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Environmental Consequences of Rubber Plantations in Kerala

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ABSTRACT

Replacement of natural vegetation with various plantation crops is a global phenomenon. Rubber was introduced in Kera1a as one of the plantation crops in the beginning of this century. At present it covers about 21% of total cropped area in the state. As an estate crop it has mostly replaced natural vegetation and as small holding crop it is being raised in the places earlier given for tapioca, cashew and even coconut. Spatial spread is controlled by physiography. Research results so far obtained from various sources indicate that there are negative environmental implications associated with rubber plantation. However farmers will continue to grow rubber plantation due to its economic benefit. Given this reality and involvement of large number of farmers it is suggested that site specific in depth studies on environmental impacts are required to arrive at tangible conclusions. Alternatives like intercropping with other crops may also be considered to neutralise some of the adverse impacts. A sustainable production system needs to internalise environmental considerations. The government agencies involved in promoting rubber plantations may consider these issues for future decision making.

1. Introduction

Rubber is an important agricultural plantation in tropics. It is rapidly expanding into both climatically optimal and sub-optimal environments in almost all rubber growing countries across the world. Large areas of natural forests, degraded forests and other crops have been cleared to grow rubber plantations, which is emerging as the most wide spread small holder tree crops. Attracted by the economic benefits and incentives to convert traditional farming areas into high value commercial crops many farmers switched to rubber cultivation. The traditional land use system evolved over a long period of time produced a unique landscape mosaic combining small agricultural plots and an array of locally adopted crops. These practices, to a great extent, were environmentally sustainable protecting the region's rich biodiversity and soil and water resources. One of the major factors driving transition to more intensive agriculture, mono-cropping and crop replacement has been population growth, including internal migration. Besides, there are infrastructural development like expansion of road network and markets making it easier for farmers to purchase agricultural inputs and to sell their crops. Government policy and incentives have also given a shift towards rubber plantation. The ability to store and transport rubber easily as well as over all return on investment make rubber superior to other cash crops. The rapid landuse change on a wide scale may result in negative impacts on the local and even the global environment. Environmental consequences of rubber plantation replacing natural vegetation and also traditional land use practices have been a matter of serious concern among the natural rubber producing countries across the World (Fox, 2014).

While this change may pose a threat to fragile local environments, it may not be possible to turn back the clock as rubber plantations have proved to be highly profitable and helped regeneration of economy in general and rural economy in particular. Given this financial realities it is unlikely that the farmers will return to traditional farming although it may be possible to evolve intercropping with rubber thereby remedying some of the negative impacts. In view of the current space of expansion, economic reality and potential environmental problems associated with the rubber plantation it may be prudent to critically examine the environmental implications of this large scale change in land use at local level. Across the rubber producing countries, there are several studies initiated on environmental consequences of rubber plantations and evidences are accumulating on negative impacts of rubber plantations on biophysical environment. Analysis of these information can provide significant insight into the problems which need due attention.

It is important to note here that questions are often raised about environmental impact of large scale conversion and mono cropping not only for rubber but also all other agricultural plantations. In one hand agriculture grows at the expanse of natural areas like forests, pastures, waste lands, wetlands etc and on the other hand intensification of agriculture results in increasing use of irrigation water, chemical fertilisers and pesticides. Therefore, alteration of natural landscape through agriculture induces physical as well as bio-geochemical changes. Due to autocatalysis, agriculture continues to grow and in the process inflict injury to the environment, which in turn adversely affects the agriculture sector itself. Therefore, agriculture management has to internalise environment management. This is well realised and accordingly, land use change has emerged as an important component of global environmental change programme and in the transition to sustainability. In view of this, we try to contextualise the case of rubber plantation in the larger frame of land use change and its theoretical background.

1.1 Land use change: an indicator of human dimension of environmental change

All human activities transform the landscape directly or indirectly and the land use/ land cover change testifies the first imprint of this modification. This change linked to human history initially began in a slow pace as demand for resources was limited, however with increase in population pressure and advent of industrial revolution the pace, magnitude and kind of change increased (Turner II et al 1990). The human imprint is so pervading and deep rooted that today separation of natural processes exclusively from the human induced conditions is not only difficult, but also analytically questionable (Clark et al, 2003, Moron et al, 2004). Human induced change in landscape and consequences of these changes have been noted since long (Marsh, 1864, Engles, 1879). The part of the human induced changes addressing landuse/landcover change is well embedded in the larger concept of global environmental change and earth system science. So dominating is the human induced processes, that the geologists term this part of the Holocene as Anthropocene. Land use/ land cover change study initiated under the Global Environmental Change (GEC) programme in 1980s is a core research agenda under International Human Dimension Programme (IHDP). The research foci consist of land use dynamics (comparative case study analysis), land cover dynamics (empirical observations and diagnostic models) and regional and global integrated models. An understanding of human dimension of environmental change requires attention to both types of research: systematic changes that operate globally through the major systems of the geosphere-biosphere, and cumulative changes that represent global accumulation of localised changes (Turner II, 1990). Landuse/landcover change (LUCC) science advanced significantly as global research identified landuse/landcover changes as a major element of the global carbon cycle both as source and sink (Moron et al, 2004) and thereby it is an important component of climate change programme.

Land use change is arguably the most pervasive socio-economic force driving changes and degradation of ecosystems, which is a matter of serious concern. Some of the fundamental causes leading to landuse change are mostly endogeneous, such as resource scarcity, increased vulnerability, and changes in social organisation even though they may be influenced by exogeneous factors as well. The other important causes such as changing market opportunities, and policy intervention are mostly exogeneous, even though the response of land users to these external forces is strongly mediated by local factors (Lambin et al, 2003). Globalisation has added another dimension to land use change analysis as ex-situ decisions play decisive role and land use change is now increasingly getting decoupled from local issues.

Although land use/ land cover analysis is a pet theme in geographical research since long renewed interest in this subject started with initiation of International Geosphere-Biosphere programme (IGBP). During the course of implementing this programme it was realized that understanding land use/ land cover change was not possible without proper understanding of human dimensions of this change, more clearly how individual land-user take decisions, an issue dealt mostly under the purview of social sciences. In view of this the IGBP and ISSC (International Social Science Council) came together and set up a working group under the

chairmanship of B. L. Turner-II to explore the possibilities of creating a joint core research programme at the International level. The working group submitted its report in 1993 (Turner II et al, 1993). IGBP programme is being implemented in several countries including India. At the instance of ISSC the International Human Dimension Programme (IHDP) was created to address full range of human dimension issues related to the environment. International Council for Science (ICSU) jointly with ISSC sponsored the IHDP. In this process IGBP, sponsored by ICSU and IHDP jointly sponsored by ISSC and ICSU tied to facilitate the LUCC programme.
The Core Project Planning Committee (CPPC-IGBP)/Research Project Planning Committee (RPPC-HDP) identified several major science questions under LUCC science plan through worldwide deliberations (Turner II et al, 1995). Some of these are listed here.

- How has land cover changed over the last 500 years as a result of human activities?
- What are the major human causes of land cover change in different geographical and historical contexts?
- How will changes in landuse affect land cover in the next 50-100 years?
- How do immediate human and biophysical dynamics affect the sustainability of specific types of land uses?
- How might changes in climate and global biogeochemistry affect both land use and land cover?
- How do land uses and land covers affect the vulnerability of land users in the face of change and how do land cover changes in turn impinge upon and enhance vulnerable and at – risk regions?

1.2 Frame work of Land use change analysis

Moron et al (2004) provided a detailed description of the development of the International land use and land cover change (LULC) research programme. As future land-change research programmes the emerging trends are increasing emphasis on place-based research, the science of forecasting, coupled human-natural systems, interdisciplinary research and relevance to decision making. Land use / land cover change trajectory passes through four broad stages: (i) Undisturbed area or landscape dominated by natural cover types, (ii) Frontier area where landscapes experiencing transformations in natural cover, (iii) Agricultural / managed landscape where management supersedes natural function and there is intensive use of inputs and (iv) Urbanised / industralised landscape dominated by residential, commercial and industrial land cover and are highly managed (Mustard et al.,2004).

Local level analysis of LUCC is significant as it helps understanding the drivers of landuse change, their complexity and variations. Societal causes for land cover change, institutional issues and linkage between social and physical processes are possible through analysis of disaggregated data at the micro level, where the actual land use change is taking place. As all micro level changes, when aggregated, have regional and global manifestation and global issues can trigger local changes it is necessary to capture these changes at local level and also at regional level. Local level investigation is necessary in order to understand site specificity for devising intervention measures to combat ill effects following these changes.

Land use change is a matter of serious concern in Kerala as these changes have far reaching impacts that can seriously impede the resource base and jeopardize the development processes in the State (Chattopadhyay & Franke 2006). The present study intends to investigate the case of rubber in Kerala. Any change of land use will have an impact on bio-physical system and also on socio-economic realm. Land use change studies should focus on analysis of drivers, assessment of impacts and consequences (Chart-1). A clear understanding of drivers is necessary to devise intervention programmes. Similarly, understanding of impacts facilitates assessment and quantification of trade off among ecosystem services. In this report we will be limiting our analysis to environmental consequences of rubber plantation. Results of research so far obtained from various studies conducted in India and abroad are used for the deliberations. Apart from this introductory section there will be two sections dealing with details of rubber plantation and environmental consequences. The last and final section deals with conclusion and recommendations.

2. Rubber cultivation, Landscape Ecology, Productivity, Land use change and Holdings

2.1 Rubber Cultivation in Kerala - An Overview

India ranks fourth in production and fifth in area coverage among the rubber producing countries in the World (Table 1). Kerala produces bulk of India's contribution (89%). Rubber is a major commercial crop in Kerala. It covers 21% of total cropped area in the state and ranks second after coconut among the crops. Area under rubber grew from 1.0 lakh hectares in 1957-58 to 5.48 lakh hectares in 2013-14. Around 14% of total geographical area of Kerala is given for rubber. The major and widespread landuse conversion in Kerala coincides with the introduction of rubber (Hevea Brasiliensis). Rubber, a native of Amazon basin in South America, was introduced as a plantation crop in the tropical Asia during late 19th century (Rubber Board, undated). It is one of the extractive tree crops having a plantation cycle of 25-30 years. There is also a gestation period of 5 to 6 years from planting to maturing. Vegetative cover that it provides to the land differs from other plantations. It is raised both as an estate crop and as small holdings. As an estate crop it replaces forest vegetation and as small holding crop it is grown in areas replacing food crops. Nevertheless, rubber plantations contributed significantly in socio-economic development and raising per capita income.

Rubber as a commercial plantation was introduced in Kerala by 1902, when Periyar Syndicate in Travancore was formed and cultivation of Hevea Brasiliensis variety started (George et al, 1988). Over the past 11decades rubber plantation has emerged as an important contributor to the agroeconomy of the state. Before discussing the details of rubber plantation it will be appropriate to have an idea about the landscape ecology of Kerala to support rubber plantation.

2.2 Landscape Ecology for rubber Plantation

Rubber grows well in the region originally occupied by tropical rainforest at an altitudinal level below 400m, having a temperature range from 21°C to 35°C and an annual rainfall of around 200 cm. A deep, well drained soil is best suited to raise this crop. The best growth of rubber has been found in the areas without a clear dry season (Polhamus, 1962). Dry spell or temperature below 18^{o}C do not affect vegetative growth but reduce latex yield (Verheye, undated). So far as

Kerala is concerned, position of the state with respect to the Lakshadweep Sea and the Westernghat mountain and physiography are two important landscape ecological factors in addition to climate and soil that favour rubber cultivation. From the coastal plain the land rises step by step towards east justifying the name of Western Ghats (Fig 1). Considering altitude the state can be divided into five major physiographic units (Table 2)**.** Each of these units is characterized by unique landform, climate, soil and landuse pattern.

Kerala records an annual average temperature of 28°C and experiences diurnal and seasonal variation of below 6°C due to marine influence. However, due to orographic effect, temperature comes down towards eastern highlands and goes below 15°C around the Anamudi covering Chinnar-Munnar area. Mean isothermal line of 20°C (limit of tropical climate) separates the high mountain region from the foot hills and adjoining uplands.

The state is well endowed with monsoon rainfall; having an annual average precipitation of more than 300 cm. Rainfall distribution pattern indicates that there are two pockets of high rainfall in the foot hill region. A small area in the eastern border is rain shadow region. Normal rainfall pattern shows that the state does not have a decided dry season in general. However, some parts like Palghat and Kasargod in the north and southeastern part of Thiruvananthapuram experience drought condition during the months of April and May.

The major soil types in Kerala are sandy, sandy loam, clay, loam, laterite soil, alluvial soil and black soil. Considering slope, depth texture, drainage and erosional aspects 38 soil mapping units have been identified (KSLUB, 1995). Due to intense chemical weathering soils in Kerala are deep to very deep. Lateritic soil is dominant upto 300m. From 300 to 600m altitudinal rise is abrupt. Temperature decreases with short distance. Within a distance of 1 km, altitudinal rise of 300m to 500m is marked. Around 72% of total land area in Kerala lies below 300m. Out of this 72% around 12% area are under valleys, lowlands and coastal plain. Soils in these areas are characterised by water logging condition, excessive wetness, excessive drainage and high acidity in isolated patches.

The Committee on Agroclimatic Zones and Cropping Patterns (Gok, 1974) identified 13 agroclimatic regions. Indian Council of Agricultural Research (ICAR, 1991) delineated 8 agroclimatic zones in Kerala. Considering geology, physiography, climate, soil and landuse 24 landscape ecological zones were marked in Kerala (Chattopadhyay 1986). In all these classifications southern midland zone (SMZ) stretching from Thiruvananthapuram to Kottayam emerged as a separate agroecological zone. Incidentally it may be noted that the core rubber producing area is mainly concentrated in this zone, although the rubber plantations are spread over the midlands and foothill zone of the entire State (Fig 2).

2.3 Spatial Trend of Area and Production of Rubber in Kerala

According to the data available for 2013-14 it is observed that 21% of total rubber area in the state is concentrated in the district of Kottayam alone followed by Ernakulam (11%) and Pathanamthitta (9%). Alappuzha records less than 1%, and the Wayanad has around 2%. The landscape ecology of Alappuzha is not suitable for rubber cultivation as it is mostly characterized by low lying areas and wetlands. On the other hand Wayanad district being a high elevation plateau (>700m) is not suitable for rubber plantation (Fig 3).

The southern districts covering Thiruvananthapuram, Kollam, Pathanamthitta, Kottayam, Idukki and Ernakulam combinedly accounts for 61% of total area under rubber in the state in 2013-14 which was 73% in 1991-92. During the year 1960-61 the district of Kottayam accounted for 36% of total area under rubber plantation in the state. However, the southern six districts combinedly covered around 73% during 1960-61 also. It emerges from these data that the growth rate in south and north Kerala remained same during a span of 30 years from 1960-61 to 1991-92. The spread of rubber in the northern district intensified since 1991-92. Globalisation, opening up of economy, high market price of rubber and emphasis on cash crop cultivation all together have contributed to this spatial spread.

Considering the growth of area under rubber plantation for the periods of 1960-61 to 1991-92 and 1991-92 to 2013-14 it is found that total area under rubber plantation grew by 247% in the first time segment (1960-61 to 1991-92), which came down to 29% during the second time segment (1991-92-2013-14) for the State as a whole. Average annual growth rate came down from 9770 ha in the first time segment to 5831ha in the second time segment. Due to problem of compatibility of data district wise growth was considered for the period from 1991-92 to 2013-14 (Table 3). It emerges that the northern districts recorded high growth rate during this pwriod with Trissur district ranking first followed by Malappuram and Wayanad. All these three districts showed more than 100% growth. Traditional rubber growth area experienced low growth and Ernakulam district recorded negative growth. This trend indicates that the traditional rubber growing areas are more or less getting saturated and the expansion is going on in the non traditional areas including the lands in high altitudes. This trend of expansion of rubber growing areas in non traditional areas is reported globally. By 2012, rubber plantations covered more than one million hectares of non traditional rubber-growing areas of China Laos, Thailand, Vietnam, Cambodia, and Myanmar (Li and Fox, 2012).

Computation of coverage of rubber in each district with respect to the total cropped area (TCA) of the district indicates that in 2013-14 two districts, namely Kottayam and Pathanamthitta recorded 57% and 50% of TCA under rubber respectively. All districts have recorded substantial growth under rubber plantation between 1985-86 (since when data for all the 14 districts are available) and 2013-14.

The productivity data have been worked out considering total area (tappable & young plants) for past 5 decennial period since 1970 – 71 and for 2013-14 (Tables 4 and 5). As a whole the state has recorded 2.4 times growth in productivity by 2013-14 compared to 19771. District wise production data shows that 21% of the total production of the state is contributed by Kottayam in 2013-14. In 1990-91, Kottayam’s share was 27%. The southern districts together produce little over 70% of total production in the state. Productivity has declined in all districts in the year 2013-14 compared to 2010-11. Pathanamthitta district reported the highest productivity (1.26 t/ ha) in 2013-14. It recorded the first rank in productivity in 2000-01 and 2010-11 also. Kollam has the highest productivity (831 kg/ha) in 1991 - 92. However, both in 1970 - 71 & 1980 - 81 the highest productivity is observed in Thrissur. In 1970 - 71 the Malappuram district recorded the same rate of productivity like Trissur. Over the years Malappuram has lost its position and now (2013-14) it’s productivity has come down below the State average. Productivity of Wayanad district is the lowest in all the years. It is 31% lower than the state average and 36% lower than the productivity of Pathanamthitta, 1st ranking district in the State in the matter of productivity in 2013-14. All districts in north Kerala reported lower productivity than the State average. The trend is more or less same since 1990-91. This perhaps indicates that the productivity in the non traditional areas is low. Although these productivity data have certain limitations as mentioned beforehand, they do indicate a pattern, which is significant.

Variable productivity can be attributed mainly to ecological factors as rubber is a well managed crop throughout the state. Low productivity in Wayanad district is perhaps an indication of physiographic constraint. It is already pointed out that if temperature goes below 18°C, latex production will come down although tree growth may not be affected. The points emerged from the above discussion can be summarised as: 1) the main concentration of rubber is in South Kerala covering southern midland zone and now it is spreading in the northern part also 2) there is a Physiographic limit of growing rubber specially in the higher elevations. Low productivity in Wayanad is an indication of ecological limit. and 3) sheltered condition as prevalent in South Kerala and in Kozhikode appears to be appropriate for rubber plantation as it requires wet condition throughout the year.

2.4 Landuse change and rubber plantation.

Kerala is experiencing strong land use change. By the turn of the century it was clearance of forest and draining of wetlands to expand net sown area and to establish plantations of tea, coffee, cardamom, and pepper. Rice and coconut cultivation was also expanding. Over the years there has been substantial change in cropping pattern. Area under food crop steadily diminished and that of cash crop increased. By 1960-61, food crop non food crop ratio was 67:33, which changed to 50:50 by 1990-91 and by 2013-14 food crop non food crop ratio stood at 37:63. Rubber plantation witnessed steady growth in all these years (Fig. 4). Plantation crops in Kerala notably rubber was introduced by replacing not only natural vegetation but also other crops. Although there is a paucity of data, map analysis has indicated certain trends which are significant in this study. Study of deforestation in Kerala from 1905 to 1984 by Chattopadhyay

(1985) and Chattopadhyay et al (1986) has brought out that Kerala's natural vegetation cover has reduced from 44% in 1905 to 14% in 1984. Deforestation in the lower altitudes (<300m) can be attributed to growth of rubber plantation. Comparison of the map on deforestation (Fig. 5) with that of concentration of rubber plantation clearly brings out the association.

As indicated earlier, rubber replaces crops like tapioca, cashew, fruit trees and also coconut in some cases. Culturable waste lands are also given for rubber plantation. At the present instance area under rubber, tapioca, cashew and wasteland are considered to understand the temporal variation from 1960 – 61 to 2013-14. It emerges from the graph (Fig. 6) that since 1975 - 76 area under tapioca records a sharp decline, whereas area under rubber steadily increased particularly from 1980-81. Field investigation points out that, cashew was replaced by rubber in many places. But, in the dry area like Kannur and Kasargode, where hard laterite is a limitation to agriculture, initial attempts to convert cashew area to rubber was not very successful. So reconversion from rubber to cashew is also marked. Waste lands are given mainly for cashew but also for rubber in some cases. The trend of curve showing rubber also indicates that rate of growth is gradually slowing down. Perhaps area under rubber plantation is reaching to a saturation point in Kerala.

To understand the exact nature of spatial expansion of rubber plantation, landuse change was examined covering an area of 500 km^2 in Thodupuzha- Painavu stretch for the years of 1911 - 12 and 1976 – 77 as the old maps were available for those two time points (Chattopadhyay, 1996). Three landuse categories namely, area under rubber, forests & grasslands and others covering settlements, trees paddy fields and other plantations could be deciphered. During 1911-12 there were five rubber estates, namely Kaliyar estate, Mundunad estate. Martoma estate, Malankara estate. Velliamattom estate. All these estates were below 100m altitude. The main landuse was forests, scrubs and grasslands, which covered nearly 60% of the total area. There were three cardamom plantation within forests. Valleys were under paddy. Dry land paddy (terrace cultivation) was also practiced particularly in the Thodupulai Ar watershed.

During 1976 - 77 (for which data are available) there is a drastic change in landuse pattern. The same numbers of rubber estates are in operation with larger area, specially spreading along the down slope. However, small holding plantations have increased significantly. Plantations have been developed even in higher altitudes. Area under different landuse categories have been given in Table 6. Additional plantations that have come up during this period are teak, eucalyptus and tea. Cardamom plantation has also grown in size. It emerges from map analysis and field visit that rubber plantation which was restricted to 300m of altitude in this area for a long time is now spreading over higher altitudes. The area under open scrub is being encroached upon initially by tree crops and subsequently by rubber plantation. Due to low soil depth on the ridges and steep side slopes, expansion of rubber plantation in this landscape is restricted. Isolated hills are under open scrubs. Grasslands occupy the higher ridges and cardamom plantation is marked in plateau above 700m of altitude.

Another exercise for Manickal panchayat has brought out spread of rubber vis – a –vis altitudes. Broad landuse for the years of 1967, 1990 and 2008 has been draped on digital terrain model showing elevations (Suresh Kumar personal communication). It may be observed from Figs 7a, 7b. 7c that rubber plantation which was initially distributed in five patches spreading over relatively higher altitudes of more than 100m in 1967 has gradually spread over throughout the panchayats and even in the river valley and flood plains by 2008.

2.4 Holding size and rubber plantation

Tree crop is a significant feature in Kerala's land use. Homestead gardens and tree crop culture added to the high biomass density. Rubber cultivation is not restricted to the estates alone; it has gradually emerged as a peasant's crop. This trend crept in since early days. In the early 20thcentury the stimulus provided by motor transport in the developed countries led to rubber plantations under the control of small farmers in parts of Malaysia, India and Sri Lanka (Redclift, 1987). Domination of small holdings increased over the years. Available data indicates that share of small holdings increased from 65% in 1960 - 61 to 93% in 2010-11 (Table 7). Between 1991-92 and 2013-14 area under estates declined particularly in the category of 400 ha to 600ha and >600 ha category (Table. 8). Rubber in Kerala is now part of homestead garden. It is found that 86% of holdings fall in the category of below 2 ha. Government initiatives in various forms are major contributing factors. Given the settlement distribution pattern it may be inferred from these data that big estates have replaced either natural vegetation, degraded forests or other plantations as large tract of land is not otherwise available. In the case of small holding size it is usually replacing tapioca, other fruit trees and coconut. Environmental responses for these two groups may not necessarily be the same. In case of replacement of natural forest the cascading impacts ranging from biodiversity loss to soil erosion and hydrological disruption. However, where rubber replaced other crops, the impact may not be of same intensity as the land has already undergone certain changes due to colonisation of non forest vegetation.

3.0 Environmental consequences of rubber plantation

There are wide spread concern about environmental impact of rubber plantations among the rubber producing countries. These impacts are related to micro climate change, negative hydrological change/ drought, nutrient/ sediment run off, eutrofication and poisoning of rivers, and severe loss of species and extinction of local species. Biodiversity loss may also lead to reduced total carbon biomass (Ziegler et al, 2009) thereby impacting climate change. Before dealing with the sector wise impacts we provide here a brief review of literature reporting international and national studies.

3.1 Brief review of literatures

Ziegler et al (2009) reported the case of conversion of natural forests into rubber plantation and associated environmental issues in the mainland South East Asia, where rubber plantation covers five lakh hectares at present and by 2050 it may be tripled. Another study in south east Asia indicated greater annual catchment water losses through evapotranspiration from the rubber dominated catchments compared to traditional vegetation cover (Gourdiola-Claramonte, et al.2010). This additional water use reduces discharges from the basin or its storage. Variations in transpiration of rubber plantation with age and over the seasons have been reported from Central Cambodia (Kobayshi et al., 2014). United Nations Mission in Liberia (undated) conducted survey on environmental conditions in selected rubber plantations in Liberia and found that in-situ environment of the people engaged in rubber plantations are poor. Rubber plantation can potentially change the partitioning of water, energy and carbon at multiple scales compared to the traditional land covers that are being replaced, thereby primary productivity and water use efficiency are possibly affected (Kumagai et al. 2013). In case of Kalimantan, Borneo rubber plantation has not replaced primary forest in large scale as it has not triggered large scale migration of people (Jong, 2001), however there are issues of environmental impact in the case of soil and water.

One of the earlier studies conducted by Chattopadhyay (1996) in Kerala indicated possible impacts of rubber plantations in the State. Some recent studies examined individual components like soil erodibility under plantations (Satish et al, 2008) and depletion of ground water due to prolonged rubber cultivation (Karunakaran, 2012). Field reports indicated that rubber plantations are affected by landslides. Warming of climate and change in rainfall may impact production of natural rubber in Kerala as indicated by experimental studies (Satheesh and Jacob, 2011). A study on earthworm community under rubber plantation in Tripura indicated that density, biomass and dominance of earthworms increased, while species diversity, species richness and species evenness of earthworm community decreased with increase in age of rubber plantation (Chaudhury et al, 2013).

3.2 Micro Climate

The physical mechanism of the effect of natural vegetation loss or change in land use land cover on the climatic condition of a region is yet to be fully understood, however, there are evidences indicating that land use changes influence micro climatic condition particularly rainfall pattern. The works of Meher-Homji (1980) in the Munnar area of Idukki and of Biswas (1980) in the Andaman & Nicobar islands concluded that the decreasing levels of rainfall and rainy days is closely related to deforestation.

The detailed study by Soman et al (1988) indicated that rainfall in south Kerala has decreased significantly during 40 years period for 1941-1980 compared to the preceding 40 years from 1901 to 1940. The analysis of data pertaining to extreme rainfall, seasonal rainfall & annual rainfall shows that in all cases there is a decrease of 15% to 20% in the foothills covering Ernakulam, Kottayam and Idukki (Fig 8). Comparing this map with that of deforestation (Fig. 5) a trend is evident. It has also been reported that water flow in the rivers flowing through this tract is reducing. Rubber as one of the major crops replacing natural vegetation may have some contribution in this scenario particularly in reduced water flow. A study in China's Xishuangbanna Prefecture reported introduction of rubber plantation can reduce flow of stream and lead to drier condition throughout the catchment (Guardiola-Clarmonte et al, 2008). It is summerised by Fox (2014) that expansion of rubber plantation may not affect rainfall across the region as a whole however the impact may be profound at the local level.

3.3 Photosynthetic Active Radiation (PAR)

Photosynthetically active radiation (PAR) is the amount of light available for photosynthesis, which is light in the range of 400 to 700 nanometer wave length range. It changes seasonally and varies depending on the latitude and time of the day. Higher PAR promotes plant growth and monitoring PAR is important to ensure plants are receiving adequate light for this processes. It focuses on the dynamics of photic zone, typically 1 to 5 m below the surface and leads to an understanding of photosynthesis, toxic algae blooms and eutrophication (nutrient loading). Land use change particularly vegetation change affects PAR. The amount of PAR absorbed by green vegetation not only influences the net primary productivity and the carbon cycle but also affects the exchange of energy and water between the atmosphere and land surface (Li et al, 1997). Distribution of photosynthetic Active Radiation (PAR) pattern in rubber plantation shows that more than 80% of PAR is intercepted by the upper canopy within 5 m from top of the canopy in case of matured plantation (Satheesan et al 1985). A study in Sumatra (Khasanah et al, undated) in April, 2006 indicated that PAR of monoculture rubber varied from 775.6 to 782.4MJ m^{-2} and light use efficiency 0.26 to 0.31gMJ^{-1}. The percentage of light under tree canopies drops to below 20% of full sunlight at the tree age of 6 to 7 years and this amount changes only slightly thereafter. The percentage of light increases significantly after the trees are 15 to 20 years old when the canopies opened up slightly. This variation is reflected in the production of dry matter. It is reported that the dry matter yield under rubber 1869kg/ha in 3rd year, 435 in 5th year, 542 in 10th year, 520 in 15th year, 628 in 20th year, 1282 in 25th year, and 1975 in 30th year (Wahab, undated).

3.4 Rubber and soil erosion

Rubber saplings are planted after removal of traditional crops/ vegetations and building terraces. Due to terracing along hill slopes small water courses and ploughed and regular drainage is affected. Terracing also enhances infiltration. Kerala is dominated by lateritic soils. During high intensity rain in the monsoon months the soil column get saturated and the contact zone between the hard rock and the over burden is liquefied, resulting in soil slip. Landslides in well terraced rubber plantations are frequently reported. Secondly due to removal of top soils the subsurface soils are exposed, which absorb water poorly. There is also soil compaction. This can lead to accelerated soil erosion, disruption of natural stream flow, elevated stream sediments, and greater risk of landslides.

On site soil erosion is one of the direct responses resulting from change in landuse. The rate of erosion depends upon slope, canopy, cover and the ground cover. Chinnamani (1975) reported that soil erosion is 0.062 t/ha/year under natural forests in the Westernghat region. It varies from 0.224 t/ha/year in a tea plantation with 95% canopy to 4.622 t/ha/year in a plantation with 15% canopy. Comparing gully formation in four plots under 1) Natural vegetation and rubber plantation, 2) Tea plantation, 3) Tea plantation and rock outcrops and 4) Mixed crop it is observed that density of gullies is the lowest (154 m/ha) under natural vegetation and rubber and highest (340 m/ha) under tea plantation (Chattopadhyay 1985).

Field observation suggests that where rubber replaces natural vegetation there will be accelerated soil erosion during initial years till canopy and or ground cover develops properly. Rubber plantations are often cultivated between rows in the early years and this practice produces significant erosion on slopes. In some places where rubber replaces tapioca, erosion reduces as tapioca being a tuber crop increases soil erosion. Estimated erosion under rubber plantation was reported to be 33+/- 10cm in a study in Jambi province of Sumatra island (Guillaume et al, 2015). Soil erosion also depends on nature of soil. All rubber growing soils have moderate to high risk of soil erosion. Soils with higher amount of intermediate size particles show more erodibility risk than the soils with higher clay and higher sand content (Satisha et al, 2008).

3.5 Soil organic carbon and nitrogen

Organic carbon and nitrogen content of soils under rubber, natural vegetation (forest) other land use categories have been investigated by researchers in different countries to understand impact of rubber plantation on soil characteristics. All these studies concluded that organic carbon and nitrogen reduces in the soils under rubber plantation. Balagopalan (1995) reported that organic carbon and total nitrogen are less under rubber plantation than forest. Observation of Karthikakutty Amma et al (1996) in four different locations brings out that in all cases, soils under forest contains more nitrogen than soils under rubber plantation and this has been attributed to the high litter production under natural forest condition. But compared to degraded forests and teak plantation soils under rubber plantation show higher value (Table. 9). Another study by Chattopadhyay and Sajna (2009) in Pamba basin indicated that organic carbon under rubber plantation is 44% of that under forest in the top layer of soil (upto 20cms depth) (Table 10a, 10b, 10c). In the case of available nitrogen, soil under rubber plantation records only 77% of the value obtained under forest in the top 20cm layer. At a depth of 100cm, soils under forest and rubber recorded more or less same value both for organic carbon and nitrogen. Similar observation has been reported from Hainan in China (Jinghua, 1990). It is pointed out that organic matter content under rubber plantation lies mostly between 10 and 20 g/kg against 158 g/kg under evergreen forests. Experimental study in Jambi province in Sumatra island indicated that organic carbon reduced by 62% under rubber plantation compared to natural forest (Guillaume, et al 2015).

This has been attributed to variations in litter production under rubber and natural vegetation. Studies in some parts of Westernghats, both in Karnataka and Kerala, (Bhatt, 1990 & Shaji & Abraham, 1994) has brought out that litter production varies from 5.09 t/ha/year to 10.24 t/ha/year in Uttar Kannada to 7.9 t/ha/year to 12.5 t/ha/year in Kallar. Litter production under rubber plantation is considerably low. Similar observations have been reported from Hainan in China also. Maintenance of nutrient cycle through litter production and decomposition partially changes under rubber plantation.

3.6 Stream flow and water use

Rubber is a native vegetation of Amazon Basin, which receives rainfall throughout the year. Kerala dominated by monsoon rainfall experience dry spell before pre-monsoon rain starts. During this period rubber tree sustains its vegetative growth by drawing moisture from deep within the soils resulting in depletion of water in the area. A study in Xishuangbanna, China indicated that introduction of rubber plantations can reduce the flow of streams, and lead to drier conditions throughout the catchment area (Guardiola-Claramonte et al, 2008). Landuse change affects stream flow and water use pattern. An experimental study conducted by Satheesan et al (1993) covering rubber, teak, coffee and cardamom plantations in some selected watersheds in Kerala reported that the ratio of direct run off to total precipitation remained very low throughout the year varying from 2.8% under tea and coffee to 5.1% under cardamom. In case of rubber it is 3%. Annual base flow is very high varying from 66% under rubber to 95% under coffee. This difference in base flow indicates that rubber plants use higher quantity of water in dry season compared to coffee.

Water use by rubber plantations is estimated to be 500mm to 600mm lower than typical tropical rain forest ecosystem. The rate of evapotranspiration is lower for rubber plantation compared to the forest ecosystem. This may contribute to the decreasing trend of local rainfall as pointed out under micro climate. However, a detailed analysis is necessary with long term observations to understand the mechanism fully.

3.7 Water quality

Linkage between land use and water quality variations is a subject matter of investigation in different parts of the World (Chattopadhyay et al, 2005). Perusal of the available studies by Soman et al (1996), Mahamaya, et al, (1996), Mahamaya, (2003), Soman and Mahamaya, (1998) and Soman et al, (2001) indicated that water quality parameters show variations corresponding to land use practices (Table 11). Physico- chemical characteristics of water samples collected from different segments of river show variations with change in landuse pattern (Table 12). Dissolved oxygen (DO) is lower in the case of samples within rubber plantation in all the rivers. Killi Ar draining a small catchment confined to lower altitudes appears to be seriously affected. The entire upper stretch of this river is covered by rubber plantation. The Vamanapuram river which is less disturbed, also shows lower value for the samples in proximity to rubber when compared to that under forest. Low value is partly attributable to complete canopy coverage resulting in poor sunlight penetration. Poor sunlight constrains photosynthesis and results in poor aeration and consequent lower DO value. The pH value indicates that the river water is generally alkaline (>6.5). The lowest pH value of 4.22 in the sample taken from the river segment of Kallada river (Ref. Table 12) perhaps manifests impact of effluent discharge from the rubber factory. The river segment of Ittikara passing through Oil Palm plantation recorded DO concentration of 4.26 and 4.10 in the months of August and March respectively. Both these values are higher compared to all other stations. Except this station the general trend is that the water flowing through the forest segment are showing elevated values for DO compared to the samples taken under other land use categories. High nutrient content in the water samples under settlement with mixed tree crops and plantations may be attributed to fertilizer application. It may be construed that one of the underlying factors leading to deterioration of water quality is change in natural vegetation cover.

4.0 Conclusion and recommendations

Rubber has emerged as an important agricultural plantation in the State. It is mainly being raised under small holdings, thereby involving a large number of farmers. Due to economic importance farmers will be attracted to raise this crop and rubber plantations will continue to grow. The southern midland zone (SMZ) is the type area for rubber. Landscape - ecological setup of the SMZ is found to be ideal locality for rubber plantation. The highest productivity has been reported from Kanjirapally in Kottayam & Kulasekharam in Thiruvananthapuram district. However in recent years, mostly under Government initiatives rubber plantations are spreading in non traditional suboptimal areas relatively drier northern districts of the State and high altitude Wayanad and Idukki districts. However, productivity will be low in these ecologically suboptimal areas. Low yield in Wayanad is perhaps an indication of ecological limitations. Lessons can be drawn from this trend. Rubber production is falling down in all districts. There may be different factors contributing to it. However, its linkage to change in rainfall pattern may not be overlooked. Rainfall is an important factor in production of latex.

The major rubber plantation areas spread over the foot hills of Ernakulam. Kottayam and Idukki experienced severe deforestation in the past. Incidentally these are the areas that recorded maximum decrease in rainfall.

Due to well managed terrain gully formation under rubber plantation is low when compared to other plantations but with increasing risk of landslides. Organic carbon and nitrogen contact of soil under rubber plantation is lower compared to forest land but higher compared to other plantation and degraded forest. There is tendency of water level depletion in the rubber dominated areas. Due to complete coverage penetration of sunlight is restricted under canopy rubber plantation. This may affect water quality of the rivers flowing under rubber plantation for a long stretch. Apart from these certain problems normally associated with mono croping like drawing on same nutrients with uniform rooting system and susceptability to disease also need due consideration.

Available research findings from India (mainly Kerala) and other countries reported here indicates that mono cropping of rubber is potent to cause negative environmental consequences. However, studies are few to draw meaningful conclusion. There is also difficulty in predicting environmental impact of land use change, carbon sequestration, carbon cycling and climate change. In view of the economic and political realities of rubber cultivation and limited data availability on environmental implications in Kerala some suggestions are advanced.

A bio-geographic analysis of rubber plantation is necessary to demarcate suitability land classes for rubber plantation. Through landscape ecologic analysis at the 2nd level suitability classification may be attempted. This is important for growth of the plantation as cost of production will multiply in the suboptimal areas. Production variability, state of growth and environmental response related to land, water and landuse are site specific therefore site specific monitoring of various environmental parameters and in depth analyses are required to arrive at definite conclusions. This could be captured systematically within a natural unit like river basin or watershed. Therefore, a river basin/watershed approach may be followed to understand the production process and environmental impacts.

Instead of mono cropping of rubber it may be a good option to include other crops with rubber plantations. Inter cropping of banana has brought good results in experimental studies in Sri Lanka. Field studies are required in Kerala to come out with specific recommendation in this context. Needless to say, socio-economic aspects have to be integrated in the total exercise as it is the society which is ultimately affected in the process. This essentially calls multi-dimensional treatment covering a whole range of variables in socio-spatial perspectives. Application of Remote Sensing and geographical Information System (GIS) thus form an integral part of this approach of understanding the socio-ecological dynamics of rubber plantations. It is important for the Government to recognise the role of multiple actors involved in rubber plantation and environmental decision making. Internalisation of environmental impacts and involvement of local people in decision making process may be part of the policy to design a sustainable Rubber Plantation Development strategy in the state.

Table 1: Area and production of rubber in selected countries of the World

Countries	**Area (000 ha), 2009**	**Production (000 tonnes), 2011**
Indonesia	3435	2982
Thailand	2756	3394
Malayasia	1237	996
China	932*	707
India	687	890
Vietnam	674	812

Source: National Multi Commodity Exchange: Natural Rubber, 2012-13, * Area refer to 2008

Table 2 Physiographic units in Kerala

Physiographic unit	Area (%)	Remarks
High ranges and mountain (>600m)	20.1	Plateau region
Foot hills and scarp slopes (300 - 600)	7.8	Bouning slope
Uplands and hills (100 - 300)	14.0	Undulating Terrain Lateritic
Midlands and low hills (70 - 100m)	38.1	Rolling Terrain Lateritic
Coastal plains and lowlands	20.0	Alluvium and lateritic

Table 3:Growth of Area under Rubber Cultivation

District	1960-61 Area (ha)	1991-92 Area (ha)	2013-14 Area (ha)	growth in % (1960-61 and 1991-92)	growth in % (1991-92 and 2013-14)	growth in % (1960-61 and 2013-14	share in total growth (1960-61 and 1991-92)	share in total growth (1991-92 and 2013-14)	share in total growth (1960-61 and 2013-14)
Thiruvanathapuram	3715	25420	31840	584.25	25.26	757.07	7.17	5.24	6.61
Kollam	21534	31146	37105	44.64	19.13	72.31	3.17	4.87	3.66
Pathanamthitta	NA	47705	50740	NA	6.36	NA	NA	2.48	NA
Alappuzha	1960	2781	4480	41.89	61.09	128.57	0.27	1.39	0.59
Kottayam	43137	108851	114260	152.34	4.97	164.88	21.69	4.42	16.72
Idukki	NA	36772	40395	NA	9.85	NA	NA	2.96	NA
Ernakulam	15889	63406	59740	299.06	-5.78	275.98	15.69	-2.99	10.31
Trissur	6260	6753	15550	7.88	130.27	148.41	0.16	7.18	2.18
Palakkad	5064	24893	37675	391.57	51.35	643.98	533.76	10.44	7.67
Malappuram	NA	19709	42470	NA	115.49	NA	NA	18.59	NA
Kozhikode	14927	11115	21800	-25.54	96.13	46.05	-1.26	8.73	1.62
Wayanad	NA	5177	10730	NA	107.26	NA	NA	4.53	NA
Kannur	10382	24354	47735	134.58	96.00	359.79	4.61	19.09	8.78
kasaragod	NA	17686	33705	NA	90.58	NA	NA	13.08	NA
Kerala	122868	425768	548226	246.52	28.76	346.19	100.00	100.00	100.00

Table 4: District-wise Area and Production of Rubber In Kerala

District	1970-71			1980-81			1990-91			2000-01			2010-11			2013-14		
	Area (ha)	production(mt)	productivity (mt/ha)	Area (ha)	production(mt)	productivity (mt/ha)	Area (ha)	production(mt)	productivity (mt/ha)	Area (ha)	production(mt)	productivity (mt/ha)	Area (ha)	production(mt)	productivity (mt/ha)	Area (ha)	production(mt)	productivity (mt/ha)
Thiruvanathapuram	7040	3581	0.509	8735	5933	0.679	22156	15513	0.700	28196	33518	1.189	30970	44930	1.451	31840	37470	1.177
Kollam	30888	16141	0.523	41091	25561	0.622	32438	26951	0.831	36771	46489	1.264	36530	54130	1.482	37105	45000	1.213
Pathanamthitta	NA	NA	NA	NA	NA	NA	42872	34264	0.799	47869	62523	1.306	50260	79220	1.576	50740	64065	1.263
Alappuzha	3584	1713	0.478	4273	2771	0.648	2901	2140	0.738	3801	4003	1.053	4380	6740	1.539	4480	5530	1.234
Kottayam	55444	26907	0.485	66926	36145	0.540	107937	82852	0.768	111301	140766	1.265	113730	172200	1.514	114260	136540	1.195
Idukki	NA	NA	NA	17897	11140	0.622	34595	26638	0.770	38076	45405	1.192	40000	57230	1.431	40395	47680	1.180
Ernakulam	26459	11907	0.450	23334	13929	0.597	51163	37586	0.735	56644	73557	1.299	59030	91700	1.553	59740	74445	1.246
Trissur	8402	5700	0.678	9386	6739	0.718	11270	9108	0.808	13373	19670	1.471	15410	22820	1.481	15550.4	18380	1.182
Palakkad	3038	1466	0.483	11084	4516	0.407	20804	12531	0.602	28933	31619	1.093	36430	49575	1.361	37674.9	43430	1.153
Malappuram	9522	6451	0.677	19281	10571	0.548	22620	14855	0.657	29209	33007	1.130	39520	50745	1.284	42470	45850	1.080
Kozhikode	19803	9011	0.455	18171	10730	0.591	16650	12769	0.767	17690	22871	1.293	21380	29920	1.399	21800.3	24950	1.144
Wayanad	NA	NA	NA	NA	NA	NA	5035	2357	0.468	6430	3955	0.615	10070	9000	0.894	10730	8720	0.813
Kannur	15079	5251	0.348	23934	12298	0.514	22880	16808	0.735	33944	38459	1.133	44780	61110	1.365	47735	58000	1.215
kasaragod	NA	NA	NA	NA	NA	NA	17150	13149	0.767	22232	24024	1.081	31740	41260	1.300	33705.2	38160	1.132
Kerala	179259	88128	0.492	244112	140333	0.575	410471	307521	0.749	474469	579866	1.222	534230	770580	1.442	548225.8	648220	1.182

Source: Data from planning board -1980-81, 1990-91, 2000-01, 2010-11, 2013-14. data from old series 1970-71

Table 5: District wise decadal net growth of productivity (kg/ha)

Districts	1970-71 to 1980-81	1980-81 to 1990-91	1990-91 to 2000-01	2000-01 to 2010-11	2010-11 to 2013-14
Thiruvanathapuram	170.56	20.95	488.58	262.01	-273.94
Kollam	99.49	208.79	433.44	217.51	-269.02
Pathanamthitta	NA	799.22	506.91	270.08	-313.59
Alappuzha	170.53	89.19	315.47	485.67	-304.44
Kottayam	54.77	227.52	497.14	249.38	-319.12
Idukki	622.45	147.54	422.49	238.27	-250.41
Ernakulam	146.92	137.69	563.95	254.86	-307.30
Trissur	39.57	90.18	662.71	9.98	-298.89
Palakkad	-75.12	194.90	490.50	267.99	-208.07
Malappuram	-129.22	108.46	473.31	154.00	-204.45
Kozhikode	135.47	176.41	525.97	106.56	-254.96
Wayanad	NA	468.12	146.96	278.66	-81.07
Kannur	165.60	220.79	398.40	231.66	-149.63
kasaragod	NA	766.71	313.90	219.33	-83.90
Kerala	83.25	174.32	472.95	220.28	-225.37

Source: old series- 1970-71 to 1990-91. planning board data: 2000-01, 2010-11 and 2013-14

Table 6. Time series landuse change in Thodupulai - Painavu stretch , Kerala

Land use type	Area (%)		
	1911 - 12	1976-77	Change
Forest , grasslands and scrub	87.1	40.9	-46.2
Rubber	0.3	3.9	3.6
Other (Settelement , Tree crops, paddy, other plantain etc.	12.6	55.2	42.6

Table 7. Temporal variation of area under rubber estates and holdings in Kerala

Year	total area	% holdings	% estate
1960-61	125487	65	35
1965-66	174561	68	32
1970-71	198424	72	28
1975-76	211808	76	24
1980-81	253784	81	19
1985-86	341506	86	14
1990-91	407821	89	11
1995-96	449000	91	9
2000-01	474365	91	9
2005-06	493800	92	8
2010-11	534228	93	7

Source: Rubber board –from 1960-61 to 2010-11

Table 8:Size class variation of area under rubber

Size class (ha)	**1960-61**		**1990-91**		**2010-11**	
	area	**%**	**area**	**%**	**area**	**%**
<2	52340	57.91	331982	83.61	553710	86.44
2 to 4	13981	15.47	33149	8.35	43320	6.76
>4 upto 20	24064	26.62	31915	8.04	43570	6.80
Total holdings	**90385**	**100**	**397046**	**100**	**640600**	**100**
20<40	7590	14.18	3320	4.25	7325	10.32
40-200	17812	33.27	12150	15.57	9546	13.45
200-400	8082	15.10	6764	8.67	7316	10.31
400-600	8768	16.38	9838	12.61	7747	10.92
>600	11278	21.07	45965	58.90	39026	55.00
Total estates	**53530**	**100.00**	**78037**	**100**	**70960**	**100**

source: Rubber board-1960-61, 1990-91 and 2010-11

Table 9: Selected soil properties under different vegetation cover

Vegetation cover	Profile Depth (cm)	Organic carbon (%)	Total nitrogen	PH
Forest	0 - 100	1.46	1.2	5.4
Degrded forest	0 - 80	0.89	0.78	6.2
Rubber (1)	0 - 100	1.28	-	-
Lowlevel rain forest (2)	0 - 90	2.07	0.90	5.3
Teak	0 - 100	1.22	1.16	5.7

Source : S - Balagopalan (1995). Rubber (1) - Plantation of 3 rd generation (Karthikakutty amma, 1995), Rubber (2) - Newly deforested

Table 10c: Distribution of Organic Carbon (%) under various land use types along depth, Pamba basin

Soil depth (cms)	Landuse			
	Forest	Grassland	Rubber	Settlement with mixed tree crops
0-20	3.24	2.79	1.44	2.38
20-60	2.04	1.41	1.28	1.57
60-100	0.92	0.40	0.85	2.26

Source: Chattopadhyay and Sajna, 2009

Table 10b: Distribution of available N (kg/ha) under different land use along depth in Pamba Basin

Soil depth (cms)	Landuse			
	Forest	Grassland	Rubber	Settlement with mixed tree crops
0-20	815.36	426.50	627.20	526.85
20-60	551.94	338.69	589.57	501.76
60-100	476.67	351.23	489.22	677.38

Table 10c: Distribution of soil pH under different land use along depth in Pamba basin

Soil depth (cms)	Landuse			
	Forest	Grassland	Rubber	Settlement with mixed tree crops
0-20	4.40	4.30	4.30	4.00
20-60	4.70	4.20	4.10	4.40
60-100	4.70	4.30	4.00	4.20

Table 11: Selected water quality parameters under different land use in four selected rivers

River	**Land use**	**Season**	**pH**	**DO**	**BOD**	**NO$_3$-N**	**PO$_4$-p**	**Source**
Pamba	Forest (4a)	May, 1998	7.41	3.90	0.62	1.33	0.09	Soman et al, 2001
		August, 1998	7.01	3.71	1.08	1.29	0.88	
	SMT including rubber(14)	May, 1998	7.22	2.81	1.00	0.90	0.81	
		August, 1998	6.90	2.89	1.46	2.95	1.04	
Kallada	Forest & Forest plantation (6)	May, 1996	7.34	3.48	0.95	2.57	1.66	Soman & Mahamaya, 1998
		Nov., 1996	7.21	3.92	0.31	0.98	1.45	
	Rubber plantation/ factory (11)	May, 1996	7.13	3.16	0.85	1.21	1.35	
		Nov., 1996	4.22	3.30	0.63	1.51	0.51	
Ittikara	Oil Palm plantation (4)	March, 1996	6.74	4.10	1.26	3.66	0.72	Mahamaya, 2003
		Aug., 1996	6.95	4.26	0.63	1.39	0.94	
Vamana-puram	Forest (3)	Feb., 1996	8.44	3.95	0.06	-	1.46	Mahamaya, 1996
		May, 1996	6.68	2.53	0.85	0.27	0.05	
	Eucalyptus and Rubber (8)	Feb., 1996	7.95	3.00	0.31	0.74	0.90	
		May, 1996	6.52	3.63	1.27	2.53	0.11	

Table 12: Selected physico chemical parameter of some river water samples under various landuse

River basin	Landuse type	Samples No.	pH	DO
Kallada	Forest	3	7.07	5.85
	Forest	8	7.24	3.63
	Teak	7	7.14	3.95
	Rubber	12	6.67	3.32
	Rubber	13	7.17	2.69
Ittikkara	Mixed trees	5	6.53	4.26
	Mixed trees & Rubber	9	6.65	3.31
	Rubber	6	6.46	3.63
	Rubber	13	6.68	1.58
	Oil palm	4	6.74	4.10
Vamanapuram	Forest	2	6.63	4.11
	Tea	1	6.92	3.79
	Mixed tree	12	7.14	3.00
	Rubber	5	6.86	3.79
	Rubber	4	6.68	2.53
Killi Ar	Rubber	6	8.79	3.85
	Rubber	5	7.33	1.26
	Mixed trees	11	9.23	3.16

Source: Soman K, Mahamya Chattopadhyay &Ouseph (1996)

Chart-1: Framework of land use analysis

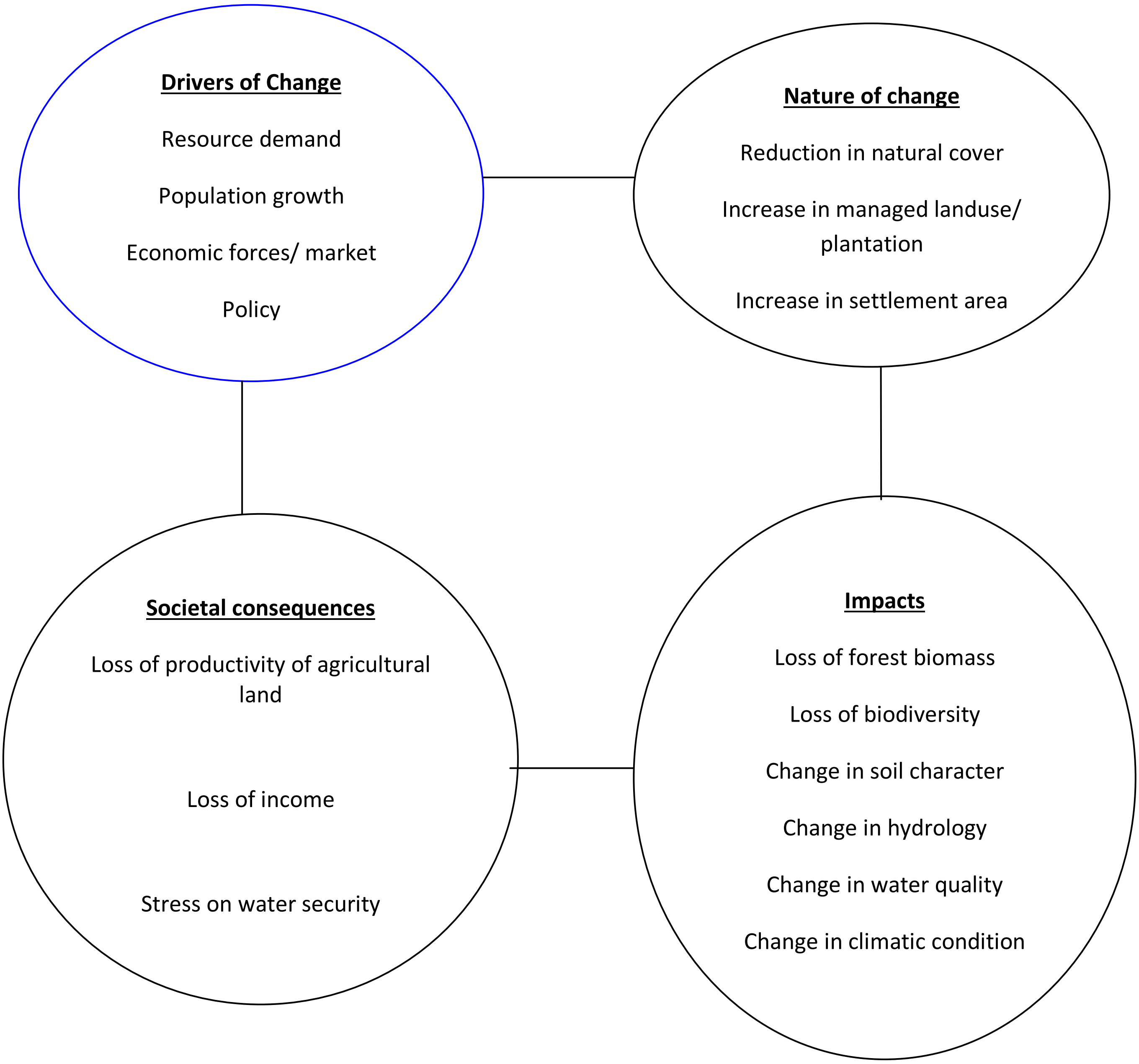
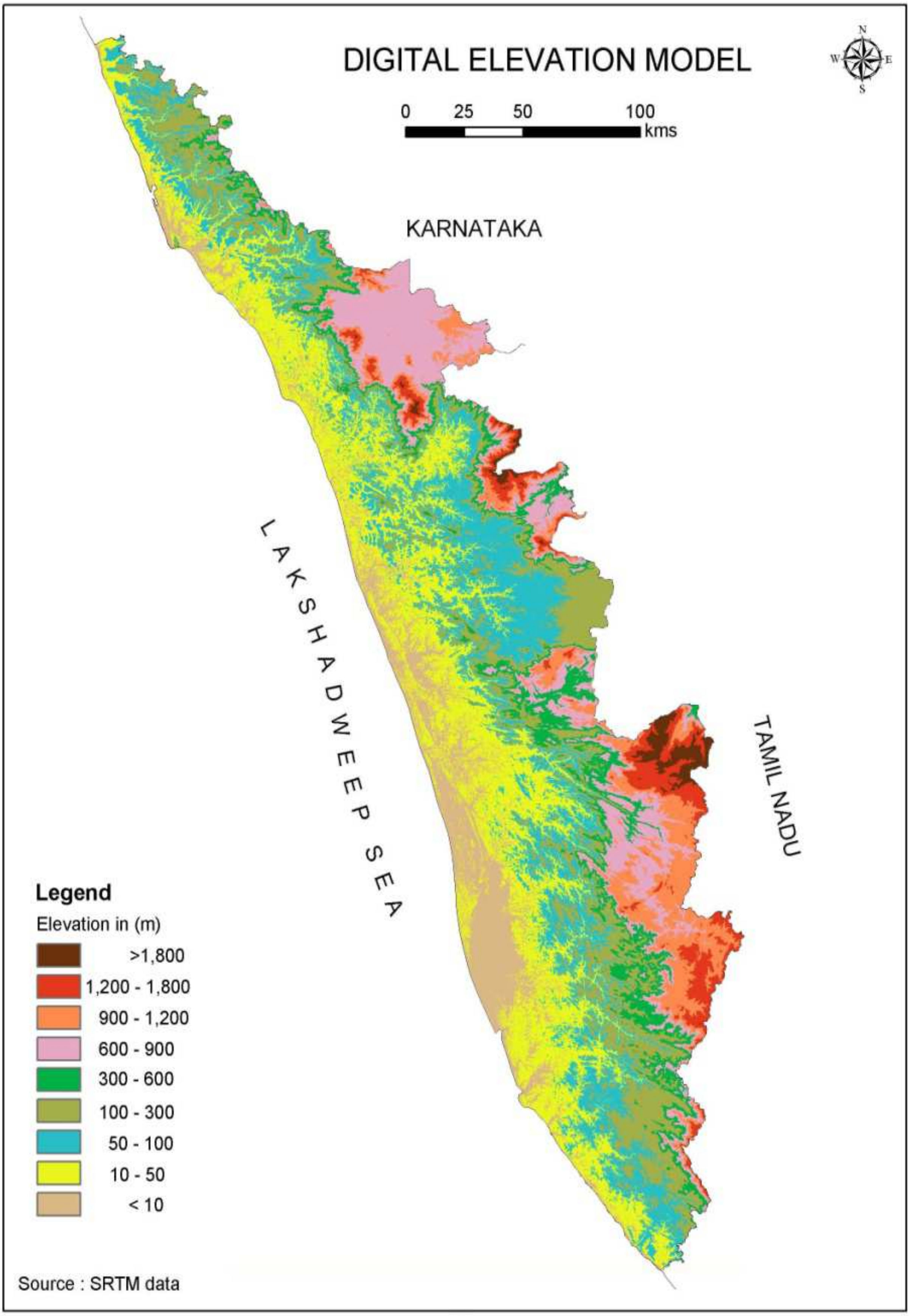


Figure-1



Source : SRTM data

Figure-2

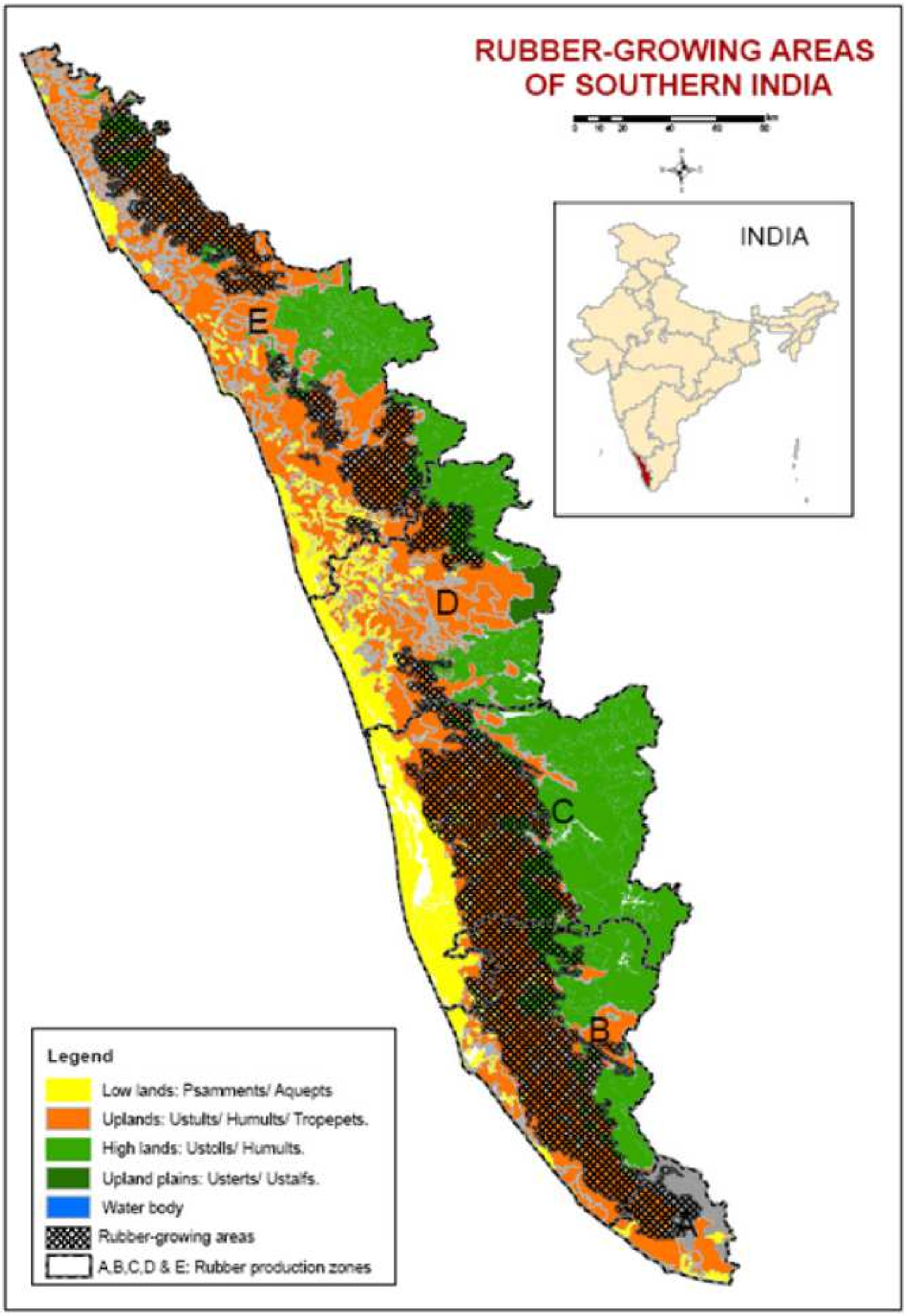

RUBBER-GROWING AREAS OF SOUTHERN INDIA
INDIA
E
D
C
B
A
Legend
Low lands: Psamments/ Aquepts
Uplands: Ustults/ Humults/ Tropepets.
High lands: Ustolls/ Humults.
Upland plains: Usterts/ Ustalfs.
Water body
Rubber-growing areas
A,B,C,D & E: Rubber production zones

Figure-3

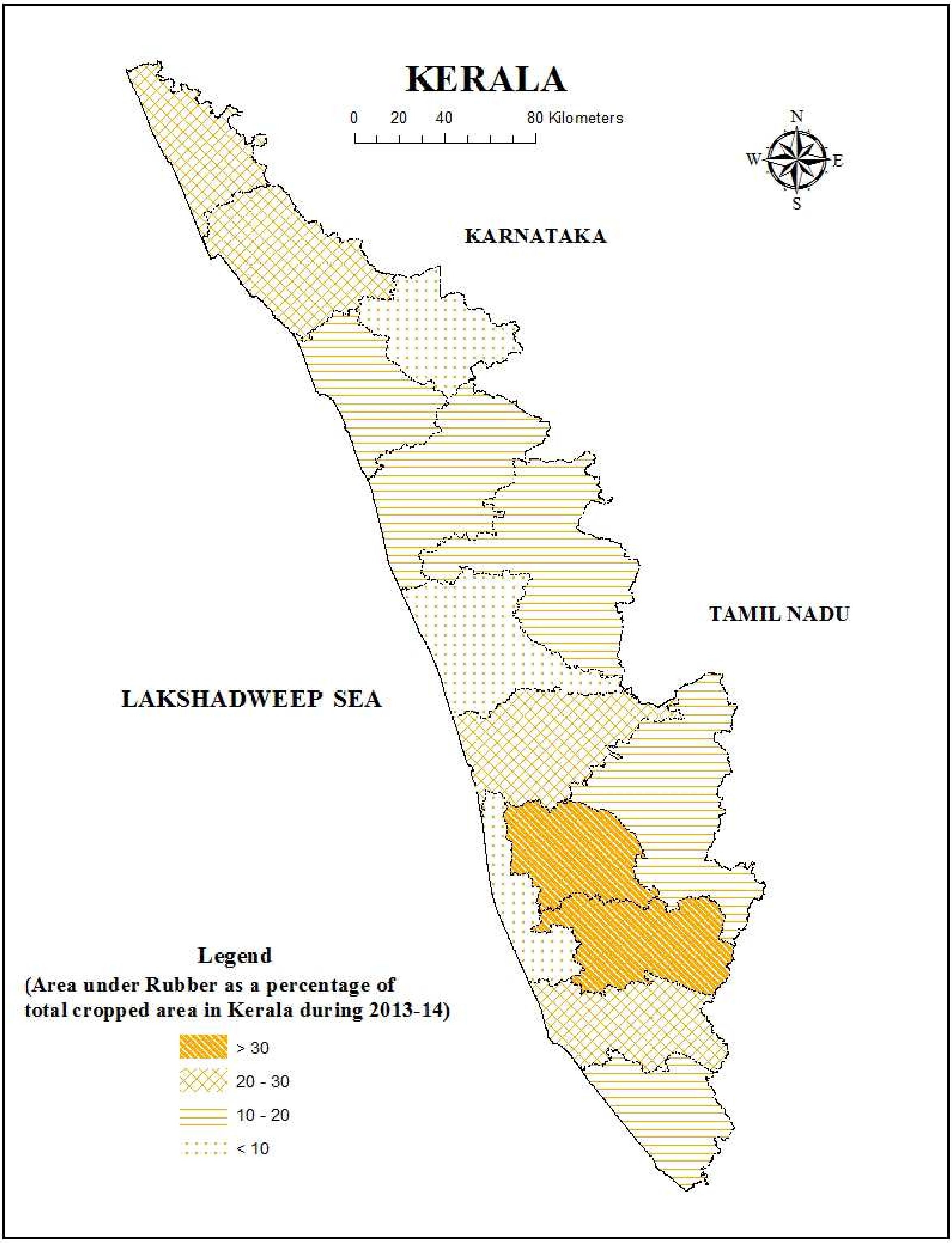
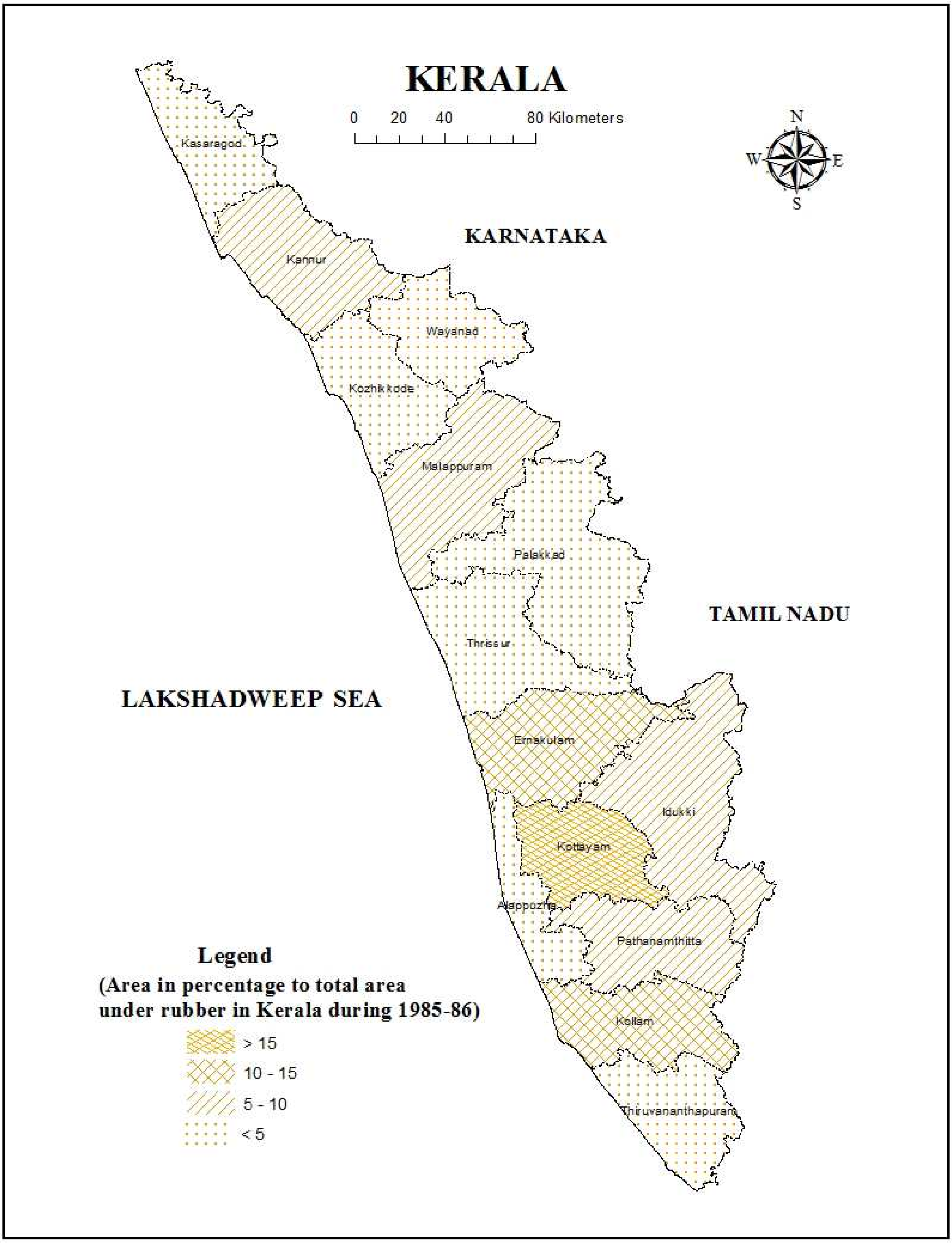

KERALA
0 20 40 80 Kilometers
N
W
E
S
KARNATAKA
TAMIL NADU
LAKSHADWEEP SEA
Legend
(Area under Rubber as a percentage of total cropped area in Kerala during 2013-14)
> 30
20 - 30
10 - 20
< 10

Figure-3.a


KERALA
0 20 40 80 Kilometers
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KARNATAKA
TAMIL NADU
LAKSHADWEEP SEA
Kasaragod
Kannur
Wayanad
Kozhikkode
Malappuram
Palakkad
Thrissur
Ernakulam
Idukki
Kottayam
Alappozha
Pathanamthitta
Kollam
Thiruvananthapuram
Legend
(Area in percentage to total area under rubber in Kerala during 1985-86)
> 15
10 - 15
5 - 10
< 5

Figure-3.b

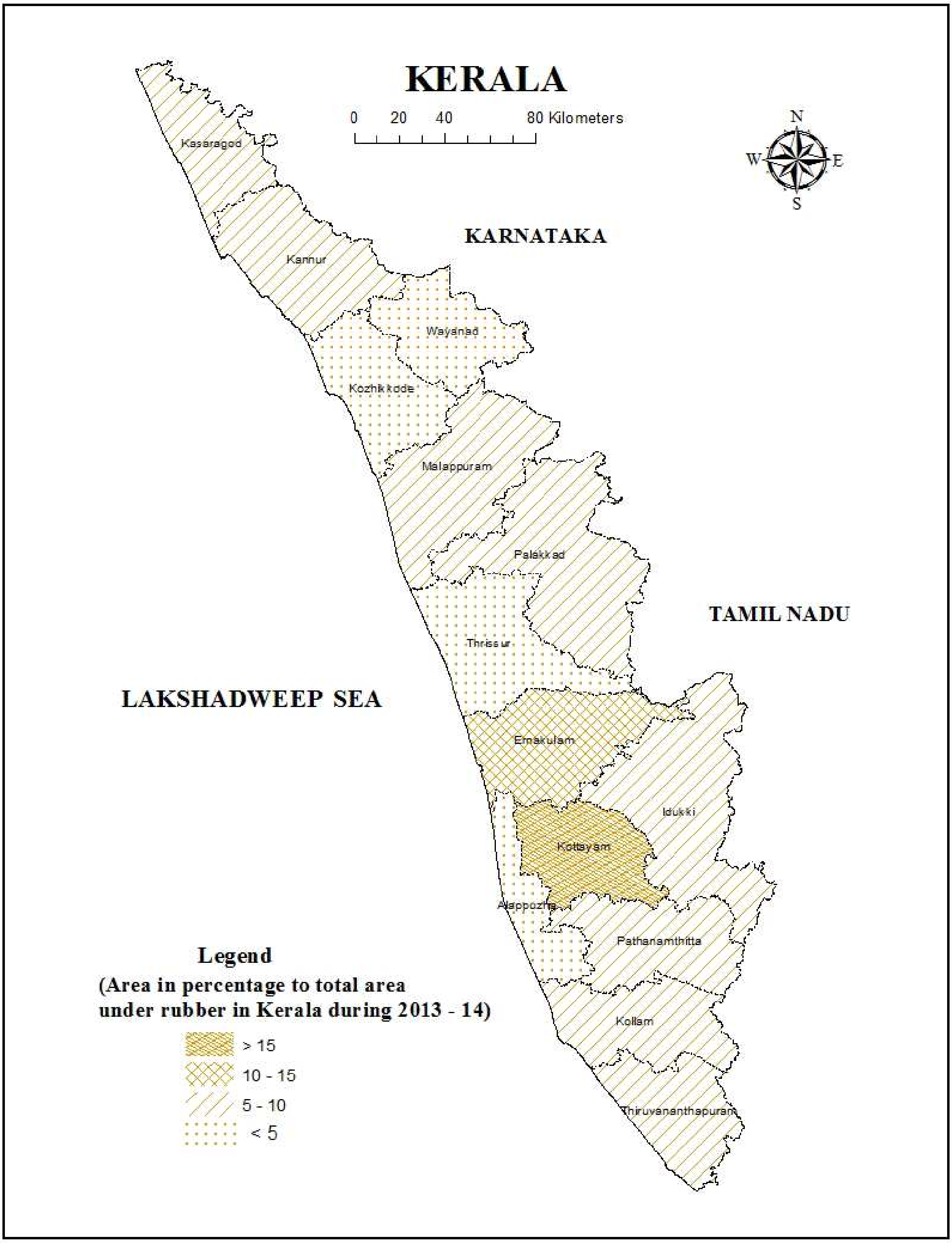

KERALA
0 20 40 80 Kilometers
N
W
E
S
KARNATAKA
TAMIL NADU
LAKSHADWEEP SEA
Kasaragod
Kannur
Wayanad
Kozhikkode
Malappuram
Palakkad
Thrissur
Ernakulam
Idukki
Kottayam
Alappozha
Pathanamthitta
Kollam
Thiruvananthapuram
Legend
(Area in percentage to total area under rubber in Kerala during 2013 - 14)
> 15
10 - 15
5 - 10
< 5

Figure-3.c

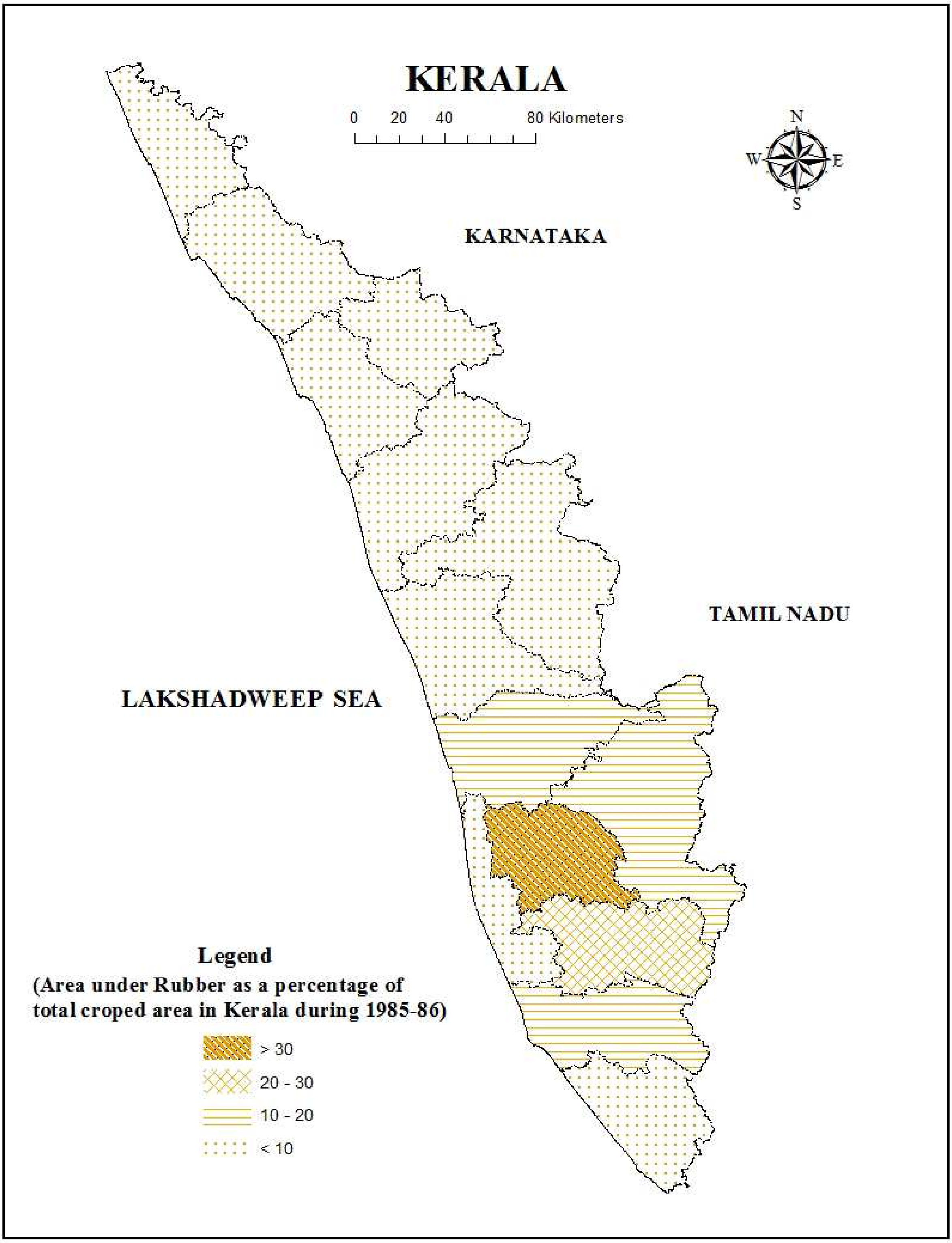

KERALA
0 20 40 80 Kilometers
N
W
E
S
KARNATAKA
TAMIL NADU
LAKSHADWEEP SEA
Legend
(Area under Rubber as a percentage of total croped area in Kerala during 1985-86)
> 30
20 - 30
10 - 20
< 10

Figure-3.d

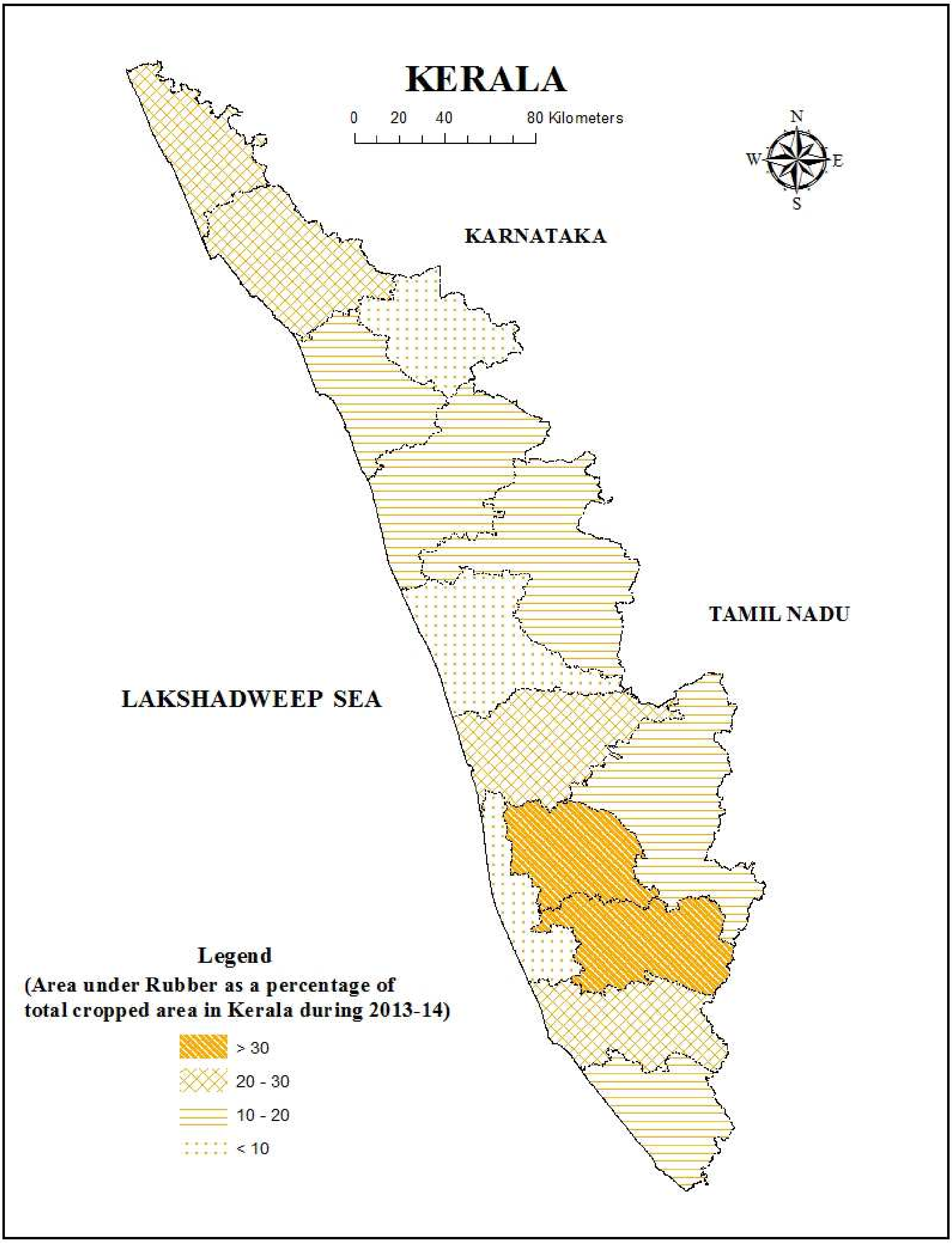

KERALA
0 20 40 80 Kilometers
N
W
E
S
KARNATAKA
TAMIL NADU
LAKSHADWEEP SEA
Legend
(Area under Rubber as a percentage of total cropped area in Kerala during 2013-14)
> 30
20 - 30
10 - 20
< 10

Figure-4: Temporal variation of area

selected crops (1960-61 to 2013-14)

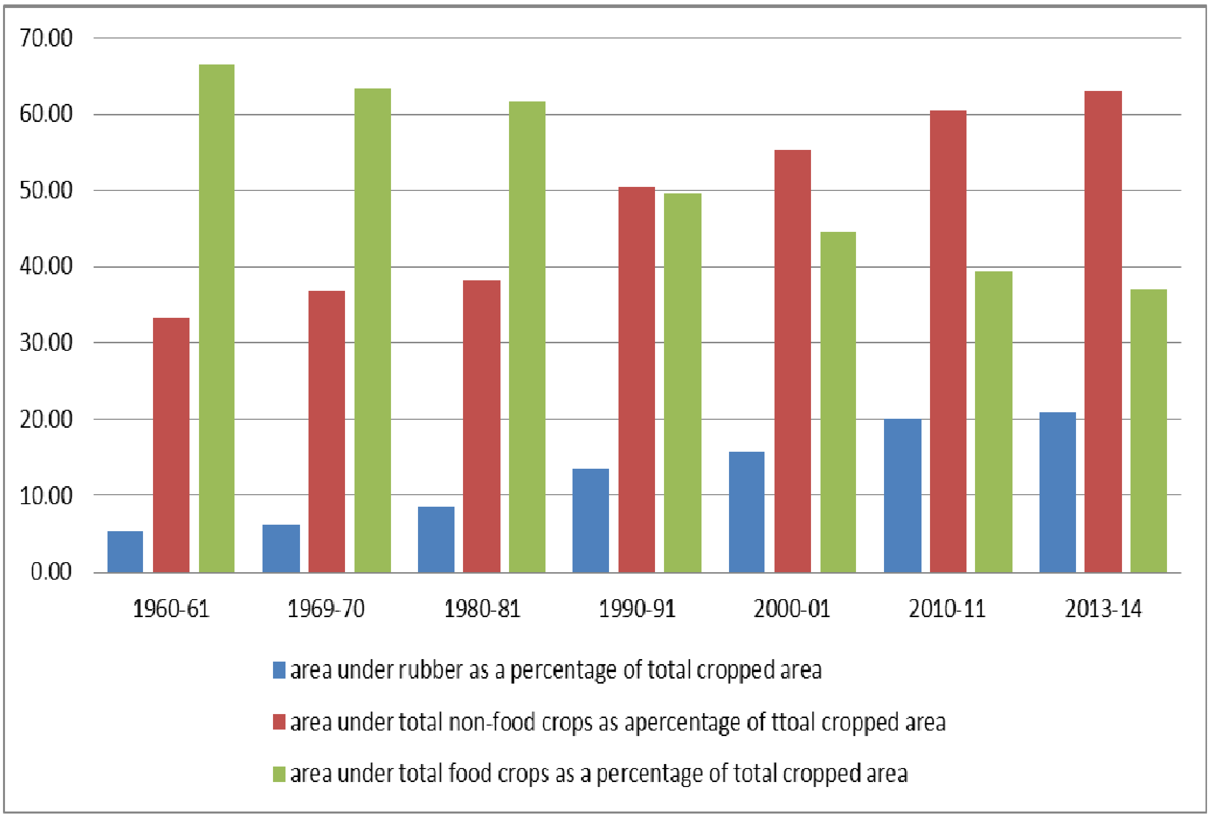


Figure-5

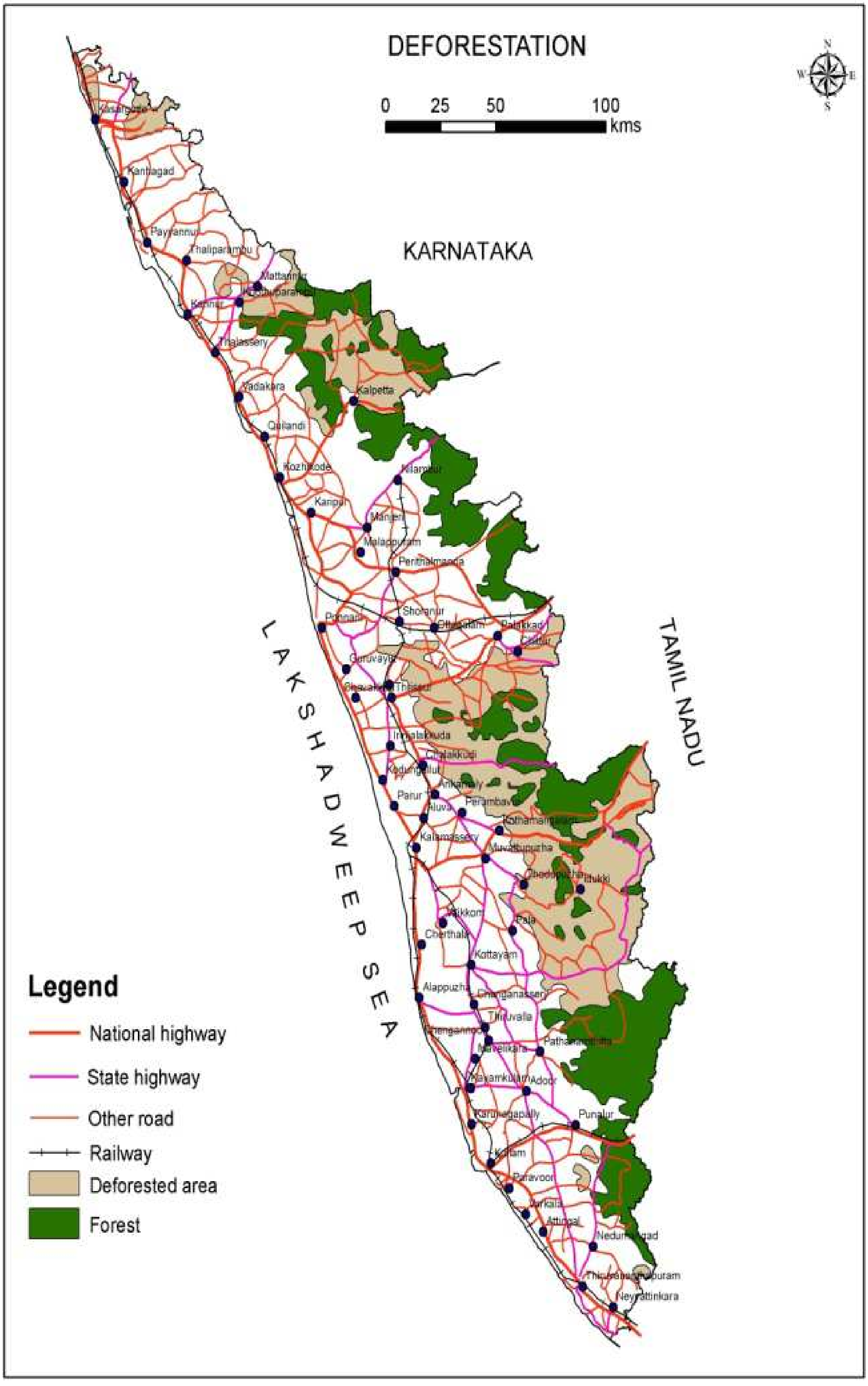

DEFORESTATION
0
25
50
100
kms
N
E
S
W
KARNATAKA
TAMIL NADU
LAKSHADWEEP SEA
Kasargode
Kanhagad
Payyannur
Thaliparambu
Mattannur
Koothuparambu
Kannur
Thalassery
Vadakara
Kalpetta
Quilandi
Kozhikode
Nilambur
Karipur
Manjeri
Malappuram
Perinthalmanna
Shoranur
Ponnani
Ottapalam
Palakkad
Chittur
Guruvayur
Chavakkad
Thrissur
Irinjalakkuda
Chalakkudi
Kodungallur
Angamaly
Parur
Perumbavur
Aluva
Kothamangalam
Kalamassery
Muvattupuzha
Thodupuzha
Idukki
Vaikkom
Pala
Cherthala
Kottayam
Alappuzha
Changanassery
Thiruvalla
Chengannoor
Pathanamthitta
Mavelikara
Kayamkulam
Adoor
Karunagapally
Punalur
Kollam
Paravoor
Varkala
Attingal
Nedumangad
Thiruvananthapuram
Neyyattinkara
Legend
National highway
State highway
Other road
Railway
Deforested area
Forest

Figure-6: Temporal variation of area

selected crops (1960-61 to 2013-14)

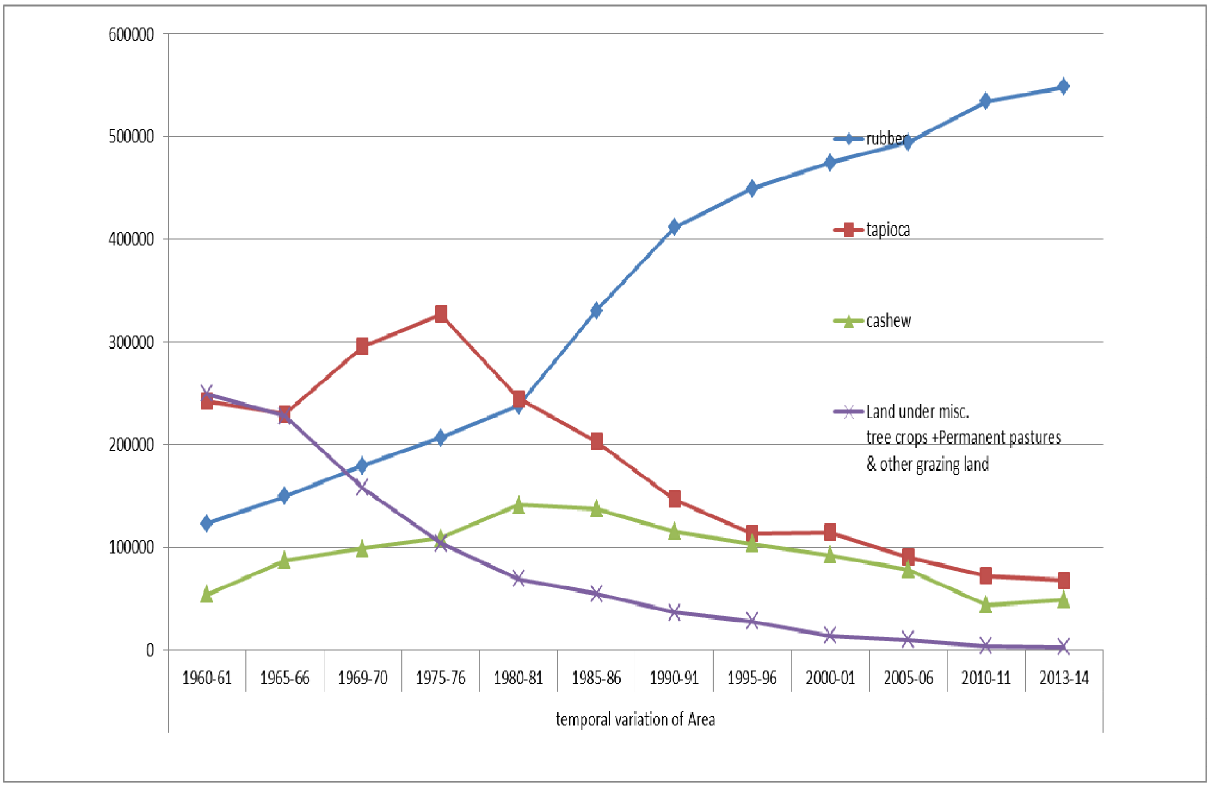


Figure-7 Expansion of rubber: Spatio-temporal dimension in Manickal Panchayat

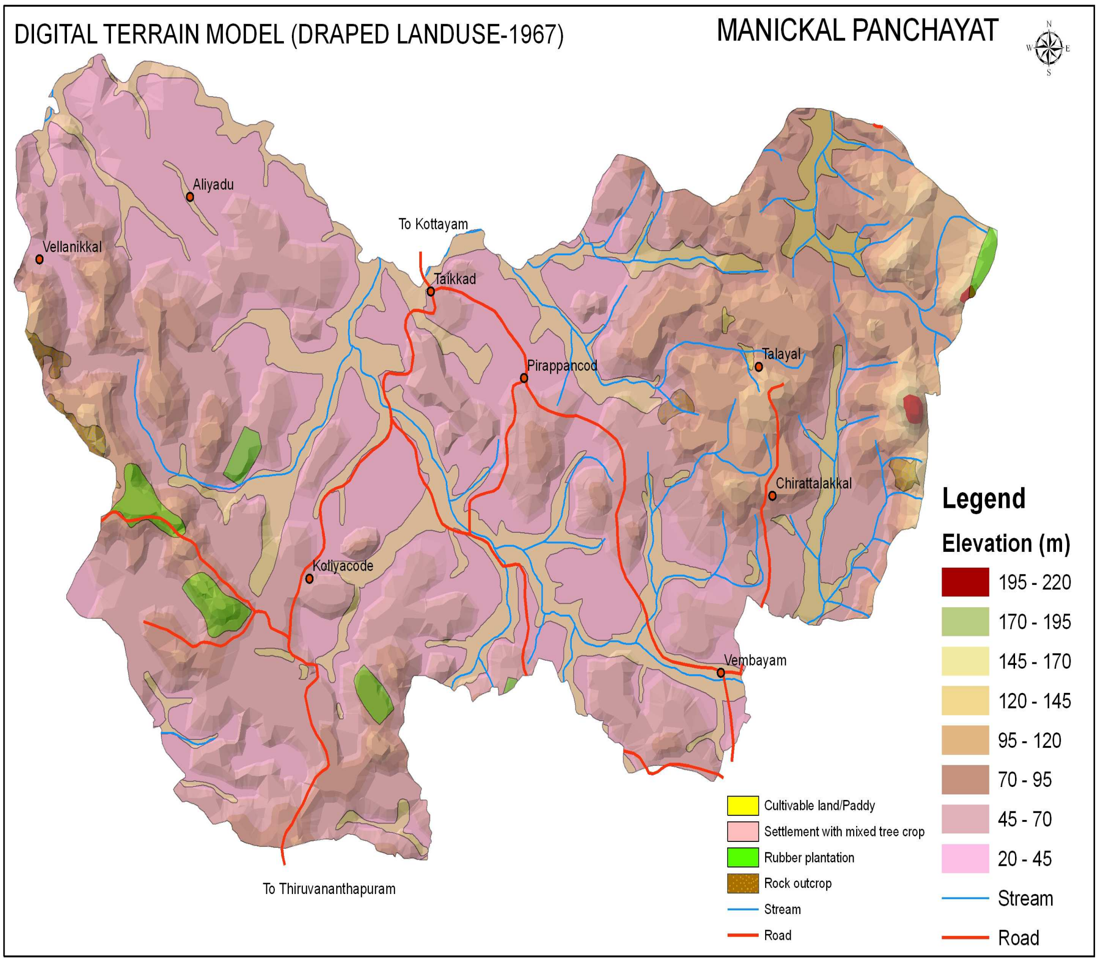


Fig.

Figure-7a

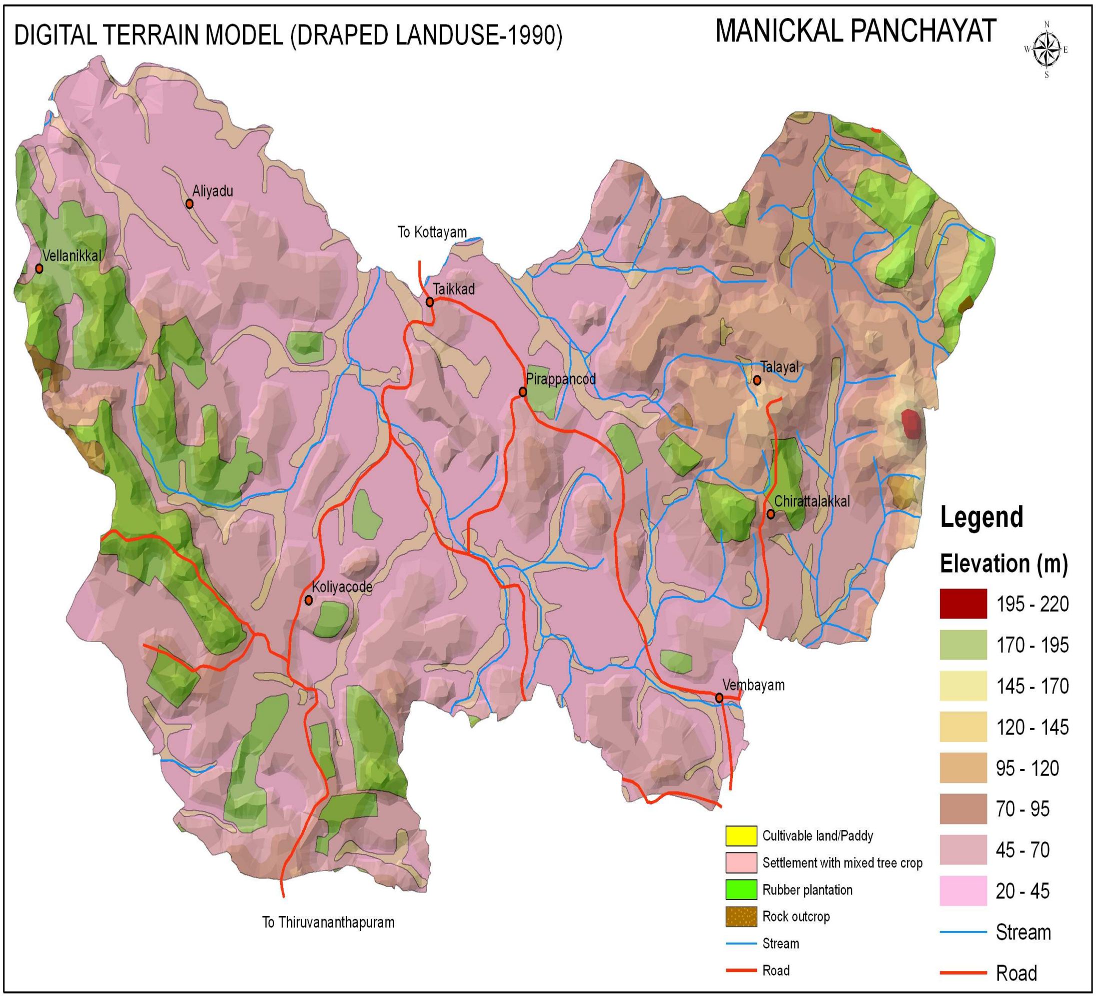


Fig.

Figure-7b

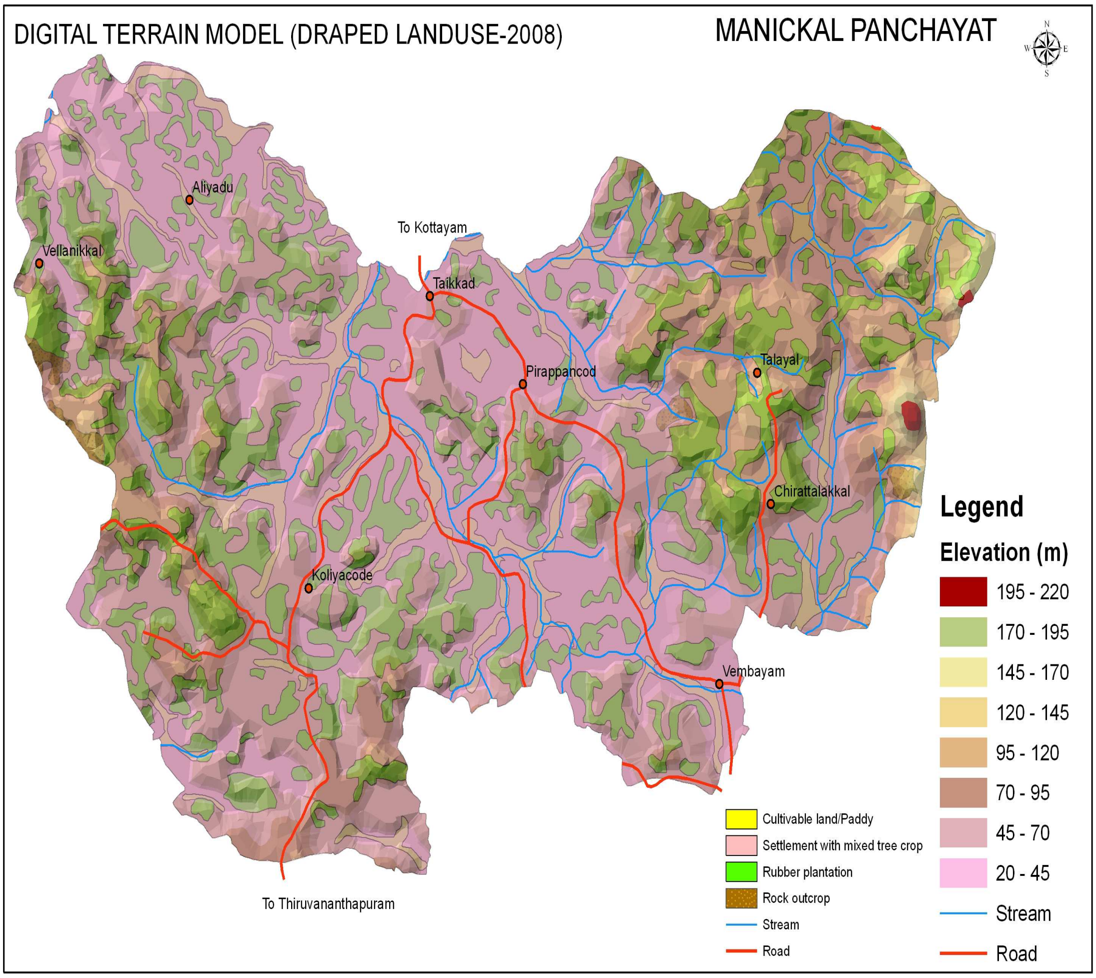
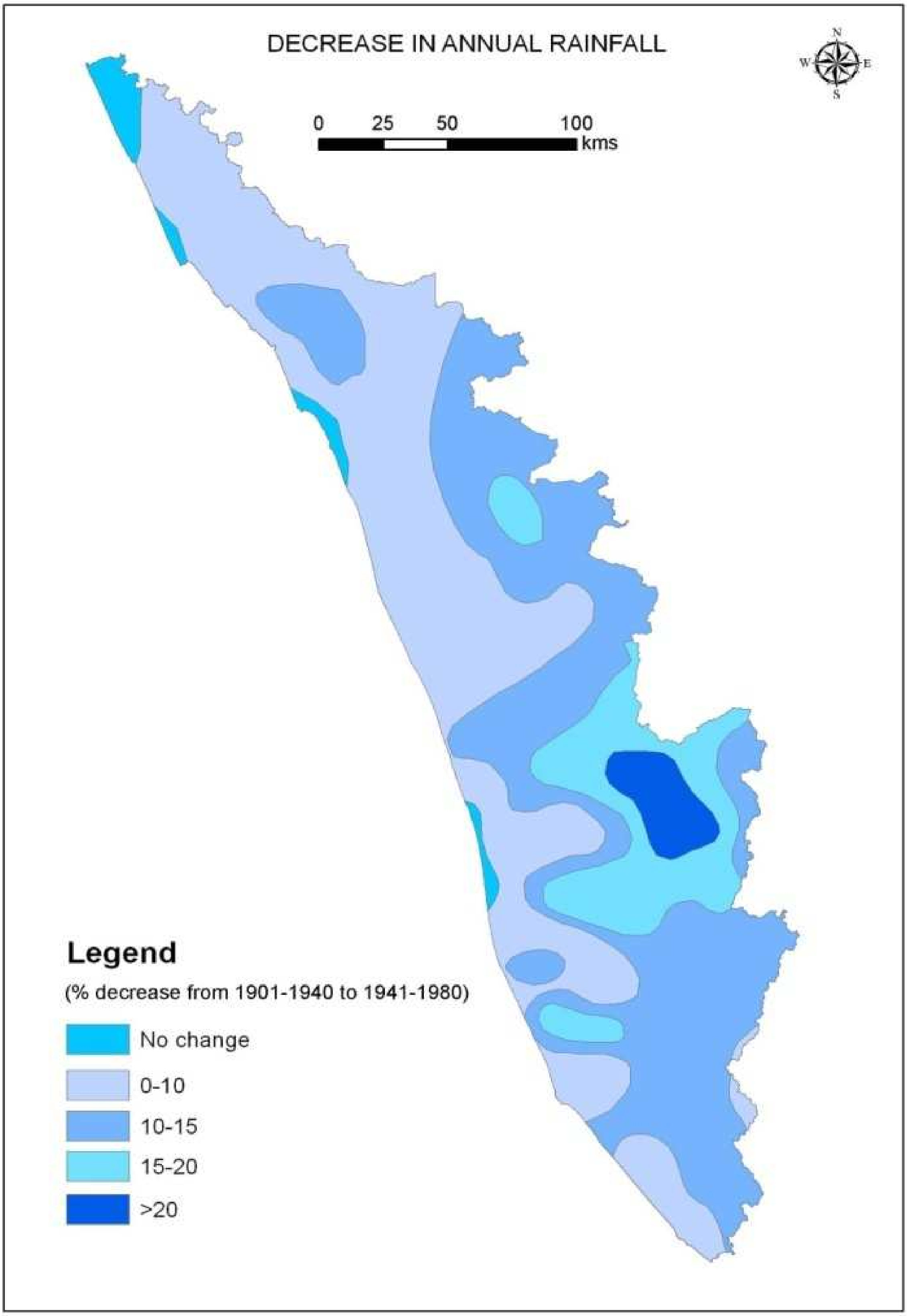


Fig.

Figure-8



DECREASE IN ANNUAL RAINFALL
N
W
E
S
0
25
50
100
kms
Legend
(% decrease from 1901-1940 to 1941-1980)
No change
0-10
10-15
15-20
>20

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References

Balagopalan, M, 1995. Changes in the distribution of organic carbon and different forms of nitrogen in soils under natural forests and teak plantations. Proc. VII Kerala Science Congress, pp. 110-112.

Bhat, D.M, 1990. Litter production and seasonality in tropical moist forest, ecosystems of Uttara Kannada district, Karna taka. Proc. Indian Acad. Sci (plan t sc i), Bangalore Vol.100 pp.139-152.

Biswas, B.C, 1980. Effect of forest cover on rainfall distribution at Andaman and Car-Nicobar Islands, Mausam, Vol.31 pp 178- 180.

Chattopadhyay , S, 1985. Deforestation in parts of Western ghat region (Kerala), India. J. Env. Mangt. Vol. 20 pp. 219-230.

Chattopadhyay, S, Velayuthan, S. and Salim, M.B, 1986. Trends of Deforestation in Kerala, In B.P. Radhakrishna & K.K. Ramachandran (ed). India's Environment: Problems and Perspectives, Geological Society of India, Bangalore, pp. 289- 298. .

Chattopadhyay, S, 1986. Land Classification - An Ecological Approach - Examples from Kerala, India. Landscape Synthesis, part- II. Martin Luther University, Germany, pp. 67-101.

Chattopadhyay, S.,1996. Rubber cultivation in Kerala: Some issues in environmental perspectives. In proceedings of the International seminar on Natural Rubber- An eco-friendly material, Trivandrum, Rubber Research Institute, Kottayam, pp 1-14.

Chattopadhyay S., Asa Rani L and Sangeetha P.V., 2005: Water quality variations as linked to landuse pattern: A case study in Chalakudy river basin. Current Science, Vo. 89 No. 12, pp 2163-2169.

Chattopadhyay S and Franke R.W, 2006: Striving for Sustainability- Environmental Stress and Democratic Initiatives in Kerala. Concept Pub. Co. New Delhi

Chinnamani, S, 1975. Soil Conservation under perennial vegetation on hills. Planter's Chronicle, Vol. 70, pp 128-29. FAD, 1981. Forest Resources of Tropical Asia, Rome, United Nations.

Chaudhuri, P.S., Bhattacharjee, S., Dey, A., Chatopadhyay, S. and Bhattacharya, D. 2013: Impact of age of rubber (Hevea brasiliensis) plantation on earthworm communities of West Tripura (India). Journal of Environmental Biology, Vol. 34, pp. 59-65.

Clark, W.A., Crutzen, P., and Schellnhuber, H. J., 2003: Earth system analysis for sustainability. Dahlem Workshop Report no. 91, MIT Press Cambridge, MA, USA

Engles, F., 1879: Dialectics of Nature- Part played by labour in the transition from ape to man (English translation 1976 printing).

Gourdiola-Claramonte, M., Torch P. A., Ziegler A. D., Giambelluca T. W., Vogler J. B. and Nullet M A., 2008. Local hydrological effects of introducing non native vegetation in a tropical catchment. *Ecohydrology* Vol.1 pp 13-22.

Gourdiola-Claramonte, M., Torch P. A., Ziegler A. D., Giambelluca T. W., Durcik M., Vogler J. B. and Nullet M A., 2010. Hydrologic effects of expansion of rubber (Hevea brasiliensis) in a tropical catchment. *Ecohydrology* Vol. 3 pp 306-314.

Guillaume, T., Muhammad, D and Kuzyakov, Y., 2015. Losses of soil organic carbon by converting tropical forest to plantation: Assessment of erosion and decomposition by new ժ13C approach. Geophysical Research Abstract Vol. 17, EGU 2015-4679.

Fox J, Castella, J.,Ziegler A.D., and Westley S B.,2014. Rubber plantations expand in Mountainous Southeast Asia: What are teh consequences for the environment. East West Center, Asia Pacific Issues No. 114, May, 2014. pp 1-8.

Jinghua. W. 1990. Regional geochemistry of rubber plantation in Hainan island of China. The Journal of Chinese Geographer, Vol. 1. pp 79-87.

Jong W de (2001): The impact of rubber on forest landscape in Borneo. Agricultural Technology and Tropical Deforestation, eds. A Angelsen and A Kaimowitz, CAB International: pp 367-381.

Karthikakutty Amma, M, Suresh, P.R, Valsa, G, Aiyer, R.S and Mathew, M, 1995. Comparative evaluation of soil organic matter status of rubber growing soils in relation to forest ecosystem. Proc. VII Kerala Science Congress, pp . 100-101.

Karthikakutty Amma, M. Suresh, P.R, Aiyer, R.S and Valsa, 1996. Effects of continuous cultivation of rubber (Hevea, Brasiliensis) on total and available nitrogen status of soil. Proc. VIII Kerala Science Congress, pp. 80-82.

Karunakaran, N., (2012): Crop diversification and ground water depletion in the Kasaragod district in Kerala. *Pragati*, Issue 122, October-December, 2012: pp 41-49

Khasanah, N., Wijana, T., Vimcent, G. and Noordwijk, M V (undated): Water status and radiation environment in rubber (HB) systems: A comparison between monoculture and mixed rubber-Acacia mangium plots. Study report under Improving the productivity of rubber smallholdings through Rubber Agroforestry System. World Agroforestry Centre-South East Asia Regional Programme.

Kobayshi, N., Kumagai, T., Miyazawa. Y., Matsumoto K., Tateshi M, Lim T K., Mudd R G, Ziegler A D., Giambelluca T W and Yim S, 2014: Transpiration characteristics of a rubber plantation in Central Cambodia. *Tree Physiology,* Online publication, March,18.

Kumagai, T., Mudd, R. G., Miyazawa, Y., Liu, W., Giambelluca, T. W., Kobayashi, N., Lim, T. K., Jomura. M., Matsumoto, K., Huang, M., Chen, Q., Ziegler, A. And Yin, S. (2013). Simulation of canopy CO2/H2O fluxes for rubber (Hevea Brasiliensis) plantation in central Cambodia: The effect of teh regular spacing of planted trees. Ecological Modelling 265, 124-135.

Kerala State Landuse Board (KSLUB), 1996. Land Resources of Kerala State, Thiruvananthapuram. p 290.

Lambin E F, Geist H J, Lepers E., 2003. Dynamics of land use land cove changes in tropical regions. Annual Review of Environmental Resources, Vol. 28 pp 205 – 241.

Li Z, Morcau L and Cihlar J (1997): Estimation of photosynthetically active radiation absorbed at the surface. Journal of geophysical research. Vol.102, No. D24, pp 29,717 – 29,727.

Li Z., and Fox J. M., 2012. Mapping rubber tree growth in mainland south east Asia using time series MODIS 250m NDVI and statistical data. Applied Geography, Vol. 32, no. 2, pp 420-432

Mahamaya Chattopadhyay, 2003: Morphogenetic processes and land use- a geoecological impact assessment in the Ittikara river basin, south Kerala. Unpublished Ph. D Thesis, School of Environmental Sciences, M G University, Kottayam

Mahamaya Chattopadhyay, Sajikumar S and Saritha D., 1996: Integrated Resource Evaluation of the Vamanapuram River Basin, South Kerala. Project report submitted to the State Committee on Science, Technology and Environment, Government of Kerala, Centre for Earth Science Studies, Thiruvananthapuram.

Marsh G.P., 1864: Man and Nature: or Physical Geography as modified by Human Action. New York, Charles Scribner

Moron E. F., Skole D.L., and Turner II B.L., 2004: The development of the international land use and land cover change (LUCC) research programme and its links to NASA's land cover and land use Change (LCLUC) initiatives. In Land Change Science, Observing, Monitoring and Understanding Trajectories of Change on the Earth's Surface. Eds. G. Gutman, A C Janetos, C O Justice, E F Moran, J F Mustard, R R Rindfuss, D. Skole, B.L. Turner II and M A Cochrane. pp. 1-16

Mustard J. F., DeFries R.S., Fisher T. and Moran E., 2004: Land-use and land-cover change pathways and impacts. In Land Change Science, Observing, Monitoring and Understanding Trajectories of Change on the Earth's Surface. Eds. G. Gutman, A C Janetos, C O Justice, E F Moran, J F Mustard, R R Rindfuss, D. Skole, B.L. Turner II and M A Cochrane, pp. 411-430

Meher-Homj i, V.M, 1980. The 1ink between rainfall and forest clearance, case studies from West Karnataka. Trans. Inst. Indian Geography. Vol.2, pp. 59-65.

Polhamus, L. G, London. 1962. Rubber-Botany, Production and Utilization,

Redclift. M, 1987. Sustainable Development. Exploring the Contradictions. Methuen, London, p.217.

Rubber Board, unda ted.p.94 + VIII Rubber and its cultivation, Kottayam,

Satheesan, K.V, Gururaja Rao, G and Sethuraj, M. Rand Raghavendra, A.S, 1984. Canopy photosynthesis in rubber (Hevea Brasiliensis). Characteristics of leaves in relation to light intersection. In C. Sybesma (ed) Advances in Photosynthesis Research. pp. 125-128.

Satheesan. K.V, Jayakumar, M, Varadan, K.M and Unn!, P.N, 1993. Effect of conversion of natural forests into plantation crops and water use in the Westernghats. Proc. V Kerala Science Congress, pp. 71-73.

Satheesh P R and Jacob, J., (2011) Impact of climate warming on natural rubber productivity in different agro-climatic regions of India. *Natural Rubber Research* Vol. 24, pp 1-9.

Satish G.C., Ulaganathan A., Karthikakutty Amma M. And Nair A N S (2008): Erodibility assessment of rubber-growing soils in Kerala, India. *Agropedology* Vol. 18, pp 116-123.

Shaji, V.M.M and Abraham, T.K, 1994. Litter Production in Forest Ecosystems of Kallar and Palode, Kerala. Proc.VI. Kerala Science Congress, pp. 94.

Soman, M.K., Krishnakumar, K, Singh, **N,** 1988. Decreasing and trend in the rainfall of Kerala. Current Science, Vol. 57, pp. 7-12.

Soman, K, Mahamaya Chattopadhyay , Ouseph, P. P. 1996 Status of Riverine Pollution in South Kerala and its Relation to Physiography and Landuse. Paper communicated for the Xth Kerala Science Congress, 1997.

Soman K. and Mahamaya Chattopadhyay, 1998: Natural Resource Inventory for Hazard Management for Kollam District- A System Approach. Project report submitted to the State Committee on Science, Technology and Environment, Government of Kerala. Centre for Earth Science Studies, Thiruvananthapuram.

Soman K., Chattopadhyay S., Ouseph P.P., Mahamaya Chattopadhyay and Shravankumar V., 2001: Natural Resource Inventory for Alappuzha and Parts of Pathanamthitta Districts falling within Pamba basin. Project report submitted to the State Committee on Science, Technology and Environment, Government of Kerala. Centre for Earth Science Studies, Thiruvananthapuram.

Turner, B.L. II, Clark, W.C., Kates R. W., Richards J. F., Mathews J.T., and Meyer, W.B. (eds.) 1990: The Earth As Transformed by Human Action. New York, Cambridge University press

Turner B.L. II, Moss R.H., and Skole D.L (eds.), 1993: Relating Land Use and Global Land Cover Change: A Proposal for an IGBP-HDP core project. Report from the IGBP-IHDP Working Group on Land use / land cover change. Joint publication of the International Geosphere-Biosphere Programme (Report No. 24) and the Human Dimensions of Global Change Programme (Report No. 5). Stockholm: Royal Swedish Academy of Sciences

Turner B.L. II, Skole D.L., Sanderson S., Fischer G., Fresco L., Leemans, R., 1995: Land use Land cover Change Science/ Research Plan, IGBP Report No. 35, and HDP Report No. 7. Stockholm

United Nations Mission in Liberia (undated): Rubber Plantations- Special Report on Environment, United Nations Rubber Plantation Task Force. 8P

Verheye W (undated). Growth and production of rubber. Soil, Plant Growth and Crop Production. Vol. II UNECSCO Encyclopaedia of Life Support System, p. 1-27.

Wahab, H. A (Undated). Forages in oil palm and rubber plantations in Malayasia (www.fao.org/ag/AGP/agpc/doc/proceedings/manado/chap4.htm)

Ziegler A.D., Jefferson M F. And Xu, J., 2009: The Rubber Juggernaut. *Science*, Vol. 324, No. 5930, pp 1024-1025.

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This research programme, established with the support of the Ministry of Commerce and Industry, Government of India, envisages to help transforming the plantation sector in India to be internationally competitive and sustainable – economically, environmentally and socially - by;

Undertaking Policy oriented Research – on all aspects of plantation economy at the regional, national and international levels

Promoting Policy advocacy – at the regional national and international level - to influence particularly the National and State level policies

Facilitating Networking – of all relevant stakeholders and

Help Capacity building - of all concerned at the regional and national levels.

The programme works under the overall guidance of a Steering Committee, chaired by the Chairman, CDS. The Steering Committee comprises of the Chairpersons of Coffee Board, Rubber Board, Tea Board, Spices Board, Joint Secretary/Director in Charge of Plantations in MoC, Director CDS and an expert on plantation sector. Chair Professor of the Programme is the Convenor. A Research Advisory Committee chaired by the Director CDS has been set up to provide guidance to the research being undertaken by the programme.

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