and pesticides.

Sea

1. Promote sustainable fishing practices.
2. Document and regulate over-fishing, especially by foreign vessels.
3. Record and check destructive harvests by community members as well as outsiders.
4. Promote maintenance of coastal areas supporting natural communities for their recreational value.

Habitation

1. Promote planting of a variety of indigenous tree and other plant species along roads and highways.
2. Promote traditional conservation practices like protection to sacred trees and animals.
3. Promote biodiverse natural communities in parks and open spaces around habitations.
4. Organize effective monitoring of pollution using more accessible bio-indicators such as lichens and chironomids.

Public health

1. Monitor populations of vectors of human diseases and devise newer methods of control as the older chemical methods are proving ineffective
2. Monitor microbial pollution of water sources and devise ways of provision of safer drinking water.

Human resources

1. Promote recording of traditional knowledge as well as grass-roots innovations associated with biodiversity such as medicinal uses, vegetable dyes, cosmetics, and pest control agents.
2. Promote recording of folk arts and crafts associated with biodiversity.
3. Involvement of students and teachers in first hand collection of information in the PBR exercises would enhance the quality of their education.
4. Use of modern Information and Communication Technologies in the PBR exercises.

4.1 Who all have to be involved?

Local people must work side by side with experts in the preparation of PBR. In any event, the specialists will need to collaborate with selected people from many different segments of the society, from every village and town, from every fishing community, from every tribal hamlet, from every camp of herders. The network will have to include government officials, researchers, workers of voluntary agencies, local community leaders, as well as teachers and students from schools and colleges. The local educational institutions, especially teachers and students in 8^{th}, 9^{th}, and 11^{th} standards, and in undergraduate colleges might play a key role in generating the more structured information under the supervision of *Biodiversity Study Groups* that might be set up by the *Biodiversity Management Committees* of the Panchayats and Municipalities and City Corporations.

4.2 The process

The very first step in the PBR process would be to communicate to people the provisions of and new opportunities under the Biological Diversity Act. These would include community regulation of access to local biodiversity resources with a prospect of sustainable harvests, and opportunities to generate funds. It would also open avenues to conserve resources and record biodiversity related knowledge, and open up possibilities of value addition. It may be reported that PBR is a document that should facilitate knowledge-based management of agriculture, livestock, fish, forests and public health so as to enhance the quality of life of the community members.

The next step in the process involves documentation of local geographic, social and economic setting. This must start with the demarcation of the boundary of the area under consideration. Since the PBR exercises are meant to support the activities of Biodiversity Management Committees in local bodies, the area under the jurisdiction of a Grama Panchayat or Municipality/Corporation would be an appropriate unit for this purpose. However, such a unit may be a little too large for the purpose, and a sub-unit such as an individual village or hamlet or a ward may be appropriate. The details of the information to be collected on the geographic, social and economic setting would depend on the identified focal issues. The information may include:

1. Prevalent land classification system. This may include different classes of (i) forest land such as reserve forest, minor forest, lands under JFM management, (ii) revenue lands (iii) private lands on which cultivation, house building, industrial sheds, shops etc may be permitted.
2. Water-bodies (iv) Rivers, streams, lakes, sea coast and any regulations regarding their ownership and use (v) Number of open and bore wells. Depth of water.
3. Customary management practices such as protection to sacred groves, regulation of grazing on pastures.
4. Human populations.
5. Livestock.
6. Irrigated and unirrigated cultivated lands, major crops.
7. Significant forest produces. Quantities recorded at the Range and Divisional Forest Offices. Forest Labour Co-operative Societies and their transactions.
8. Significant freshwater fish productions. Auctions of ponds.
9. Significant estuarine and marine fish productions. Number and type of fishing craft. Fish landings at nearby fishing ports.
10. Mining and quarrying activities.
11. Sources and extent of air, water and soil pollution.
12. Prevalence of water borne diseases such as gastroenteritis or of vector-borne diseases such as malaria from Primary Health Centers.
13. Educational institutions.
14. Co-operative Societies.
15. Self-help groups.
16. Youth and Ladies Clubs.
17. Active NGOs.

4.2.1 Participatory mapping

People do have a mental picture of the landscape of their surroundings, including the relative extent and interrelations of the various elements in the landscape. People also have locally prevalent individual landscape elements as well as generic terms. The use of such local names of landscape elements can greatly facilitate communication. Therefore, it is best to begin by preparing an inventory of the LSE/WSE types and sub-types present and a sketch map as a participatory exercise.

Preparation of the sketch map may be followed by identification of specific elements of interest in terms of the selected focal issues. Information may then be collected, through field work as well as interviews, on the landscape/waterscape and landscape/waterscape element types as a whole, as well as those elements of special interest. This documentation of the landscape/waterscape may be followed by that of the lifescape or incidence of the species/varieties of cultivated plants/land races of domesticated animals of interest. In parallel with the efforts to ascertain scientific names, field work and interviews will have to be initiated to collect local level information on the focal species/varieties. In parallel with collection of information on status and trends in focal species and habitats, information on the current patterns of their management and peoples' preferences on how these may be managed will also be generated. This would serve as the basis for the preparation of a Management Plan to support the activities of the Biodiversity Management Committee (BMC).

4.2.2 Title of the forms used for field as well as group discussions

1.1 Details of locality and study team.

1.2 Activities of local people, especially those linking them to the natural resources. (Group discussions)

1.3 Activities of outsiders, with special emphasis on those linking them to the natural resources. (Group discussions)

1.4 Composition of Local User Groups

1.5 Description of External user groups

1.6 Drivers and impact of (Local/External) user groups (Group discussions)

1.7 Recording the movement of Nomadic populations

1.8 List of Knowledgeable individuals: local

1.9 List of Knowledgeable Individuals: external (Group discussions)

1.10 LSE/WSE types and subtypes (group discussions)

1.11 Locally known life-forms

1.12 Functional species- groups

1.13 Background information -I

1.14 Background information – 2

1.15. Background information – 3mj

1.16 Background information – 4

1.17 Historical and cultural information (Group discussions, study of documents, field observations)

1.18 Key concerns (Group discussions)

1.19 Landscape status and dynamics (Group discussions)

1.20 Landscape management (Group discussions)

1.21 Waterscape status and dynamics (Group discussions)

1.22 Waterscape management (Group discussions)

1.23 Focal landscape elements field survey (Field observations)

1.24 Focal landscape elements vegetation cover (Field observations)

1.25 Focal waterscape elements field survey (Field observations)

1.26 Focal waterscape elements sampling studies (Field observations)

1.27 Focal landscape elements history (Group discussions)

1.28 Focal landscape elements management

1.29 Focal waterscape elements history (Group discussions)

1.30 Focal waterscape elements management (Group discussions)

1.31 Focal taxa abundance field survey

1.32 Focal taxa abundance field survey

1.33 Domesticated biodiversity

1.34 Focal taxa status & trends in abundance (Group discussions)

1.35 Focal taxa status & trends in management (Group discussions)

1.36 Focal taxa management user group perspectives (Group discussions)

1.37 Focal taxa status & trends in value/ uses (Group discussions)

1.38 Folk knowledge of population ecology, life history and behavior (Group discussions)

1.39 Management plan components

5. Limitations of PBR

A number of constraints in PBR exercise are identified which are to be considered for the purpose of improvisation under different situations.

1. The PBR exercise may have to be limited to the range of earthscape elements of human concern only.
2. The PBR exercise may not be enough to express the BD information regarding many organisms the microflora, soil mites or even assigning varietal status.
3. Extra care has to be taken for building capacity of the PBR actors and also for cross checking as well as validation of the information generated by them.
4. PBR exercise has to be linked to the provisions of PPV and FR Act, and also with Patent Act. Recording special knowledge of possible commercial value would be dangerous as it may fall into the wrong hands.

6. Conclusion

The PBR exercise will have to be an enterprise bringing together knowledge of the local people with scientific knowledge. In part, the technical inputs may be derived opportunistically from a variety of local sources such as Krishi Vigyan Kendras, Universities and colleges, research institutes and NGOs. However, simultaneously, efforts would have to be organized at the State and National levels to develop resource material, training modules, a network of experts and technical institutions to support PBR activities everywhere, and a database designed to organize the locally collected PBR information and integrate it with a broader networked Biodiversity Information System.

Peoples Biodiversity Register is to put in place a pattern of development compatible with the objectives of conservation and sustainable use of biodiversity and equitable sharing of benefits with the co-operation of all stakeholders. However, it is not possible to arrive at an adequate set of prescriptions for implementing these objectives as a one-time effort. To reiterate, the PBR process cannot be a one-time activity; we have to continually strive towards conserving biodiversity, using it sustainably and attempt to put in place a fair pattern of benefit sharing. This has to be an on-going process of learning while doing.

References

Arunachalam, A and Arunachalam, K (2008) Biodiversity utilization and conservation. Aavishkar publishers, Jaipur (Raj.) India p284

Ashwini Chhatre, (1998), SRISHTIGYAAN, A methodology Manual for People's Biodiversity Registers, Srishti Jigyasa Parivar, CES, IISc, Bangalore, p 140

Madhav Gadgil, (2003) People's Biodiversity Register Methodology Manual, Volume I, Centre for Ecological Sciences, Indian Institute of Science, Bangalore, p 147.

Madhav Gadgil, (2003) People's Biodiversity Register Methodology Manual, Volume II, Centre for Ecological Sciences, Indian Institute of Science, Bangalore, p 122

Secretariat on the convention on Biodiversity (2006) Handbook of the convention on Biological Earthscan publication limited p. 690.

People's Movement for Environment Conservation- the Case of Silent Valley National Park

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Silent Valley Movement is the tale of a battle against the State to protect a pristine evergreen rainforest of Kerala. Silent Valley is situated in *Palghat* district and contains India's last substantial stretch of tropical evergreen forest. It is the only vestige of near virgin forest in the whole of Western Ghats. It is estimated to have a continuous record of not less than 50 million years of evolution. The name Silent Valley gained an epic dimension, when the Save Silent Valley Movement stirred by the missionary zeal and fervour of NGO's, the scientific community and conservation activists with social awareness resulted in the decision to abandon a hydroelectric project which would have otherwise submerged 830 hectares of rich tropical rainforests in Silent valley. It was the decision of the British government to build a dam across *Kunti* River, which originates from the Silent Valley forest. Somehow, the project was not implemented at that time. In 1951, the first survey for hydroelectric project was done by the state government and in 1973; Planning Commission of India approved the project plan. That was the beginning of a historical debate on whether to opt for the conservation of nature or to promote development.

The uniqueness of Silent Valley is that it harbours at least 108 varieties Orchids. The forest is a repository of medicinal plants with 80% of the drug listed in standard Pharmacopoeias and 66% of the species and aromatic plants used world over. It is a valuable source of some genetic variants. At least 21 flowering plants discovered in the valley are new to Science. The presence of 23 mammalian species, including three endangered species like Tiger, Lion-tailed Macaque, and Nilgiri Langur has been recorded. The teachers and scientists who realized the importance of Silent valley came forward to protest against the project. Later in 1976 National Committee on Planning and Coordination (NCEPC) recommended a stay on the project in order to study its environmental impact. Kerala Natural History Society and

Bombay Natural History Society demanded the cessation of the project in 1978. Kerala Sastra Sahitya Parishad (KSSP), a renowned People's Science Movement (PSM) from Kerala published their report on the ecological, economic, and social impacts of the hydro-electric project. Several Committees had been appointed by the Central and State Governments, among which Dr. M. S. Swaminathan Committee and Dr. MGK Menon Committee strongly opposed the project citing the environmental impact. In between, several campaigns were led by KSSP, teacher-student organizations and so on. It might be the first time in the Indian history, that eminent creative writers joined together to fight for such a cause. Through poems and drama, stories and articles, speeches and *kavi sammelan* (Poet's meet) they conveyed the message to the Kerala's literate public. The supporters of the project argued that the people who oppose the power project were against the nation's interests and prefer monkeys rather than the human beings. The KSEB pointed the low unit cost of power offered by the high watershed of Silent Valley which covered four districts of Malabar. The debate went on for a long time and at last in 1983, the then Prime Minister Mrs. Indira Gandhi advised the state to abandon the project and she announced Silent Valley as a National Park. In 1985 Prime Minister Rajiv Gandhi gifted the national park to the nation.

Relevance of the movement

Silent Valley movement was the continuation of the development debate which had already started in India with the Chipko movement. The success of the movement opened a new paradigm of development which ensures environmental sustainability and rights of the non-human world. Especially in Kerala, the movement created public awareness that the development which harms the environment is short-term, and hence it will adversely affect the social and economic life of the future generations. The development vs. monkey debate and the victory of the cause of endangered species proved the fact that the non-human world has the same right to live on earth. The inclination of the movement towards the left rewrote the Marxist notion of nature as a resource base to nature as a treasure which has to be protected. The ideological split within the Marxist party regarding the Silent valley issue was the reflection of the alteration in the idea of development. It was a hefty task imposed on KSSP to educate the local people, who were fascinated by the industrial benefits of the power project and its employment opportunities, about the significance of the rainforest which would be submerged. The incessant struggle fought by KSSP and various groups taught them the first lesson of environmentalism that without protecting the nature we cannot protect ourselves. The environmental history of the nation, as well as the state shows that the success of Silent Valley movement influenced the people to protest against the environmental injustices in their vicinity. The movement also contributed to the activities of ecological Marxists in India which follows the Gandhian non-violent strategy.

The Silent Valley movement became a meeting place for different ideas regarding the development and the management of natural resources. KSSP itself published and distributed several pamphlets and study reports on the issue. One of the important pamphlets, *The Silent valley Project: Parishad's Stand and Explanation* argue that "the Silent Valley issue raised some serious concerns like people's attitude towards development, the conflict between various interest groups, the development of Palghat- Malappuram districts, providing adequate amount of energy to the Malabar zone, the electricity generating policies of Kerala government etc." KSSP faced many challenges from the Marxist party itself; one of its foremost leaders E. Balanandan wrote in favour of the project ignoring the idea of Silent Valley as an ecological paradise. The people who preferred the project conversed that the project wouldn't do any harm to the rain forest; the project area covers only 830 hectares of land among the total area of 8952 hectare. Against this argument KSSP argued that "this attitude is like saying the size of human heart is insignificant comparing the size of the whole body, and therefore the ruin of the heart will not affect the body." All these debates on the Silent Valley project kept the movement active throughout the period and forced people to think in favour of the environment.

Environmental Impact Assessment

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Introduction

An important principle of sustainable development is the integration of economic, social and environmental concerns. Sustainable development recognizes that the economy and environment are closely interrelated. This principle is at the heart of international agreements and various national policies and strategies. Therefore, there is a need to consider environmental factors along with social and economic factors while planning development projects for maintaining ecological health and environmental quality. Environmental Impact Assessment (EIA) is a tool to accomplish this. EIA is a concept that evolved in the search for ways to maintain compatibility between development and environment in a complex and interdependent world of today. It enables the characterization of environmental consequences of a project in advance and account for it in the project design so as to ensure that the development option under consideration is sustainable.

What is environmental impact?

Any alteration of environmental conditions or creation of a new set of environmental conditions, adverse or beneficial, caused or induced by an action or set of actions is defined as environmental impact. Generally, impacts can be categorized as either primary or secondary. Primary impacts are those that can be attributed directly to the proposed action. Secondary impacts are indirect or induced changes, likely to be stimulated or induced by the proposed action. Another way to describe the difference between primary and secondary impacts is that "inputs" generally cause primary impacts and project "outputs" generally cause secondary impacts. Primary impacts are generally easier to analyse and measure, while secondary impacts are relatively more complex to delineate and measure. The secondary impacts are often more significant than primary impacts.

What is EIA?

EIA is a process that attempts to identify and predict the impacts of proposals, policies, programs, projects or operational procedures on the biophysical environment and on human health and well-being. It interprets and communicates the details of those impacts and investigates and proposes means of their management. EIA, therefore, involves evaluation of environmental implications and incorporation of necessary safeguards for those activities having a bearing on environmental quality.

Objectives

The objective of EIA is to

2. 1. Foresee and address potential environmental problems/concerns at an early stage of a project during its planning and design phase. Assist planners and authorities during the decision making process to identify and understand the key impacts/issues and formulate the mitigation measures.
3. Explore and achieve sustainable development options with minimal environmental degradation
4. Enable the communication of environmental implications and mitigation possibilities of a project to the project proponent, regulatory agencies, stakeholders and other interest groups.
5. Integrate the environmental concerns of development activities right at the time of examining its feasibility.
6. Prevent future liabilities or expensive alterations to a project design.

Major types of EIA

1. Strategic Environmental Assessment (SEA): It is a formalized, systematic and comprehensive process of evaluating the environmental effects of a policy, plan or programme and its alternatives. It is prepared with a policy focus and facilitate publicly accountable decision making.
2. Project EIA: It is done for a specific individual project or an action to assess the internal

and near-field impacts of different activities involved in a project on various environmental aspects. It has a defined time frame of a particular season or seasons round the year depending on the type of data to be gathered and criticality of vital environmental aspects. Accordingly, an EIA carried out based on one season (a season critical to the vital environmental aspects) data is termed as Rapid EIA and four season (year round) data is termed as Comprehensive EIA.

3. Cumulative Environmental Assessment (CEA): It aims to assess the combined impacts of different projects of the past, present or reasonably foreseeable future on the environment of a specific area regardless of the agency or proponent who undertakes the impacting actions. Cumulative impacts can result from individually minor, but collectively significant actions taking place over a period of time in a specific zone. CEA assesses near-field and far-field impacts.

EIA cycle and procedures

The EIA process in India is made up of the following phases:

- Screening
- Scoping
- Project appraisal
- Description of baseline environment
- Impact prediction
- Delineation of mitigation measures
- Analysis of alternatives
- Environmental monitoring plan
- Additional studies
    - Risk assessment
    - Social impact assessment
    - Rehabilitation and Resettlement Action plans
- Evaluation of project benefits

- Environmental cost-benefit analysisEnvironment Management Plan
- Public consultation
- Appraisal of environmental impact statement (EIS)
- Environmental clearance & Clearance conditions
- Monitoring the clearance conditions

Screening

Screening is carried out to find out whether the project proposed to be undertaken falls under a regulatory framework and if so, it requires a clearance from the environmental angle as per the statutory notifications. Screening criteria are generally based on the type and location of the development as well as magnitude and intensity of its influence on environment.

Scoping

Scoping is a process of detailing the terms of reference (ToR) of an EIA. It has to be done by an expert/consultant in consultation with the project proponent and with the guidance, if need be, from the regulatory authority entrusted with the responsibility of providing clearance to the project from the environmental angle (Impact Assessment Authority- IAA) or from the expert committee authorized to appraise the environmental aspects of the project (Environmental Appraisal Committee- EAC) to IAA. The following questionnaire is relevant while drafting the ToR:

- Whether the actions involved in the construction, operation or decommissioning phases of the project causes physical changes in the locality (topography, land use, water bodies etc) and their details?
- Whether any resources (such as land, water, materials, energy etc)) for the construction and operation of the project are non-renewable or in short-supply and the details?
- Whether the use, storage, handling or production of substances or materials are harmful to human health or the environment or can raise concerns about actual or perceived risks to human health and the details?

- Whether there is production of solid or liquid wastes during the construction or operation or decommissioning phases and the details?
- Whether there is release of pollutants or hazardous, toxic or noxious substances to air and the details?
- Whether there is generation of noise, vibration and emissions of light and heat and the details?
- Whether there are risks of contamination of land or water from the release of pollutants into the ground or into sewers, surface waters, groundwater, coastal waters or sea and the details?
- Whether there is risk of accidents during construction or operation of the project, which could affect human health or the environment and the details?
- Whether there are factors which should be considered, such as consequential development, which could lead to environmental effects or the potential for cumulative impacts with other existing or planned activities in the locality?
- How sensitive is the area with respect to environmental aspects or the environmental sensitivity of the area?

The ToR generally includes the project description, assessment of baseline environment, impact prediction, mitigation planning, analysis of alternative resources and technologies, environmental monitoring programme, additional studies required and environmental management plan. The Ministry of Environment issues to be addressed in the EIA study for the respective sector. Accordingly, quantifiable and Forests, Govt. of India has published EIA guidelines for different sectors, which outline the significant impacts of a project are to be assessed on the basis of its magnitude, prevalence, frequency and duration as well as the non-quantifiable impacts (such as aesthetic or recreational value). Further, the significance of such impacts is also to be determined through socio-economic criteria. Generally, an impact zone is demarcated, where the project could have significant impact, as the main focus area.

Project appraisal

The salient features of the project that is subjected to assessment should be appraised in terms of its purpose, process, resource input, resource availability, environmental implications, environmental safeguards, risk involved, social implications, financial viability etc. Generally, the following aspects of the project need to be understood with clarity.

a. Project background, especially the project objectives as well as the necessity.
b. Resource requirements considering, the construction and operational phases.
c. Technology and materials used in construction and operation phases.
d. Emission abatement procedures and their technological viability.
e. Resource recovery in terms of sustainable use of raw materials, water and energy and the reuse of waste streams, both solid and liquid.
f. Critical phases in the project cycle including land acquisition, possible resettlement of people, design, construction, commissioning, operation and, dismantling.
g. Implementation schedule including capacity planning, development of supply and distribution system.
h. Interaction with other projects depending on the question whether common effects of different projects will be increased or reduced due to interaction with each other.

Baseline data

Baseline data describes the existing environmental status of the identified study area, i.e. the impact zone. The site-specific primary data should be monitored for the identified parameters and supplemented by secondary data, if available. A description of the present environmental status of the impact zone can be developed by assessing various environmental attributes given in the table below using standard procedures.

Environmental attributes		
LAND	**GROUND WATER**	**ECOLOGY**
Landform	Water table	T. flora
Soil	Flow regime	Wildlife
Slope stability	Water quality	Aquatic life/species
Seismicity/landslides	Recharge	Game fish
Flood plains/Swamps	Aquifer character	Birds
Land use	Existing use	Endangered species
Mineral resources	**NOISE LEVEL**	T. Communities
Buffer zones	Intensity	Aquatic habitats
SURFACE WATER	Duration	Endangered habitats
River banks	Frequency	**HEALTH**
River floor	**AESTHETICS**	Physical safety

Flow variation	Biota	Psychological well being
Water quality		Diseases
Drainage pattern	Wilderness	Accidents
Water balance	Atmospheric quality	**SOCIO-ECONOMIC**
Flooding	Tranquility	Employment
Existing use	Sense of community	Housing
AIR	Manmade objects	Education
Climatic changes	Landscape	Settlements
Visibility		

Impact prediction and assessment

Impact prediction is a way of 'mapping' the environmental consequences of a project and its alternatives. Environmental impact, generally, cannot be predicted with absolute certainty and therefore, all possible factors are taken into consideration and all possible precautions are taken for reducing the degree of uncertainty.

The following impacts of a project are generally assessed:

- Air quality: changes in ambient levels and ground level concentrations due to total emissions from point, line and area sources and effects on soils, materials, vegetation, human health and atmospheric visibility.
- Noise: changes in ambient levels due to noise generated from equipment and movement of vehicles and effect on fauna and human health
- Water: availability to competing users, changes in quality, sediment transport and ingress of saline water
- Land: changes in land use and drainage pattern, changes in land quality including effects of waste disposal and changes in shoreline/riverbank and their stability
- Biological: deforestation/tree-cutting and shrinkage of animal habitat, impact on fauna and flora (including aquatic species if any) due to contaminants/pollutants, impact on rare and endangered species, endemic species, and migratory path/route of animals and impact on breeding and nesting grounds
- Socio-Economic: impact on the local community including demographic changes, impact

on economic status, impact on human health and impact of increased traffic

- **Assessment of alternatives**
- The possibility of alternatives of a project, especially with respect to both project location and process technologies should be identified and environmental attributes compared. While exploring the possibility of alternatives, 'no project' option should also need consideration. The alternatives, so identified and evaluated, should then be ranked for selection of the best environmental option for maximum economic benefits to the community at large.
- **Delineation of mitigation measures**
- Once alternatives have been reviewed and decided and impact predicted, mitigation measures should be drawn up for alleviating the adverse impacts as well as enhancing the environmental benefits of the
- selected option. These mitigation measures are integrated into an Environmental Management Plan (EM P) that could be incorporated into the project for implementation so as to overcome the environmental adversities of the project.
- **Environmental monitoring programme**
- The EIA is generally carried out using data monitored on a short-term basis and therefore, there could be variations induced by natural processes and human activities later. Therefore, there is a necessity of monitoring critical environmental parameters on a regular basis so as to account for future changes in environmental quality. The environmental monitoring can also ensure that new attributes, other than those identified during EIA study, do not become critical during the operation phase of a project.
- **Environmental impact assessment report**
- An EIA report should ensure that it provide clear information to the decision-maker on the different environmental scenarios without the project, with the project and with project alternatives. The report should also suggest the environmental uncertainties, if any, of the project. The report, in addition to the project description should necessarily contain the following aspects:

  Air Environment
- Determination of impact zone (through a screening model) and developing a monitoring network
- Monitoring the existing status of ambient air quality within the impacted region (7-10 km from the periphery) of the proposed project site

- Monitoring the site specific meteorological data, viz. wind speed and direction, humidity, ambient temperature and environmental lapse rate
- Estimation of quantities of air emissions including fugitive emissions from the proposed project
- Identification, quantification and evaluation of other potential emissions (including those of vehicular traffic) within the impact zone and estimation of cumulative of all the emissions/impacts
- Prediction of changes in the ambient air quality due to point, line and areas source emissions through appropriate air quality models
- Evaluation of the adequacy of the proposed pollution control devices to meet gaseous emission and ambient air quality standards
- Delineation of mitigation measures at source, path ways and receptor

Noise Environment

- Monitoring the present status of noise levels within the impact zone, and prediction of future noise levels resulting from the proposed project and related activities including increase in vehicular movement
- Identification of impacts due to any anticipated rise in noise levels on the surrounding environment x Recommendations on mitigation measures for noise pollution

Water Environment

- Study of existing ground and surface water resources with respect to quantity and quality within the impact zone of the proposed project
- Prediction of impacts on water resources due to the proposed water se/pumping on account of the project Quantification and characterization of waste water including toxic organic, from the proposed activity
- Evaluation of the proposed pollution prevention and wastewater treatment system and suggestions on modification, if required
- Prediction of impacts of effluent discharge on the quality of the receiving after body using appropriate mathematical/simulation models
- Assessment of the feasibility of water recycling and reuse and delineation of detailed plan in this regard

Biological Environment

- Survey of flora and fauna clearly delineating season and duration.
- Assessment of flora and fauna present within the impact zone of the project
- Assessment of potential damage to terrestrial and aquatic flora and fauna due to discharge of effluents and gaseous emissions from the project
- Assessment of damage to terrestrial flora and fauna due to air pollution, and land use and landscape changes
- Assessment of damage to aquatic and marine flora and fauna (including commercial fishing) due to physical disturbances and alterations
- Prediction of biological stresses within the impact zone of the proposed project
- Delineation of mitigation measures to prevent and / or reduce the damage.

Land Environment

- Studies on soil characteristics, existing land use and topography, landscape and drainage patterns within the impact zone
- Estimation of impacts of project on land use, landscape, topography, drainage and hydrology
- Identification of potential utility of treated effluent in land application and subsequent impacts
- Estimation and characterization of solid wastes and delineation of management options for
- minimization of waste and environmentally compatible disposal

Socio, cultural, economic and health environment

- Aesthetic aspects of the impact zone
- Archaeological sites/places in the area
- Assessment of economic benefits arising out of the project
- Assessment of rehabilitation requirements with special emphasis on scheduled areas, if any.

Risk Assessment

- Hazard identification taking recourse to hazard indices, inventory analysis, dam break probability, Natural Hazard Probability etc.
- Maximum Credible Accident (M CA) analysis to identify potential hazardous scenarios
- Consequence analysis of failures and accidents resulting in fire, explosion, hazardous releases and dam breaks etc.
- Hazard & Operability (HAZOP) studies
- Assessment of risk on the basis of the above evaluations
- Preparation of an onsite and offsite (project affected area) Disaster Management Plan

Environment Management Plan

- Delineation of mitigation measures including prevention and control for each environmental component and rehabilitation and resettlement plan.
- Delineation of monitoring scheme for compliance of conditions
- Delineation of implementation plan including scheduling and resource allocation

Public consultation

It refers to the process by which the concerns of the local people of the project impact zone and others, who have plausible stake in the environmental impacts of the project or activity, are ascertained. This is to take into account all the material concerns of the project or activity design appropriately. The public consultation process is organized by the State Pollution Control Board at the site or in its close proximity, district wise through a panel after serving notice and making available the EIA report for reference.

Decision making

The decision on environmental clearance is made through a number of steps including detailed scrutiny of the EIA and EM P by an Expert Appraisal Committee. Based on the recommendations of the committee, the IAA, the authority to clear the project from environmental angle, makes the decision whether to give clearance to a project or not within a stipulated time-frame.

Monitoring the clearance conditions

Monitoring should be done during both construction and operation phases of a project. This is not only to ensure that the commitments made are complied with but also to observe whether the predictions made in the EIA reports are realistic or not. The monitoring facilitates corrective actions wherever the impacts exceed the predicted levels. Monitoring will enable the regulatory agency to review the validity of predictions and the conditions of implementation of the Environmental Management Plan (EM P).

Methods and techniques of impact identification and prediction

The major step in an EIA and the step that requires the greatest degree of scientific application of technology are the impact identification, prediction and evaluation. The prediction involves projecting the environmental setting to the future without the proposed action and then performing the necessary studies for actually predicting the impact of the proposed action and assessing the consequences. A number of methods are available for impact identification and prediction, each having its own strengths and weakness. The most popular methods are listed in the table below.

Methods	Strengths	Weakness
1. Questionnaires, Interviews and Panels	• Flexible • Can deal with subjective Information	• Cannot quantify • Comparison of alternatives is subjective.
2. Checklists	• Systematic • Concise	• Can be inflexible • Do not address interactions or cause effect relationships
3. Matrices	• Comprehensive presentation	• Do not address space or time
	• Comparison of alternatives • Address multiple projects	• Can be cumbersome • Do not address cause effect
4. Networks and Systems	• Facilitate conceptualization • Addresses cause-effect • Relationships	• No likelihood for secondary effects • Problems of comparable units

Diagrams	•	• Do not address space or time
5. Modeling	• Can give unequivocal results • Addresses cause-effect • Relationships • Quantification	• Need a lot of data • Can be expensive • Intractable with many
6. Trends Analysis	• Addresses accumulation over time • Problem identification	• Need a lot of data in relevant • Extrapolation of system thresholds is still
7. Map overlay and G IS	• Addresses spatial pattern and • proximity of effects • Effective visual presentation • [illegible]	• Limited to effects based on location • Do not explicitly address indirect effects
8. Carrying capacity analysis	• True measure of cumulative • effects against threshold • Address impact in system • Addresses time factors	• Rarely can measure capacity • May be multiple thresholds • Requisite regional data are often absent.
9. Ecosystem Analysis	• Uses regional scale and full range of components and interactions • Addresses ecosystem sustainability	• Limited to natural systems • Requires species surrogates for system • Landscape indicators still under development.
10. Economic Impact Analysis	• Address economic issues Models provide definitive, quantified results.	• Utility and accuracy of results dependent on data quality and model assumptions [illegible]
11. Social impact analysis	• Addresses social issues • Models provide definitive, quantified results	• Utility and accuracy of results dependent on data quality and model assumptions

The EIA involves prediction of changes over time in various environmental factors as a result of the project. The foundation for such predictions is the professional knowledge and judgment of appropriate substantive area experts; which can be facilitated by the use of a variety of prediction techniques. Some of the specific techniques that could be used for impact prediction are given below.

- Air environment: Emission inventory, Urban area statistical models, Receptor monitoring, Box models, Single to multiple source dispersion models, Monitoring from analogues, Air quality indices
- Surface water environment: Point and nonpoint waste loads, QUA L-IIE and many other quantitative models, Segment box models, Waste load allocations, Water quality indices, Statistical models for selected parameters, Water usage studies
- Ground water environment: Pollution source surveys, Soil and/or ground water vulnerability indices, Pollution source indices, Leachate testing, Flow and solute transport models, Relative subsurface transport models
- Noise environment: Individual source propagation models plus additive model, Statistical model of noise based on population, Noise impact indices
- Biological environment: Chronic toxicity testing, Habitat-based methods, Species population models,
- Diversity indices, Indicators, Biological assessments, Ecologically-based risk assessment,
- Historical/archaeological environment: Inventory of resources and effects, Predictive modeling,
- Prioritization of resources
- Visual environment: Baseline inventory, Questionnaire checklist, Photographic or photomontage approach, Computer simulation modeling, Visual impact index methods
- Socioeconomic environment: Demographic models, Econometric models, Descriptive checklists, Multiplier factors based on population or economic changes, Quality-of-life (QOL) indices, Health-based risk assessment.

Conclusion

India is one of the first in the world to recognise the importance of environmental conservation. The Indian constitution makes it a "fundamental duty of every citizen to protect and improve the natural environment including forests, lakes, rivers and wildlife and have ecological compassion for living creatures". It also provides the framework for creating a Welfare State by optimally utilizing the finite natural resources without affecting either the health of the people or the environment. Therefore, we must make conservation-oriented development choices to avert the progressive pressure on natural resources and life-support systems. It involves evaluation of environmental implications and incorporation of necessary safeguards for those activities having a bearing on environmental quality. Ministry of Environment & Forests has taken several policy initiatives and enacted environment and pollution control legislations to prevent indiscriminate exploitation of natural resources and to promote integration of environmental concerns in development projects. One such initiative is the Notification on Environmental Impact Assessment (EIA) of developmental projects issued on 27.1.1994 and revised on 14.9.2006 under the provisions of Environment (Protection) Act, 1986 making EIA mandatory for 39 categories of developmental projects as given in Annexure I. Further, EIA is also used as a tool to evaluate and communicate the impact of any activity on nature which is now increasingly used for decision making on development interventions, wherever necessary.

Greening Our Accounts

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Introduction

India is one of the fastest growing economies in the world, with an expected Gross Domestic Product (GDP) growth rate of nine percent in the near future. At the same time the conflicting interests of growth and conservation philosophies pose challenges in policy making sphere. India is also known for its rich in natural resource and harbours one of the twelve biodiversity hot spots of the globe. While the nation is shining in economic sphere, whether the quality and quantity of our natural resources perform in a similar way? Do the environment that we live in, improves/maintains her quality along with economic development? The contribution of primary sector (agriculture, forestry, fisheries and mining) to our economy has been steadily declining for the past several years. But this does not reflect the changes in qualitative base of these resources as well as that of environmental services.

Now, we may have to see whether our economic growth is at the expense of our natural resource wealth. Our current system of national accounting (GDP) does not take into account the services provided by the environment and the damages caused to the environment and hence does not reflect the environmental quality damages. So we need to have a modified system of national accounting which will take into account the environmental aspects into the GDP. Green accounting is an alternate system of national accounts accommodating environmental aspects along with economic signals for arriving at an alternate indicator of economic performance.

GDP is an indicator of economic growth which reflects the total monetary value of goods and services produced in a country during a year. It is a market based indicator. There is an internationally agreed standard set of practices for estimating GDP and is known as System of National Accounts (SNA). It measures economic activity in accordance with strict accounting conventions based on economic principles and it gives a clear picture of the economy as a whole. The SNA is designed for economic analysis, decision taking and peace-making, whatever is the industrial structure or stage of economic development reached by a country.

As already pointed out, GDP neglects the value of services which are rendered free of charge, value of changes in the quality of health and value of changes in the quality and extent of environmental resources. Thus, the scarcity of natural resources that can pose a serious threat to sustained economic development is not reflected in the current GDP estimates. The traditional GDP focuses on flows only and ignores stocks. In turn, these stocks influence the interactions between natural ecosystems and human society. For e.g. consider the case of forest resources, GDP takes into account only the value of timber and non-timber forest products. It doesn't take into account other services provided by forests such as soil conservation, augmentation of ground water, carbon storage, biodiversity related services etc. Negative externalities such as environmental pollution, forest fire, deforestation etc. are not taken into account in the assessment of economic performance and progress.

In order to overcome the shortcomings of traditional GDP there was the need of alternative or modified indicator which reflect the services provided by the environment and the damages caused to the environment. It was in this background the concept of green GDP was evolved.

Green GDP

Green GDP is the environmentally adjusted gross domestic product. It is meant to account for nature's value on an equal footing with the market economy. It measures benefits arising from public goods provided by nature for which there are no market indicators of value. It aggregates all sources of wellbeing including all marketed goods and services into a single index. In effect green GDP adds the missing ecological elements to conventional GDP.

Green GDP measure and accommodates the level of consumption, degradation and replenishment of natural resources and thus societies should be able to see how market consumption affects the consumption of public goods like beautiful views, clean air, clean water etc. So it reveals the effect of current consumption on future wellbeing.

The concept of green GDP became important after the United Nations World Summit on Sustainable Development at Johannesburg in 2002 concerning consumption and production patterns. Green GDP is taken as an indicator of sustainability or a way to achieve sustainable development.

The existing System of National Accounting (SNA) does not support the estimation of green GDP. Hence we need an alternative or modified system of accounting which could accommodate aspects of green GDP, the indicator of sustainable development. This modified system of national accounting is called green accounting.

Green Accounting

Green accounting helps to measure and introduce non-market values of natural capital appropriately into standard economic accounting models. The aim of green accounting is to reform the system of national accounting policy tool, to make sure that it takes account of important environmental issues and it helps policy makers steer economic development towards a more sustainable state. Green accounting is based on the concept that a proper assessment of a country's income and wealth needs to account for the contributions of activities made by all sectors of the economy and their impact on resource depletion and degradation. Incorporating the real value of natural resources as well as their depletion and degradation allows for better allocation of priorities, thereby helping to address the causes of current major environmental problems including the over-exploitation of natural resources such as forests.

There are mainly two approaches to green accounting as suggested by UNEP.

1. **Separate or Satellite accounts.**

   Separate or satellite accounts will be created along with the traditional national accounts, which capture changes in natural resources but do not integrate them within the framework of the traditional SNA. These accounts allow for the valuation of resource use and depletion as well as estimations of expenditures for environmental protection to be made. This valuation allows countries to maintain accounts of annual resource use and depletion. While satellite accounts are linked to the existing system of national accounts, they are not an integral part of them.

2. Integrate environmental accounts with traditional SNA.

The purpose of this approach is to link environmental data directly into existing economic accounting. Countries have to modify their existing system of national accounts to incorporate environmental assets. Most often, the integration of natural resources is limited to easily valued resources (such as oil, coal, and timber) and as yet does not account for all environmental aspects, particularly environmental pollution.

SEEA (System of Integrated Environmental Economic Accounting), the most universally accepted method of green accounting comes under this approach. This method was introduced by United Nations Statistical Division, OECD (Organisation of Economic Co-operation Development), Eurostat, the World Bank and many other national statistical offices, in 1995. SEEA consists of stocks and flows of environmental goods and services.

Steps in the estimation of green GDP

1. Accounting of the status of natural resources.

It is the first step in SEEA and is mostly done by physical scientists. Based on the existing data, a database will be created.

2. Valuation of the loss in quantity and quality of the non-marketed ecological services.

This is usually done by the environmental economist and is the most tedious task as the valuation of ecological services is difficult as it is not marketed. This is usually done by taking some proxy variables.

3. Adjustment procedure for estimating green GDP.

In this step, the benefits from ecological services are added to the normal GDP and damages caused to environment are deducted to arrive at green GDP estimate.

Though some of the nations (Sweden, Norway, France) have already way ahead with the system of estimating green GDP, India has not yet adopted it. A pilot project in this aspect was implemented in India in 2004 by Green Indian States Trust which was funded by Deutsche Bank India Foundation. *'Green Accounting for Indian States and Union Territories Project (GAISP) – Accounting for the Ecological Services of India's Forests: Soil Conservation, Water Augmentation and Flood Prevention'* was aimed to set up top-down economic models for state-wise annual estimates of adjusted GSDP for all major Indian states and Union Territory economies. GAISP proposed to build a framework of adjusted national accounts that represents genuine net additions to national wealth. This will encourage the emergence of sustainable development as a focus of economic policy.

In this project, identified services from forests were considered for this exercise and Environmental State Domestic Product (ESDP) for 2002/2003 was estimated by adjusting for the net value of these services. Then by integrating ESDP with GSDP of the corresponding year, it was found that there was a reduction of about 10% in green GDP of Kerala, as compared to that of GSDP. This loss was mainly because of the decline in the forest area as compared to that of 2001 and as a result the benefits from forest services also reduced. If we were able to conserve or even maintain the forest area as that of 2001, at least we could able to maintain the status quo. The statistics with respect to NE states shows that forest resources in the north eastern states as managed well and the growth is not resource intensive. This highlights the importance of natural resource management for achieving the sustainable development goals as envisaged in the Millennium Development Goals.

A similar attempt was done by China in 2004 and published the green GDP. As per these estimates the environmental damage was found to be around three percent of national income (more than US$ 66 billion). But, they did not continue with the exercise.

Green GDP may be significantly lower than GDP in those areas where economic growth is resource intensive. And those areas where natural resources are better conserved will have positive adjustments to the GDP that is a higher green GDP which indicates a sustainable growth.

History

It was in the United Nations Conference on the Human Environment at Stockholm in 1972, the importance of accounting environmental services were first emphasised. Following that Norway became the world's first country to have a ministry of environment. Norway, the Netherlands, and France were the "early adopters" of environmental accounting, developing their own methods during the 1970s and 1980s in response to their own environmental and economic priorities. In 1978 Norway constructed the world's first environmental accounts. Most of the countries have developed and followed their own method for accounting the non-marketed services of environment and hence there was no universal method for environmental accounting. In 1995, United Nations Environmental Programme has introduced a universal method called System of Environmental and Economic Accounting (SEEA) for accounting the ecological services. Now many countries like Sweden, France, Canada, Namibia, Germany, Denmark, Austria, Finland, Netherlands, Philippines etc. follow green accounting.

Norway

Norway was among the first countries to make a commitment to environmental accounting and an innovator in the development of accounting frameworks. Their work began in the 1970s, in response to the Club of Rome's publication of *Limits to Growth* and a growing environmental movement. The Norwegians became concerned that their natural resources, on which their economy is relatively dependent compared to other European countries, would run out. They therefore developed accounts that tracked their use of natural resources, focusing on forests, fisheries, energy, and land. These accounts were integrated into models used for macroeconomic planning, taking into account the roles of resource-based sectors in economic growth. The accounting work was commissioned by the Ministry of Environment. The Research Department of Statistics Norway did much of the work, and integrated the data into their macroeconomic models.

The Netherlands

The Netherlands was also a leader in the development and adoption of environmental accounting. They have developed a model called NAMEA (the National Accounts Matrix including Environmental Accounts). The NAMEA builds on the input/output framework of the national income accounts by introducing additional columns containing physical data on air pollutant emissions by sector. Netherlands continues to calculate the green national incomes based on environmental preferences.

France

France was a third early-adopter of environmental accounting. In the 1980s it began developing its own approach to the design of environmental accounts, referred to as the *'Comptes du patrimoine'*, or patrimony accounts. These were an integrated system structured around three distinct but linked units of analysis; resource, place and agent accounts. French Institute for the Environment (IFEN, the Institut Français de l'Environnement) was created in 1992 and they took over the countries environmental accounting work. France is one of the pilot countries for the Eurostat development of forest accounts. IFEN has also been engaged for several years in building water accounts. The French water accounts are designed to present information about water quality, quantity, and pollutant emissions.

France is one of the few countries studied that has attempted to build biodiversity into its accounts. However, their work in this area is limited in biodiversity conservation, such as protected areas management. IFEN is now working on organizing energy use and greenhouse gas emissions data in order to link them to the national accounts.

Sweden

Sweden has been working on environmental accounting through much of the 1990s, and made an official decision to make this a routine government activity in 1996. The environmental accounting is carried out by environment statistics section of Statistics Sweden and the National Institute for Economic Research. The core work of the Swedish accounts has been on energy, air pollutant emissions, and climate change models. The Ministry of Finance routinely undertakes medium-term economic forecasts which use environmental accounting data to link emissions to productive sectors and assess the economic impacts of different environmental goals. Swedish government have created national commissions on climate change, growth and environment, and green taxes, all of which have commissioned analytical work relating the economy and the environment. These commissions are central to the Swedish process for framing policy issues and analysing strategies to resolve them. They are also estimating green GDP based on SEEA method.

The Philippines

The Philippines offers two separate, parallel projects on environmental accounting. In 1991 the Environment and Natural Resources Accounting Projects (ENRAP) began in the Department of Environment and Natural Resources (DENR), with financial support from the United States Agency for International Development (USAID). In the mid-1990s, the National Statistical Coordination Board (NSCB), the government agency responsible for the national income accounts, began implementing the United Nations' System of Integrated Economic and Environmental Accounting, or SEEA. The NSCB work was referred to as Environmental and Natural Resources Accounting or ENRA. They built resource accounts for forests, minerals, fish, and soil, and estimated the costs of preventing pollution of air and water. Both the projects estimated green GDP.

The United States

The United States' accounting situation is different from the other countries. The US government has not undertaken any environmental accounting as such, since 1995, when Congress halted the work that had been launched in the Bureau of Economic Analysis (BEA) and explicitly prohibited the agency from using any of its funds for this purpose). However, the US Environmental Protection Agency (EPA) maintains database on pollution control and emissions that would form the building blocks of portions of an environmental accounting system. EPA also maintains data that could contribute to the development of environmental accounts.

Some recent developments in green accounting:

In 2010 the World Bank launched a new initiative called the Global Partnership for Ecosystems Valuation and Wealth Accounting. It brings together a group of developed and developing countries to test out and implement expanded measures of natural wealth and including these in countries' national accounts. The goal, among other things, is to properly value ecosystem services like coastal protection from mangroves and hydrological services from forests (World Bank, 2011).

As part of our unilateral domestic action towards managing climate change threats, India is planning towards a system of computing green GDP. This forms a part of national action plan on climate change. Prime Minister's Office has asked the Ministry of statistics and programme Implementation to work out a system for natural resource accounting. Our Union Minister of State for Environment and Forests, Sri. Jairam Ramesh announced that by 2015 India will start reporting green GDP, to strike the balance between development and conservation. India has set up an expert group chaired by eminent environmental Economist, Sir. Partha Das Gupta of Cambridge University, for this purpose.

Statisticians, economists and ecologists and policy makers across Asia have met in Bangkok during October, 2013 to look at ways to calculate the value of natural resources that could reshape the way country success is measured.

In Asia Pacific region, Australia has established natural capital accounts for water, energy, minerals, land and environmental protection expenses. Both Mexico and UK have also adopted natural capital accounting.

Challenges of green accounting

Despite the hard work by United Nations Statistical Division, World Bank and other international organisations to have a smooth green accounting system, there are certain challenges which are to be addressed so as to have an efficient accounting system.

Data support or generation: The quantification of the ecological benefits is cumbersome and has the problem of double counting.

Valuation of the intangible benefits: By practice value of a commodity is taken as its market price. Since many of these services do not enter the market, such an option is not there. This naturally poses great challenges in valuation.

High market imperfections exist in many cases, either due to market failure or policy failure. In such cases the prices fail to reflect the true value of the resource and hence depending on the market price may lead to undervaluation.

Capacity building: Environmental services are often considered as free goods, even now. This demands for a concerted effort for education and awareness build up, at all levels. Moreover the experts in the field are also to be capacitated to apply modern tools in valuation.

Conclusion

Conservation and development have always been on opposite sides and conflicts existed. The conventional indicators of development often considered only the marketed goods and services and failed to accommodate the environmental services which support the life system. Realising the importance of developing an integrated indicator of development that reflects both marketed and non-marketed goods and services, there has been several global efforts to standardise a methodology. Green GDP is an indicator in these lines. The estimation of green

GDP forms the basis for developing management plans towards achieving sustainable development. India, among many other nations is on the free to assess the green GDP.

Only the countries that have devised sustainable means to manage their natural wealth would move up and will remain in the development ladder World Bank reminds. Along with industrialisation, urbanisation and other developmental activities, only if we are taking care of our natural wealth we will be able to achieve true development i.e. sustainable development.

Green Buildings:Concepts, Technologies & Materials

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Introduction

Green Building refers to a structure and using process that is environmentally responsible and resources efficient throughout a building's life cycle: from sitting to design, construction, operation, maintenance, renovation and demolition. This requires close cooperation of the design team, the Architects, the Engineers and the Client at all projects stages. The building practice expands and compliments the classical building design concerns of economy, utility, durability and comfort.

In response to visible evidence of environmental damage and rising fuel prices on one hand and the impossibility to meet the demand for water and energy faced by urban municipalities on the other, terms like 'sustainable building' or 'green building' are being popularized as an attempt to bring about awareness of the mindless depletion of natural resources and a reversal of unsustainable trend in the field of building design and construction.

Until the late 19th century, before the widespread dependencies on electricity for heating, cooling and illumination, buildings were naturally more climate-responsive and architects were familiar with and excelled in what are today termed 'passive' techniques in combination with mechanical devices to illuminate and ventilate the interior spaces of complex buildings, whether high-rise or long span. The early skyscrapers of Europe and America or the long-span of train stations and exhibition spaces provide endless examples of how architects responded to the need for taller and larger buildings while also meeting the comfort levels of the users and providing for the necessary light and ventilation.

With the advent and widespread use of air-conditioning systems, architecture gradually moved away from these 'passive' techniques and a skyline with smooth reflecting glass boxes emerged where even the windows ceased to be openable. William McDonough mentions his astonishment that the Wall Street Journal devoted an entire front page to an office building designed by his firm, because it had windows that could actually be opened!

As architecture manages to reach a total disconnection with the natural world and environment, human beings are subject to living and working in environments that even may not be provided with natural illumination, in spite of acknowledged consequences such as the 'sick building syndrome'. Modern buildings seem to look alike regardless of where they are situated and what their climatic context is. Moreover, the influence of these trends established in the developed world, on the emerging developments in developing countries, is resulting in an apparent affordability of such new buildings, with a total lack of awareness of the real costs of fossil fuel depletion, not only in terms of money.

The 'green architecture' movement began around the 1960s with mostly single homes and small–scale buildings, but soon expanded to address public buildings. The past decade has seen a synergy of effort from professionals from related fields in bringing about the awareness of sustainability issues, and the terms 'sustainable building design – though still considered as 'alternative' – has become widespread, with many architects the world over dedicated to new approach.

The conventional building industry relies on energy intensive materials and does not use the resources judiciously resulting in the depletion of key resources, adverse effect on the environment and climate change. Building industry consumes about 40% raw stone, gravel and sand; 25% of wood; 40% of energy; 16% of water every year. Building industry that depends on diminishing resources will become costly and unsustainable as the resources will continue to be depleted. A decision system and policy prescriptions are needed for selecting environmentally responsible materials and construction technology.

Objectives of sustainable development

Sustainable development can be considered to have the following four main objectives.

1. Social progress, recognizing the needs of everyone.
2. Effective protection of the environment.
3. Prudent use of nature resources.
4. Maintenance of high and stable levels of economic growth and employment.

The importance of achieving sustainable development is a topic subject to rapid development of new ideas, new materials, and new technologies. It is important to recognize that the clients, customers or users of development schemes should be able to identify with the principles of sustainable included in the establishment of a particular project. To a large extent, therefore, their demands and aspirations will determine the way in which sustainability is to be incorporated into scheme.

"Green or environmentally responsible architecture burst onto the international scene in the 1970s in response to a visible evidence of environmental damage and rising fuel costs. The first green architect focused primarily on single-family houses, although some promising work was also done on office buildings. In the ensuring years, however, architects interested in environmental issues have increasingly directed their efforts towards skyscrapers, apartment buildings, convention centres, shopping malls, and other such large- scale commercial building that consume enormous amount of energy, release large quantities of carbon dioxide, use the most wasteful construction practices and possess poor indoor air quality.

Most conventional practitioners of modern design and construction find it easier to develop buildings in a vacuum as if nature and place do not exist. Use of fossil fuels and electricity make building habitable by lighting, cooling, and heating them. An ecologically aware architect would design such buildings differently. His/her intention would be to design a building that creates aesthetic, economical, social, and ecological sense and adds these values to the surrounding human and natural communities.

Sustainability aspects of habitat design

Sustainability, in context of building and habitat design, has multi- dimensional effects, which can be summarized as below.

- Environmental sustainability
- Social sustainability
- Economic sustainability

A sustainable building/habitat is one that is economically viable, environmentally benign, and socially acceptable.

Energy in Construction Sector

Buildings, as they are designed and used today, symbolize unrestrained consumption of energy and other natural resources, with a consequent negative environmental impact. In India, the residential and commercial sectors consume 25% of the total electricity usage of the country, and a major portion of this is utilized in buildings. Most buildings that are presently being designed and used are far from being ecofriendly or sustainable. Their energy consumption and imposition on natural resources is massive.

According to the World Watch Institute, about 40% of the total energy use is dedicated to construction and operation of buildings. In 1990, residential, commercial, and institutional building sectors globally consumed 31% of the global energy and emitted 1900 mega tones of carbon. By 2050, this share will rise to 38%, emitting 3800 mega tones of carbon (Watson, Zinyowera, and Moss (eds) 1996).

The design and development of new building based on sound concepts of sustainability, and application of sustainable retrofit options to the existing building could substantially improve energy-use efficiency in the building sector, with an associated reduction in both local as well as global emissions.

Pattern of Energy Consumption

- Capital Energy (Cap Energy)
- Recurring Energy (Rec Energy)

Capital Energy is the total embodied energy or the energy content of the materials used for the construction. The embodied energy is the total of the energy consumed in acquiring and transforming the raw materials into finished products and transporting them to the place of installation or the building site.

Recurring Energy is the energy that is being used perennially for the operation and functional purposes. Both **Cap Energy and Rec Energy** have to be minimized to mitigate climate change.

An overall evaluation of the total energy and environmental impact of the material and its creation process, as well as the long- term efficiency of the material (maintenance and replacement costs along with the possible energy savings) is needed to determine the sustainability of materials. Materials that have a higher sustainability generally have a less initial and lifetime environmental impact. The process of making a material more sustainable can happen in various way, including reducing the travel time of transporting the materials (which reduces the environmentally harmful emissions of the vehicles used to transport them), reusing materials to eliminate the initial energy requirements and the environmental damage caused during extraction or harvesting, selecting materials that have a manufacturing process with a low energy requirement and the least amount of environmentally damaging by products, and so on.

The understanding of the life cycle of a material, the structure, property-energy relationships and the environmental burdens that accrue through the extraction, processing, use and reuse of the product forms the basis of selection of sustainable building materials. This information would help in specifying materials that are required for a sustainable planet. This analysis is done based on the energy or energy content of a building material, which acts as a rough guide to its environmental friendliness.Materials that are environmentally preferable and have a less degree of adverse impact on the environment and human ecosystem, when compared with equivalent products.

Classification of Materials

Building materials are broadly classified as

a. High Energy Materials
b. Medium Energy Materials
c. Low Energy Materials

- High energy - > 5 GJ/Tonne
- Medium -0.5-5/Tonne
- Low - 0.5/Tonne

Transport Energy Costs

- Road:Truck – 2.85 MJ/Tonne/Km
- Railways - 0.90
- Sea - 0.09
- Inland - 0.90

Very High Energy

- Aluminium - 200 -250 Gj/Tonne
- Stainless Steel - 50 – 100
- Plastics - 100+
- Copper - 100+

High Energy

- Steel - 30-60
- Lead - 25+
- Glass - 12-25
- Cement - 5-8
- Plaster Board - 8-10

Low Energy

- Sand, Aggregate - < 0.5
- Fly ash - < 0.5
- Blast Furnace slag - < 0.5

The practices of using materials consuming low energy have to be encouraged and promoted.

Sustainably managed materials

The use of sustainable managed materials is an environmental responsibility in contributing towards a sustainable habitat. On the one hand, the phenomenal growth of the building industry results in the unplanned and unchecked exploitation of natural resources. On the other hand, the growth catalyses the need for the intensive efforts to standardize energy – efficient production process, reuse production wastes, and some basis to analyse a material in terms of its 'sustainable quotient'. A sustainably managed building material that is both environmentally friendly and readily available is made from renewable raw material that uses only renewable energy in its extraction, production and transport, and can be reclaimed and recycled. Besides being healthy for the occupants it will be almost impossible to find. To meet the goal of finding the 'perfect' material, there needs to be a frame of reference to select materials based on environmental concerns.

The huge quantities of wastes and by-products generated could form secondary resource materials for the production of alternative building materials, and thus provide effective savings in primary grade raw materials, energy, labour and capital investments in the plant. There could be a way to make the waste environmentally friendly and relieve perennial pressures on the land and environment.

The overall aim is to ensure that the materials being used for construction do not get depleted over time or to ensure the continuation of the global environment and prevent ecological damage. There are a number of ways to accomplish this from using harvested products, such as using lumber from sustainable forests, reusing construction materials, and using materials with the least negative environmental impact.

Sustainable materials have five major benefits.

1. They have a similar or lower price compared to traditional materials.
2. They do not exhaust the existing supplies of finite materials.
3. They save energy and reduce harmful emissions.
4. As they are encouraged by the building control, planning permissions are more likely to be received.
5. Since they are less harmful to occupants, they make healthier buildings.

Checklist of sample characteristics for sustainably managed materials

Characteristic	**Checklist**
Regional availability	Local extraction/manufacture of low material
Recyclability	How many times the materials can be recycled and retain their viability
Reusability/salvaged	Use as a secondary resource material for alternative building materials
Durability and life span	Durable, useful life
Life cycle cost impact	Financial impact on the life cycle cost of building operations
Energy efficiency	Low energy content
Resources efficiency	Low consumption of resources like water
Certified wood	Manufactures (in parts or whole) from wood (from well- managed forests) that has been certified by the forest council standards
Non. Toxic emissions	Relatively low levels of toxic emissions, irritating or hazardous substances that have an adverse impact on human health
Material cost	Relative cost to equivalent products that are not sustainable

Savings	Savings on energy and on other materials that might not be used in the life cycle of the building owing to the use of sustainably managed material
Material reduction	Serving the functional purpose with minimal use of materials at each stage of the life cycle than typically used
Gender Sensitiveness	Involvement of women in all stages

For the same application sustainably managed materials. The basic characteristics that differentiate them are their ability for natural resource conservation, low energy content, potential of recyclability, and reuse and low emissions of toxic substances or pollutants at each stage of their life cycle.

The understanding of the life cycle of a material, the energy input and waste output at each stage becomes the base analysis to derive its sustainable potential in very stage.

Principles of sustainable development in building design

The basic principles of sustainable development in building design are outlined below.

- Maximizing the use of renewable and natural resources in the building environment

- Minimizing energy and water use and the negative environmental effects of buildings.

- Ensuring process to validate building-system function and capabilities for proper maintenance and operation.

Integrated approach to building design and characteristics of sustainable building

An 'integrated approach' to building design involves the judicious use of resources and application of efficiency measures. Further, building should reflect the above concern by providing and/or adopting the following measures.

- Improved building envelope and system design
- Water conservation and efficiency measures.
- Energy conservation and efficiency measures
- Increased use of renewable energy resources

- Reduction or elimination of toxic and hazardous substances in facilities, process and their surrounding environment
- Improved indoor air quality and interior and exterior environments, leading to increased human productivity and performance and better human health
- Efficient use of resources and materials
- Selection of materials and products that minimize safety hazards and cumulative environmental impacts
- Increased use of recycled content and other environmentally preferred products

- Salvaged and recycling of waste and building materials created during construction and demolition
- Prevention of generation of harmful materials and emissions during construction, operation, and decommissioning/demolition
- Implementation of maintenance and operational practices that reduce or eliminate harmful effects on people and the natural environment.

The adoption of the above features results in buildings that have

- lower maintenance costs
- reduced operational energy
- lower emissions of air pollution
- healthier and more productive occupants

- less material usage, and
- longer building life.

Design areas in sustainable built environments

Architecture, with profound ability to create new relationships to places, has a unique position in leading to a new renaissance of sustainable development.

The following are the areas of design that need to be addressed in order to achieve sustainable built environments.

- Site planning, which essentially looks into the design aspects and optimum utilization of resources available at the site.
- Various water management and water conservation techniques, including rainwater harvesting.
- Solid waste management, which includes segregation at the individual house level, techniques for solid waste utilization, etc.
- Traditional and modern concepts of solar passive designing introduction to software tools and other designing instruments for calculations and providing design measures for buildings that take advantages of solar energy in reducing energy consumption and providing better living conditions.
- Use old energy-efficient building materials so as to reduce embodied energy in buildings and provide guidance in buildings and provide guidance on energy-efficient materials and their databases.
- Review of various energy-efficient building technologies and construction methods which reduce construction wastage and details of various construction techniques for more efficient methods for the same.
- Incorporate various energy systems into buildings, such as air conditioning systems, lighting systems etc. efficiently with the building system.

Conclusion

Green building is one of the major components of Green Economy. Green economy results in improved human well-being and social equity while significantly reducing environmental risks and ecological scarcities. In its simplest expression, a green economy can be thought of as one which is low carbon, resource efficient and socially inclusive. The future path of the development is that of Green Economy. This development path should maintain, enhance and where necessary rebuild natural capital as a critical economic asset and source of public benefits, especially for poor people whose livelihood and security depends strongly on nature.

References

Architecture of the People: Dr. Laurie Bajer

Sustainable Buildings(Collection): TERI Publications

Architecture in India since 1990: Ar. Rahul Mehrotra

U.S. Environmental Protection Agency. (October 28, 2010). Green Building Home.

Berge, Bjorn, The Ecology of Building Materials, Oxford: Architectural Press, 2000

Green Banking and role of Banks in Natural Resource Management

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"...history will remember Arrhenius, most for being the first to propose (way back in 1896) that burning of fossil fuels would eventually hike the planets temperature.......looking at contemporary consumption of coal, he thought that doubling the atmospheric concentration of carbon dioxide would take three thousand years; he did not realize that the century then dawning would see such remarkable economic growth, almost all of it underwritten by fossil fuels"

(A century of writing about climate change-The Global warming Reader-Edited by Bill Mckibben)

1. An overview of Banking Structure in the country

Before discussing the topic on Green Banking and role of banks in NR Management, it would be desirable to give an overview of banking structure in our country.

Number of Commercial banks (including RRBs)	173
Total number of Bank offices	101261
Population per office	13000
Percapita deposit of Scheduled Commercial Banks	Rs 51,106

Per capita credit of Scheduled Commercial Banks	Rs 39,909
Co-operative Banks	
Number of SCARDBS	20
Number of PCARDBs	697
Number of State cooperative Banks	31
Number of branches of State cooperative Banks	1047
Number of DCCBs	371
Number of branches of DCCBs	13495
Total no PACS	92432

(Data as on 2012 Source RBI/NABARD)

The banking network in the country has improved substantially over the years and there are presently more than two lakh credit outlets, though the distribution of the branch network is skewed and not uniformly spread across the country. As against 8000 bank branches at the time of Nationalisation, the branch net of commercial banks (including RRBs) have now increased to more than one lakh. Banks have a market share of 63% of financial assets of all agencies. As per the latest census, 58.70% of households in the country avail credit as against only 35% in the year 2001. The average population per branch in the country has come down from 15583 in 2001 to 12601 in 2012. In order to ensure adequate institutional credit flow to the vulnerable sectors, RBI has mandated that banks should lend a minimum of 40% of their lending to the Priority Sectors. This includes advances to agriculture, small scale industries, weaker sections, exports, education etc. A sub-target of 18% is also fixed for lending exclusively for agriculture. The Priority sector advances as at the end of March 2013 in respect of commercial banks was Rs. 16,94,472 crores. In addition, year after year increasing targets are set for agriculture credit disbursements in the Union Budget. As against the targeted credit flow of Rs. 5,75,000 crores for agriculture during 2012-13 the achievement was Rs. 6,07,375 crores. A target of Rs. 7,00,000 lakh crores is fixed for the current year.

2. Green Banking and sustainable growth

Green Banking is creating a buzz in the financial world. It is banking taking into account the social and environmental impacts and its main motive is to protect environment. Broadly this refers to banking business conducted in such a manner that promotes overall sustainable development and which helps in reduction of carbon emission and carbon footprint. Without environmental viability no project could be successful and it is closely linked to commercial viability. Any financial institution would be exposed to credit, legal and reputational risk if it's borrowing unit goes out of business due to environmental issues. Environment impact assessment should therefore form an integral part while considering financial viability of a project.

3. Potential for Green Finance

It has been indicated in the Economic Survey of 2012-13 that the" preliminary estimates indicate a sum of Rs. 230000 crores will be required to fulfill the main objectives under National Action Plan on Climate Change (NAPCC), let alone other carbon strategies and environment policies and programmes of the Government". Credit agencies can to a great extent supplement the efforts of the Government in supporting financially viable projects. The publication of the results of the latest Agriculture Census (2010-11) has brought out that of the 138 million farm holdings in the country ,117 million are small and marginal holdings .From 62% in the year 1960-61 the share of small and marginal holdings are now close to 85% and holds 44% of the cultivated area. Credit becomes a critical factor for such small holdings. 70% of agriculture is rainfed and subject to the vagaries of monsoon. Our country will therefore be among the countries which would be hit hard by climate change. Any action to mitigate climate change ultimately involves costs. Currently, India is heavily depending on domestic sources of finance. The cess on coal and international funding support from World Bank, Asian Development Bank etc., may not be adequate to meet the huge requirement of funds. Institutional credit support and investment by the private sector will therefore have to play a major role in filling the resource gap. Public-Private partnership and active involvement of Voluntary Agencies together with funds flow from banks can be used for scaling up the investments to service vulnerable sectors. Equally important is creation of awareness among investment community financial institutions and public in general.

4. Components of Green Banking

Green Banking can have broadly three components. The first is the green initiatives by the bank in conduct of its own business. To implement the green initiative of the Government, RBI has been issuing guidelines from time to time to banks to increase paperless banking and gradual phase out of cheques in banks day to day transactions. All the public sector banks and financial institutions have also been advised to take up e-governance in a proactive manner. Most of the banks have already brought their branch network under Core Banking Solutions (CBS), which has resulted in substantial reduction in paper work. All public sector banks have also been advised by RBI that with effect from 1st September 2011, they should have put in place effective and elaborate video conferencing facilities for review of performance of branches and other field units. RBI has also issued guidelines to all licensed banks to participate in centralized payment system like NEFT and RTGS. Guidelines have been issued to banks to issue KCC in the form of ATM enabled debit card. Mobile phones as a medium of extending banking services have been attaining great significance and it is being used as an alternate channel for banking services. Detailed guidelines in this regard had been issued to all banks by RBI vide their circular dated 8 October 2008.

In order to meet the energy requirement for day to day operations, a large number of bank branches are now using solar energy for meeting their power requirement of their branches. Solar energy is economical, environment friendly and involves almost nil transmission loss. SBI has become the first bank in the country to venture into generation of green power by installing wind mills for captive use for some of their branches.

The second dimension relates to banks intervention in Carbon trading /CDM which is a new branch of environmental finance. Many banks such as ICICI bank, Rabo Finance, IDBI Bank and State Bank of India have been engaged in providing end to end solutions, funding for CDM projects, acting as intermediary and providing consultancy services.

The third dimension and the most important one relates to the end use of bank credit. Banks need to give thrust for financing environmental friendly projects/schemes under primary, secondary and tertiary sectors. Indiscriminate deployment of credit could, though improve the standard of living in the short term, can result in the degeneration of environment which is at times irreversible. Credit can play a major role in striking a balance between the demand for economic development and sustainability. Banking sector is one of the major sources of financing for industrial projects like steel, paper, cement, chemical fertilizers etc. There is a need to promote more CDM projects and the Board of each bank need to review its progress in green financing periodically. In this regard a mention may be made about the UK Green Finance Bank, the first bank of its kind in the world set up with the objective of financing green projects. Set up as a Public Company it has become fully operational in Oct 2012. The Bank acts as a catalyst to accelerate private sector investments for green projects. The Bank's major objectives are reduction of CHG emission, advancement in the use of natural resources, protection of natural environmental, protection or enhancement of Biodiversity and promotion of environmental sustainability.

Following are a few green projects which could be supported by banks in our country. Many of these projects are already being financed.

- Renewable energy projects-Solar Power based equipments like solar pump, solar home light, solar street light.
- Fuel substitution projects - Biomass energy, Rice husk etc.
- Cultivation of Bio fuel - Forestry, processing value chain addition.
- Fuel efficient vehicles.
- Projects for recycling of waste, vermicompost.
- Rain water harvesting schemes.

- Soil conservation/watershed structures-on farm development.
- Green KCC.
- Bio fertilizer and biopesticides.
- Organic farming, SRI method, Zero tillage.
- Improved jute retting.
- Cultivation of aromatic and medicinal plants.
- Rural and Eco-tourism.
- Integrated farming models.

5. NABARD and NRM

The National Agriculture Policy of India focuses on sustainable development of Agriculture by promoting technically sound and economically viable and socially acceptable use of country's natural resources. Ensuring adequate food and water to all and achieving sustainable rural development and livelihoods for current and future generations depend upon the responsible management of natural resources. One important aspect of NRM that needs to be highlighted is the empowerment of rural communities to plan and manage these resources. About 65% of the workforce are engaged in agriculture and related sectors. The key interventions that would be necessary to mitigate the impact of climate change are to develop and promote sustainable agriculture models with emphasis on resource conservations and management. The IPCC (Inter Governmental Panel On Climate Change) has pointed out that developing economy rely more heavily on climate sensitive sectors like agriculture which operate close to environmental and climatic tolerance levels.

NABARD is the apex development finance institution in the country for promotion of agriculture and rural development. The Bank's policy on NRM seeks in "enhancing livelihoods and quality of life of the rural community through improved resource conditions."

Apart from providing refinance to banks for their lending for NRM activities NABARD has taken various initiatives under NRM. A brief account of these programmes is given below.

a) **Umbrella Programme on Natural Resource Management (UPNRM)**

The programme aims at augmenting private investment in NRM sector and assist in developing a suitable policy environment. The objective of UPNRM is to demonstrate the viability of loan based community owned approaches to NRM. NABARD has made a disbursement of Rs. 217.57 crores as at the end of March 2013. Assistance is provided in the form of soft loan and grant assistance to NGOs, Corporates, MFIs, etc. Some of the projects funded under UPNRM include Integrated animal husbandry, medicinal aromatic crops, honey, soil and water conservation,.etc.

b) **Watershed Development**

NABARD supports water-shed development projects that involve human resource development, soil and land management, water management, afforestation, pasture development, agriculture development, livestock management and micromanagement in watershed areas. Community mobilization and SHG bank linkage are also important part of the activities. NABARD anchors the following four programmes under water shed.

- Participatory Watershed Development Programmer under Watershed Development fund.
- Prime Ministers Relief package for distressed districts in four states.
- Integrated Watershed Development Programmer in Bihar and
- Indo-German Watershed Development Programme in Maharashtra, Andhra Pradesh, Gujarat and Rajasthan

These four programmes together cover an area of about 18 lakh/ha.

c) **Tribal Development Fund**

NABARD maintains Tribal development Fund out of which assistance is provided to NGOs for livelihood projects of tribal communities. Under the project each household is provided grant assistance in developing a plot of land with fruit trees/forest trees. Apart from improving income levels of tribal families it also helps in reducing pressure on existing forests.

d) **Climate Change adaptation project in Maharashtra**

NABARD in collaboration with Swiss Development Corporation (SDC) is supporting Climate Change Adaption project in 25 villages in Maharashtra. The major interventions include social mobilization, watershed structures, lift irrigation schemes, biodiversity, renewable energy etc.

e) **NABARD accredited as National Implementing Entity**

Developing countries that are particularly vulnerable to adverse effects of climate change and are parties to the Kyoto Protocol can apply for projects/programme funding. The project proposals should be submitted through National Implementing Entity (NIE). The NIEs are accredited by the Adaption Fund Board. The NIE will bear the full responsibility for overall management of projects/progammes financed by the Adaptation Fund; including that of financial, monitoring and reporting responsibilities. In view of the longstanding experience of NABARD in implementation of NRM projects NABARD was accredited as NIE. NABARD is the only agency from India and 12th in the world to have been accredited as NIE. The accreditation as NIE is expected to open up new opportunities for NABARD in terms of access to funds for implementing its NRM interventions and also training, monitoring and evaluation of various adaptation projects.

The other programmes being implemented by NABARD include assistance provided out of Farm Innovation and Promotion Fund, Farmers Technology Transfer Fund, Rural innovation Fund, Financial Inclusion Fund, Financial Inclusion Technology Fund, Research and Development Fund etc., all of which have a bearing on NRM. NGOs, Farmers Organisations, Universities/Research organizations, etc. are all eligible for support out of these funds.

6. Credit linked subsidy Schemes of Govt. of India

Govt. of India is implementing various central sector schemes where release of subsidy is linked to bank loan. Following are two such green projects which are being successfully implemented in the country with institutional credit support.

a) **Scheme for installation of Solar off-Grid and decentralized applications**

A credit linked subsidy scheme under Jawaharlal Nehru National Solar Mission (JNNSM) was launched by the Ministry of New and Renewable energy in 2010 to encourage replacement of nonrenewable energy sources with solar energy. Subsidy to the extent of 40% is provided under the scheme. In the last there years since the programme has been launched more than 1, 14, 000 units have been installed mostly in rural households. A subsidy assistance of Rs. 109.82 core have been released so far under the project.

b) **National Project on Organic Farming**

Credit linked subsidy is provided for setting up of vegetable/fruit market waste compost and bio pesticides and bio fertilizers. More than 650 units have been provided subsidy under the scheme as on 31 March 2013.

7. Credit requirement under National Missions

Credit support is one of the interventions envisaged under the National Mission for Sustainable Agriculture (NMSA). There is also credit potential in respect of other Missions set up under the National Action Plan for Climate Change (NAPCC). However no attempt appears to have been made to quantify the credit requirement for the various programmes under these Missions. The credit requirement once assessed could be disaggregated block wise and dovetailed with branch credit plan and the same could be reviewed by SLBC and NABARD.

8. Educational Loans - Social Sustainability

Creation of more jobs and skill development is vital for effective controlling of environment degradation. Budget allocation by Central and State Govts alone cannot meet the massive requirement of funds for this purpose. Banks do play a major role in this regard by providing educational loans and supporting skill development programmes. As at the end of 31 March 2012, commercial banks alone have provided educational loans to the extent of Rs. 48,000 crores covering 24,81,000 accounts. Apart from government agencies a large number of NGOs and banks are involved in conduct of skill development and entrepreneurship development programmes.

9. Corporate Social Responsibility

Under the recently amended Company's Act, business houses are required to spend 2% of profit on Corporate Social Responsibility (CSR). With the enactment of the Bill, India became the first country to mandate spending on CSR. Funding for education, poverty alleviation, protecting environment, etc. are all eligible activities under CSR. Banks could join/collaborate with Private Sector/NGOs in implementation of CSR projects in the area of NRM.

10. Action points/Recommendations

Government of India/State Government

- On the lines of the credit linked scheme of solar lighting/water heating and National Project for Organic Farming being implemented, Government of India/State Government may consider formulating similar credit linked schemes under NRM sector.

- The Rural Infrastructure Development Fund was instituted in NABARD with the objective of providing low cost loans to State Governments for implementation of infrastructure projects. Projects for mitigation of climate change and projects under NRM may be given preference for providing support out of RIDF.

- The feasibility of setting up/support in setting up a Green Investment Bank may be explored.

Banks

- Financing green projects may be given thrust by banks and progress made may be reviewed at the highest level.

- There is a need to improve awareness among the bank staff on climate change and NRM. Periodic workshops and training programmes may be organized to sensitize the bank/branch staff on the subject.

- The progress in financing green projects may be reviewed by BLBC,DLCC,SLBC under the Lead Bank Scheme

- Banks may consider charging a differential rate of interest for green projects to give a fillip for credit flow under this sector.

- Banks could join hands with Business Houses in implementing various schemes under CSR for NRM sector.

RBI/NABARD

•RBI may issues specific guidelines to banks on green finance and incorporate the same in the Master Circular on Priority Sector .RBI may also considering fixing a sub-target under Priority Sector exclusively for green finance.

•NABARD may provide refinance to banks at concessional rates of interest for disbursements may by banks for green projects.

•Under co -finance, NABARD may be earmark funds for financing green projects.

•The district wise Potential link Plans being prepared by NABARD (which forms the basics for banks to prepare their credit plans) may include a separate chapter on the potential for green finance/NRM projects. Model schemes under the sector may also be prepared and circulated for the benefit of banks and entrepreneurs.

•The credit requirement as envisaged under the various Missions constituted under NAPCC could be dovetailed with the Bank/branch Credit Plan and the progress made by the Mission could be monitored periodically by SLBC/NABARD. Suitable guidelines may be issued in this regard.

Conclusion

The twelfth Five Year Plan document has emphasized the need for faster and more inclusive sustainable growth and it has been made the theme for the Plan Document. Since the year 2011-12 the Economic Survey has introduced a separate chapter on Sustainable Development and Climate Change. Govt. of India has taken various steps to meet the challenge posed by climate change. Setting up of various Missions under NAPCC and initiating appropriate action as envisaged in the strategy, providing budgetary support and extending incentives are just a few of them. Private Sector, Research Organizations, Voluntary agencies, Banks and every citizen will have to join hands in this movement to realize the goals set for our country. Creating awareness among all sections of the society and also the channel partners are vital to achieve the desired results. Resources are a critical factor for the success for any such programme, more so in the present case. Banks therefore will have to take a proactive role without compromising financial viability.

Tail piece

Clive Hamilton who holds Vice Chancellor's Chair in Sturt University, Australia, in his new book "Earthmasters" discusses the issue of Geo-engineering as a plausible solution to climate change.Few would agree with the action plan discussed in the Book.

Geographical Information System (GIS) in Natural Resource Management

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1. Introduction

GIS, in simple terms, is a data base management system capable of dealing with spatially referenced data. Conventional data base management system involves only non spatial data. Whereas in GIS, both spatial and non spatial data are collected and processed, having more of the former type. A GIS may be defined as a database system in which most of the data are spatially indexed upon which a set of procedures operated in order to answer queries about spatial entities in the database.

1.1 General Components of a GIS

Broadly, we can say that a GIS has the following components:

1.1.1 Hardware: It consists of the equipments and support devices that are required to capture, store process and visualize the geographical data. These include computer with hard disk, digitizers, scanners, printers and plotters etc.

1.1.2 Software: Software comes at the centre of a GIS system. The GIS software must have the basic capabilities of data input, storage, transformation, analysis and providing desired outputs. The interfaces could be different for different softwares. The GIS softwares available today belong to proprietary or open source category. ArcGIS by ESRI is the widely used proprietary GIS software. Others in the same category are MapInfo, Microstation, Geomedia etc. The development of open source GIS has provided us with freely available desktop versions such as Quantum, GRASS, MapWindow, ILWIS etc.

1.1.3 Data: The data is captured or collected from various sources (such as maps, field observations, photography, satellite imagery, etc) and is processed for analysis and presentation. A GIS uses both spatially referenced and non spatial data.

1.1.4 Procedures: These include the methods or ways by which data has to be input in the system, retrieved, processed, transformed and presented.

1.1.5 People: This component of GIS includes all those individuals (such as programmer, database manager, GIS researcher, etc.) who make the GIS work, and also the individuals who are at the user end using the GIS services, applications and tools.

1.2 History of GIS

The history of GIS can be traced back to the art of map making of BCs. It is reported that earth surface was shown as map in the middle east as early as 1000 BC. The source of spatial data for GIS is of various types of maps. Putting layers of data on a series of base maps to analyze geographical entities has been into existence much longer than the introduction of computers to the geographical world. The introduction of computers in the field of geography was a major step in understanding and learning the subject better. Change in cartographic analysis due to improved graphics, development of theories of spatial processes in economic and social geography, anthropology and regional science, increased social awareness and improvement in education. The integrated transportation plans of the US during the period of 1950s and 1960s used information on routes, origin, destination, and time to produce the maps of traffic flow and volume is a best example of integration of computer technology with geographical data.

1.3 Application of GIS

Today, GIS has various applications in applied and social sciences. These include topographical mapping, socioeconomic and environment modeling, and education. The role of GIS is best illustrated with respect to some of the representative application areas that are mentioned below:

1.3.1 Natural resources management

Most important natural resources linked with the life of humans and animals are land, water and biomass. As these resources are highly variable with time and space, their spatial and temporal mapping is very essential. Agriculture, geology and hydrology are some of the sciences that utilize the capabilities of GIS in a big way. Agriculturists make use of the GIS techniques to map the cropping pattern and to predict the yield of different crops, requirement of inputs such as manure, water and labour. A geologist describes the spatial pattern of rocks and other sub surface features with the help of different digital layers and their super position. A hydrologist can develop a Digital Elevation Model (DEM) of a terrain of interest, drainage network, prediction of surface and groundwater flow using the principles of GIS. Watershed management is an area encompassing various aspects of natural resources management under one umbrella. Watershed management starts with the delineation of the watershed, delineation of the drainage network, preparing various thematic layers of topography, soil and vegetation

1.3.2 Transportation and other network analysis

In the analysis of road, power and communication network GIS is very widely used. Determining alternate travel route, probable peak values of traffic, future demand etc are some of the commonly used applications of GIS in this field. It is necessary for the shipping companies to know where their warehouses should be located, which routes should the transport follow that ensures minimum time and expenditures to deliver the parcels. All such logistics decisions need GIS support.

1.3.3 Business

Approximately 80% of all business data are related to location. Businesses manage a world of information about sales, customers, inventory, demographic profiles etc. Demographic analysis is the basis for many other business functions: customer service, site analysis, and marketing. Understanding your customers and their socioeconomic and purchasing behavior is essential for making good business decisions. A GIS with relevant data such as number of consumers, brands and sites they go for shopping can give any business unit a fair idea whether their unit if set up is going to work at a particular location the way they want it to run.

2. GIS basics

Whatever be the field of application of GIS, knowledge of some basic premises of the technique associated with data preparation and analysis are always needed as a prerequisite.

2.1 Map and map scale

To represent a large area on a small sheet of paper, proportionate linear distances along the two principal axes will have to be chosen. It is achieved by choosing an appropriate reduction scale. The scale represents the proportion of distance on the ground to that on the paper. There are three ways in which a map can be depicted on a map.

1. As a word statement: the distance on the ground corresponding to a unit distance on the map will be given by a word statement. Eg: "1 cm on the map measures is 100 m on the ground".
2. As a representative fraction: It is represented as a fraction. Eg: a representative fraction of 1:50000 indicate that the distance on the ground is 50000 times more than the corresponding distance on the map.
3. As a graphic: The scale is shown as strip where the strip is further divided into equal parts. The graph indicates the distance on the ground corresponding to a specified distance on the map. A graphical representation is preferred in a map representation in GIS.

2.2 Georeferencing

It is the process of assigning geographical coordinate values to the digital map. A number of (five or more) Control points are needed for georeferencing. Ground control points refer to those points on the map whose geographical coordinates are known. To get the geographical coordinates of some desired points either a base map or GPS system may be used.

2.3 Spatial DBMS

A database management system with spatial data is the essence of GIS software. Data models used in a GIS system may be of the following type, viz. hierarchal data model, a network data structure and relational data base structure. Among these, the relational database structure is the more efficient.

2.4 Spatial data input & editing

Collecting data and creating a GIS database is a time consuming but an important task. There are many sources of geographic data and many ways to enter that data into a GIS. A data pool can be generated by either data capture or data transfer. The data sources are divided into following two main classes:

Primary data: Data collected through direct measurement is called primary data. Some of the examples of primary data pertaining to a GIS work are surveying and collecting ground details. Engineering surveying involves measurements of angles and linear distances of the land surface using conventional equipments such as a theodolite and a chain or with the modern equipment called total station. After the field measurements a topographic map is prepared and this is used as a primary input for most GIS project. Another example of primary data is remote sensing data capture. In this, the information of the land surface is obtained through the principle of reflection of electromagnetic radiation. Data collection through remote sensing imagery is very fast with extensive area coverage.

Secondary data: It refers to data obtained from existing sources such as maps and documents prepared by some other agencies. A secondary data can be incorporated into a GIS project through scanning and vectorisation. Data from external sources is also widely used in GIS assignments.

2.5 Spatial analysis

Spatial analysis is the core to the GIS, since all the hard work done in compiling and processing of the spatial data is to achieve this important outcome. It is only through spatial analysis that answers to a range of questions are found. Thus the spatial analysis helps in decision making. The range of methods deployed for spatial analysis varies with respect to the type of the data model used. Some of the commonly used analysis procedures are 'measurement' and 'querying'. Measurement of length, perimeter and area of the features is a very common requirement in spatial analysis. However different methods are used to make measurements based on the type of data used i.e. vector or raster.

Query is a logical question that is performed on the database to retrieve specific information. Queries are useful for checking the quality of the data and the results obtained. There are two types of queries that can be performed in GIS: Aspatial or attribute queries questions about the attributes of the feature. These do not include any spatial information. "Who practice paddy cultivation?" is a simple query that does not involve analysis of any spatial component. Such queries could be performed by database software alone. Spatial queries involve selection of features based on location or other spatial information. "Which are the locations of irrigated paddy fields?" is a spatial query. Two or more queries can be combined together to identify features of interest. Boolean operators such as AND, OR, NOT, and XOR are used to combine queries.

3. GIS in natural resources management

All natural resources management issues deal with the analysis of large area with a number of spatial themes and a large number of attribute data. GIs will be very handy in these kinds of situations. Some of the often used natural resources projects in GIS may be related to watershed management, geology, forestry, oceanography, etc. A detailed discussion on the use of GIS for watershed management is given here as a typical example.

3.1 GIS for watershed management

Watershed management is an important aspect of natural resources management and the sequence of procedures performed for watershed management projects using GIS is described below.

3.1.1 Development of Digital thematic layers

a) Digital Elevation Model (DEM)

A DEM is a digital thematic map showing the elevation of every grid points considered during the interpolation process. It can be prepared from the topographic maps by digitizing the contour lines. Or it can be developed from aerial photographs using the photogrammetric principles. Different grid resolutions are possible for a DEM. For an undulating terrain, a grid resolution of 30 m x 30 m and 100 m x 100 m can be chosen for a moderately sloping ground. Degree of slope, direction of slope and shape of slope are determined from the DEM for the hydrologic analysis of the watershed.

b) Drainage network

Drainage network of the watershed can be developed from the DEM. However, all the watershed analysis processes will be more accurate if the actual drainage network of the watershed can be fed to the GIS software along with other thematic layers.

c) **Soil map**

In majority of the cases, soil map for the entire area of interest may be available in print form and not as digital. Hence, analog soil map are digitized, polygonised and rasterised to form a digital soil map in grid format. Physical properties of different soil series used in the study are prepared as attribute table.

d) **Land use map**

Multispectral satellite imagery of resolution 25 m x 25 m or lower is used for the preparation of land use map. For very large area even coarser resolution can also be considered. LISS III of IRS P6 can be chosen as an ideal data set for the preparation of land use map for majority of land use maps required for micro watershed studies Band I, II & III are used to prepare the FCC and further supervised classification. Georeferencing of the imagery can be done by providing the coordinates of landmark points from the topographic map or by an accurate GPS. Supervised classification method is usually adopted for the land use classification of the watershed area. Adequate ground truthing exercise has to be done with the help of hand held GPS to remove errors in the classification and to make the classified map more reliable. Superposition of road network on the imagery can make the field survey for ground truthing easier. A "majority filter" may be used to refine the classified map.

3.1.2 Attribute data

Climatological data such as rainfall, temperature and humidity need to be collected for the past several years and they are presented as tables in the format specified by the GIS software. If this information is available in digital format there will be much relief for the physical data entry job. Location tables of all weather gauge stations will also be needed to prepare spatial distribution of climatic parameters. Similarly attribute tables in the required format is required to feed information on physical properties of soil and land use information.

3.1.3 Watershed Delineation

From the DEM and drainage network it is possible to delineate the main watershed boundary for the outlet chosen on the main drainage channel for the main watershed. Delineation of subwatershed boundaries is also possible with the help of DEM and drainage network. The size of subwatershed can be specified by the user and can be given to the software. After the delineation, physical characteristics of all subwatersheds can also be generated with the help of

GIS. Important physical characteristics include area, mean elevation, mean land slope, channel length, mean channel slope from the point of view of watershed management.

3.1.4 Watershed Response

Hydrological response of the main watershed as a whole and that of the individual watershed can easily be simulated if GIS software is integrated with watershed modeling software. Channel flow, sediment outflow, surface flow from land area, lateral flow and base flow are the most important hydrological response of the watershed. Some of the watershed models that can be coupled with GIS software are Soil and Water Assessment Tool (SWAT), System Hydrologic European (SHE) and Water Erosion Prediction Process (WEPP). By comparing the hydrological response of different micro watersheds it is possible to prioritize them for various interventions aimed at improving the soil, water and biomass resources of the watersheds.

Figure 1. Watershed and subwatershed boundaries of Kunthipuzha river basin in Kerala delineated by ArcGis and SWAT model

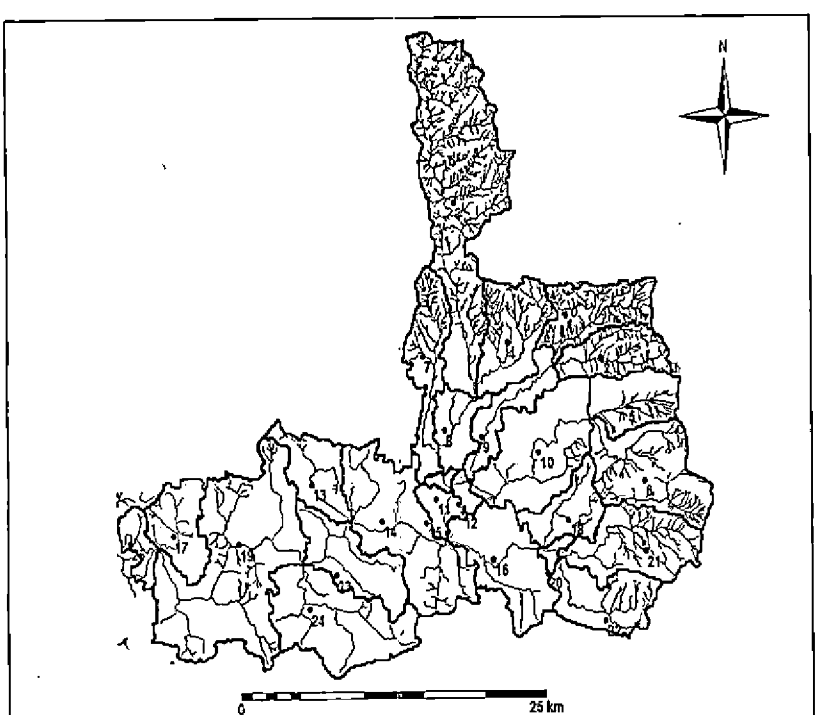
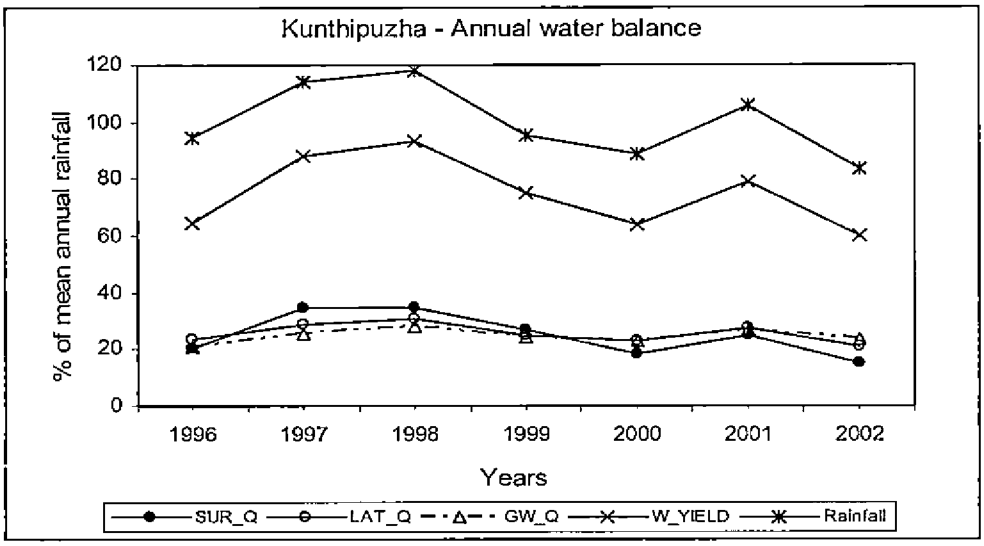


Figure 2 Hydrological response of Kunthipuzha watershed showing surface runoff, lateral flow, groundwater flow and total water yield



4. References

Arnold, J.G., Srinivasan, R., Muttiah, R.S., Williams, J.R., 1998. Large area hydrological modeling assessment. Journal of the American Water Resources Association 34 (1). 28-42.

Neitsch, S.L., Arnold, J.G., Kiniry, J.R., Williams, J.R., King, K.W., 2005. SWAT theoretical documentation version 2005. Soil and Water Research Laboratory, ARS, Temple Texas, USA.

Burroughs, P.A. and McDonnel, R.A., 1998. Principles of Geographic Information system. Oxford University Press.

Chow, V.T., 2000. Hand Book of applied Hydrology, McGraw Hill.

Information Communication Technologies for Sustainable Management of Natural Resources: Principles, Practices and Applications

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Introduction

Deterioration and depletion of natural resources have become key concerns of our times and are being attributed to a resource intensive development paradigm. As the thrust on natural resources becomes heavier day by day, we are cautioned of indiscriminate exploitation and uncontrolled consumption and the several consequent perils in the offing (Hardin, 1968; Tongia et al 2005, Ostrom, 2011). The major concerns include climate change, depletion of biotic and abiotic resources, loss of biodiversity and ozone layer depletion. There are also issues such as land degradation, deforestation and diminishing water resources to cite a few, that impact life of the people directly. Being a matter of tremendous global importance which has found a place in the UN's millennium development goals, multi faceted efforts to seek remedies to these problems are actively on. As evinced by the global deliberations and the multilateral agreements, the focus is mainly to avoid ecological disasters through diplomatic cooperation among nations and by helping individuals and communities optimally manage resource use and consumption. Nonetheless, undertaking this responsibility also implies matching of diverse interests and concerns of the various stakeholders in the complex web of transactions involved in it. There are innumerable dimensions to this problem and regulating the use of natural resources without affecting the livelihood options of the people who depend on it is indeed challenging.

The strategies to ensure sustainable management of natural resources involve several approaches and tools. They are multi disciplinary and multi level in nature, which would essentially include formulating regulatory policies, instituting mechanism for monitoring, enhancing capabilities of stake holder agencies, individuals and communities, and keeping vigil at the grassroots level. Needless to say, these interventions are information intensive and require careful management of data and information for efficient planning, implementation and monitoring. This has necessitated employment of ICTs in this mammoth effort. Ranging from worldwide interventions to local level applications, ICTs for sustainable management of natural resources involve sophisticated information systems, remote sensing, maps, databases, simulation tools, educational tools etc. Several applications are in vogue to enable governments, organizations, community groups and individuals to intervene in sustainable natural resource management (NRM) efforts systematically and effectively. However, even while there are large number of applications, societal interface of these technologies is still in a stage too early to facilitate local level interventions.

As the nature and magnitude of issues vary, these applications may have to be customized according to specific conditions. There is immense scope to develop specialized applications to address these problems, taking into consideration the wide local variations in natural resources and the problems related to their conservation. For that matter, any technological intervention towards this objective will have to be grounded on the geographical and bio physical characteristics of the location and the socio economic attributes of the people, who are the major stakeholders. This in turn calls for context specific applications intended for broader outcomes and sustainable conservation goals with a long term perspective. Taking cues from the extensive literature on NRM practices with people at the centre, there is immense scope for developing ICT applications that envisage community participation, capacity building, establishing and maintaining institutions and providing information support to people's initiatives.

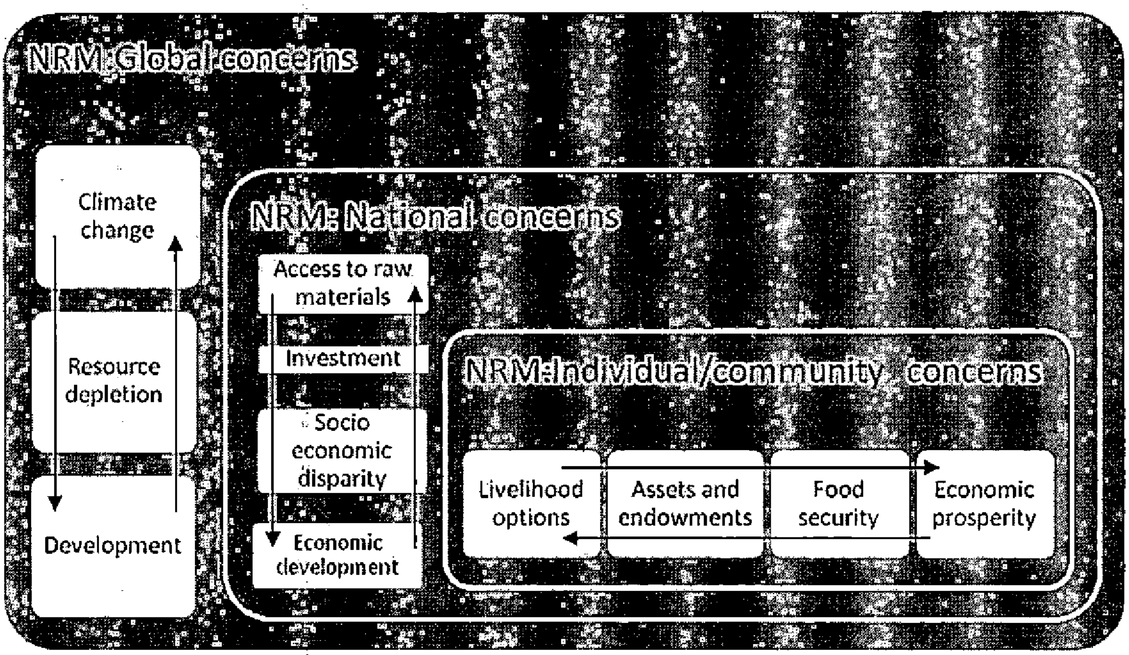
In the light of the above, we shall try to characterize the pre requisites of a people oriented ICT strategy for natural resource management at the grassroots level. It is attempted by analyzing the predominant theoretical tenets on community based natural resource management (NRM) and looking into the details of some widely known applications of ICTs for sustainable management of natural resources deployed at different parts of the world in different contexts. An overview of these applications in the light of the growing body of knowledge on community based NRM would perhaps help us formulate context specific ICT programmes for effective and long standing NRM. Though ICTs would surely provide us with the tools to support NRM interventions, it requires an understanding of the socio- economic and political context in which such efforts would unfurl to devise appropriate strategies for employing the tools and rolling out the programme.

Socio- political dimensions of NRM: Growing evidence on the importance of community based intervention

Managing natural resources is not as easy as it might appear, as the process has become too complex with the bludgeoning population, increasing demand on resources and the uneven grounds that make a large section of the population disadvantageous. However, it should not be forgotten that NRM fundamentally involves the approach to resource intensive development, which cannot be either halted all of a sudden or allowed to continue unbridled. There are several issues that remain to be tackled in this connection. One is the predominance of pro industrialization growth model pursued relentlessly by many developing economies, in spite of the inherent perils of resource depletion and unsustainable practices. Secondly, this entails severe thrust on the livelihood options of indigenous and marginalized communities, which would again have its toll on development objectives. Community based NRM, therefore invariably throws up conflicting concerns and contradictory interests when it is discussed in relation to development. Striking a balance between these two seemingly disagreeing propositions make any intervention, including the application of ICTs difficult.

The context in which NRM strategies work shall be depicted as given in Fig.1. There are three broad levels of concerns: global, national/state and individual/community. The macro level issues involve climate change, resource depletion and the question of development, which also constitute the major framework for intervention at the lower levels. However, when it comes to the national level, it has implications on capital investment, which is a pre requisite of economic development and is greatly influenced by access to resources. It also involves socio economic disparity which is a function of several factors such as power equations, uneven distribution of resources, ownership of assets etc. Interestingly, this further implies economic prosperity at the grassroots level, which is dependent on access to resources for livelihood options and food security. The contradictory interests that have been mentioned earlier operate within this framework.

Fig.1 Facilitating NRM: Concerns at different levels of intervention



It is in this milieu, intervention for natural resource management is considered to be more of socio- economic and political than technological in nature, particularly in developing economies. Managing resources is rather perceived as a social intervention involving multiple actors and processes. The extensive literature on natural resources and properties of the commons agrees upon the significance of evolving new mechanisms of conservation by involving all possible stakeholders, resolving conflicts and promoting consensus.

Social dimensions of natural resource management has gained importance with the phenomenal contributions of Ellinor Ostrom, who argued for poly centric systems for conservation of natural resources and mitigating the possible threats of climate change[i]. According to her, even while the global policy is frequently posited as the only strategy needed, there could also be several positive actions underway at multiple, smaller scales to start the process of climate change mitigation and needless to say, conservation of natural resources. She emphasizes the need to understand the strength of polycentric systems where enterprises at multiple levels may complement each other. According to her, "Building a global regime is a necessity, but encouraging the emergence of a polycentric system starts the process of reducing greenhouse gas emissions and acts as a spur to international regimes to do their part"

Considering all the above, an ICT programme for sustainable NRM should be robust enough to provide the stakeholders at all levels with the huge information and data, support required to enable realistic resource appraisal, optimal use of resources, efficient project administration, effective monitoring, wider networking and extensive awareness building. Though ICTs can be put to use in every dimension of NRM, designing and implementing a people centric programme require substantial consultation among stakeholders and careful consideration of the multitude of interests they possess.

Employing ICTs for NRM: Possibilities

Employing ICTs for NRM would require an examination of the nature of ICT applications that are currently used in the process. Leaving out the use of ICTs in the form of sophisticated equipments and programmes in research and commercial enterprises, application of these technologies directly at the grassroots level is alarmingly low in developing economies. Though there are several anecdotal references to successful ICT interventions in NRM, there are no comprehensive programmes that address issues of equity and sustainability. Observation by Jhunjhunwala and Aiyar (2006) that 'only a few organisations in India have taken up ICT initiatives in any comprehensive manner and have tried to build services which can be scaled up and have a long-term sustainable impact on the society' remains absolutely true for NRM.

The ways by which ICTs could be employed in NRM shall be summarized as below:

- Collecting data without physically visiting a place. For example, captured data, i.e. recorded digital data from remote sensing satellites or areal photographs would be of immense help in delineating geographical entities and assessing resources

- Interpretation of data captured or collected. Eg. Interpretation of data from remote sensing
- Record text, drawings, photographs, audio, video, process descriptions, and other information in digital formats. For example digitization of maps in different scales
- Creation of databases and information systems by employing Geographical Information System tools
- Transfer of data and information over a network
- Simulation of future scenarios by processing spatial and temporal data, using mathematical models
- Communication of useful information to the general public as well as stakeholders by providing greater interactivity in communicating, evaluating, producing and sharing useful information and knowledge
- Information systems for planning, implementation and monitoring of development interventions
- Databases that could be integrated at various levels
- E- governance applications for increasing efficiency and enhancing transparency of development agencies

Different contexts of NRM would require any one or a mix of several applications listed above. Most of these applications involve collection of data and tools for working with those data made available either in analog form or digital form about a phenomenon in the real world. Choosing the appropriate application demands objective evaluation of the situation, infrastructure facilities, economic feasibility of the technology, capability of the human resources to employ various tools, policy guidelines etc. A comprehensive ICT programme for sustainable NRM may have to integrate several of these applications to suit the situation under consideration. To be more precise, any ICT programme for NRM should primarily identify the intervention that can assist realization of information and communication needs of the community and find out whether there exist any effective linkages among different actors who would require the information. It should also find out how the nature of interactions among the actors affect the quality of information accessed by the beneficiaries of the programme. Most importantly, such initiatives should also be preceded by an objective assessment of the gaps in information.

ICT applications for NRM: A Global Review

Characteristics of an ICT programme for NRM as described earlier would be clearly understood from a review of ICT enabled NRM initiatives reported from different parts of the world. These are location specific or issue specific applications used by various actors, including government agencies, private agencies, NGOs; local governments etc.

Table 1. ICT Programmes for sustainable NRM: A Global Review

Sl No	Name	Agency/Country	Intervention	Major Features
1	Application of ICTs in land surveys and registration systems Participatory 3D mapping in the Philippines	The Philippine Association For Intercultural Development (PAFID) - NGO that assists indigenous communities to regain and secure ancestral domains	Conservation of ancestral domains	Participatory mapping and GIS integration
2	*Global Fire Monitoring Centre (GFMC)*	Joint FAO/UNECE/ILO Committee on Forest Technology, Management and Training	Disseminate core outputs of the Economic Commission for Europe (ECE) in the field of forest fires as well as the periodic online collection and publication of fire statistics of the member states, and online publication of the ECE/FAO Team of	*Providing data to agencies and governments*

Sl No	Name	Agency/Country	Intervention	Major Features
			Specialists on Forest Fire. The fire statistics from all Western and Eastern European Countries are collected and evaluated by the UN-ECE Trade Division, Timber Section, Geneva.	
3	Food Insecurity and Vulnerability Information and Mapping System for Asia (Asia FIVIMS)	FAO	Coordinates efforts to identify the most food insecure and vulnerable populations at sub-national level	*Provide data/information support to countries to formulate targeted policies and programmes to improve the food security and nutritional status of affected population and livelihood groups*
4	Logging Off - Malaysia	The Uma Bawang Residents' Association (UBRA) an indigenous community	UBRA uses participatory tools, such as mapping and modelling to represent land and the associated resources to reinforce	*Mapping by communities* *Maps later digitized for formulating*

Sl No	Name	Agency/Country	Intervention	Major Features
		The Borneo Project, Sahabat Alam Malaysia	bottom-up development and collective decision-making	*community interventions*
5	Hanoi Land Information Management	Canadian International Development Agency – CIDA, the University of Montreal, the City of Montreal and the City of Hanoi	A land information system (LIS) and a parallel training programme in Geographic Information Systems (GIS) for Hanoi, to improve the city's land management and urban planning practices	*Developing geo referenced Information Systems for urban planning* *Transparent access to information*
7	Mekong River Commission, South East Asia	Mekong River Commission,South East Asia	Aims at providing access to information about participatory natural resource management in Cambodia, Laos, Thailand and Vietnam. The platform is intended to contribute to the empowerment and the support of actors working in the region to share their experiences and joint efforts in	*Building information repository and providing access to various stakeholders for formulating action plans to manage river resources* *Facilitates the emergence of regional and*

Sl No	Name	Agency/Country	Intervention	Major Features
			further research and practices	*sector knowledge networks and communities of practice*
8	Environmental Information Circulation and Monitoring System on the internet	ITU (International Telecommunication Union, UNITAR and the Observatory for the Sahel and the Sahara (OSS)	Developing information heritage relating to the environment, improving access to and exchange of environmental information, creating synergies and coordinating environmental operators	*Information System on Desertification (ISD) – Environmental Information Circulation and Monitoring System on the Internet (EISI) in Africa*
9	Thailand Integrated Water Resource Management	Royal Development Projects Board in collaboration with the Suksapattana Foundation, and the Thailand Research Fund (TRF)	Developing an information system on water resources and promoting the linkage of information to improve management in terms of preventive measures and problem solving after disasters. The data is made publicly available or further developed to raise awareness among the people. Reducing	*Computerized information system on water resources* *Awareness creation among people by using the output of the information system*

Sl No	Name	Agency/Country	Intervention	Major Features
			the risks from floods and droughts directly minimizes financial losses	
10	Satellite-based Fishery Vessel Monitoring System in Mauritania	Gtz, Germany and Martime Ministry, Mauritania	Manage the threatened fishery resources in the country's Exclusive Economic Zone (EEZ) in a sustainable manner.	A near real time satellite-based vessel monitoring system on top monitoring vessels, radar surveillance and fishery inspectors
11	UN Water Virtual Learning Centre	Asian Institute of Technology and the University of the South Pacific	*Enhance local, national and basin-scale capacities for sustainable water management in the developing world*	Educational programme with a user friendly interactive curricula Resource databank containing copyright-free materials, public domain images, graphics, documents and databases. Electronically transcribed

Sl No	Name	Agency/Country	Intervention	Major Features
				materials available online and offline
12	Ocean Data and Information Network for the Central Indian Ocean region (ODINCINDIO)	UNESCO	*Enhance marine research, exploitation and development by facilitating the exchange of oceanographic data and information between participating Member States and by meeting the needs of users for data and information products. Member States have established over 60 oceanographic data centres in as many countries* *Collect, control the quality of, and archive millions of ocean observation- physical oceanography, chemical, biological- and makes these available to Member*	ICTs for data management and dissemination Decentralized network of data centres accessible and searchable over the Internet instead of traditional model of centralized data centres at national or global scale Enable easy access to data, data products and information by a wider range of user communities Capacity building through training

Sl No	Name	Agency/Country	Intervention	Major Features
			States	
13	*Fund for Sustainable Biodiversity Management*	Hivos & Partners, Africa	*Contribute to the sustainable management of biodiversity in primary production processes that are accessible and beneficial for small scale producers*	Supports regional and global civil society organizations and networks that promote access to and sustainable use of biodiversity by marginalized sectors of society Database creation, Capacity building and funding
14	*National Animal Tracing Database - Switzerland*	Swiss Confederation of Professional Associations	Website on animal health management commercial transaction	Facilitate the every-day interactions with governmental administration services as well as with other organizations. Up-to date users information for relevant

Sl No	Name	Agency/Country	Intervention	Major Features
				technologies is also posted on a regular. Helps know the history of a particular animal, round the clock through SMS
15	*Internet-Linked Boats for Ecological Awareness - Bangladesh*	*Shidhulai Swanirvar Sangstha (SSS), Commonwealthof Learning*	Reduce pesticide use, improve water quality, and increase incomes in isolated river basin farming communities through distance learning programs on water health and rights provided by Mobile Internet-Educational Unit Boats (MIEUB)	Address the water education needs of a large but commonly neglected population living in the deserted islands during floods and other disasters .
16	*New Zealand Ecological Restoration Network*	NERN (NGO)	Sharing knowledge and experiences about ecological restoration in New Zealand Provide communities with useful information	On line resources on environment preservation and valorization Virtual arboreta (living collections of trees and

Sl No	Name	Agency/Country	Intervention	Major Features
			on resources in the country Conduct awareness programmes by involving the community A web based tool for recording observations and receiving analysis to aid more informed decision making	shrubs in a parkland setting), BirdGuide (including list of bird species found in New Zealand, recording observations by locality as well as historical information about previous bird distribution), Bush Library (referring to books, magazines, articles, maps, downloads, videos, images related subject), Climate & Soil Directories and Land Resource Inventory

Sources: Brandl et al(2002), Gessa (2008), ITU (2012)

ICT strategy for natural resource management: Typology of ICT interventions

A critical look at the global programmes and similar other local level interventions show some distinct components that mark the current ICT interventions for NRM. Though many of them are based on data captured through satellite imagery and remote sensing, there are also interventions at the ground level involving communities. While general prescriptions regarding macro level interventions are possibly available from captured data, it is important to look into the mechanisms by which the stakeholders at the ground level make use of them. Interestingly, ICT programmes for sustainable NRM do not remain techno centric. Rather, the tools and approaches are chosen in response to the specific issues a certain beneficiary community or communities face. The programmes also include components of social action, which should go hand in hand with the technology oriented components. Given below is a typology of ICT interventions elicited from the review done above.

Observation: Monitoring natural resources and their use through satellite and human observation, and generating data archives. This is a key area where satellite technologies, remote sensing applications GIS, mapping , sensor technologies, in situ data collection and data mining are now used regularly. ICT enabled observation has become an integral part of natural resources management and monitoring.

Modeling and simulation: This involves computational, analysis, and processing tools. Satellite and aerial borne data together with in situ and other archived data is used for forecasting trends and /or scenario building to enable well informed decision making. Used in studies on climate change, resource depletion etc

Databases, data products and data services: Generate extensive as well as location specific databases either based on field level primary observations or with community participation. It includes digitization of existing legacy databases or generation of new databases based on transactions. Since database creation incurs heavy cost, sharing databases among the members of a group is becoming popular.

Policy analysis & planning: This category includes Decision Support Systems and alert tools. These together with the above tools are the tools for intelligent decision making. Customized applications that would help organizations and policy makers derive useful conclusions while making decisions fall under this category

Socio-economic analysis: Monetary valuation tools and statistical tools. The impact of use or loss of natural resources is measured through various approaches. This has several applications in the context of benefit sharing related to common property resources and the eco services provided by natural resources.

Capacity building & cooperation: They include a wide variety of off line and online tools for e-learning. Creating active e- forum platforms, centres for data gathering and analysis are possible in every . There is immense possibility to develop innovative content on sustainable NRM for various users. Online and off line training programmes would help organizations, activists, government officials etc to learn the principles and practices of sustainable NRM.

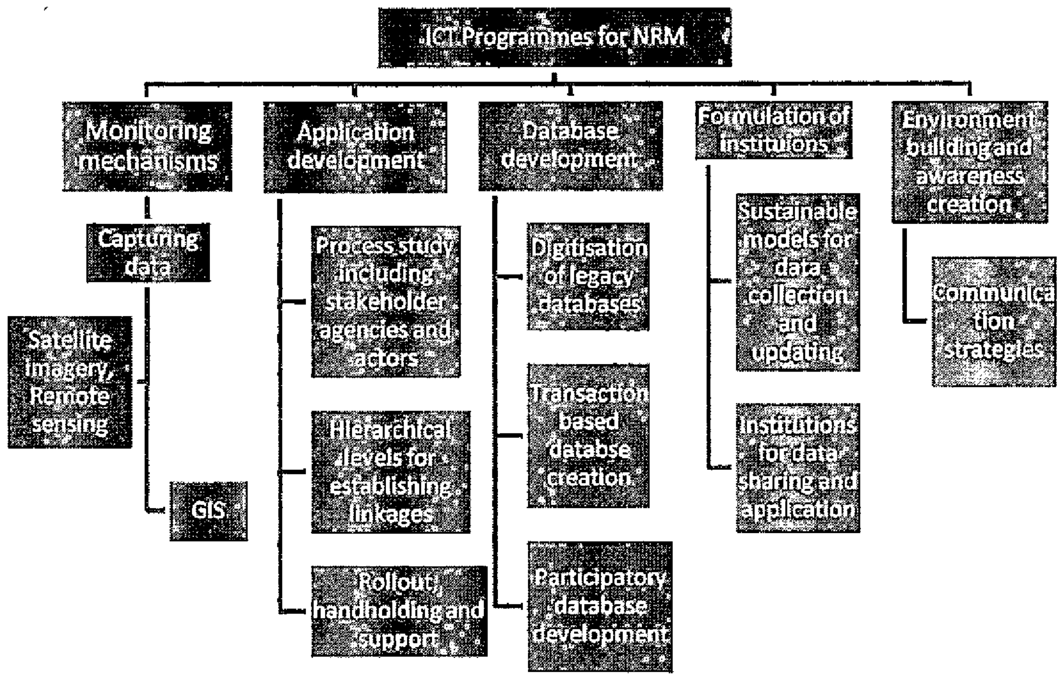
Research and academic networking : This type of intervention is very important in facilitating academic research in the field of NRM, by sharing resources from across academic institutions and research organizations.

Monitoring grassroots level interventions: Community based Management Information Systems for assessing and recording resources and monitoring their use by stakeholders. This could be deployed in local self government institutions and would be helpful in planning conservation programmes.

Awareness building: Most of the applications are designed for the purpose of information sharing and knowledge management in the field of NRM. There are several online as well as offline resources that facilitate awareness building. Content development and management are the prominent activities involved in this type.

As understood from the global experiences reviewed above, the major components of a comprehensive ICT programme for sustainable NRM and their relationships can be delineated and represented as given in Fig.2

Fig.2 Key components of a comprehensive ICT programmes



Based on the components identified, we shall now attempt to list and describe plausible actions required for effective ICT interventions for sustainable NRM.

ICT enabled NRM: Action points for effective intervention

Drawing from the cases above and as under stood from the discussion on the dimensions of sustainable NRM, the key action points of a comprehensive ICT programme to practice and promote sustainable NRM shall be conceived as given below.

1. Enhancing access to information: Mechanisms for easy access to useful information for sustainable growth are limited. In fact, latest information on resources, technology, climate, markets, prices and trends are required by rural communities for scheduling their operations and deciding upon production and marketing strategies. Customised information systems that provide such information would safeguard the communities against the odds of exploitation and depletion of resources. Other than providing content, this implies establishment of community information kiosks on a large scale with consultative functions. An enhanced and multifunctional model of the Village Knowledge Centres established by MSSRF would be able to meet the requirements of rural communities for effective NRM.

2. Online and off line transfer of technology and e- learning: Among various ICTs, the Internet plays the most vital role in the process of technology dissemination. However, this mode of technology transfer is constrained by lack of infrastructure, relevant content in local language and the pedagogical limitation of virtual learning. These constraints should be overcome by devising illustrative multimedia demonstrations of NRM practices as much interactively as possible. Tools for self instruction should be made available at rural kiosks in order to enhance the adoption of sustainable technologies. Interactive multimedia products based on resources, crops, cultural and conservation practices etc could be produced and deployed in large scales, with emphasis on local conditions and issues. Need less to speak, all these products could also be made available online in regional languages.

In addition, existing mechanisms such as call centres, video conferencing, consultation with research and training institutes etc shall be strengthened and scaled up with provisions to deal with specific issues to sustainability instead of conventional querries on package of practices.

Research institutions, voluntary organisation etc shall initiate exclusive courses on sustainable development through their e- learning and distance education centres. Courses on concepts of sustainability and farm level interventions to enhance sustainability can be developed and offered to the public.

3. Grassroots level resource maps and resource data bases: Apart from the huge information systems that are maintained by national organisations, dynamic information systems that can monitor resource utilisation at the grassroots level could be developed. This can be done only by developing comprehensive databases of natural resources on a land parcel basis, with the participation of the people. This is not impractical as several pilot programmes have been successful in making participatory resource databases using GIS tools. For example, resource mapping by the Kerala Sathra Sahithya Parishad and resource maps and other databases developed at Thanalur in Malappuram District by the Information Kerala Mission have been utilised by the concerned local self government institutions for grassroots level planning

4. Updating legacy databases: There are several data bases that are being traditionally used by development agencies. The basic registers of agriculture at the agricultural offices, building register at the local government institutions, cadastral maps, land registers, lists of beneficiaries, etc are all databases that could be put to effective use in planning for sustainable NRM. However, these invaluable data sources are incomplete and are not updated. The recently debated databank on wetlands and paddy fields in Kerala is a classic example of generating natural resource database from existing records for formulating policies and local interventions

Digitisation of legacy databases to make use of the geographic, demographic and socio economic and resource related features of an area effectively could be a major ICT programme for sustainable use of resources. However, as seen from the review of ICT programmes on agriculture, no programme has been found to attempt this humungous task, which is also a pre requisite for robust and reliable planning process at the grassroots level.

5. e-governance for better coordination of development agencies: Better co-ordination among development agencies would result in responsive intervention, which is an important pre requisite for sustainable development. The archaic systems of service delivery of traditional development departments which are also lethargic tend to be counterproductive, in many cases. This would also lead to decision making process without any relevant inputs from related domains. This can be overcome only by comprehensive e- governance applications that could render co ordination and integration among various development departments effective. It is widely reported that e- governance applications that ensure integration among departments are fewer in number (Keniston and Kumar 2008). This is of great relevance in agriculture as well as

NRM as development in this sector requires dynamic integration among various departments and service providers for the farmers to fully benefit from their interventions.

5. ***Information systems:*** Information on sustainable NRM practices, optimisation of inputs, development and use of eco friendly technologies, sources of sustainable technologies, training resources etc can be made available to grassroots level organisations and development departments for wider adoption of sustainable alternatives.

6. ***Decision support systems:*** Local governments at various levels and development agencies can avail decision support systems developed exclusively for using common property resources and drawing up local level plans. This would require integration of various rural databases and development related information. Tools for impact assessment and estimation of eco system services, resource optimisation etc can be employed for grassroots level planning. Access to information on natural resources and dynamic data on climate, land use etc from authorised agencies shall also be integrated with these systems. Decision support systems with a view to facilitate local level planning have not been attempted so far, on an impressive scale.

7. ***Devising ICT enabled participatory tools:*** Instead of centralised mechanism for resource appraisal as done in the case of soil survey, effective ICT enabled participatory tools can be developed and employed to collect data on local level needs and resources. For instance, Akshaya kiosks in villages can be tremendously instrumental in preparing ward level resource maps, problem matrices, databases, local information systems etc that can be further used in development planning. Problems reported by farmers shall also be consolidated and reported to concerned agencies or institutions through this mechanism.

Repositories of local traditional knowledge on crops, cultural practices, adaptation techniques, traditional tools and farming equipments etc shall also be developed locally with facilities to access the information systematically and functionally.

8. ***Organising local groups and ICT enabled capability building:*** Since participation of stakeholders is the most important pre requisite for wider adoption of sustainable NRM practices,

local resource groups of farmers and entrepreneurs have to be organised to facilitate adoption of sustainable practices. Existing farmer collectives shall also be trained on the concepts and issues of sustainability with local relevance. These groups can be imparted ICT enabled training to understand the issues better and to function as animators and change agents for supporting the community to find out sustainable alternate solutions.

As far as research in the field of ICT applications for sustainable natural resource management is concerned, the main research demand would include:

Conclusion

Information support to sustainable NRM is becoming increasingly important consequent to the sweeping transformational changes in the developing economies. Though it is a daunting task, no effort can be spared to pursue it. Considering the global as well as local concerns on sustainable growth, robust mechanisms to devise and implement alternatives to input intensive development should be put in place without any further delay. At the same time, feasibility and profitability of such alternate options also should be seriously considered as the less endowed rural communities the world over are striving to make an existence in the face of rampant globalisation. Any ICT programme with a focus on sustainability should address these two seemingly contradictory concerns. A robust ICT programme therefore should improve the knowledge and wisdom of communities to manage their natural resources scientifically with an eye for a very distant future. It should also facilitate the mundane institutions for resource management that would evolve out of necessity and conviction. Having said this, development of infrastructure as well as relevant content to enhance accessibility deserves prime attention at this point. It should also be accompanied by better co ordination and integration among the change agencies and development departments for sharing information and developing new content. Discrete and solitary efforts in this regard have to be integrated with common objectives and strategies. Capacity building for local governments, line departments, civil society organisations and rural communities also seems to be necessary to drive this objective. Interaction between policy makers and other stakeholders needs to have a new sense of purpose and commitment to bring about innovations in this domain.

Reference

Alex, J. P. (2010) Facilitating Democratic Decentralization in Kerala: An overview of the ICT Solutions for Development Administration through LSGIs, International Conference on 'Reaching out to People, Achieving Millennium Development Goals through Innovative Public Service Delivery'. NAPSIPAG-IMG, Trivandrum, Kerala, 11-13 December, 2010

Brandl, F.E., Preuss, S. and Rock, F.(2002) Watershed Management in the Lower Mekong Basin A Component of the Agriculture, Irrigation and Forestry Programme of the Mekong River Commission, Working Paper 10, MRC-GTZ Cooperation Programme Available at: *http://www.mekonginfo.org/assets/midocs/0002942-inland-waters-watershed-management-in-the-lower-mekong-basin.pdf*

Gessa, S. D. (2008) Participatory Mapping as a Tool for Empowerment: Experiences and Lessons Learned from the ILC Network, International Land Coalition, Italy, 53p.

Hardin, G. (1968) "The Tragedy of the Commons", Science (AAAS) 162 (3859): 1243–1248. doi:10.1126/science.162.3859.1243. PMID 5699198

ITU (2012) ICTs for Sustainable Resource Management, Available at : *http://www.itu.int/ITU-D/ict_stories/themes/resources.html*

Jhunjhunwala and Aiyar (2006) Case Study: Connecting Rural India with Broadband Wireless, *http://www.itu.int/ITU- D/study groups/SGP_2006-010/events/Case_Library_old/asia_pacific/ITU%20India%20Case%20Study%2028%2006%2007.pdf_, accessed 20 July 2012.*

Keniston, K. and Kumar, D. (2003), The Four Digital Divides, Sage Publishers, New Delhi,India

Ostrom, E 2012, Nested externalities and polycentric institutions: must we wait for global solutions to climate change before taking actions at other scales? Economic Theory , February 2012, Volume 49, Issue 2, pp 353-369

Pretty, J. (2002) Agri-Culture: Reconnecting people, Land and Nature. London: Earthscan

_______(2008) Agricultural sustainability: Concepts, Principles and Evidence, *Phil. Trans. R. Soc. B* 363, pp 447-465

Souter, D., MacLean, D., Akoh, B. and Creech, H. (2010) ICTs, the Internet and Sustainable Development: Towards a New Paradigm, International Institute for Sustainable Development (IISD), Canada

Sulaiman, ., V., Kalaivani, N.J., Mittal, N and Ramasundaram P (2011) ICTs and Empowerment of Indian Rural Women, Centre for Research on Innovation and Science Policy, Hyderabad

Sulaiman, R. V., Hall, A., Kalaivani N.J., Dorai, K. and Reddy, V. T. S. (2012): Necessary, But Not Sufficient: Critiquing the Role of Information and Communication Technology in Putting Knowledge into Use, *The Journal of Agricultural Education and Extension*, 18(4) pp 331-346

Tongia, R., Subrahmanian, E. and Arunachalam, V. S. (2005) Information and Communications Technology for Sustainable Development. Defining a Global Research Agenda, Allied Publishers, Bangalore

Intellectual Property Rights in Agriculture

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Introduction

The recognition of agriculture as a rule-bound enterprise of investment and profit making became obvious with its inclusion in the intergovernmental negotiations for the General Agreement on Tariffs and Trade (GATT) for the first time in the Uruguay Round (1986-1994). This round led to the establishment of the World Trade Organization (WTO) in January 1995.

Now, the WTO has at least half a dozen intergovernmental agreements that directly affect agriculture. These are Agreements on Agriculture (AoA), Applications of Sanitary and Phytosanitary Measures (SPS), Technical Barriers to Trade (TBT), Anti-Dumping, Subsidies and Countervailing Measures, Safeguards, and Trade Related Aspects of Intellectual Property Rights (TRIPs). An understanding of the implications and the application of these agreements, particularly the TRIPs, has become more important than ever before at every stage of planning, research, up-scaling and commercialisation of agricultural technologies.

Trade-Related Aspects of Intellectual Property Rights (TRIPS)

The TRIPs Agreement is covered in an elaborate document — comprising 73 articles in 7 parts, namely,

(i) General provisions and basic principles
(ii) Standards concerning availability, scope, and use of IPRs
(iii) Enforcement of IPRs
(iv) Acquisition and maintenance of IPRs and related *inter partes* procedures
(v) Dispute prevention and settlement

(vi) Transitional arrangements

(vii) Institutional arrangements.

TRIPS were negotiated in the 1986-94 Uruguay Round. It introduced intellectual property rules into the multilateral trading system for the first time. Ideas and knowledge are an increasingly important part of trade. Most of the value of new medicines and other high technology products lies in the amount of invention, innovation, research, design and testing involved. Films, music recordings, books, computer software and on-line services are bought and sold because of the information and creativity they contain, not usually because of the plastic, metal or paper used to make them. Many products that used to be traded as low-technology goods or commodities now contain a higher proportion of invention and design in their value — for example branded clothing or new varieties of plants.

Creators can be given the right to prevent others from using their inventions, designs or other creations — and to use that right to negotiate payment in return for others using them. These are "intellectual property rights". They take a number of forms. For example books, paintings and films come under copyright; inventions can be patented; brand names and product logos can be registered as trademarks; and so on. Governments and parliaments have given creators these rights as an incentive to produce ideas that will benefit society as a whole.

The extent of protection and enforcement of these rights varied widely around the world; and as intellectual property became more important in trade, these differences became a source of tension in international economic relations. New internationally-agreed trade rules for intellectual property rights were seen as a way to introduce more order and predictability, and for disputes to be settled more systematically.

The second part of the TRIPS agreement looks at different kinds of intellectual property rights and how to protect them. The purpose is to ensure that adequate standards of protection exist in all member countries. Here the starting point is the obligations of the main international agreements of the World Intellectual Property Organization (WIPO) that already existed before the WTO was created. There are seven forms of intellectual property rights recognised in the TRIPs Agreement. These include, Copyright and related rights, Trademarks including service marks, Geographical Indications, Industrial Designs, Patents, Layout-Designs (topographies) of integrated circuits, and protection of undisclosed information including trade secrets. This agreement also covers provisions related to control of anti-competitive practices in contractual licenses, although, it does not directly relate to IPR.

International Intellectual Property Law

Until recently the multilateral and plurilateral treaties administered by the World Intellectual Property Organization (WIPO) constituted the bulk of the international law on intellectual property. The relevant treaties for IPRs related to agriculture are the Paris Convention on the Protection of Industrial Property, 1883 as revised up to 1967, and related plurilateral treaties which deal with areas such as patents, trademarks, appellations of origin or unfair competition. The Paris Convention established certain minimum agreed standards and procedures for the treatment of industrial property, the most important of which were national treatment i.e. the same treatment for nationals and foreigners and the right of priority or the according of a grace period in the filing of industrial property applications in member states. However, it still left considerable freedom to individual members to tailor their laws according to their developmental and technological requirements.

The Union Internationale pour la Protections des Obtentions Vegetables (UPOV) or the International Union for the Protection of New Varieties of Plants has a multilateral treaty for the protection of new plant varieties which it administers in cooperation with the WIPO. The UPOV Convention facilitates a uniform formulation of the extent and scope of plant breeders' rights. The UPOV Convention was signed in 1961, came into force in 1968 and was revised in 1972, 1978, and 1991. The 1978 version was in force till April 1998, when the 1991 version entered into force. There are at present 38 members of UPOV. The 1991 version substantially enlarges the scope of breeders' rights and restricts farmers' and researchers' exemptions, provides for a longer term of protection for the universe of species/genera of plants, although this can be introduced in a phased way. Very few developing countries have instituted plant variety protection and fewer are members of UPOV. While TRIPS obliges the adherence to the substantive provisions of the Paris Convention, it goes further in limiting the freedom of countries on several aspects of their intellectual property laws. This agreement is a part of the single package of the results of the Uruguay Round that are binding on all members of the WTO and is intrinsically linked to the most important advantage of the multilateral trading system, namely, the Most Favored Nation (MFN) treatment.

TRIPS obliges non discriminatory treatment in terms of national treatment between nationals and others as well as m.f.n. treatment among nationals of all WTO members. TRIPS also lays down stringent standards for the protection and enforcement of intellectual property. The TRIPS Agreement of the WTO obliges members to either provide protection for plant varieties either through patents or through an effective *sui generis* law or through any combination of the two. While TRIPS calls for the institution of an effective *sui generis* system of plant variety protection, there is no reference to UPOV or a call to adhere to any version of it, making it the only exceptional case in TRIPS where the current international treaty on the subject is not referred to. More importantly, TRIPS obliges the patenting of micro-organisms and microbiological and non-biological processes for the production of plants and animals. It, however, presently allows the exclusion from patents of plants and animals and essentially biological processes for their production. Considerable freedom is, however, given in interpreting the criteria for patentability viz. novelty, non-obviousness and industrial applicability. Narrow or narrowly interpreted patent claims can resolve some of the issues arising from broad, blocking patents. It must be noted that TRIPS calls for "strong" process patents, strong in the sense that the rights of the patentee extend to the product made by the patented process and that there is a provision for the reversal of the burden of proof in any infringement proceedings. Such process patents are very similar in effect to product patents. It is yet unclear whether such an extension of rights would imply rights over the product, if where such products are explicitly excluded, as is the case of plants and animals. In other words, would a process patent for a genetically engineered animal extend to the animal itself? The provisions of Article 273 (b) of TRIPS concerning on biotechnological patents are to be reviewed by 1999 when it can be expected that pressure will build up to delete the exclusion for plants and animals. The TRIPS Agreement also ensures a universal, minimum level of protection of commercial marks such as trademarks and geographical indications.

Geographical indications used on wines and spirits are given an absolute level of protection where use, even without the likelihood of deception of the consumers, is prohibited. For the first time in international law, trade secrets have also been accorded the status of IPRs. The TRIPS Agreement goes beyond the provisions of the Paris Convention on unfair competition, explicitly introducing in Section 7, trade secret protection in international law and considerably strengthening it by extending the liability to third parties that induced breach of a trade secret. Under Section 7 protecting undisclosed information in the TRIPS Agreement, test data submitted for obtaining marketing approvals of new pharmaceutical and agricultural chemical products is protected against unfair commercial use. The provisions of this section lend themselves to various interpretations.

Under the TRIPS Agreement, the protection granted for IPRs can be tempered by appropriate provisions in competition law, particularly relating to practices or conditions of licensing of IPRs which have an adverse effect on trade or transfer and dissemination of technology. In addition to international Intellectual property law, the Convention on Biological Diversity (CBD), concluded at 'Rio Earth Summit' in 1992, is an important landmark relevant to a discussion of IPRs and agriculture. The stated objectives of the CBD are the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of benefits. There are two provisions relating to IPRs in the CBD. Much is made of the provision on compulsory access to and transfer of technologies relevant to conservation under 'fair and most favourable terms' given in Article 16 of this treaty. However, with the provision that such access and transfer shall be consistent with the adequate and effective protection of IPRs, there is no cause to imagine that this treaty will force transfer of technology on any terms other than those set commercially in the market. Even the provision to cooperate to ensure that IPRs are supportive of and do not run counter to the objectives of the CBD is subject to international law, which now includes the TRIPS Agreement.

Unfortunately, the fair and equitable sharing of benefits from the commercial use of genetic/biological resources or traditional/indigenous knowledge would remain as a good intention till there are internationally accepted legal instruments to implement these provisions. Material Transfer Agreements (MTAs) are in the nature of bilateral contracts which are to be voluntarily concluded and do not by themselves ensure fairness. There are also as yet no internationally accepted ways to reward what are sometimes called community IPRs or CIRs i.e.

indigenous or traditional knowledge passed down, usually orally, over many generations. Many feel that traditional knowledge should be registered so that it is not incorporated into patents without the knowledge or consent of the concerned communities. Consent would be given only after ensuring fair and equitable sharing of benefits. Others view rural, contemporary innovations as important for progress in agriculture and advocate the institution of new kind of IPRs, like some kind of a global registration system to cover these.

Intellectual Property Rights

Intellectual property rights (IPRs) can be broadly defined as legal rights established over creative or inventive ideas. Such legal rights generally allow right holders to exclude the unauthorized commercial use of their creations/inventions by third persons. The rationale for the establishment of a legal framework on IPRs is that it is a signal to a society that creative and inventive ideas will be rewarded. This does not mean that there is no other way of rewarding such ideas or that this system is absolutely necessary, even less sufficient, to reward inventiveness or creativity. Nevertheless, it would be difficult to deny that IPRs do have a role to play in setting up of any such reward system. There are two broad categories of IPRs: industrial property covering IPRs such as patents, trademarks, geographical indications, industrial designs, copyright and related rights covering artistic and literary works, performances, broadcasts and the like. IPRs that do not fit into this classical division are termed *sui generis*, meaning one-of-its-kind. Such *sui generis* rights include those covering lay-out designs of semi conductor chips and plant breeders' rights. Several of the IPRs mentioned above are relevant to the agricultural sector in that they can be used to protect goods or services produced in the agricultural sector. These are mainly patents, plant breeders' rights, trademarks, geographical indications and trade secrets. It is possible to include lay-out designs for chips that are designed to perform certain functions related to agriculture, but these are assumed to be incorporated in machines produced in the industrial sector. Similarly, scientific papers or television programmes covering ideas related to agriculture are not seen as directly being produced in this sector.

Forms of IPR

Patents

Patents are probably the most important IPR today for agricultural goods and services as they provide, wherever these are available, the strongest protection for patentable plants, animals and biotechnological processes for their production. Patents universally give the patentee the right to prevent third parties from making, using or selling the patented product or process. Patents, however, have to be disclosed to the public through the patent documents. This enables researchers to develop further useful products or services. Patentable products have to meet the criteria of patentability, viz., novelty, i.e. that which is not known in the prior art, non-obviousness i.e. that which involves an inventive step and usefulness i.e. that which is industrially applicable. With some nuanced differences the patent laws of all countries follow these criteria. However, not all countries allow the patenting of plants and animals or even microorganisms or biotechnological processes.

Biotechnology is the sector that holds the most potential for advances in agriculture to improve productivity. Biotechnology R&D is mostly concentrated in the hands of large multinational enterprises in the US, Europe and Japan. It is in this field of technology more than others, where proprietary rights over knowledge are gaining ground at fast rate. Today, in the United States, patents are even granted to animal inventions and human gene sequences, if these are eligible for such protection. The European Union has been slow to follow suit on the patenting of plants and animals due to the opposition it faced from environmental activists in the European Parliament. This has now been largely overcome with the imminent finalization of the new Biotechnology Directive by the European Parliament, authorizing the grant of patents to plants and animals, with limited exceptions. Thus, research on the cloning of animals, which is advancing rapidly, would be eligible for patents in at least some developed countries. Many countries have developed plant breeders' rights to reward conventional plant breeding efforts. Such *sui generis* protection is weaker than patent protection in that the right holders can only prevent third parties from commercially exploiting the protected material. The criteria used to grant such protection are also lower than that used to determine patentability as these are distinctness, i.e. distinguishable from earlier known varieties, uniformity i.e. display of the same essential characteristics in every plant and stability i.e. the retention of the essential characteristics on reproduction. Such protection encourages breeding efforts in the private sector. Historically, in developing countries, such efforts have emanated from the public sector or from international research institutions. It is only in recent years that developing countries have begun to institute such protection.

Geographical Indications

One category of commercial marks more often used in agriculture than industry is geographical indications, including appellations of origin. These are marks associated with products originating from a country, region or locality where the quality, reputation or other characteristics of the product are essentially attributable to its geographical origin. Most geographical indications relate to agricultural products or those derived from them, as in the case of wines and spirits. Protection of such marks prevents third parties from passing off (to pretend that something is different from what it really is) their products as those originating in the given region. Famous examples are 'Champagne' for sparkling wine and 'Roquefort' for cheese from France or 'Darjeeling' for tea from India. It is not necessary for these indications to be in geographical names as in the case of 'Feta'for cheese from Greece or 'Basmati' for rice from India and Pakistan as there are no places, localities or regions with these names. Plant varieties developed with traditional knowledge and associated with a particular region can also be protected as geographical indications. The advantage in such protection is that it is not time-limited, unlike the case of plant patents or plant breeders' rights. However, needless to say, commercial benefits can be derived from the protection of geographical indications only when the name becomes reasonably famous.

Copyrights and Related Rights

Copyright is a legal term describing rights given to creators for their literary and artistic works. The kinds of works covered by copyright include: literary works such as novels, poems, plays, reference works, newspapers and computer programs; databases; films, musical compositions, and choreography; artistic works such as paintings, drawings, photographs and sculpture; architecture; and advertisements, maps and technical drawings. Copyright subsists in a work by virtue of creation; hence it's not mandatory to register. However, registering a copyright provides evidence that copyright subsists in the work & creator is the owner of the work.

Creators often sell the rights to their works to individuals or companies best able to market the works in return for payment. These payments are often made dependent on the actual use of the work, and are then referred to as royalties. These economic rights have a time limit, (other than photographs) is for life of author plus sixty years after creator's death.

Trade Marks

A trademark is a distinctive sign that identifies certain goods or services as those produced or provided by a specific person or enterprise. It may be one or a combination of words, letters, and numerals. They may consist of drawings, symbols, three dimensional signs such as the shape and packaging of goods, audible signs such as music or vocal sounds, fragrances, or colours used as distinguishing features. It provides protection to the owner of the mark by ensuring the exclusive right to use it to identify goods or services, or to authorize another to use it in return for payment. It helps consumers identify and purchase a product or service because its nature and quality, indicated by its unique trademark, meets their needs. Registration of trademark is prima facie proof of its ownership giving statutory right to the proprietor. Trademark rights may be held in perpetuity. The initial term of registration is for 10 years; thereafter it may be renewed from time to time.

Industrial Designs

Industrial designs refer to creative activity, which result in the ornamental or formal appearance of a product and design right refers to a novel or original design that is accorded to the proprietor of a validly registered design. Industrial designs are an element of intellectual property. Under the TRIPS Agreement, minimum standards of protection of industrial designs have been provided for. As a developing country, India has already amended its national legislation to provide for these minimal standards.

The essential purpose of design law it to promote and protect the design element of industrial production. It is also intended to promote innovative activity in the field of industries. The existing legislation on industrial designs in India is contained in the New Designs Act, 2000 and this Act will serve its purpose well in the rapid changes in technology and international developments. India has also achieved a mature status in the field of industrial designs and in view of globalization of the economy, the present legislation is aligned with the changed technical and commercial scenario and made to conform to international trends in design administration. This replacement Act is also aimed to enact a more detailed classification of design to conform to the international system and to take care of the proliferation of design related activities in various fields.

Lay Out Design of Integrated Circuits

Semiconductor Integrated Circuit means a product having transistors and other circuitry elements, which are inseparably formed on a semiconductor material or an insulating material or inside the semiconductor material and designed to perform an electronic circuitry function. The aim of the Semiconductor Integrated Circuits Layout-Design Act 2000 is to provide protection of Intellectual Property Right (IPR) in the area of Semiconductor Integrated Circuit Layout Designs and for matters connected therewith or incidental thereto. The main focus of SICLD Act is to provide for routes and mechanism for protection of IPR in Chip Layout Designs created and matters related to it. The SICLD Act empowers the registered proprietor of the layout-design an inherent right to use the layout-design, commercially exploit it and obtain relief in respect of any infringement. The initial term of registration is for 10 years; thereafter it may be renewed from time to time. Department of Information Technology Ministry of Communications and Information Technology is the administrative ministry looking after its registration and other matters.

Trade Secrets

It may be confidential business information that provides an enterprise a competitive edge may be considered a trade secret. Usually these are manufacturing or industrial secrets and commercial secrets. These include sales methods, distribution methods, consumer profiles, and advertising strategies, lists of suppliers and clients and manufacturing processes. Contrary to patents, trade secrets are protected without registration. A trade secret can be protected for an unlimited period of time but a substantial element of secrecy must exist, so that, except by the use of improper means, there would be difficulty in acquiring the information. Considering the vast availability of traditional knowledge in the country the protection under this will be very crucial in reaping benefits from such type of knowledge. The Trades secret, traditional knowledge are also interlinked/associated with the geographical indications.

Trade secret protection can be used by the agricultural sector to protect, for instance, hybrid plant varieties. Thus, even in countries that do not recognize plant breeders' rights, the use of hybrids gives a certain degree of appropriability as long as it can be kept secret. Trade secrets can be protected against third party misappropriation through laws relating to unfair competition or to restrictive trade practices or to contract law. In the United States there are separate trade secret laws at the State level. Protection of trade secrets is not limited in time but, unlike patents, the disadvantage of this type of protection is that it is lost the moment it is discovered independently by a third party. The advantage, at least to the proprietor, is that, unlike patents, there is no obligation to disclose the inventive or creative ideas to society.

Global and National Scope of IPR

Broadly, protection of all forms of IPR may be relevant in agriculture but its application has to be limited to the relevant domestic Acts in vogue. Hybrids in plants and animals may be protected *de facto* by not disclosing the parents, whereas protection for plant varieties may be availed by a *sui generis* system. The provision for Plant Variety Protection (PVP) made under the TRIPs Article 27.3(b), allows countries to provide such protection either through patent, or an effective *sui generis* PVP system or any combination of the two.

Patents, in India, are so far available to new processes but not to all products *per se*. In agriculture, patents may be obtained for processes related to agrochemicals, growth promoters and regulators, vaccines, drugs, hides and wool, dairy technology, food technology, fuel and biogas production, bioreactors, standardisation of various laboratory protocols, environment management, etc. Copyrights and related rights, on the other hand, may be registered for databases, bioinformatics, genes and gene sequences, amino acid sequences, antibodies, etc. Application of industrial designs and the topographies of integrated circuits would be relevant, particularly in agricultural engineering.

Nevertheless, in the days to come, IPR is likely to dominate the agricultural scenario irrespective of whether the technology in question is conventional or modern—biotechnology or information technology. Countries are required to enact/amend their domestic laws in accordance with the TRIPs Agreement and the between-country disputes have to be resolved at the WTO platform, according to its dispute settlement procedures. In this context, it is important to have in place well enacted laws corresponding to the different forms of IPR that do not only keep in view the basic needs of the country but are also capable of tackling complexities, which might arise at the international level. In India, the Patents Act, 1970, constituted the basic Principal Act on the subject. This Act hardly included innovations in agriculture under the patentable subject matter. In particular, it excluded methods of agriculture and horticulture as well as all innovations in the areas of treatment, protection of plants and animals from pestilence or those aimed at increasing their productivity and value of their produce. This broad exclusion had historical impact and implications in respect of IPR protection in agriculture in the country.

India is bound by all the provisions of TRIPs Agreement, which oblige the country to enact/amend relevant domestic laws. Further, with such shifts in legal provisions and also national policies, increased private participation in agricultural R&D and far more public private relationships, including both competition and cooperation in relevant areas, are imminent. Several legislative and institutional adjustments are being made in the country to gear up and face the challenges of globalisation. These include enactment of new legislations on Protection of Plant Varieties and Farmers' Rights Act, 2001 and Geographical Indications of Goods (Registration and Protection) Act, 1999, and amendment of Patents Act, 1970 in 1999 and 2002. The Biological Diversity Bill, 2000 is in the process of enactment and revision of the Seeds Act, 1966. The need to provide for protection in the areas specific to farm animal sector is also being realised.

Conclusions and Policy Implications

Recognizing the inherently complex nature of institutional development, prime consideration should be given to genuine requirement of resources and building an enabling environment to capitalize on the strengths. Opportunity for IPR protection in agriculture and allied sectors should be improved along with mechanisms for enforcement, access to resources and technology, benefit sharing, equity and justice in order to give durable effect to the national agricultural policy and the inherent basic principles of our constitution. A long lasting national commitment should be made in respect of effective institutional mechanisms and reforms, including the administrative, regulatory, legislative and judicial reforms at all levels of government functioning. Short and medium fiscal term plans must include elements of these reforms by providing resources to help meet the costs of adjustment. Resources should be tied to commitments by successive central and state governments with much needed incentive to innovators commensurate with the invention.

It is important to understand that developed economies are likely to benefit greatly from an organised IPR system due to their inherent capabilities to capitalise on such opportunities. Realisation of the gains, principles of equity and the need for a level-playing field is a real challenge. Nevertheless, in keeping with the spirit of the intergovernmental agreements, application of IPR and also maintenance of equity and social justice must be effectively addressed at the national level. Enhanced competitiveness together with increased production should be the target for various agricultural commodities having export prospects. These include high value commercial crops, animal breeds, spices, medicinal and aromatic plants, and products like milk, meat, fish, leather and wool. Reduction in the cost of production at small farms should also be aimed at so that Indian exports become more competitive. Market-driven quality consciousness should be applied to lay far greater R&D emphasis and efforts to produce quality products that may fetch increased monetary returns per unit area, input and time.

The classical IPRs relevant to agriculture are patents, particularly on biotechnological inventions, plant breeders' rights, trademarks and geographical indications. Trade secrets and the protection of undisclosed test data are considered to be part of IPRs and these are relevant to the agricultural sector also. Farmers' rights and community IPRs are the forms of intellectual property in the stage of initial conceptualisation at the international or national level. In days to come, when application of various forms of IPR in different areas of agriculture is put into practice, we may face serious problems unless timely remedial measures are taken, awareness campaign are made and also due emphasis is given on IPR literacy, higher education and capacity building in the country. Following establishment of the international institutional mechanisms, such as, the Convention on Biological Diversity (CBD) and the WTO, and further, signing of International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), the growing importance and the global scope of IPR in agriculture are well realised and recognised. The IPR, after long debate, is recognised as an asset and means of rewarding and harvesting the fruit of agricultural research and development. Recognition of intellectual property rights provides an effective means of protecting and rewarding innovators. This acts as a catalyst for technological and economic development. The essence of regulation of IPR by law is to balance private and public interests. At the same time, equitable benefit sharing is, although, agreed upon under the CBD, is yet to be realised in effective terms.

Effective implementation of IPR related legislations in place and those in the offing is expected to have significant impact on the course of agricultural R&D in the country. Therefore, it is considered important to identify and develop various national policy options for addressing the emerging areas of IPR in agriculture, including the access to various protected technologies to the Indian farmers, entrepreneurs and users. It is high time that a critical analysis of the system is undertaken for its strengths, weaknesses, opportunities and threats (SWOT), to convert threats into opportunities and mitigate weaknesses through timely action.

References

A. Ravi Shankar. (1996). Intellectual Property Right and Indian Agriculture :
NCAP Policy Brief , National Council for Agricultural Economics and Policy Research, New Delhi .

Jayashree Watal (1998). Intellectual property rights in Indian Agriculture
Indian Council for Research on International Economic Relations: Working Paper No.44 New Dlehi-110 003

National Academy of Agricultural Sciences, (2003), Intellectual Property Rights in Agriculture Policy Paper 19, National Academy of Agricultural Sciences, India

Science of Carbon Sequestration and Carbon Sequestration in Agriculture

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The Carbon cycle:

About half the dry weight of most living organisms is carbon. Living biomass holds between 600 and 1,000 gigatons of C, while about 1,200 gigatons of carbon are stored in the terrestrial biosphere as dead biomass. The carbon cycle is the biogeochemical cycle by which carbon is exchanged among the biosphere, pedosphere, geosphere, hydrosphere, and atmosphere of the earth. The global carbon cycle is usually divided into the following major reservoirs of carbon interconnected by pathways of exchange:

1. The atmosphere
2. The terrestrial biosphere
3. The oceans, including dissolved inorganic carbon and living and non-living marine biota
4. The sediments, including fossil fuels, fresh water systems and non-living organic material, such as soil carbon
5. The Earth's interior, carbon from the Earth's mantle and crust. These carbon stores interact with the other components through geological processes

The carbon exchanges between reservoirs occur as the result of various chemical, physical, geological, and biological processes. The ocean contains the largest active pool of carbon near the surface of the Earth. The natural flows of carbon between the atmosphere, ocean and sediments are fairly balanced, so that carbon levels would be roughly stable without human influence.

Carbon pools in the major reservoirs on earth.	
Pool	**Quantity (gigatons)**
Atmosphere	720
Oceans (total)	38,400
Lithosphere	
Sedimentary carbonates	> 60,000,000
Kerogens	15,000,000
Terrestrial biosphere	2,000
Aquatic biosphere	1 - 2
Fossil fuels	4,130

Most of the earth's carbon is stored inertly in the earth's lithosphere. Much of the carbon stored in the earth's mantle was stored there when the earth formed. Some of it was deposited in the form of organic carbon from the biosphere. Of the carbon stored in the geosphere, about 80% is limestone and its derivatives, which form from the sedimentation of calcium carbonate stored in the shells of marine organisms. The remaining 20% is stored as kerogens formed through the sedimentation and burial of terrestrial organisms under high heat and pressure. Organic carbon stored in the geosphere can remain there for millions of years. Carbon can leave the geosphere in several ways. This CO_2can be released into the atmosphere and ocean through volcanoes and hotspots. It can also be removed by humans through the direct extraction of kerogens in the form of fossil fuels. After extraction, fossil fuels are burned to release CO_2into the atmosphere.

Carbon in the earth's atmosphere exists in two main forms: CO_2 and CH_4. Both of these gases absorb and retain heat in the atmosphere and are partially responsible for the greenhouse effect. Methane produces a large greenhouse effect per volume as compared to CO_2, but it exists in much lower concentrations and is more short-lived, making CO_2 the more important greenhouse gas of the two. Carbon dioxide leaves the atmosphere through photosynthesis, thus entering the terrestrial and oceanic biospheres. CO_2 also dissolves directly from the atmosphere into bodies of water, as well as dissolving in precipitation as raindrops fall through the atmosphere. When dissolved in water, CO_2 reacts with water molecules and forms carbonic acid, which contributes to ocean acidity. It can then be absorbed by rocks through weathering. It also can acidify other surfaces it touches or be washed into the ocean.

The terrestrial biosphere includes the organic carbon in all land-living organisms, both alive and dead, as well as carbon stored in soils. About 500 gigatons of carbon are stored above ground in plants and other living organisms, while soil holds approximately 1,500 gigatons of carbon. Most carbon in the terrestrial biosphere is organic carbon, while about a third of soil carbon is stored in inorganic forms, such as $CaCO_3$. Organic carbon is a major component of all organisms living on earth. Autotrophs extract CO_2 from the air converting it into organic carbon, while heterotrophs receive carbon by consuming other organisms. Carbon leaves the terrestrial biosphere in several ways and on different time scales. The combustion or respiration of organic carbon releases it rapidly into the atmosphere. It can also be exported into the oceans through rivers or remain sequestered in soils in the form of inert carbon. Carbon stored in soil can remain there for up to thousands of years before being washed into rivers by erosion or released into the atmosphere through soil respiration. The length of carbon sequestering in soil is dependent on local climatic conditions and thus changes in the course of climate change.

Oceans contain the greatest quantity of actively *cycled carbon* in the world and are second only to the lithosphere in the amount of carbon they store. The oceans' surface layer holds large amounts of dissolved organic carbon that is exchanged rapidly with the atmosphere. Carbon enters the ocean mainly through the dissolution of atmospheric CO_2, which is converted into carbonate. It can also enter the oceans through rivers as dissolved organic carbon. It is converted by organisms into organic carbon through photosynthesis and can either be exchanged throughout the food chain or precipitated into the ocean's deeper, more carbon rich layers as dead soft tissue or in shells as $CaCO_3$. It circulates in this layer for long periods of time before either being deposited as sediment or, eventually, returned to the surface waters. Oceanic absorption of CO_2 is one of the most important forms of carbon sequestering limiting the human-caused rise of CO_2in the atmosphere. However, this process is limited by a number of factors.

Human activities have changed carbon pools by significantly increasing the amount of carbon in the atmosphere, mainly in the form of CO_2, both by modifying ecosystems' ability to extract CO_2 from the atmosphere and by emitting it directly, e.g. by burning fossil fuels and converting forests.

Carbon sequestration: the concept and context

There has been a drastic increase in the atmospheric concentration of CO_2 and other greenhouse gases (GHGs) since the industrial revolution. The major reason for increase has been the burning of fossil fuels and large scale deforestation. Atmospheric CO_2 concentration increased at the rate of 0.05-0.1 ppm yr^{-1} during 1750-1850, and then at the rate of 0.5 ppm yr^{-1} till 1950 and currently at the rate of 1.8 ppm yr^{-1}. During this period the concentration increased from 280 ppm in 1750 to reach over 391 ppm in September 2012. At the present level, it may increase to >425 ppm by the year 2025 if the world continues to do "business as usual". Anthropogenic enrichment of GHGs in the atmosphere and the cumulative radioactive forcing of all GHGs have led to an increase in the average global surface temperature. Since the early 20th century, Earth's mean surface temperature has increased by about 0.8 °C, with about two-thirds of the increase occurring since 1980. Climate model projections were summarized in the 2007 Fourth Assessment Report (AR4) by the Intergovernmental Panel on Climate Change (IPCC) indicates that during the 21st century the global surface temperature is likely to rise a further 1.1 to 2.9 °C for their lowest emissions scenario and 2.4 to 6.4 °C for their highest. However, climate change is a hotly debated term: in spite of the evidence that the earth's surface temperature has risen globally, there is a raging controversy about the extent to which this rise is caused by anthropogenic reasons.

Future climate change and associated impacts is expected to vary from region to region around the globe. The effects of an increase in global temperature include a rise in sea levels and a change in the amount and pattern of precipitation and increased pace of desertification in sub tropical areas. Warming is expected to be strongest in the Arctic. Other likely effects of the warming include more frequent extreme weather events including heat waves, droughts and heavy rainfall; ocean acidification; and species extinctions due to shifting temperature regimes.

Effects significant to humans include the threat to food security from decreasing crop yields and the loss of habitat from inundation.

Policy responses to global warming include ***adaptation*** to its effects and ***mitigation*** by emissions reduction. *Adaptation* attempts to tackle effects of climate change. Adaptation is defined as "the adjustment in natural or human systems to a new or changing environment". Climate change adaptation aims at developing strategies to reduce the negative impacts. Major adaptation strategies are: enhancing the soil's resilience by increasing soil organic carbon (SOC), adopting efficient land-use systems, and improving the net primary productivity. The goal of climate-change *mitigation* is to reduce net emissions of GHGs and address the causes of climate change, The IPCC defines mitigation as "an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases". Efforts to mitigate the greenhouse gas problem have traditionally focused on abating CO_2 production by reducing fossil fuel use or switching to less CO_2 intense fossil fuels (typically referred to as "*CO_2 abatement*"). CO_2 abatement, however, requires sizable investments and has to overcome considerable socio-economic inertia. One alternative to CO_2 abatement is CO_2 capture and storage referred to as "*CO_2 sequestration*"). Carbon sequestration involves the net removal of CO_2 from atmosphere and storage in long-lived pools of C. Such pools include the aboveground plant biomass; belowground biomass such as roots, soil microorganisms, and the relatively stable forms of organic and inorganic C in soils and deeper subsurface environments, and the durable products derived from biomass (e.g., timber).

Although C sequestration has been a hot topic of research and discussions during the past two decades, considerable variations exist among different user groups about the concept, so that the term is not used or understood uniformly. The United Nations Framework Convention on Climate Change (UNFCCC) defines carbon sequestration as the process of removing C from the atmosphere and depositing it in a reservoir. It entails the transfer of atmospheric CO_2, and its secure storage in long-lived pools. Sequestration of atmospheric CO_2 in long-lived pools could reduce CO_2 concentration in the atmosphere and thereby the GHG-induced global warming. The role of soil organic matter (carbon) in maintaining soil fertility and soil qualities to support plant production in cultivated soils is an important byproduct of C sequestration. Hence, enhancing C storage in soils—which is the main mechanism for C sequestration in terrestrial ecosystems has become desirable goal.

Carbon dynamics in agricultural systems

Agriculture activity is a major determinant of the terrestrial carbon cycle. Carbon dioxide emissions from agricultural systems occur from: (a) plant respiration; (b) the oxidation of organic carbon in soils and crop residues; (c) the use of fossil fuels in agricultural machinery such as tractors, harvesters and irrigation equipment; and (d) the use of fossil fuels in the production of agricultural inputs such as fertilizers and pesticides. Using estimates from 2005, 2007 and 2008, the researchers found that agricultural production releases up to 12,000 megatonnes of CO_2 equivalent a year — up to 86% of all food-related anthropogenic greenhouse-gas emissions. It is followed by fertilizer manufacture, which releases up to 575 megatonnes, the researchers found that the whole food system released 9,800–16,900 megatonnes of equivalent into the atmosphere in 2008, including indirect emissions from deforestation and land-use changes.

Agricultural soils are among the planet's largest reservoirs of carbon and hold potential for expanded carbon sequestration. It is estimated that the global stock of soil organic C is in the range 684–724 Pg to a depth of 30 cm and 1462–1548 Pg to a depth of l m. Thus the quantity of organic carbon in the 0–30 cm layer is about twice the amount of C in atmosphere and three times that in global above-ground vegetation. It was estimated in the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) that the annual release of CO_2 from deforestation (coming from both vegetation and soil) is currently some 25% of that from fossil fuel burning. Decreasing carbon stocks in the biosphere, including agricultural soils, have historically been a net source of CO_2 emissions to the atmosphere, but this process is amenable to reversal and net carbon flows from the atmosphere to the biosphere are feasible. Carbon sequestration in agriculture involves primarily the uptake of atmospheric CO_2 during photosynthesis and transfer of fixed C into vegetation, detritus, and soil pools for "secure" storage. It occurs in two major segments of agriculture: aboveground and belowground. Each can be partitioned into sub-segments: the former into specific plant parts (stem, leaves, etc. of plants), and the latter into living biomass such as roots and other belowground plant parts, soil organisms and C stored in various soil horizons. Overall, the land-use systems can be ranked in terms of their soil organic carbon content in the order: forests >agroforests> tree plantations > arable crops. Understandably, the large differences among the land-use systems are a reflection of the biophysical and socio-economic characteristics of the system parameters like the region, the type of system (and the nature of components and age of perennials such as trees), site quality, previous land-use etc. Accumulation of organic carbon in soil can occur following changes in management that either increase the production of residue remaining on the field or decrease the loss of organic carbon in the form of CO_2. Humification (conversion of biomass into humus), aggregation (fonnation of organo-mineral complexes as secondary particles), translocation of biomass into subsoil by deep roots, and leaching of soil inorganic C into groundwater as bicarbonates are the processes that lead to C sequestration in agricultural lands.

It has been established that, cultivation generally causes a decline in both C and N storage in soils as it alters C inputs and losses from its natural cycles. In terms of inputs, arid or low-nutrient landscapes, after being irrigated and fertilized, may experience large increases in C inputs than normal. In systems where much crop residue is removed for various uses (or the surface residue is burned off), C inputs may be much lower than the natural rates. In terms of C loss rates, tillage of the soil almost universally increases rates of organic-matter decomposition leading to rapid and pronounced declines in C storage. There are several reasons for this increase. First, tillage produces a disturbed soil structure that may have persisted for long periods. This exposes organic matter that was unavailable for decomposition for thousands of years. Second, soil temperature may increase in cultivated land because dark soil, with its low albedo, is exposed to the sun and absorbs solar energy. This warming stimulates microbial activity. There are cultivation practices that reduce rates of decomposition too. Conversion of floodplains or other areas to flooded rice agriculture (which lowers the O_2 content of the soil) is an example of an agricultural practice that is more effective in retaining and increasing soil C storage.

There have been several major regional or global-scale studies of the effect of cultivation on soil C storage. Some general conclusions from these studies suggest the following hypotheses:

1. Soils initially low in C (typically on hot, dry sites) commonly gain C upon cultivation. The combined increased C inputs (e.g. from irrigation and N fertilization) and possible decreases in decomposition (e.g. from rice cultivation) combine to yield small but measurable increases in C storage.
2. Averaged globally, cultivation reduces the original soil C content by ~30%. This average estimate ignores the likely variability in soil C response to agriculture, but it provides a rough estimate of assessing the effects of global agriculture. Using this value, an estimate of the total soil C lost by cultivation can be easily made based on the global cultivated-land area ($21.2 \times 10^{12}\ m^2$) and its total C storage (167.5 Gt per C). The result of this calculation indicates that agriculture has released ~70 Gt of C to the atmosphere.
3. The rate of C loss is a function of climate. Cultivation studies along gradients of climate have revealed that the rate of C loss increases with increasing temperature and precipitation. Because the essential plant nutrients N and, to a lesser extent, P are part of soil organic matter, the temperature dependence of C loss explains the observation that economically viable agriculture, in the absence of N fertilization, can occur for decades in northern latitudes, whereas it can be carried on for only a few years in tropics. It indicates that soils in some regions might be more potent atmospheric CO_2 sources, if converted to agriculture, than would soils in other regions. Second, the long-term C sequestration potential of agricultural soils restored to natural flora may vary regionally, and some soils may have a more important long-term sequestration potential than previously thought.
4. Following a change in agricultural management practices, soil organic carbon will gradually approach a new steady state that depends on the new set of practices. Empirical observations of sites cultivated for different periods of time suggest that the approach to a new steady state is rapid at times because cultivation enhances the decomposition of a fairly labile pool of soil organic carbon, which is exhausted at rates that vary with temperature.
5. Carbon sequestration proceeds slow in abandoned land due to low N levels. Long-term agricultural lands, in addition to having lost significant amounts of C as CO_2, commonly lose proportionally equivalent amounts of N owing to crop removal and N leaching or gaseous losses. Thus, from an ecological perspective, abandoned lands are N limited and

must gain N through atmospheric N deposition (or biological N fixation) to sequester additional units of C.

6. Data suggest that fractional loss of C as a result of cultivation is influenced by initial C content. C loss in soil increases with increasing C content. Management options for sequestering soil organic carbon include a decrease in tillage intensity, a change from continuous to rotation cropping, and a decrease in fallow period.

A variety of land-management practices are recommended for increasing the agricultural land carbon soil stock. Some of these practices would increase the amount of carbon stored, either above and/or below ground, while others would decrease the loss of carbon from the biosphere.

1. Reduced tillage
2. Restoration of degraded lands
3. Retirement of agricultural lands into permanent grass cover,
4. Increased forested area with conversion of land from agricultural uses
5. Management of residues in agricultural harvests.
6. Longer rotation for forest trees

Agriculture response agenda to Kyoto protocol

Agriculture can respond to a greenhouse gas emission reduction target of Kyoto protocol in a number of ways. In particular, there are at least five ways in which agriculture might be affected by greenhouse gas mitigation efforts and emission trading markets:

1. Agriculture contributes to emissions of greenhouse gases to the atmosphere by releasing substantial amounts of CH_4, N_2O and CO_2. Consequently, agriculture may need to reduce emissions and there may be cost effective options involving actions such as reducing fertilizer use, altering livestock feeding, reducing rice acreage, etc.
2. Agriculture provides a potential means for mitigating emissions by offering opportunities for enhancing carbon sinks.
3. Agriculture may be able to produce biofuels as an alternative source of fuel to displace fossil fuel combustion.

4. Agriculture may find itself operating under policies designed to reduce global greenhouse gas emissions and that influence agricultural input and output prices.
5. Products from the forest sector compete in the market with other, often more energy-intensive, products like concrete, glass, and steel. Policies inspired by the Kyoto Protocol may change the demand for such products.

The Land Use, Land Use Change and Forestry (LULUCF), an approach that became popular in the context of the Kyoto Protocol to the UNFCCC allows the use of C sequestration through afforestation and reforestation as a form of GHG-offset activities (Article 3.3) and prescribes debits for deforestation. Forest-, crop-, and grazing-land management, and revegetation were added to the detailed list of LULUCF activities in 2001. Agricultural soils are treated in Article 3.4 but only as a possible item for future inclusion. Specifically, the Protocol states that the Conference of the Parties will "decide upon modalities, rules and guidelines as to how, and which, additional human-induced activities related to changes in greenhouse gas emissions by sources and removals by sinks in the agricultural soils and the land-use change and forestry categories shall be added to, or subtracted from, the assigned amounts ...". Simply stated, sequestration in agricultural soils is not now permitted to produce carbon sequestration credits under the Kyoto Protocol, but the door is left open for its addition.

Further reading

Amundson, R.2001. The carbon budget in soils. Annu. Rev. Earth Planet. Sci. 2001. 29:535–62

Baker, J.M., Ochsner, T.E., Venterea , R.T. and Griffis, T.J. 2007. Tillage and soil carbon sequestration— What do we really know? Agriculture, Ecosystems and Environment 118: 1–5

IPCC. 2000. Special report on land use, land-use change and forestry. Cambridge, UK: Cambridge University Press.

IPCC. 2001. Climate change 2001: the scientific basis. Contribution of working group I to the third assessment report of the intergovernmental panel on climate change. Cambridge, UK:Cambridge University Press.

IPCC. 2003. Good practice guidelines for greenhouse gas inventories for land-use, land-use change & forestry. Kanagawa, Japan: Institute of Global Environmental Strategies (IGES).

Keller, K., McInerney, D and Bradford, D.F. 2008. Carbon dioxide sequestration: how much and when? Climatic Change (2008) 88:267–291

Lal, R. 2007. Carbon Sequestration. *Philosophical Transaction of the Royal Society* (U.K.), 363 (1492),: 815-830.

Lal, R. 2004. Soil carbon sequestration in India. Clim. Change 65, 277–296

Marland, G., West, T.O., Schlamadinger, B. and Canella, L.2003. Managing soil organic carbon in agriculture: the neteffect on greenhouse gas emissions *Tellus (2003), 55B, 613–621*

Paustian, K., J.M. Antle, J. Sheehan, and E.A. Paul. 2006. Agriculture's Role in Greenhouse Gas Mitigation. Arlington, VA: Pew Center on Global Climate Change. 76 pp

Powlson, D.S., Whitmore, A.P. and Goulding, K.W.T. 2011. Soil carbon sequestration to mitigate climate change: a critical re-examination to identify the true and the false. *European Journal of Soil Science*, , 62, 42–55

Natural Resource Management & the Law – an Introductory Overview

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I. Introduction

It is often said that there is no environmental law but there are environmental laws. By this it is meant that there is no single law that covers every aspect of environmental protection or management. Thus the expression "environmental law" might at times appear to be a misnomer. The complexity of this branch of law is exacerbated by the numerous legislative Acts, administrative authorities and legal machinery that administer this branch of law. However, there are a few legal principles that touch environment and often principles of law that were not immediately connected to or concerned with the environment has been used by courts to deal with environmental issues. Detailing every aspect of these numerous laws and legal principles lie beyond the scope of this paper and it is left best to the writers of thick text books. The purpose of this paper is only to give an insight into the nature of legal regulation of the natural resources and discuss a few applicable principles. To this end, the paper deals with the following: (1) How does law view environment, environmental protection and the relation between man and environment; (2) Some of the principles involved in protection and use of natural resources; (3) The legal remedies and avenues for enforcing environmental laws. For the more inquisitive reader, the references and the list for further reading provided at the end of this paper can be good starting points.

III.Environment, Man& The Law

The constitution of India, as originally enacted did not contain the expression "environment" and environmental protection received scant attention from the courts and in legal circles. It was post 1980s that the Indian Legal system underwent a sea change in its approach to environmental issues.[2] The Constitution of India contains a provision that guarantees to all the citizens a "right to life"[3] and the Supreme Court interpreted this provision to include the "right of the people to live in a healthy environment with minimal disturbance to ecological balance".[4] The reason for this was that "...it would be reasonable to hold that enjoyment of life and its attainments and fulfillment guaranteed by Art. 21 of the Constitution embrace the protection and reservation of nature's gifts without (which) life cannot be enjoyed."[5] In more poetic language, the High Court of Kerala observed that "The Right to sweet water and the right to free air are attributes of the right to life, for these are the basic elements which sustain life itself."[6]

However, the duty cast by law to protect the environment transcends beyond this anthropocentric formulation. The law recognizes protection of the environment and maintenance of the ecology as an end in itself. It has been observed that "Article 21 of the Constitution of India protects not only the human rights but also casts an obligation on human beings to protect and preserve a specie becoming..."[7] The approach to conservation must hence be an "eco–centric one". When the question arose whether Asiatic lions found in Gujarat could be transported elsewhere in the interests of conservation, overruling the objections of the State of Gujarat, the Supreme Court held that "...The cardinal issue is not whether the Asiatic lion is a "family member" or is part of the "Indian culture and civilization", or the pride of a State but the preservation of an endangered species for which we have to apply the "species best interest standard". Our approach should not be human-centric or family-centric but eco-centric. "Scientific reasoning" for its re-location has to supersede the family bond or pride of the people and we have to look at the species best interest especially in a situation where the specie is found to be a critically endangered one and the necessity of a second home has been keenly felt."[8]

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[2] Kilaparti Ramakrishna, *The Emergence of Environmental Law in the Developing Countries : A Case Study of India*, 12 ECOLOGY LAW QUARTERLY 907 (1984-85).
[3] Art. 21, The Constitution of India, 1950.
[4] *The Rural Litigation and Entitlement Kendra v. State of Uttarpradesh*, AIR 1985 SC 652, available at: < http://www.indiankanoon.org/doc/1949293/>
[5] *T. Damodar Rao v Special Officer, Municipal Corporation of Hyderabad*, AIR 1987 AP 171, p.181., available at: < http://www.indiankanoon.org/doc/205063/>
[6] *F. K. Hussain v. Union of India*, AIR 1990 Ker. 321., available at: < http://www.elaw.org/node/2497>
[7] *Centre For Environment Law, WWF-I v. Union of India and Ors.*, Judgment of the Supreme Court of India dated 15.04.2013, available at: < http://indiankanoon.org/doc/27900105/>.
[8] *Ibid.*

The law declared by the Supreme Court is binding on all courts, authorities and governmental agencies in India.[9] This means that the positions of law that was just discussed is the law of the land and binds the Government and the private individuals as a matter of a constitutional mandate. Further, Article 48A of the Constitution makes protection and improvement of the constitution a directive principle of State policy.[10] The courts have often invoked this provision to direct the executive to take action to prevent pollution or environmental degradation.[11]

To sum up, the law states that there is a responsibility on the government to prevent environmental degradation and protect the environment. The basis of this is both the right of the citizen to clean and healthy environment. Further, the approach towards conservation needs to be an eco-centric one for which the "species best interest standard" needs to be applied.

IV. Legal Principles in Natural Resource Management

While the "right to environment" and the duty to protect it has a firm legal foundation, to resolve specific disputes with deeply contested claims, this normative framework is insufficient. When questions arise concerning the ownership of natural resources, the best means to protect them or which entity is to pay reparations for damage caused, "right to environment" is just a vague legal formulation which provides no concrete answers. To remedy this, the courts in India have used certain legal principles. Extending the existing principles to the environmental context, developing new principles and grafting developments in the international legal order into Indian law are all strategies that the Supreme Court pursued in filling the normative vacuum. This section aims to provide an introduction to these principles.

The principles are broadly grouped here under two heads: (1) The Preventive Principles - which seek to prevent damage to the environment and the (2) Principles of Reparations – that seek to provide monitory resources from cleaning up the damage caused. However, the readers are reminded that the reparatory principles are also of some preventive value as the possibility of

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[9] Article 141, The Constitution of India,1950.
[10] Directive Principles of State Policy, found in Part IV of the Constitution are not enforceable through the courts. However, Article 37 mandates that they are nevertheless fundamental in the governance of the country and it shall be the duty of the State to apply these principles in making laws.
[11] For illustrative examples of such cases *see* P. Leelakrishnan, ENVIRONMENTAL LAW IN INDIA (2nd Ed), Lexis Nexis Butterworths (2005), pp. 209-212.

monitory loss is one of the techniques of prevention. Thus the possibility that monitory damages will be extracted does encourage industries not to pollute.

1. **The Preventive Principles**

(A) ***Ownership of Natural Resources – The Doctrine of Public Trust.***

The Doctrine of Public Trust has its origins in the Roman law.[12] The doctrine is based on the idea that there are certain common properties that are held by the State for the benefit of the public. Though the Constitution of India makes no explicit reference to the doctrine, it was read into Indian Law by the Supreme Court decision in *M. C. Mehta v. Kamal Nath And Others.*[13] Over the years, the doctrine was applied more extensively by the Court through a series of decisions mostly in the context of the right to access and use water bodies, parks, natural gas etc.[14] In 2012, the Supreme Court expanded the ambit of public trust once again to cover all natural resources. It was held that "State is the legal owner of the natural resources as a trustee of the people and although it is empowered to distribute the same, the process of distribution must be guided by the constitutional principles including the doctrine of equality and larger public good."[15] The effect of the doctrine is that the government would be prevented from allocating the resource for exclusive private exploitation or from transferring ownership rights to any particular private entity *in toto*. Functionally, the doctrine essentially sets standards of conduct for state action, and makes room for the courts to judicially review governmental action based on this standard.

(B) ***Development Vs. The Environment & the Principle of Sustainable Development***

While the law calls for preservation of the environment, it is equally aware of the needs of development. Absolute preservation at the cost of development would attract public wrath, especially in India, which presents a puzzling paradox of poverty in the midst of abounding

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[12] For a discussion of the doctrine of public trust – its origins, scope and relevance to natural resource management *See Generaly* : *Joseph L. Sax, The Public Trust Doctrine in Natural Resource Law: Effective Judicial Intervention,* 68 (3) MICHIGAN. L REV. 471 (1970).

[13] (1997)1 SCC 388, available at : < http://www.indiankanoon.org/doc/1514672/>.

[14] *M.I. Builders v. Radhey Shyam Sahu,* [(1999) 6 SCC 464] was a case relating to certain constructions made over a park. , *Intellectuals Forum v. State of A. P.*, [(2006) 3 SCC 549], related to the use of two large water tanks. *Reliance Natural Resources Ltd. v. Reliance Industries Ltd* , (2010) 7 *SCC* 1 was a decision in the context of allotment and pricing of natural gas blocks.

[15] *Centre For P.I.L. & Ors. vs Union Of India & Ors.*, Judgment dated 2 February 2012, para. 72 available at: <http://www.indiankanoon.org/doc/116116642/> last accessed on 30 march 2013.

natural resources. Thus achieving a balance between ensuring development and protecting the environment is what the law aims at.

The principle of sustainable development was a creation of the international legal order – In 1982, the General Assembly of the United Nations adopted the World Charter for Nature and Principles of Sustainable Development. The Agreement had recognized the principle as a legal principle and explained it as using living resources in a manner that does not exceed their natural capacity for regeneration and using natural resources in a manner which ensures the preservation of the species and ecosystems for the benefit of future generations.[16] The popular formulation of the principle can be found in the Brundtland Commission Report which defined the expression as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[17]

A concomitant aspect of the principle of sustainable development is the principle of "intergenerational equity". Principle 3 of the Rio Declaration captures the scope of this principle in the words "the right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations."[18] The object behind the principle is thus to ensure that the present generation does not abuse the non-renewable resources in a manner that deprives the future generations of these resources.

The principle of sustainable development is a part of Indian Law by virtue of the Supreme Court Judgment in *Vellore Citizens Welfare Forum v The Union of India.*[19] In this case the court considered a public interest litigation highlighting discharge of toxic waste and polluted water from the large number of tanneries in the State of Tamil Nadu. The Court led by Justice Kuldip Singh adopted a very strict stand against the polluting tanneries, holding that the principle of sustainable development would demand a balance between protection of the environment and developmental activities and ordered the closure of the polluting tanneries.[20]

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[16] World Charter for Nature, Resolution of the General Assembly of the United Nations, A/RES/37/7 (28 October 1982), paragraphs 9 and 10.

[17] Our Common Future :Report of the Word Commission on Environment and Development (1987), available at: < http://www.un-documents.net/our-common-future.pdf>

[18] Rio Declaration on Environment and Development, United Nations Conference on Environment and Development, Rio De Janeiro (1992).

[19] (1996) 5 SCC 647, available at: <http://www.indiankanoon.org/doc/1934103/>

[20] The other important decisions concerning sustainable development are: *The Rural Litigation and Entitlement Kendra v. State of Uttarpradesh*, AIR 1985 SC 652 ; *M. C. Mehta v. Union of India*, 1997 (2) SCC 353; *F.B. Taraporwala* v. *Bayer India Ltd.* (1996) 6 SCC 58 & *M.C. Mehta (Badkal and Surajkund Lakes Matter* v. *Union of India* (1997) 3 SCC 715.

(C) The Precautionary Principle

According to the law, any action that is taken by authorities (in this case the pollution control board or the government) needs to be supported by reasons for the same. It then flows from this that when ordering closure of polluting industries or denying permission to start a polluting industry, there must be sufficient scientific proof to establish the connection between the activity and expected damage. However, scientific proof of an absolute nature may not always be readily available in at least some of such cases. Allowing the activity to continue unabated in such cases may not lie in the interests of conservation and protection too. The precautionary principle was developed to remedy this situation.

The principle is a product of international legal developments[21] and it emphasizes on a preventive approach. The principle is best explained in the words of the Rio Declaration, which states that:

> *"In order to protect the environment, the precautionary approach shall be widely applied by the States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost effective measures to prevent environmental degradation."*[22]

The aforesaid principle has been made a part of the Indian legal order by virtue of the Supreme Court judgment in *Indian Council for Enviro Legal Action v. Union of India*.[23] According to the court, the principle has the following three aspects: (1) Environmental measures must anticipate and prevent the cause of environmental degradation; (2) Lack of scientific certainty must not be used as a reason for postponing measures to protect the environment or prevent damage; (3) The onus of proof lies on the actor to show that his action does not cause damage.[24]

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[21] Principle 15 of the Rio Declaration on Environment and Development, United Nations Conference on Environment and Development, Rio De Janeiro (1992). For a discussion on the principle *see :* David Freestone, *The Road From Rio : International Law After the Earth Summit*, 6 Journal of Environmental Law 193 (1994), pp. 210-215.

[22] *Supra.*

[23] AIR 1996 SC 1446. *See also : Vellore Citizens Forum Case, Supra* n.18.

[24] *For a brief study on the precautionary principle see David Cole, The Precautionary Principle – its Origins and Role in Environmental Law*, available at: <http://www.edo.org.au/edosa/research/david%20cole%20on%20precautionary%20principle.doc.> Last Accessed on 05 August 2013.

2. The Principles of Reparations

(A) The Polluter Pays Principle

The simplest way to explain the principle is "If it is your mess you clean it up" The polluter pays principle makes no reference to the idea of 'fault'. This means that for the polluter to be held liable, he need not have caused pollution intentionally. The mere fact that pollution was caused by an activity is sufficient to hold the person who did that activity to be held accountable for it.[25] The polluter is, under this principle, responsible for compensating and repairing the damage caused by the pollution.

(B) The Principle of Absolute Liability

Another novel principle developed by the Supreme Court of India which can be mentioned here is the principle of Absolute Liability. Normally law recognizes certain exemptions from liability for damage caused – such as for damage caused due to natural forces and circumstances that could not be foreseen. According to the principle of absolute liability, persons who are engaged in inherently hazardous activities are liable for any damage that arises out of its working with no exceptions to this rule whatsoever.[26] .However, it needs to be noted that the compensation fixed must be commensurate with the size of the industry and the damage caused.[27]

V. The Forums for Enforcement

Law as we all know does not work on its own – forums to enforce them and remedy their transgression are inevitable. This section of the paper provides and introduction to these forums.

(A) The Ordinary Civil and Criminal Courts

The ordinary civil and criminal courts indeed have numerous powers that can be used with some craft to forge remedies in situations of environmental distress. However, it needs to be pointed out that the practice of this is scarce in India and it is still in its nascent stages.

The Executive Magistrate under the Code of Civil Procedure (Which is in most cases the District Collector or in some cases the Revenue Divisional Officer) is empowered under the code to

[25] *M C Mehta v. Union of India,* AIR 1986 SC 1086.
[26] *Ibid.*
[27] *Deepak Nitrite Limited v. State of Gujarat,* (2004) 6 SCC 402.

remove all cases of public nuisance in the first instance with a conditional order and then with a permanent one.[28] This provision can be used to remove nuisance of an environmental nature.[29]

The civil courts are empowered to issue mandatory injunctions to stop pollution caused to the public or to any particular person. The injunction can be a temporary one that last while the case is tried and decided or a permanent one, which is issued once the case is finally decided.[30] The Civil courts can consider evidence in detail and hence where technical questions with contested claims are involved, the civil courts are the appropriate forum to decide them. The civil courts can also award monitory damages for the losses caused, however, a court fee proportionate to the damage claimed will have to be paid. The Civil Courts no longer have jurisdiction over those matters over which the National Green Tribunal has jurisdiction.[31]

(B) The Supreme Court and The High Courts

The Supreme Court of India under Article 32 and the High Courts of the States under Article 226 are empowered by the Constitution to issue writs (which literally means a command) to enforce the law. Under normal circumstances only a person who is directly aggrieved by any particular issue is entitled to approach the courts (in technical terms this is called the rule of *locus standi* – or entitlement to sue). However, the Supreme Court has watered down this rule considerably and evolved the idea of Public Interest Litigations (for short PILs) wherein any member of the public can bring issues to the attention of the courts. It needs to be pointed out here that all the principles that we discussed in the previous section is a product of PILs.

Since the courts have recognized a "right to environment", the Supreme Courts and the High Courts entertain numerous petitions that relate to environmental degradation and pollution. Any member of the public is entitled to bring such issues before the court, as long as it is not to

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28 Section 133, Code of Criminal Procedure, 1973. The district magistrate or the sub-divisional magistrate or any other executive magistrate empowered on this behalf by the State government can make a conditional order to remove such nuisance and after enquiry make the order an absolute one. The Magistrate can act under this provision upon a police report, or any other information and he can take such evidence as he thinks fit.

29 *Municipal Council, Ratlam v. Vardichan*, AIR 1980 SC 1622.

30 Temporary Injunctions are granted under O. 38 of the Code of Civil Procedure and Permanent Injunctions are granted under the Specific Relief Act.

31 Section 29 (1) of the National Green Tribunal. The jurisdiction of the Tribunal is explained in this chapter.

pursue some private gain. The courts have generally been sympathetic to such issues and active and remedying them.[32]

(B) The National Green Tribunal

For a long time numerous agencies and experts kept highlighting the need for a specialized environmental court or tribunal. The National Green Tribunal is a product of this felt need. The Tribunal is a product of the National Green Tribunal Act of 2010. The tribunal has dedicated jurisdiction on all environment related matters and it can provide speedy environmental justice.

The tribunals has jurisdiction over all civil cases where there is a substantial question relating to the enforcement of any legal right relating to the environment or if any question arises relating to the implementation of any law mentioned in Schedule 1 of the Act.[33] Section 2(m) of the Act defines Substantial Question to include instances where there is a direct violation of any statutory duty by which the community by large is affect or is likely to be affected or the damage to the environment or public health is substantial and measurable. The Tribunal also has jurisdiction over orders issued by the tribunals under the Air & Water Acts and some of the governmental orders under the Forest Act.[34] It is important that the tribunal needs to be approached within 6 months of the issue arising, failing which the tribunal cannot entertain the matter. The Tribunal is empowered to provide relief and compensation to the victims of pollution and other environmental damage. It can order for restitution of any property damaged or of the environment in such area or areas that the tribunal determines.[35]

Since the tribunal is not bound by the procedure under the Code of Civil Procedure (which is cumbersome and time taking) it is expected to be faster and cheaper. The tribunal is only bound by the principles of natural justice (which in brief can be said to be hearing both sides before passing an order, passing reasoned orders, the judge not following the orders of a superior and

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[32] For a more detailed study of the role of PILs in dealing with environment related issues, *see : see* P. Leelakrishnan, ENVIRONMENTAL LAW IN INDIA (2nd Ed), Lexis Nexis Butterworths (2005), pp. 248 – 275.

[33] Section 14 of the National Green Tribunal Act. Schedule One covers the Air Act, Water Act, Environmental Protection Act, The Biological Diversity Act and the Public Liability Insurance Act – the major environmental legislations in India.

[34] Section 16, National Green Tribunal Act.

[35] Section 15 of the National Green Tribunal Act.

the judge concerned not hearing a case where he has some personal interest). The Tribunal sits principally at Delhi and it also has benches at Bhopal, Kolkatta, Pune and Chennai.

The major advantages of the tribunal are the presence of technical members on board, the simple and inexpensive procedure and less time taken to dispose the matters. However, the fact that it has presence only in select cities is one of the major factors that make its access more difficult. The tribunal is already active in ensuring protection of the environment and several orders of the tribunal have captured public as well as academic attention. The tribunal has all the potential to fill the vacuum of specialized environmental courts in our country.

V. A Window for Further Reading and Other Resources

(A) Books:

P. Leelakrishnan, ENVIRONMENTAL LAW IN INDIA (2nd Ed), Lexis Nexis Butterworths (2005)

Shyam Divan & Armin Rosencranz, Environmental Law and Policy In India (2nd Ed.), Oxford University Press: New Delhi (2002).

(B) ***Internet Resources:***

CEERA INDIA maintains a good website that provides information on developments in Environmental Laws, which can be accessed at: <http://www.ceeraindia.org/>

Central Pollution Control Board: <http://cpcb.nic.in/>

Environmental Information System: <http://envis.nic.in/>

Ministry of Environment and Forests: <http://www.moef.nic.in/>

National Green Tribunal: http://www.greentribunal.in/

Greenhouse gas mitigation in agriculture

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Abstract

Agricultural lands occupy about 40 to 50 per cent of the earth's land surface. Agriculture accounts for 52 and 84 per cent of global anthropogenic methane and nitrous oxide emissions (US-EPA, 2006a). Agriculture also emits CO_2 estimated to be 40 Mt CO_2-eq. in 2000 (US-EPA, 2006b), less than 1 per cent of global anthropogenic CO_2 emissions. The primary sources of methane from agriculture include rice cultivation, animal digestive processes and the storage and handling of manure (Mosier *et al.*, 1998). Soil contributes to a major amount of nitrous oxide emission. The major sources are fertilizer and manure application, soil cultivation and burning organic material and fossil fuels. Many agricultural practices can effectively mitigate GHG emissions. The most prominent mitigation options in agriculture are improved cropland and grazing land management (including improved agronomy and nutrient, tillage and residue management) and restoration of degraded lands (Smith *et al.*, 2007). Lower, but still significant mitigation potential is provided by water and rice management, land use change, livestock management and manure management. In addition, GHG emissions could be reduced by substitution of fossil fuels for energy production by agricultural feedstocks (e.g. crop residues and dung).The global mitigation potential from agriculture (excluding fossil fuel offsets from biomass) by 2030, considering all gases, is estimated to be approximately 5500 to 6000 Mt CO_2-eq. per year, with economic potentials of approximately 1500 –1600, 2500 –2700 and 4000 – 4300 Mt CO_2-eq..per year at carbon prices of up to 20, 50 and 100 US$ CO_2-eq. per year, respectively (Smith *et al.*, 2008).

Introduction

Agriculture releases to the atmosphere significant amounts of CO_2, CH_4, or N_2O (Cole *et al.*, 1997; IPCC, 2001a; Paustian *et al.*, 2004). CO_2 is released largely from microbial decay or burning of plant litter and soil organic matter (Smith, 2004b; Janzen, 2004). CH_4 is produced when organic materials decompose in oxygen-deprived conditions, notably from fermentative digestion by ruminant livestock, from stored manures, and from rice grown under flooded conditions (Mosier *et al.*, 1998). N_2O is generated by the microbial transformation of nitrogen in soils and manures, and is often enhanced where available nitrogen (N) exceeds plant requirements, especially under wet conditions (Oenema *et al.*, 2005; Smith and Conen, 2004). Agricultural greenhouse gas (GHG) fluxes are complex and heterogeneous, but the active management of agricultural systems offers possibilities for mitigation. Many of these mitigation opportunities use current technologies and can be implemented immediately. It is theoretically possible to increase carbon storage in long lived agricultural products (e.g., strawboards, wool, leather, bio-plastics) but the carbon held in these products has only increased from 37 to 83 Mt C per year over the past 40 years. Assuming a first order decay rate of 10 to 20 % per year, this is estimated to be a global net annual removal of 3 to 7 MtCO2 from the atmosphere, which is negligible compared to the other mitigation measures. This paper describes in details agricultural practices that may mitigate GHGs, with many practices affecting more than one GHG by more than one mechanism. These practices include: Cropland management, grazing land management/pasture improvement, management of agricultural organic soils, restoration of degraded lands, livestock management, manure/bio-solid management, bio-energy production.

Emission Trends

With an estimated global emission of non-CO_2 GHGs of 5969 Mt CO_2^{eq}. yr^{-1} in 2005 (US-EPA, 2006a), agriculture is estimated to account for about 14% of total global anthropogenic emissions of non-CO_2 GHGs and 47% and 84% of total anthropogenic CH_4 and N_2O emissions in 2000, respectively (US-EPA, 2006a). N_2O emissions from soils and CH_4 from enteric fermentation constitute the largest sources, with 44% and 31% of total non-CO_2 emissions in 2005, respectively (US-EPA, 2006a). Rice production (11%), manure management (7%) and biomass burning (7%) account for the rest.

Emissions of CO_2 from agricultural soils are not normally estimated separately, but are included in the land use change and forestry sector (e.g. in national GHG inventories) so there are few comparable estimates of emissions of this gas in agriculture. However, US-EPA (2006b) recently estimated that agriculture emitted 40 Mt CO_2^{-eq}. of CO_2 into the atmosphere in 2000, less than 1% of global anthropogenic CO_2 emissions.

Trends since 1990

Globally, agricultural emissions have increased by 14% from 1990 to 2005 with an average annual emission of 49 Mt $CO_2^{-eq}.yr^{-1}$ (US-EPA, 2006a). N_2O from soils, N_2O from manure management, and CH_4 from enteric fermentation were the agricultural sources showing the greatest increase in emissions, at 21, 18 and 12%, respectively, while N_2O and CH_4 emissions from biomass burning decreased by 8 and 6%, respectively. N_2O emissions increased by 31 Mt $CO2^{-eq}.yr^{-1}$, almost twice the rate of increase seen for CH_4 emissions (US-EPA, 2006a).

Future global trends

Agricultural N_2O emissions are projected to increase by 35-60% up to 2030 due to increased nitrogen fertilizer use and increased animal manure production (FAO, 2003). Similarly, US-EPA (2006a) estimated that N_2O emissions will increase by about 50% by 2020 (relative to 1990). If demands for food increase, and diets shift as projected, then annual emissions of GHGs from agriculture may escalate further. But improved management practices and emerging technologies may permit a reduction in emissions per unit of food (or protein) produced, and perhaps also a reduction in emissions per capita food consumption. If CH_4 emissions grow in direct proportion to increases in livestock numbers, then global livestock-related methane production is expected to increase by 60% up to 2030 (FAO, 2003).

However, changes in feeding practices and manure management could ameliorate this increase.

Results of experiments conducted on methane emission from rice fields of lateritic soils of Kerala.

Table 1. Diurnal variations in methane flux (mg m^{-2} hr^{-1}) during the different growth stages

i) First crop season

Growth stages	**Morning**				**Noon**				**Evening**				**Mean**
	Ch I	Ch II	Ch III	Mean	Ch I	Ch II	Ch III	Mean	Ch I	Ch II	Ch III	Mean	
Tillering	0.29	1.21	1.50	1.00	0.80	0.13	0.69	0.54	0.36	0.46	0.39	0.40	**0.65**
Panicle initiation	0.72	0.66	0.87	0.75	1.04	0.85	0.82	0.90	0.99	0.91	0.94	0.95	**0.87**
Booting	1.41	2.61	1.88	1.97	3.08	2.17	3.92	3.06	3.11	3.05	2.15	2.77	**2.60**
Flowering	1.48	3.73	2.97	2.73	2.17	1.89	2.13	2.06	3.32	3.56	2.07	2.98	**2.59**
Maturity	3.00	2.99	1.48	2.49	1.49	1.31	1.15	1.32	2.12	2.74	2.71	2.52	**2.11**
Mean				**1.79**				**1.57**				**1.92**	

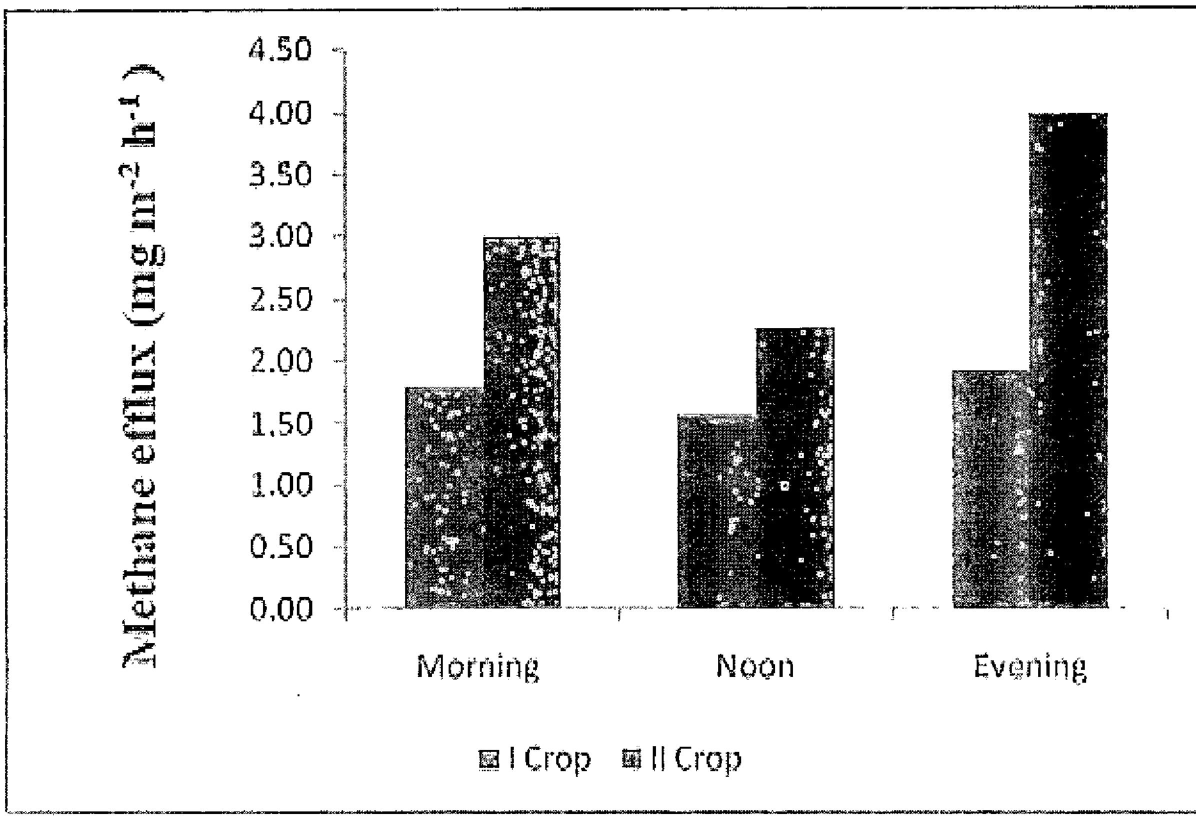
ii) Second crop season

Tillering	0.78	2.41	1.69	1.62	2.95	4.87	3.91	3.91	3.88	6.11	5.51	5.17	**3.57**
Panicle initiation	1.61	1.70	2.23	1.85	5.51	3.76	4.61	4.63	2.24	3.20	2.97	2.80	**3.09**
Booting	4.94	6.62	5.10	5.55	3.80	2.10	2.36	2.84	3.70	2.83	3.02	3.18	**3.86**
Mean				**3.01**				**2.27**				**3.98**	

Ch– Channel (Mathew, 2003)

It was observed in table (1) that methane emission was maximum in the evening at all stages of growth except at tillering and panicle initiation.

Fig. 1. Diurnal and seasonal variations in methane emission during the first and second crop seasons



(Mathew, 2003)

Mitigation Technologies and Practices

Table 2. Proposed measures for mitigating greenhouse gas emissions from agricultural ecosystems, their apparent effects on reducing emissions of individual gases where adopted (mitigative effect), and an estimate of scientific confidence that the proposed practice can reduce overall net emissions at the site of adoption.

		Mitigative effects[1]			Net mitigation[2] (confidence)	
Measure	Examples	CO_2	CH_4	N_2O	Agree-ment	Evi-dence
Cropland man-agement	Agronomy	+		+/-	***	**
	Nutrient management	+		+	***	**
	Tillage/residue management	+		+/-	**	**
	Water management (irrigation, drainage)	+/-		+	*	*
	Rice management	+		+/-	**	**
	Agro-forestry		+		***	*
	Set-asisde, land-use change	+		+/-	***	***
.		+/-	+	+		
Grazing land management/ pasture improvement	Grazing intensity	+		+/-	*	*
	Increased productivity (e.g. fertilization)	+		+/-	**	*
	Nutrient management	+		+/-	**	**
	Fire management	+		+/-	*	*
	Species introduction (including legumes)	+		+/-	*	**
				+/-		
Management of organic soils	Avoid drainage of wetlands	+	-	+/-	**	**
Restoration of degraded lands	Erosion control, organic amendments, nutrient amendments	+		+/-	***	**
Livestock management	Improved feeding practices		+		***	***
	Specific agents and dietary additives		+		**	***
	Longer term structural and management changes and animal breeding		+		**	*
Manure/biosolid management	Improved storage and handling		+	+/-	***	**
	anaerobic digestion		+	+/-	***	*
	more efficient use as nutrient source	+		+	***	**

Bioenergy	Energy crops, solid, liquid, biogas, residues	+		+/-	***	**

Source: (Smith *et al.*, 2008)

Notes:

1. + denotes reduced emissions or enhanced removal (positive mitigative effect)
2. - denotes increased emissions or suppressed removal (negative mitigative effect)
3. +/- denotes uncertain or variable response
4. A qualitative estimate of the confidence in describing the proposed practice as a measure for reducing net emissions of greenhouse gases, expressed as CO_2^{-eq}
5. Agreement refers to the relative degree of consensus in the literature (the more asterisks, the higher the agreement); Evidence refers to the relative amount of data in support of the proposed effect (the more asterisks, the more evidence).

KYOTO PROTOCOL.

The Kyoto Protocol in 1992, many nations alarmed at the increase in greenhouse gases (GHGs), signed the United Nations Framework Convention on Climate Change (UNFCCC), which had a legally non-binding, voluntary pledge stating that the major developed nations would reduce their GHG emissions to 1990 levels by the year 2000. Parties to the treaty decided, in 1995, to enter into negotiations on a protocol to establish legally binding limitations, or reductions in GHG emissions. The negotiations took place in 1997 at Kyoto in Japan. Eight Conferences of the Parties (COPs) have been held since 1992. The Kyoto meeting was the fourth.

International Emission Trading

Under IET mechanism, countries can trade in the international carbon credit market. Countries with surplus credits can sell the same to countries with quantified emission limitation and reduction commitments under the Kyoto Protocol. In 1992, India signed the United Nations Framework Convention on Climate Change as a non-Annex I country, meaning it is not obligated to reduce its emissions of carbon and greenhouse gases (GHG). India ratified the agreement in 1993. While India recognizes the importance of reducing these harmful emissions, the Indian government also places a high priority on economic development. As such, India is not a signatory to the Kyoto Protocol that mandates specific commitments by countries to reduce their emissions of greenhouse gases by an average of 5.2% below 1990 levels by the agreed 2008-2012 time frame. Nevertheless, India accepted (ratification was not necessary) the Kyoto Protocol on August 26, 2002. In India, majority of the projects taken up for GHG reductions fall under CDM, since India is a developing country (non-annex I country).

Bioenergy

Increasingly, agricultural crops and residues are seen as sources of feedstock for energy to displace fossil fuels. A wide range of materials have been proposed for use, including grain, crop residue, cellulosic crops (e.g., switch grass, sugarcane), and various tree species (Paustian *et al.*, 2004). These products can be burned directly, but can also be processed further to generate liquid fuels such as ethanol or diesel fuel. Such fuels release CO_2 when burned, but this CO_2 is of recent atmospheric origin (via photosynthetic carbon uptake) and displaces CO_2 which otherwise would have come from fossil carbon. The net benefit to atmospheric CO_2, however, depends on energy used in growing and processing the bioenergy feedstock.

Latin America, Sub-Saharan Africa, and Eastern Europe are promising regions for bio-energy, with additional long-term contributions from Oceania and East and Northeast Asia. Major transitions are required to exploit the large potential for bioenergy. Improving agricultural efficiency in developing countries is a key factor. It is still uncertain to what extent, and how fast, such transitions could be realized in different regions. Under less favorable conditions, the regional bioenergy potential(s) could be quite low. Also, technological developments in converting biomass to energy, as well as long distance biomass supply chains (e.g., those involving intercontinental transport of biomass derived energy carriers) can dramatically improve competitiveness and efficiency of bio-energy (Hamelinck *et al.*, 2001).

Carbon Sequestration

Increasing awareness of GHG has opened eyes worldwide. Agriculture emits and stores atmospheric gases that absorb radiation. All organic substances contain carbon (C). The C cycle, through which carbon dioxide from the atmosphere is converted to organic forms by plant photosynthesis and then returned to the atmosphere through respiration, is the basis for life on earth. Soil organic matter (**SOM**) contains three times as much C as is found in vegetation, on a worldwide scale. Therefore, soil organic matter plays a critical role in the global C balance and the greenhouse effect. In fact, when SOM is measures, it's actually soil organic carbon (SOC) that is measured, and then a conversion factor is used to calculate SOM.

Two options for reducing the amount of carbon in the atmosphere are to increase the amount of land planted with permanent grassland or forest vegetation and to reduce the frequency or intensity of tillage operations. Either option would store or sequester additional carbon on the affected lands. Carbon sequestration refers to the provision of long – term storage of carbon in the terrestrial biosphere, underground, or the oceans so that the buildup of carbon dioxide (the principal greenhouse gas) concentration in the atmosphere will reduce or slowdown. In some cases, this is accomplished by maintaining or enhancing natural processes, in other cases, novel techniques are developed to dispose of carbon. Carbon sequestration rates vary by climate, topography, soil type, past management history, and current practices. Various global and national estimates for potential soil carbon sequestration have been made. These estimates are usually based on overall carbon gain for a suite of practices and the available area on which these practices could be applied, resulting in estimates of biological or technical potential. (Paustian *et al.*, 1998) estimated a global potential from improved agricultural soil management of 400 to 600 MMT of carbon per year, and the Intergovernmental Panel on Climate Change (IPCC, 2000) estimated potential rates from improved cropland, grazing land, and agroforestry of 390 MMT of carbon per year by the year 2010 and 780 MMT of carbon per year by 2040, assuming a lag-time in the adoption of improved practices. In the United States, Lal *et al.* (2003) estimated an overall potential for soil carbon sequestration (excluding forest related activities) of 70 to 221 MMT of carbon per year for a combination of practices including land set-asides, restoration of degraded lands, conservation tillage, irrigation and water management, and improved cropping and pasture systems. This overall figure represents net increases, taking into account increased GHG emissions associated with the management improvements.

Conclusion

GHG emissions from agriculture have large uncertainties and it is difficult to assess the effectiveness of GHG mitigation measures under the changing conditions of the future.

For sustainable development and environment quality improvement, some countries have started several climate and non-climate policies, majority of which are believed to have direct effects on mitigating GHG emissions from agriculture.

Global sharing of innovative technologies for efficient use of land resources and agricultural chemicals, to eliminate poverty and malnutrition, will significantly mitigate GHG emissions from agriculture. Economic constraints might limit implementation of agricultural GHG mitigation to less than 35% of the total biophysical potential by 2030. The challenge for successful agricultural GHG mitigation will be to remove these barriers by implementing creative policies. Identifying policies that provide benefits for economic, social and environmental sustainability will be critical for ensuring that effective GHG mitigation options are widely implemented in the future. Every country should develop an integrated package of GHG free agriculture. It should minimize and where possible, eliminate the contributions of farm operations to the release of CO_2, CH_4 and N_2O in the atmosphere.

References

Cole, C.V., Duxbury J., Freney, J., Heinemeyer, O., Minami, K., Mosier, A., Paustian, K., Rosenberg, N., Sampson, N., Sauerbeck, D. and Zhao Q. 1997.Global estimates of potential mitigation of greenhouse gas emissions by agriculture. *Nutr. Cycl. Agroecosyst.* **49:** 221-228.

FAO [Food and Agriculture Organization]. 2003. World agriculture: towards 2015/2030. An FAO perspective. Rome, FAO, pp. 26-41.

Hamelinck, C.N., Suurs, R.A.A. and Faaij A.P.C. 2004. *Techno-economic analysis of international bio-energy trade chains. Biomass Bioenerg* **29:** 114–134.

IPCC [Intergovernmental Panel on climate Change]. 2001a. The Scientific Basis. In: Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., Van Der Linden, P.J., Dai, X., Maskell, K. and Johnson, C.A. (eds.), *Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, 881 p.

Janzen, H.H. 2004.Carbon cycling in earth systems - a soil science perspective. *Agric. Ecosyst. Environ.***104:** 399-417.

Lal, R., Follett, R.F. and Kimble, J.M. 2003. Achieving soil carbon sequestration in the United States: a challenge to the policy makers. *Soil Sci.* **168:** 827-845.

Mathew, R. 2003. Methane emission from wetland rice fields of Kerala. Ph.D thesis, Kerala Agricultural University, Thrissur, 132p.

Mosier, A. R., Duxbury, J. R., Freney, O., Heinemeyer, K. and Johnson, D.E. 1998. Mitigating agricultural emissions of methane. *Clim. Chang.* **40:** 39-80.

Oenema, O., Wrage, N., Velthof, G.L., Van Groenigen, J.W., Dolfing J. and Kuikman, P.J. 2005. Trends in global nitrous oxide emissions from animal production systems. *Nutr.Cycl. Agroecosys.* **72:** 51-65.

Paustian, K., Babcock, B.A., Hatfield, J., Lal, R., McCarl, B.A., McLaughlin, S., Mosier, A., Rice, C., Robertson, G.P., Rosenberg, N.J., Rosenzweig, C., Schlesinger, W.H. and Zilberman, D. 2004. *Agricultural Mitigation of Greenhouse Gases: Science and Policy Options.* Council on Agricultural Science and Technology (CAST) Report, 2004.120p.

Smith, K.A. and Conen, F. 2004. Impacts of land management on fluxes of trace greenhouse gases. *Soil Use Manag.* **20:** 255-263.

Smith, P. 2004b.Engineered biological sinks on land. In: Field, C.B. and Raupach, M.R. (eds.), *The Global Carbon Cycle. Integrating Humans, Climate, and the Natural World,* pp. 479-491.

Smith, P., Martino, D., Cai, Z., Janzen, H., Kumar, P., McCarl, B., Ogle, S., O'Mara, F., Rice, C., Scholes, B., Sirotenko, O., Howden, M., McAllister, T., Pan, G., Romanenkov, V., Schneider, U., Towprayoon, S. and Smith, J. 2008. Greenhouse gas mitigation in agriculture. *Phil. Trans. R. Soc. Biol. Sci.* **363** (1492): 789-813.

Smith, P., Powlson, D. S., Smith, J. U., Falloon, P. D. and Coleman, K. 2007. Agriculture Climate Change 2007. In: Metz, B., Davidson, O., Bosch, P., Dave, R. and Meyer, L. (eds.), *Mitigation Contribution of Working Group Third to the Fourth Assessment*

Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, pp. 497–540.

US-EPA. 2006a. Global anthropogenic non-CO_2 greenhouse gas emissions: 1990 - 2020, United States Environmental Protection Agency, EPA 430-R-06-003, Washington, DC: US-EPA. Available: http://www.epa.gov/nonco2/econ-inv/international.html. [20 Sept. 2013].

US-EPA. 2006b. Global mitigation of non-CO_2 greenhouse gases. United States Environmental Protection Agency, EPA 430-R-06-005, Washington, DC: US-EPA. Available: http://www.epa.gov/nonco2/econ-inv/international.html. [20 Sept. 2013].

Economics of Climate Change Adaptation in India

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The Madras School of Economics (MSE), the M S Swaminathan Re-search Foundation (MSSRF) and the South Asian Network for Development and Environmental Economics (SANDEE) organised a brainstorming workshop on the "Economics of Climate Change -Adaptation" on 12-13 February 2010 at the MSE, Chennai to identify policy gaps, research questions and capacity-building needs related to India's- need to adapt to climate change. This note provides a summary of the discussions at this workshop and draws some conclusions for future policy analyses.[1] Besides talks and discussion, the work-shop also had a panel discussion on "Challenges in Mainstreaming Climate Change Adaptation", chaired by M S Swaminathan. Climate change impact assessment and adaptation studies require predictions from climate models. To plan for adaptation, some important changes are required- in the inputs provided by current climate models.

• First, climate predictions are needed at finer spatial resolutions than are currently available from the global climate models. This is beginning to happen. For example, the Indian Institute of Tropical Meteorology has developed high resolution (50 square kilometres) regional climate change scenarios for India using the Had-ley Centre regional climate model PREdicting Climate for Impact Studies (PRE-CIS). Similar exercises are underway to develop a suite of high resolution future climate scenarios for India by running a range of regional climate models, and using- lateral boundary conditions from a variety of Intergovernmental Panel on Climate- Change (IPCC) Fifth Assessment Report (AR5) coupled models (Krishna Kumar 2010).

• Second, future scenarios of climate need to go beyond predictions on temperature and precipitation. Along with these primary variables, impact and adaptation- experts would benefit from knowledge on secondary variables such as heating degree- days, combining information on available temperature range over the growing period of agricultural crops, heat index, starting and ending days of seasonal monsoon rainfall, storm surges, etc (Patwardhan-2010)

As locally downscaled climate information becomes available, advances in policy responses and examination of climate implications will become more feasible.

Adaptation as a Development 'Continuum'

Any discussion on climate change adaptation must recognise two sometimes contrasting perspectives on the nature of adaptation: (1) climate change imposes a distinct and additional burden on society;

(2) Climate adaptation is one response among many to a host of socio-economic and environmental pressures, and cannot necessarily be isolated from regular development activities.

Under some circumstances, the additional vulnerability of economic agents to climate change and specific measures to reduce this vulnerability can be clearly identified. For example, if climate change is expected to increase precipitation and flooding in certain areas, the additional economic damages from these floods and "adaptive" investments required to reduce these damages can be established. Thus, in these circumstances, it may be possible to identify clearly the additional burden of climate change and adaptation.

However, climate adaptation may be rendered ineffective if policies are not designed in the context of other development concerns. For instance, a comprehensive strategy that seeks to improve food security in the context of climate change may include a set of coordinated measures -related to agricultural extension, crop -diversification, integrated water- and pest management, and agricultural information services. Some of these measures may have to do with climatic changes and -others with economic development. Thus, in the broader development context, building adaptive capacity is much more than developing climate--related adaptation strategies. It is thus useful to examine climate adaptation, whether it is spontaneous or policy- driven, in tandem with other economic development options.

Costs of Adaptation

The origins of research on adaptation costs can be traced to climate change impact studies, where the objective was not to assess adaptation costs per se, but to refine impact estimates with proper ac-counting of adaptation to climate change. In this strand of literature, adaptation costs are defined as the expected value of avoided climate damages in the future, conditional upon some future state of socio-economic vulnerability. In a recent survey of such studies, Agrawala and Fankhauser (2008) argue that with the exception of coastal protection, knowledge on adaptation costs and benefits is fairly limited. Other studies examine- "welfare" in future scenarios with and without climate- change, estimate the costs of adapting to climate change and examine the "benefits" in terms of reduced vulnerability (improved welfare) to climate change (Nelson- et al 2009).

Even though consensus on a central -estimate of adaptation cost has not emerged, a relatively narrow range of estimates has emerged from various studies following a variety of methodologies (see for example, United Nations Framework Convention on Climate Change 2007, Parry et al 2009, Economics of Adaptation to Climate Change Study 2009, Nelson- et al 2009). With a view to supplement existing knowledge- on adaptation cost estimates, Basque Centre for Climate- Change (BC3) and The Energy and Re-sources Institute (TERI) have attempted to estimate costs of adaptation for India. This collaborative -effort identifies many methodological challenges and data needs (Mishra and Markandya.2010). In another ongoing effort, the World Bank, Japan International Cooperation Agency (JICA) and Asian -Development Bank (ADB) are assessing damage costs from climate induced -flooding and required adaptation "investment costs" in four major cities of the developing world, including Kolkata in India. Future research in this context should focus more on fine-tuning methodo-logies and understanding a range of estimates and tradeoffs, and less on arriving at specific cost estimates. Research should also focus on integrating climate change concerns with other existing- and emerging concerns-.

Climate Adaptation in Agriculture

It is well established that climate change will have significantly adverse impacts on agriculture, especially in developing countries like India. Given the large proportion of the population dependent on agriculture directly and indirectly adverse effects on agriculture could easily translate into an escalation of poverty.

Increase in carbon dioxide concentration to 550 parts per million (ppm) could increase yields of rice, wheat, legumes and oilseeds by 10-20%. However, a one degree increase in temperature may reduce yields of wheat, soyabean, mustard, groundnut, and potato by 3-7% (Aggarwal 2009). The yield losses are likely to be much higher at higher temperatures. Studies assessing the economic impacts of climate change on agriculture have -focused mostly on impacts on cereal crops like rice and wheat. New research findings from crop models on non-cereal and commercial crops have not been integrated yet into economic models.

Kumar and Parikh (2001) and Sanghi and Mendelsohn (2008) have estimated that under moderate climate change scenarios, there could be about 9% decline in farm-level net revenues in India. More adverse- impacts are predicted in high-- value agricultural regions such as Punjab, Haryana and Uttar Pradesh and dry regions- such as Gujarat and Rajasthan. On the other hand, the eastern states of Bihar and West Bengal could benefit marginally.

Nelson et al (2009) have estimated that the daily per capita calorie availability in south Asia will decline by about 8 percentage- points in 2050 due to climate change impacts on cereal crop yields compared to levels in 2000. In terms of the distributional effects of climate change impacts on agriculture, available preliminary evidence suggests that changes in poverty rates are not highly localised even though the adverse impacts are concentrated in the northern parts of the country for example, Punjab is proportionately harder hit due to climate change but is a richer region to start with (Jacoby et al 2009).

Citing the presence of strong spatial -autocorrelation in the agricultural output data in India, Kumar (2009) argues in -favour of controlling for spatial effects in climate change impact estimation. Among other things, strong flow of information amongst farmers may contribute to farmers being better able to adapt to climate change. Research priorities in this context include exploring the factors that facilitate information diffusion in agriculture.

Based on field-level work carried out in Andhra Pradesh and Rajasthan, MSSRF (2008) suggests that there are effective ways to make farmers more adaptive to climate changes. They recommend specific changes in traditional water management practices such as *harren* in Rajasthan, establishing smart farmer networks that enable farmers to share knowledge on farm management practices, utilising weather data from simple agro meteorological stations operated by the farmers and use of some new rice farming techniques such as systems of rice intensification. While many such options appear rational at a case study level, the next step is to demonstrate through rigorous research their effectiveness when appropriately scaled-up.

Water and Coastal Sectors

Water and coastal resources are two other important sectors that could face significant adverse impacts in India due to climate- change. Like agriculture, these sectors also face considerable non-climatic pressures. Hence, the challenge is to integrate responses to non-climatic stresses with those that can minimise potential climate change impacts.

For India's National Communications (NATCOM) to the United Nations Frame-work Convention on Climate Change (UNFCCC), river-basin specific impacts of various climate change scenarios and vulnerability to drought and floods has been estimated at the catchment, sub-catchment and watershed levels, as well for administrative units such as districts.[2] While such exercises are useful, given the multiple pressures that act on water re-sources, integrated watershed modelling might be more appropriate. Following such a strategy, Badiger (2010) has stud-ied the Malaprabha catchment area of the Krishna basin in detail and argues that much of the perceived water scarcity in the study area is attributable to farming and land use practices. Janakarajan (2010), on the other hand, examined the current adaptation strategies of stakeholders in the Cauvery delta of Tamil Nadu and argued that the responses to -climatic and non climatic pressures have largely been ad hoc and hence could be -inadequate and unsustainable in the long term. Some existing practices may have adverse implications as well. An example is the destruction of mangroves. Through a detailed analysis of the Orissa super -cyclone in 1999, Das (2007) has shown that mangroves have significant influence on reducing human and property losses, even compared to institutional preparedness measures such as cyclone warning and evacuation.

The IPCC predicts that sea-level rise may be the greatest threat to sustainable development in south Asia. The consequences in terms of flooding of low-lying deltas, re-treat of shorelines, salinisation and changes in water table could cause potentially serious problems to large populations. Unlike other causes that force people to migrate, sea-level rise poses a permanent problem, with little or no scope for migrants to return home. Byravan and Chella Rajan (2009) argued that existing institutional arrange-ments may not be sufficiently equipped to handle within and across country migration -resulting from sea-level rise. More detailed studies can be undertaken at selective hot-spot areas and on state-level policies and individual sectors.

Adaptation Cost Curves

A research priority with regard to economics of climate change adaptation would be assessment of adaptation costs for India as well as sub-regions such as states. Such estimates would be important for climate negotiations as well as for resource allocation. Here, a useful way forward may be in constructing adaptation cost curves, which demonstrate the costs of multiple adaptation strategies. Economics of Climate Adaptation (2009), for example, has estimated the costs of a variety of adaptation strategies in response to drought in Maharashtra. Establishing such cost curves is necessary if we are to identify least cost options. We note that while cost calculations can be relatively straightforward, careful attention may be required if the benefits of each strategy differ.

Adaptation Instruments

In addition to the costs and benefits of adaptation strategies, careful economic analysis is required of instruments that could facilitate adaptation. Some emerging areas of research priority include:

- assessing the usefulness of local weather stations in agriculture: It is often argued that weather data from simple agro-meteorological stations can be of significant use to farmers for their farm management practices. This is well documented through studies undertaken by MSSRF (2008) in India and the Stockholm Environment Institute (SEI)

(2008) in Africa. However, since this evidence is not based on random experiments, further analysis is needed to deal with the problems of selfselection by farmers and the associated implications for understanding farm-level outcomes.

- Effectiveness of insurance as adaptation strategy: It is widely believed that insurance could serve as an appropriate adaptation strategy. In India, the entry of private insurance companies to offer index insurance to farmers has given rise to optimism. However, the costs of designing a contract are still very high and it is hard to establish basis risk.[3] Ramaswami (2010), for example, argues that while index insurance is potentially valuable to business entities and local governments that are exposed to pooled agricultural

Impacts at Policy-Relevant Scales

From the above discussion, it is clear that an important first step in the economic analysis of adaptation to climate change is assessment of the impacts of various climate change scenarios at disaggregated levels. The existing knowledge base in this regard is sketchy. While the NATCOM under the Ministry of Environment and Forests (MoEF) is working towards this objective, the social science component of the NATCOM network is weak. Further, in addition to a national analysis, state-level exercises will be needed for designing -effective adaptation strategies. Given the focus on adaptation, impact assessment exercises need not fine-tune or over emphasise further improvements in our understanding of potential impacts. Instead, the focus should be on getting estimates at a disaggregated level so thatrisks, it may not be very effective for -individual farmers. For individual farmers (or households), catastrophe insurance may be more valuable. These issues need further research. Further, insurance as an instrument is amenable to fluctuations in weather around a stable climate. Its effectiveness in addressing fluctuations in weather around changing climate is unclear

- Addressing the challenges of migration as an adaptation strategy: The usual development paradigm has seen migration of people from inland towards coastal regions. However, with rise in sea levels and coastal inundation, reverse migration may be witnessed. An important researchable issue in this context relates to the triggers associated with sea level rise and inundation that prompt migration. There is already much that is known about the behavioural dimensions of migration; how this knowledge applies to climate related migration needs to be more carefully examined.

• The role of information diffusion as adaptation strategy: Often lack of information can lead to catastrophic consequences. While the government might be doing its bit in undertaking campaigns, say for instance, to reduce heat stroke effects, it may not be reaching the targeted end users due to lack of adequate understanding about information diffusion pathways. Similar examples exist in case of knowledge dissemination in agriculture. Insights from behavioural and network economics may provide useful inputs- in this context along with tools such as agent based models.

o Economics of ecosystem based adaptation: While the general analysis points to the significant role of ecosystem services in mediating climate impacts, there is less evidence regarding actual adaptation costs. By linking such costs with payments for ecosystem services, climate change adaptation can be effectively integrated with environmental management.

Building Capacity

Finally, adaptation to climate change and associated economic analysis are not widely understood, especially in policy circles and to some extent, in research circles in south Asian countries. Hence there is an urgent need for designing short-term training programmes for different stake-holders and for careful long-term learning through collaborative research.

Notes

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1 The Chennai workshop was attended, among others, by K Krishna Kumar (Indian Institute of Tropical Meteorology, Pune), Anand Patwardhan (Indian Institute of Technology, Mumbai), K S Kavi Kumar (MSE, Chennai), Sumana Bhattacharya (Winrock International India, Delhi), A V M Subba Rao (Central Research Institute for Dryland Agriculture, Hyderabad), Bharat Ramaswami (Indian Statistical Institute, Delhi), A Arivudai Nambi (MSSRF, Chennai), Shrinivas Badiger (Ashoka Trust for Research in Ecology and the Environment, Bangalore), S Janakarajan (Madras Institute of Development Studies (MIDS), Chennai), Sujatha Byravan (Institute for Financial Management and Research, Chennai), Saudamini Das (Swami Shradhanand College, Delhi), Sudhir Chellarajan (Indian Institute of Technology, Chennai), Pranab Mukhopadhyay (Goa University, Goa), Arabinda Mishra

(TERI University, Delhi), Priya Shyam- sundar (SANDEE), Anupam Khanna (Global Development- Network, Delhi), Shantanu Mitra (DFID, Delhi), S Vidya (British Deputy High Com-mission, Chennai), S Vaideeswaran (World Bank, Delhi), A Vaidyanathan (Economist, Chennai), U Sankar (MSE, Chennai), Brinda Viswanathan (MSE, Chennai), Indira Devi (Kerala Agricultural University Thissur), Chandra Sekhar Bahinipati (MIDS, Chennai), and Sukanya Das (MSE, Chennai).

2 For more information and results, see http:// gisserver.civil.iitd.ac.in/natcom

3 The mismatch between what a policy-holder expects- insurance policies to cover and what the insurance contracts actually provide as loss indemnification- represents the basis risk in insurance-.

References

Aggarwal, P K (2009): "Vulnerability of Indian Agri-culture to Climate Change: Current State of Knowledge", presented at the National Workshop

– Review of Implementation of Work Programme Towards Indian Network of Climate Change As-sessment, MoEF, New Delhi, 14 October. Accessed 14 March 2010: http://moef.nic.in/downloads/ others/Vulnerability_PK%20Aggarwal.pdf

Agrawala, S and S Fankhauser (ed.) (2008): *Economic Aspects of Adaptation to Climate Change: Costs, Benefits and Policy Instruments* (Paris: OECD).

Badiger, S (2010): "Integrated Modelling Framework for Assessing Impacts of Changes in Land-use and Climate on Hydrologic Regimes and Water Distri-bution", presentation at the workshop "Economics of Climate Change Adaptation", MSE, Chennai, 12-13 February.

Byravan, S and S Chella Rajan (2009): "Warming-up to Immigrants: An Option for US Climate Policy", *Economic & Political Weekly*, 44(45): 19-23.

Das, Saudamini (2007):, "Storm Protection by Mangroves- in Orissa: An Analysis of the 1999 Super Cyclone", SANDEE Working Paper 25-07, Kathmandu.

Economics of Adaptation to Climate Change Study (2009): "The Costs to Developing Countries of Adapting to Climate Change: New Methods and Estimates", Consultation Draft, World Bank, Washington DC.

Economics of Climate Adaptation Working Group (2009): "Shaping Climate Resilient Development

– A Framework for Decision Making", Climate-Works Foundation, European Commission, Glo-bal Environment Facility, McKinsey & Company, Rockefeller Foundation, Standard Chartered Bank, Swiss Reinsurance Company.

Jacoby, H, E Skoufias and M Rabassa (2009): "On the Distributional Implications of Climate Change: A Methodological Framework and Application to Rural India", World Bank, Washington DC. Ac-cessed on 14 March 2010: http://go.worldbank. org/XDJN920PA0

Janakarajan, S (2010): "Understanding the Impacts of Climate Change in the Context of Coastal Tamil Nadu", presentation at the workshop on "Eco- nomics of Climate Change Adaptation", MSE, Chennai, 12-13 February.

Krishna Kumar, K (2010): "Climate Models: What Is Known and What Is Needed for Adaptation Assessment?" presentation at the workshop "Economics of Climate Change Adaptation", MSE, Chennai, 12-13 February.

Kumar, K S Kavi (2009): "Climate Sensitivity of Indian Agriculture: Do Spatial Effects Matter?", SANDEE Working Paper 45-09, Kathmandu.

Kumar, K S Kavi and Jyoti Parikh (2001): "Indian Agri-culture and Climate Sensitivity", *Global Environ-mental Change*, 11(2): 147-54.

Mishra, A and A Markandya (2010): "Costing Adapta-tion: Preparing for Climate Change in India", presentation at the workshop "Economics of -Climate Change Adaptation", MSE, Chennai, 12-13 February.

MSSRF (2008): *A Road Map for Policy Development: Community Level Adaptation to Climate Change and Its Relevance to National Action Plan* (Chennai: MSSRF).

Nelson, G C, M Rosegrant, J Koo, R Robertson, T Sulser, T Zhu, S Msangi, C Ringler, S Msangi, A Palazzo, M Batka, M Magalhaes, R Valmonte-Santos, M Ewing and D Lee (2009): "Climate Change: Impact on Agriculture and Costs of Ad-aptation", International Food Policy Research In-stitute, Washington DC.

Parry, M, N Arnell, P Berry, D Dodman, S Fankhaus-er, C Hope, S Kovats, R Nicholls, D Satter-thwaite, R Tiffin and T Wheeler (2009): *Assess-ing the Costs of Adaptation to Climate Change – A Review of UNFCCC- and Other Recent Studies* (London: International Institute for Environment- and Development and Grantham Institute for Climate Change, Imperial College London).

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SEI (2008): "Effective Use of Climate Science to Improve- Adaptation in Africa", Policy brief, SEI, Stockholm.

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Annexure

NATIONAL AMBIENT AIR QUALITY STANDARDS

CENTRAL POLLUTION CONTROL BOARD

NOTIFICATION

New Delhi, the 18th of November, 2009

No.B-29016/20/90/PCI-L – In exercise of the powers conferred by Sub-section (2) (h) of section 16 of the Air (Prevention and Control of Pollution) Act, 1981 (Act No.14 of 1981), and in supersession of the Notification No(s).S.O.384(E), dated 11th April, 1994 and S.O.925(E) dated 14th October, 1998, the Central Pollution Control Board hereby notify the National Ambient Air Quality Standards with immediate effect, namely:-

NATIONAL AMBIENT AIR QUALITY STANDARDS

S.No	Pollutant	Time Weighted Average	**Concentration in Ambient Air**		
			Industrial. Residential, Rural and Other Area	Ecologically Sensitive Area (Notified by Central Government)	Methods of Measurement
(1)	(2)	(3)	(4)	(5)	(6)
1	Sulphur Dioxide (SO_2), $\mu g/m^3$	Annual* 24 hours**	50 80	20 80	- Improved West and Gaeke - Ultraviolet fluorescence
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	(NO_2), $\mu g/m^3$				
3	Particulate Matter (size less than 10 μm) or PM_{10} $\mu g/m^3$	Annual* 24 hours**	60 100	60 100	- Gravimetric - TOEM - Beta attenuation
4	Particulate Matter (size less than 2.5 μm) or PM_{25} $\mu g/m^3$	Annual* 24 hours**	40 60	40 60	- Gravimetric - TOEM - Beta attenuation
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6	Lead (Pb) $\mu g/m^3$	Annual* 24 hours**	0.50 1.0	0.50 1.0	- AAS/ICP method after sampling on EPM 2000 Or equivalent filter paper - ED-XRF using Teflon filter
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11	Arsenic (As) $\mu g/m^3$	Annual*	06	06	- AAS/ICP method after sampling on EPM 2000 or equivalent filter paper
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* Annual arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week, 24 hourly at uniform intervals.

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[ADVT-III/4/184/09/Exty.]

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Economics of Climate Change Adaptation in India

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The Madras School of Economics (MSE), the M S Swaminathan Re-search Foundation (MSSRF) and the South Asian Network for Development and Environmental Economics (SANDEE) organised a brainstorming workshop on the "Economics of Climate Change -Adaptation" on 12-13 February 2010 at the MSE, Chennai to identify policy gaps, research questions and capacity-building needs related to India's- need to adapt to climate change. This note provides a summary of the discussions at this workshop and draws some conclusions for future policy analyses.[1] Besides talks and discussion, the work-shop also had a panel discussion on "Challenges in Mainstreaming Climate Change Adaptation", chaired by M S Swaminathan. Climate change impact assessment and adaptation studies require predictions from climate models. To plan for adaptation, some important changes are required- in the inputs provided by current climate models.

• First, climate predictions are needed at finer spatial resolutions than are currently available from the global climate models. This is beginning to happen. For example, the Indian Institute of Tropical Meteorology has developed high resolution (50 square kilometres) regional climate change scenarios for India using the Had-ley Centre regional climate model PREdicting Climate for Impact Studies (PRE-CIS). Similar exercises are underway to develop a suite of high resolution future climate scenarios for India by running a range of regional climate models, and using- lateral boundary conditions from a variety of Intergovernmental Panel on Climate- Change (IPCC) Fifth Assessment Report (AR5) coupled models (Krishna Kumar 2010).

• Second, future scenarios of climate need to go beyond predictions on temperature and precipitation. Along with these primary variables, impact and adaptation- experts

would benefit from knowledge on secondary variables such as heating degree- days, combining information on available temperature range over the growing period of agricultural crops, heat index, starting and ending days of seasonal monsoon rainfall, storm surges, etc (Patwardhan-2010)
As locally downscaled climate information becomes available, advances in policy responses and examination of climate implications will become more feasible.

Adaptation as a Development 'Continuum'

Any discussion on climate change adaptation must recognise two sometimes contrasting perspectives on the nature of adaptation: (1) climate change imposes a distinct and additional burden on society;

(2) Climate adaptation is one response among many to a host of socio-economic and environmental pressures, and cannot necessarily be isolated from regular development activities.

Under some circumstances, the additional vulnerability of economic agents to climate change and specific measures to reduce this vulnerability can be clearly identified. For example, if climate change is expected to increase precipitation and flooding in certain areas, the additional economic damages from these floods and "adaptive" investments required to reduce these damages can be established. Thus, in these circumstances, it may be possible to identify clearly the additional burden of climate change and adaptation.

However, climate adaptation may be rendered ineffective if policies are not designed in the context of other development concerns. For instance, a comprehensive strategy that seeks to improve food security in the context of climate change may include a set of coordinated measures -related to agricultural extension, crop -diversification, integrated water- and pest management, and agricultural information services. Some of these measures may have to do with climatic changes and -others with economic development. Thus, in the broader development context, building adaptive capacity is much more than developing climate--related adaptation strategies. It is thus useful to examine climate adaptation, whether it is spontaneous or policy- driven, in tandem with other economic development options.

Costs of Adaptation

The origins of research on adaptation costs can be traced to climate change impact studies, where the objective was not to assess adaptation costs per se, but to refine impact estimates with proper ac-counting of adaptation to climate change. In this strand of literature, adaptation costs are defined as the expected value of avoided climate damages in the future, conditional upon some future state of socio-economic vulnerability. In a recent survey of such studies, Agrawala and Fankhauser (2008) argue that with the exception of coastal protection, knowledge on adaptation costs and benefits is fairly limited. Other studies examine- "welfare" in future scenarios with and without climate- change, estimate the costs of adapting to climate change and examine the "benefits" in terms of reduced vulnerability (improved welfare) to climate change (Nelson- et al 2009).

Even though consensus on a central -estimate of adaptation cost has not emerged, a relatively narrow range of estimates has emerged from various studies following a variety of methodologies (see for example, United Nations Framework Convention on Climate Change 2007, Parry et al 2009, Economics of Adaptation to Climate Change Study 2009, Nelson- et al 2009). With a view to supplement existing knowledge- on adaptation cost estimates, Basque Centre for Climate- Change (BC3) and The Energy and Re-sources Institute (TERI) have attempted to estimate costs of adaptation for India. This collaborative -effort identifies many methodological challenges and data needs (Mishra and Markandya 2010). In another ongoing effort, the World Bank, Japan International Cooperation Agency (JICA) and Asian -Development Bank (ADB) are assessing damage costs from climate induced -flooding and required adaptation "investment costs" in four major cities of the developing world, including Kolkata in India. Future research in this context should focus more on fine-tuning methodo-logies and understanding a range of estimates and tradeoffs, and less on arriving at specific cost estimates. Research should also focus on integrating climate change concerns with other existing- and emerging concerns-.

Climate Adaptation in Agriculture

It is well established that climate change will have significantly adverse impacts on agriculture, especially in developing countries like India. Given the large proportion of the population dependent on agriculture directly and indirectly adverse effects on agriculture could easily translate into an escalation of poverty.

Increase in carbon dioxide concentration to 550 parts per million (ppm) could increase yields of rice, wheat, legumes and oilseeds by 10-20%. However, a one degree increase in temperature may reduce yields of wheat, soyabean, mustard, groundnut, and potato by 3-7% (Aggarwal 2009). The yield losses are likely to be much higher at higher temperatures. Studies assessing the economic impacts of climate change on agriculture have -focused mostly on impacts on cereal crops like rice and wheat. New research findings from crop models on non-cereal and commercial crops have not been integrated yet into economic models.

Kumar and Parikh (2001) and Sanghi and Mendelsohn (2008) have estimated that under moderate climate change scenarios, there could be about 9% decline in farm-level net revenues in India. More adverse- impacts are predicted in high-- value agricultural regions such as Punjab, Haryana and Uttar Pradesh and dry regions- such as Gujarat and Rajasthan. On the other hand, the eastern states of Bihar and West Bengal could benefit marginally.

Nelson et al (2009) have estimated that the daily per capita calorie availability in south Asia will decline by about 8 percentage- points in 2050 due to climate change impacts on cereal crop yields compared to levels in 2000. In terms of the distributional effects of climate change impacts on agriculture, available preliminary evidence suggests that changes in poverty rates are not highly localised even though the adverse impacts are concentrated in the northern parts of the country for example, Punjab is proportionately harder hit due to climate change but is a richer region to start with (Jacoby et al 2009).

Citing the presence of strong spatial -autocorrelation in the agricultural output data in India, Kumar (2009) argues in -favour of controlling for spatial effects in climate change impact estimation. Among other things, strong flow of information amongst farmers may contribute to farmers being better able to adapt to climate change. Research priorities in this context include exploring the factors that facilitate information diffusion in agriculture.

Based on field-level work carried out in Andhra Pradesh and Rajasthan, MSSRF (2008) suggests that there are effective ways to make farmers more adaptive to climate changes. They recommend specific changes in traditional water management practices such as *harren* in Rajasthan, establishing smart farmer networks that enable farmers to share knowledge on farm management practices, utilising weather data from simple agro meteorological stations operated by the farmers and use of some new rice farming techniques such as systems of rice intensification. While many such options appear rational at a case study level, the next step is to demonstrate through rigorous research their effectiveness when appropriately scaled-up.

Water and Coastal Sectors

Water and coastal resources are two other important sectors that could face significant adverse impacts in India due to climate- change. Like agriculture, these sectors also face considerable non-climatic pressures. Hence, the challenge is to integrate responses to non-climatic stresses with those that can minimise potential climate change impacts.

For India's National Communications (NATCOM) to the United Nations Frame-work Convention on Climate Change (UNFCCC), river-basin specific impacts of various climate change scenarios and vulnerability to drought and floods has been estimated at the catchment, sub-catchment and watershed levels, as well for administrative units such as districts.[2] While such exercises are useful, given the multiple pressures that act on water re-sources, integrated watershed modelling might be more appropriate. Following such a strategy, Badiger (2010) has stud-ied the Malaprabha catchment area of the Krishna basin in detail and argues that much of the perceived water scarcity in the study area is attributable to farming and land use practices. Janakarajan (2010), on the other hand, examined the current adaptation strategies of stakeholders in the Cauvery delta of Tamil Nadu and argued that the responses to -climatic and non climatic pressures have largely been ad hoc and hence could be -inadequate and unsustainable in the long term. Some existing practices may have adverse implications as well. An example is the destruction of mangroves. Through a detailed analysis of the Orissa super -cyclone in 1999, Das (2007) has shown that mangroves have significant influence on reducing human and property losses, even compared to institutional preparedness measures such as cyclone warning and evacuation.

The IPCC predicts that sea-level rise may be the greatest threat to sustainable development in south Asia. The consequences in terms of flooding of low-lying deltas, re-treat of shorelines, salinisation and changes in water table could cause potentially serious problems to large populations. Unlike other causes that force people to migrate, sea-level rise poses a permanent problem, with little or no scope for migrants to return home. Byravan and Chella Rajan (2009) argued that existing institutional arrange-ments may not be sufficiently equipped to handle within and across country migration -resulting from sea-level rise. More detailed studies can be undertaken at selective hot-spot areas and on state-level policies and individual sectors.

Adaptation Cost Curves

A research priority with regard to economics of climate change adaptation would be assessment of adaptation costs for India as well as sub-regions such as states. Such estimates would be important for climate negotiations as well as for resource allocation. Here, a useful way forward may be in constructing adaptation cost curves, which demonstrate the costs of multiple adaptation strategies. Economics of Climate Adaptation (2009), for example, has estimated the costs of a variety of adaptation strategies in response to drought in Maharashtra. Establishing such cost curves is necessary if we are to identify least cost options. We note that while cost calculations can be relatively straightforward, careful attention may be required if the benefits of each strategy differ.

Adaptation Instruments

In addition to the costs and benefits of adaptation strategies, careful economic analysis is required of instruments that could facilitate adaptation. Some emerging areas of research priority include:

• assessing the usefulness of local weather stations in agriculture: It is often argued that weather data from simple agro-meteorological stations can be of significant use to farmers for their farm management practices. This is well documented through studies undertaken by MSSRF (2008) in India and the Stockholm Environment Institute (SEI)

(2008) in Africa. However, since this evidence is not based on random experiments, further analysis is needed to deal with the problems of selfselection by farmers and the associated implications for understanding farm-level outcomes.

- Effectiveness of insurance as adaptation strategy: It is widely believed that insurance could serve as an appropriate adaptation strategy. In India, the entry of private insurance companies to offer index insurance to farmers has given rise to optimism. However, the costs of designing a contract are still very high and it is hard to establish basis risk.[3] Ramaswami (2010), for example, argues that while index insurance is potentially valuable to business entities and local governments that are exposed to pooled agricultural

Impacts at Policy-Relevant Scales

From the above discussion, it is clear that an important first step in the economic analysis of adaptation to climate change is assessment of the impacts of various climate change scenarios at disaggregated levels. The existing knowledge base in this regard is sketchy. While the NATCOM under the Ministry of Environment and Forests (MoEF) is working towards this objective, the social science component of the NATCOM network is weak. Further, in addition to a national analysis, state-level exercises will be needed for designing -effective adaptation strategies. Given the focus on adaptation, impact assessment exercises need not fine-tune or over emphasise further improvements in our understanding of potential impacts. Instead, the focus should be on getting estimates at a disaggregated level so thatrisks, it may not be very effective for -individual farmers. For individual farmers (or households), catastrophe insurance may be more valuable. These issues need further research. Further, insurance as an instrument is amenable to fluctuations in weather around a stable climate. Its effectiveness in addressing fluctuations in weather around changing climate is unclear

- Addressing the challenges of migration as an adaptation strategy: The usual development paradigm has seen migration of people from inland towards coastal regions. However, with rise in sea levels and coastal inundation, reverse migration may be witnessed. An important researchable issue in this context relates to the triggers associated with sea level rise and inundation that prompt migration. There is already much that is known about the behavioural dimensions of migration; how this knowledge applies to climate related migration needs to be more carefully examined.

• The role of information diffusion as adaptation strategy: Often lack of information can lead to catastrophic consequences. While the government might be doing its bit in undertaking campaigns, say for instance, to reduce heat stroke effects, it may not be reaching the targeted end users due to lack of adequate understanding about information diffusion pathways. Similar examples exist in case of knowledge dissemination in agriculture. Insights from behavioural and network economics may provide useful inputs- in this context along with tools such as agent based models.

• Economics of ecosystem based adaptation: While the general analysis points to the significant role of ecosystem services in mediating climate impacts, there is less evidence regarding actual adaptation costs. By linking such costs with payments for ecosystem services, climate change adaptation can be effectively integrated with environmental management.

Building Capacity

Finally, adaptation to climate change and associated economic analysis are not widely understood, especially in policy circles and to some extent, in research circles in south Asian countries. Hence there is an urgent need for designing short-term training programmes for different stake-holders and for careful long-term learning through collaborative research.

Notes

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1 The Chennai workshop was attended, among others, by K Krishna Kumar (Indian Institute of Tropical Meteorology, Pune), Anand Patwardhan (Indian Institute of Technology, Mumbai), K S Kavi Kumar (MSE, Chennai), Sumana Bhattacharya (Winrock International India, Delhi), A V M Subba Rao (Central Research Institute for Dryland Agriculture, Hyderabad), Bharat Ramaswami (Indian Statistical Institute, Delhi), A Arivudai Nambi (MSSRF, Chennai), Shrinivas Badiger (Ashoka Trust for Research in Ecology and the Environment, Bangalore), S Janakarajan (Madras Institute of Development Studies (MIDS), Chennai), Sujatha Byravan (Institute for Financial Management and Research, Chennai), Saudamini Das (Swami Shradhanand College, Delhi), Sudhir Chellarajan (Indian Institute of Technology, Chennai), Pranab Mukhopadhyay (Goa University, Goa), Arabinda Mishra

(TERI University, Delhi), Priya Shyam- sundar (SANDEE), Anupam Khanna (Global Development- Network, Delhi), Shantanu Mitra (DFID, Delhi), S Vidya (British Deputy High Com-mission, Chennai), S Vaideeswaran (World Bank, Delhi), A Vaidyanathan (Economist, Chennai), U Sankar (MSE, Chennai), Brinda Viswanathan (MSE, Chennai), Indira Devi (Kerala Agricultural University Thissur), Chandra Sekhar Bahinipati (MIDS, Chennai), and Sukanya Das (MSE, Chennai).

2 For more information and results, see http:// gisserver.civil.iitd.ac.in/natcom

3 The mismatch between what a policy-holder expects- insurance policies to cover and what the insurance contracts actually provide as loss indemnification- represents the basis risk in insurance-.

References

Aggarwal, P K (2009): "Vulnerability of Indian Agri-culture to Climate Change: Current State of Knowledge", presented at the National Workshop

– Review of Implementation of Work Programme Towards Indian Network of Climate Change As-sessment, MoEF, New Delhi, 14 October. Accessed 14 March 2010: http://moef.nic.in/downloads/ others/Vulnerability_PK%20Aggarwal.pdf

Agrawala, S and S Fankhauser (ed.) (2008): *Economic Aspects of Adaptation to Climate Change: Costs, Benefits and Policy Instruments* (Paris: OECD).

Badiger, S (2010): "Integrated Modelling Framework for Assessing Impacts of Changes in Land-use and Climate on Hydrologic Regimes and Water Distri-bution", presentation at the workshop "Economics of Climate Change Adaptation", MSE, Chennai, 12-13 February.

Byravan, S and S Chella Rajan (2009): "Warming-up to Immigrants: An Option for US Climate Policy", *Economic & Political Weekly*, 44(45): 19-23.

Das, Saudamini (2007): "Storm Protection by Mangroves- in Orissa: An Analysis of the 1999 Super Cyclone", SANDEE Working Paper 25-07, Kathmandu.

Economics of Adaptation to Climate Change Study (2009): "The Costs to Developing Countries of Adapting to Climate Change: New Methods and Estimates", Consultation Draft, World Bank, Washington DC.

Economics of Climate Adaptation Working Group (2009): "Shaping Climate Resilient Development

– A Framework for Decision Making", Climate-Works Foundation, European Commission, Glo-bal Environment Facility, McKinsey & Company, Rockefeller Foundation, Standard Chartered Bank, Swiss Reinsurance Company.

Jacoby, H, E Skoufias and M Rabassa (2009): "On the Distributional Implications of Climate Change: A Methodological Framework and Application to Rural India", World Bank, Washington DC. Ac-cessed on 14 March 2010: http://go.worldbank. org/XDJN920PA0

Janakarajan, S (2010): "Understanding the Impacts of Climate Change in the Context of Coastal Tamil Nadu", presentation at the workshop on "Eco- nomics of Climate Change Adaptation", MSE, Chennai, 12-13 February.

Krishna Kumar, K (2010): "Climate Models: What Is Known and What Is Needed for Adaptation Assessment?" presentation at the workshop "Economics of Climate Change Adaptation", MSE, Chennai, 12-13 February.

Kumar, K S Kavi (2009): "Climate Sensitivity of Indian Agriculture: Do Spatial Effects Matter?", SANDEE Working Paper 45-09, Kathmandu.

Kumar, K S Kavi and Jyoti Parikh (2001): "Indian Agri-culture and Climate Sensitivity", *Global Environ-mental Change*, 11(2): 147-54.

Mishra, A and A Markandya (2010): "Costing Adapta-tion: Preparing for Climate Change in India", presentation at the workshop "Economics of -Climate Change Adaptation", MSE, Chennai, 12-13 February.

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