Sustainable Land Management in Kerala, India

A Biophysical Approach

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1. Introduction

Kerala, covering an area of 38,860 sq.km. and accommodating a population of about 30 million (1991 Census), lies in the tiny State of Kerala in the south western corner of the Indian Peninsula. It has the second highest population density among all the states of Indian union. This state has drawn global attention in recent years due to its exemplary achievement in physical quality of life and human resource development in spite of low per capita income. The Kerala experience demonstrates that people need not have to wait to cross the economic hump to enjoy the basic necessities to live a full human life. Redistributive policy of the Government and determined people's initiative are considered to be main contributory factors (Franke,1993 and Sen & Dreze,1996). Diagnosis of the Kerala scenario indicates that apart from social factors it is the natural resource endowment covering land, water and biomass and the physiography that played a very vital role in the emergence of the Kerala model. It is important to note that conducive biophysical backdrop is available for appropriate social action. There are certain definite natural opportunities that facilitate pursuing the socio-economic aspirations of the people. However, in recent years, deterioration of the natural resource base that evidently had far reaching consequences are well evident.

Natural forest has reduced from 44% in 1905 to 14% in 1983 (Chattopadhyay et al 1986). Mono cropping is increasing at an alarming rate. Rubber plantations cover about 18% of the total agricultural land and 11% of the total geographical area of the State.

Analysis of data pertaining to extreme rainfall, seasonal rainfall and annual rainfall shows that in all cases there is a decrease of 15 to 20% in the hilly tracts of Ernakulam, Kottayam and Idukki districts (Chattopadhyay 1996).

Field experience shows that the temperature of the forest area has increased significantly. Many of the rivers are drying up. For rain-fed rivers like ours in Kerala, it is the catchment ecology that provides base flow. Decrease in rainfall and change in basin ecology lead to non-perenniality.

Due to mono cropping there are also problems of soil nutrients and water quality. River water quality is further affected by urban and industrial effluent discharge and lack of sanitation in the rural areas. The DO values are low in the majority of the rivers in their various stretches. As a result, river water can not be used for domestic purposes. One of the contributory factors in the Kerala model is free availability of water all through the state. With restricted usability of water the natural advantage of wide spread availability of the resource is eroded.

Sand mining from the riverbed and clay mining from the river terrace / floodplain add further complexity to the hydrological regime of the river. Construction of dams in the upper reaches of the river restricts regular flow and also sediment movement.

Changes in vegetation and deforestation add sediment. On the one hand, life of a reservoir is reduced. On the other hand, the lower riparian tract is deprived of sediment. This, coupled with excessive riverbed mining, changes the sediment budget, which also affects the coastal regions. There is also evidence of sand removal from the coastal dunes. Reclamation of wetland is another factor adding to the ecological transformation of the State (Centre for Earth Science Studies, 1997).

The backwaters are polluted due to a variety of reasons. Agricultural pollution does contribute in this sphere. Since 1975, agriculture is in a state of stagnation. Decline of the inherent capability of soils, soil erosion, lack of water and natural vagaries are some of the prime physical factors responsible for this scenario.

What is increasingly a matter of concern in the State is that environmental degradation has set in leading to gradual shrinking of opportunities and imposing constraints on resource use. This has a serious negative impact on the development process.

In this context it is now increasingly felt that a strategy for sustainable land management has to be evolved to arrest deterioration of the resource base of the State and thus to consolidate Kerala's achievement.

It is now important to briefly deal with the concept of sustainable land management and the biophysical approach.

2. Sustainable Land Management and the Bio Physical Approach

The term sustainable development, popularized with the publication of Our Common Future (WCED 1986) is being interpreted in more than one ways by various disciplines.

Although Earth Summit (1992) and Earth Summit +5 (1997) took place and Agenda 21 is accepted by the Nations there is not much headway in evolving a clear cut methodology to apply the concept.

Munasinghe and McNeely (1995) in their review of "Key concept and Terminology of Sustainable Development" concluded that one useful practical approach to sustainable development that may be more comprehensible to policy makers and the public might be to maximize the net benefits of economic and social development, subject to maintaining the services from the quality of natural resources over time.

Interdependence of economic production systems and biophysical systems is well established even on the micro scale.

In fact one of the significant contributions to the debate on sustainable development is recognition of the biophysical dimension of the production process. In this context sustainable development has been defined as a production system in which the technological and management inputs do not adversely affect the biophysical potentiality of the system including its resilience limits for obtaining output (Chattopadhyay and Carpenter, 1991).

Application of the sustainability principle to land management highlights a type of landuse practice that is ecologically suitable and economically viable. In other words output from the landuse is within the carrying capacity of the land. In another plane sustainable land management from biophysical perspectives is linked with the idea that the dynamic processes of the natural environment can become unstable as a result of stress imposed by landuse practices.

Although, the landuse pattern has originally developed in close correspondence to the biophysical system, more precisely, landscape ecology, especially in tropical countries, there occurred certain a transgression / regression over the years.

Today, it is no more dealing with virgin land, much of the earth surface bears imprints of thousands of years of human occupancy, the intensity of which has greatly increased with modern development. It is the increasing load to accommodate our real or perceived needs that has led to the disruption of the landscape ecology / -landuse relationship. Which has resulted in change in environment, degradation of land and isolation of natural systems. This hinders the ecosystem's capability to recover from disturbances and creates impediments to sustainability. In this complex scenario a sustainable landuse pattern has to be designed.

By virtue of its formation, the characteristics of land vary from one place to other. Each parcel of land is unique in character and has a definite production potential. Even the desert has its own production potential. Application of the biophysical approach in land management is therefore a task of identifying the biophysical limits of land units. Landscape ecological analysis provides a unique opportunity in this context. Based on landscape ecological analysis it is possible to characterise each unit of land in terms of topography, soil type, drainage condition, state of water availability and over all environmental capacity. Hence a landscape ecological unit will exhibit a biophysical set up that is different from the rest of the area in the context of production potential.

Thus a broad apportioning of the area for various uses can be worked out by classifying the land. A list of landuse practices may be worked out for each of the identified landscape ecological units. Emphasis on landscape ecology is particularly required since most threats to a sustainable biosphere involve changes in landuse at a large scale (O'Neill et al 1995). Remote sensing data products, topo maps, existing information and field investigation have provided the data base. Landscape ecological analysis is done using the methodology developed by the ITC, The Netherlands.

3. Biophysical Set up of Kerala

Kerala, as a part of the tropical rain forest area is sandwiched between the Lakshadweep sea in the West and the Westernghat mountain in the east. It extends over a distance of 560 km along the coast. The Westernghat crest line reaches to a maximum altitude of 2695 m at the Anaimudi and lies within a short distance from the coast. The Western ghats mountain being the plateau scarp of the south Indian shield has a pronounced effect on the terrain character of Kerala.

Geologically, Kerala is occupied by four major rock formations:

- Crystalline rocks of Precambrian age
- Sedimentary rocks of Tertiary
- Laterities capping the crystalline and the sedimentary rocks
- Recent and sub recent sediments forming the low-lying areas and river valleys (Geological Survey of india, 1976).

The Precambrian crystalline rocks are the dominant rocks. Tertiary rocks occur in a narrow belt along the coastal tract. The recent and sub-recent formations consist of sand, clays and silts with shells and peat beds. The river valleys and a narrow strip along the coast constitute this formation. Laterite occurs as a cap rock over these formations.

The lineament analysis of Kerala indicated that there are three sets of prominent lineaments. These lineaments trend NW-SE, WNW-ESE, N-W and NE-SW. Distribution of land masses, placement of rivers, configuration of the western ghats and coastline alignment point to tectonic activities being responsible for their development.

The relief distribution in terms of area - altitude ratio is asymmetric. Around 62% of the total geographical area lies below 100m. Kerala is endowed with heavy rainfall (>350 cm annually).

Around 60% of this rainfall precipitates during the monsoon months. Seasonal variation in temperature is low. Influence of the sea and orography is well pronounced in climatic condition.

Lateritisation, a consequence of humid tropical conditions, controls the terrain type to a great extent. Laterites are marked as mesa (duri crust), mounds, interfluves and also form slopes.

Mesa formation or hard crust laterite surfaces are confined to below 300m. In the west it can be found right at the coast. Mesa formations are distinct at the altitudinal ranges of 160 m to 220m, 60m to 160 m and 20 m to 60m which were identified as planation surfaces in north Kerala. Mesa surfaces are well preserved in the Malabar region. Distribution of these features parallel to the channel in a linear fashion can be taken as structurally controlled features. Parallel slope retreat is the dominant process in the lateritic terrain on account of which the valleys are broad and flanked by near graded side slope.

Most river courses are straight, indicating structural control. Most of the rivers do not have a continuous floodplain and in some places river courses pass through steep gorge like valleys. Analysis of long profiles of different rivers indicates a high-level knick point at 500-300m altitude, which corresponds to the boundary between the highlands and midlands. Similarly, a major knick point at the midland-lowland junction is evident in the elevation range of 90 to 150 m. Due to the abrupt fall in altitude the rivers lose much of their gradient. In conjugation to the rise in sea level during the past 35000 years need to be considered (Nair, 1995). Due to this rise, which was most probably abrupt, the outfall of the rivers is variously affected. As a result all, rivers enter the sea through some backwater system running parallel to the coast. Prior to entering the coastal plain some of the rivers, particularly in the south, take a northward bulge (convex upward) indicating a structural influence on river course alignment. Another point to note is that many of the rivers are incising.

Laterite and laterite derived materials dominate the soil. Other soil materials include forest loam, riverine alluvium, coastal alluvium, black soil, red loam and peat. Indian Council of Agriculture Research has identified 38 soil mapping units in the State (Kerala State Landuse Board, 1995).

This brief description of the broad biophysical setting of the state that is provided here to give an overall idea about the landscape ecological analysis will be discussed hereafter.

4. Landscape Ecological Analysis

Based on morphogenetic processes, lithology, topography, climate, soil and biomass, a landscape ecological analysis has been attempted. The basic information is drawn from a study on Terrain Analysis of Kerala conducted by Chattopadhyay and Chattopadhyay (1995). At level I, the state can be divided into seven landscape ecological zones (LCZ), namely, Mountain ecosystem (24% of the total geographical area of the state), Hill ecosystem (8%), Palghat gap zone (4%), Lateritic landscape (50%), Alluvial valleys and Flood plain ecosystem (6%), Coastal ecosystem (5%) and Wetland ecosystem (3%). Further analysis brings out that there are 22 landscape ecological units (LEU) at level II. A brief description of each LCZ is provided here before dealing with the LEUs.

Mountain Ecosystem: This zone lying above 600m altitude has been marked in two patches. The Westernghat mountain is characterised by steep slopes, deep valleys, scarp faces, elongated ridges and plateau surfaces. Wayanad plateau in the north and the Munnar-Periyar plateau in the south are conspicuous features. The highest peak in Kerala - Anamudi (2665m) lies in the northeastern corner of the Munnar plateau. Average rainfall of this mountainous region is below 250 cm. However, in some rain shadow zones precipitation is recorded to be below 100cm. Diurnal variation of the temperature is comparatively higher than in the plains.

Provenance of all the rivers in Kerala this zone is characterised by wet ever green, semi evergreen, deciduous forests and grass lands. Agricultural plantations include cardamom, coffee and tea.

Other hill products like ginger, turmeric etc also grow. Paddy, tapioca and coconut are grown in limited areas. The soils are loamy with high organic matter contents. Deforestation, landslides and soil erosion are major problems. The population density is low.

Hill Ecosystem: The area lying between 300m to 600m constitutes this zone. Elongated east west ridges, deep intervening valleys and scarp faces are the major landforms.

Rainfall is above 350 cm and in some places it is even more than 600 cm. Steep slopes are covered with natural vegetation of wet and semi evergreen forests. Scrub forests, grasslands and shola are also found. Soil is dominated by gravelly loam, residual laterite and red loam. Some of the small streams have originated in this zone. Agricultural plantations of tea and coffee occur to a limited extent. Rubber plantations are wide spread.

Other tree crops include coconut, arecanut and fruit trees like jackfruit, mango etc. Land slides, soil erosion and deforestation are major environmental problems. Population density is low.

Palghat Gap Zone: Palghat gap with an width of 30 km is one of the most conspicuous features in the Western ghats that divides the monolithic mountain region into two separate blocks. This gap connects Kerala with the Tamil Nadu plain.

Climatically this zone is significantly different. The converging wind pattern has a profound impact on agroclimate. Temperature is remarkably high in Kerala standard. In some summer days it is recorded to be above 40 C. in some places. Annual rainfall is between 250 cm to 300 cm. A patch of black soil is marked in this zone. Red loam and alluvium are other dominant soil types. Paddy is the main crop. Other important crops are tapioca, coconut, palmyra, groundnut and cotton. Rubber plantations are also recorded.
The settlement pattern is similar to that of Tamil Nadu.

Lateritic Landscape: This is the dominant landscape system in the state. It extends from 10 m to 300 m of altitude. This zone stretches from the northern end to the southern tip of the state.

The landforms are characterized by lateritic mesa, mounds, slopes and ridges. There are certain spatial variations in chemical composition of laterites. Average rainfall is around 250 cm.

Temperature variation is low. The soil is a lateritic, gravelly loam type. Crop productivity, wasteland management and soil erosion are major problems. Settlements are scattered and linearly placed along the ridges. All the urban centres are located in this zone and the population density is high.

Alluvial plains and Flood plains: This landscape occurs in the central part of the state and indents in other units. A sizeable area under this zone is known as "Kuttanad ecosystem" in Alleppey district and "Kole ecosystem" in Trichur district. Soil texture is loam, silty clay loam and clay. Black peat soil is recorded in some places. Water logging during the monsoon season is widely observed. Landform type includes old and new flood plains, levees, back swamps and saucer shaped basins.

Paddy is the main crop. Coconut is also grown. Reclamation of flood plains and valleys is common. Flooding is a major problem. Agricultural pollution is another major issue that warrants due attention. Settlements are spreading over this zone from the adjoining urban centers.

Table 1. Terrain units and their characteristics

Unit name	Symbol	Slope (%)	Dissection	Relative Relief (m)	Drainage density (km/km^2)	Broad Soil Type	Land use	Environmental Evaluation
Beach	C1	<0.5	N	<10	-	S	1	Eroding in places to be protected
Coastal cliff	C2	<1.5	L	<30	-	R.I.	1b,3a	Erosional feature
Coastal Plain	C3	<0.5	N	<10	<1	CA	2b,3a ,7	Densely populated, urban pollution
Coastal Plain-lat.	C4	<0.5	N	<20	<1	I.	3a,7	Do
Tidal/Mud flat	C5	<0.5	N	<05	-	CL	6	Partly reclaimed, submessible
Plain with Palaco strandlines	C6	<0.5	N	<10	<1	S	2a,3a ,7	Densely populated prominent sand ridges
Flood plain	F1	<0.5	N	<20	>1	A	2a,7	Narrow, discontinuous, water logged during monsoon, partly reclaimed
River terrace	F2	<1.0	L	<40	>1	A, Co	2a,3b	Narrow
Allluvial Plain-I	P1	<0.5	N	<05	>1	A	2a,2b	Drainage congestion, flooding
Alluvial Plain-II	P2	<0.5	N	<05	>2	A	2b	Flooding, agricultural pollution
Transitional Plain	P3	<1.0	N	<20	<1	A,S,Co,L	3a,3b ,7	Clay laterite interface
Fluvio-Lacustrine Plain	P4	<0.5	N	<05	>2	A	2b,6	Flooding, agricultural pollution
Basin/water logged area	P4-1	<0.5	N	<05	-	A	2b,6	Prolonged water logging
Low rolling terrain	D1	<1.5	L	>20	<1	L,A	3a,3b ,7	Partly erosion affected
Moderately undulating terrain	D2	<2.5	M	<40	>1	I.	3a,3b ,7,4a	Erosion affected
Highly undulating terrain	D3	<3.5	N	>100	>3	L,Re	3b,7, 4a	Deforested, Erosion affected, landslide
Hilly area	D4	>3.5	N	>300	>3	Re,V	4a,5a ,5b,5c	Deforested, erosion affected
Isolated residual hill	D5	>3.5	N	>200	>3	Re,V,L	4a,5b ,7	Deforested, erosion affected
Scarp slope	D6	>100	N	>300	>3	Re,R,V	5a,5c	Landslide, Erosion affected
Mesa surface	M1	<1.0	L	<20	<1	D,L	1c,5c, 7	Edaphic draught, no soil cover
Mesa side slope	M2	<3.5	M	>20	>1	L,CI	3a,3b	Erosion affected
Hummocky terrain	H1	<3.5	M	>40	>1	L,A	3a,3b ,7	Erosion in pateclus

Coastal Ecosystem: This zone lies mostly below 10m of altitude as a continuous stretch along the West Coast. In cliff sections the elevation is higher. Annual rainfall is around 300 cm and the temperature is more or less through the day. Sandy soil is dominant. Landforms are characterized by sandy ridges, paleao sand dunes, mud/ tidal flats and coastal cliffs. Coconut is the major crop. Some seasonal crops are also grown. Population density is high to very high. Coastal erosion, sea surge and water pollution are environmental issues that deserve immediate attention.

Wetland Ecosystem: Kerala is endowed with a chain of back water systems. The Vembanad estuary around Cochin is the largest water body followed by the Asthamudi lake. There are some fresh water lakes also. Wetlands are least utilized in the State. Shrinking of the area under wetlands and pollution are major problems.

Further detailed analysis of each of these LEZs except the Wetland Ecosystem has been taken up. It may be deciphered from the above discussion that 5 morphogenic processes namely marine, estuarine, fluvial, denudational cum accumulational and denudational are operating in the state. Following a hierarchical classification system, 22 terrain units have been identified and characteristic features have been worked out to identify the biophysical limit to the land units. Details are given in table 1.

It has been brought out that around 85% of the total area of the state falls under the denudational category. The scarp face that is the near vertical slope of the Westernghats accounts for 4% area. Around 11% of the area has an average slope of 10%. A little over 30% of the area is steeper than 35%. It may be noted that these slopes are the average slopes of the unit as a whole. The area lying below 100 meters altitude accounts for 58% of the total geographical area of the state. A little over 45% of the total area is susceptible to erosion. The highly vulnerable area is about 11,000 sq.km or 28% of the total area.
The isolated hills are mostly structurally controlled and consist of hard crystalline rocks.

The coastal areas marked under 6 units are intensely used. Flood plains and river valleys are also utilized. These areas accommodating principal crop in the state like coconut and seasonal agriculture like paddy, banana and vegetables are over loaded. The same is the case with the laterite slopes. Lateritic mesa surfaces are prominent in north Kerala, particularly in the districts of Kasaragod and Cannanore. Most of the hard crust mesas are lateritic wastelands with seasonal grass cover.

Settlements are widely distributed over almost all the units. Maps of 1:250,000 scale showing these units have been prepared for the entire state to provide district level information on land management plans.

5. Conclusion

This paper brings out significant biophysical information on the landuse pattern of the state. Land characteristics, existing landuse and environmental problems identified for each of the units provide definite indications to be considered when formulating an intervention program. The units can be digitized as spatial data and computed characteristics will form the attribute data in a GIS environment. In this context this study can be used to integrate data from biophysical, economic and social systems and therefore it generates a basic matrix for sustainable land management in Kerala.

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