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APPLICATION OF REMOTE SENSING AND GIS FOR ESTIMATING AREA UNDER NATURAL RUBBER CULTIVATION IN INDIA

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Area under natural rubber (*Hevea brasiliensis*) cultivation is expanding globally due to its increasing demand in engineering and industrial applications. In India, natural rubber (NR) traditionally grown in Kerala and Kanyakumari district of Tamil Nadu plays a central role in the economy of the country and large areas are being brought in to rubber cultivation in parts of Karnataka, Maharashtra, Assam, north-eastern states *etc*. Estimation of area under NR cultivation and its spatial distribution are vital for planning and decision making by the Rubber Board, under Government of India to promote and develop NR in the country. The present study aims at mapping the area under NR cultivation in Kerala and Kanyakumari district of Tamil Nadu using satellite images and to study its distribution with respect to elevation, slope and Soil Management Units (SMU). Multi date satellite data of IRS P6 LISS III was classified to delineate spatial extent and distribution of district-wise NR area. The total area under NR cultivation above three years estimated in Kerala and Kanyakumari district of Tamil Nadu using satellite data was 5,19,909 ha. According to survey statistics this was 5,14,524 ha. Natural rubber accounted for 12.2 per cent of the total geographical area as of 2005-06 and its spatial distribution was mainly confined in the mid altitudes (up to about 500 m MSL). Natural rubber area as per cent of geographical area was the highest in Kottayam district (48.1%) followed by Ernakulam (23.5%) and Pathanamthitta districts (20.5%) of Kerala. The present study showed that IRS P6 LISS III can be used effectively for mapping NR area at macro scale. GIS based overlay analysis indicated that 70 per cent of the area under NR in Kerala and Kanyakumari was situated in the elevation 0-100 m, above MSL 35 per cent of the NR area was situated in the 5-10 per cent slope and 20 per cent area in 3-5 per cent slope. More than 50 per cent of the NR area was in SMU 2, 3 and 4. This study shows the potential of remote sensing tools in estimating area under NR cultivation, its spatial distribution and usefulness of GIS platform in analysing, interpreting and extracting useful information such as elevation, slope and SMU with respect to NR cultivation.

Keywords: GIS, Natural rubber, Overlay analysis, Remote sensing

INTRODUCTION

Natural rubber (*Hevea brasiliensis*) is one of the world's most important economic crops and India ranks fourth in world production (IRSG, 2011) and its major share comes from the area covering Kerala state and Kanyakumari district of Tamil Nadu. Reliable and timely estimates of crop area statistics is paramount important for Rubber Board under the Ministry of Commerce and

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Industries, Government of India for taking appropriate policy decisions regarding production, pricing, procurement, marketing, export or import, public distribution *etc.* So far NR area is estimated by Rubber Board based on the sample survey done at regular interval. This sample survey is time consuming, expensive and lacks spatial information and hence this data cannot be integrated with other spatial information for integrated analysis and decision making. Spatial data has a key role in agricultural planning.

Remote sensing and GIS provide a flexible environment for collecting, storing, displaying and analysing digital data. Satellite imagery has been demonstrated to be a cost effective method for land-cover mapping throughout the world (Trisurat *et al.*, 2000). Feasibility of mapping NR area distribution using remote sensing technique has been reported earlier (Gopinathan and Samad, 1989; Menon, 1991; Menon and Ranganath, 1992; Rao *et al.*, 2001, 2003 and 2003a). But no attempts were made for integrated analysis under GIS along with soil and topographic parameters so as to derive useful information for the farmers, planners, and researchers. Rubber Board has many schemes for the NR growers like planting subsidy, soil and water conservation measures, *Corynespora* disease control campaign *etc.* NR cultivation is fast spreading outside traditional midland as well as beyond traditional NR growing tract. Taking into consideration of NR being cultivated in varied physiography soil and climate, Rubber Board needs timely and accurate statistics on NR area regularly to monitor as well as to take suitable measures in the interest of the Indian NR sector. Use of satellite images along with ground survey data in obtaining the reliable crop acreage estimation has been proved in other crops like coffee (Cordero-Sancho and Sader, 2007), tea (Menon and Ranganath, 1992; Dutta, 2011), paddy (Sahoo *et al.*, 2005) and cassava (Eiumnoh and Sreestha, 1999).

The present study was taken up with the aim of estimating the total area under NR cultivation in Kerala and Kanyakumari district of Tamil Nadu and also to assess the spatial distribution of NR area over different classes of elevation, slope and Soil Management Units (SMU).

MATERIALS AND METHODS

Study area

The study area covered NR growing regions of entire state of Kerala and Kanyakumari district of Tamil Nadu in India. Figure 1 shows the geographical location of the study area which lies between 74° 48′ 33.10″ to 77° 38′ 35.43″ East longitudes and 7° 58′ 56.27″ to 12° 53′ 19.11″ North latitudes, covering a geographic area of 40550.63 km^2. This area is characterized by highly undulating topography and elevation ranging between 0-2692 above MSL. Physiography of the study area is such that on eastern side covered with high land Western Ghats and on western side with coastal low land. Natural rubber is mainly concentrated in between them *i.e.*, in the midland. The annual rainfall ranges from 2000-5000 mm with an average of 3000 mm. Soils are mainly laterite and lateritic.

Data used and processing

Administrative boundary was digitized from geo-referenced Survey of India toposheet of scale 1: 2,50,000 covering study area. Indian Remote Sensing (IRS) P6 LISS III scenes covering Kerala and Kanyakumari district were used for the delineation of NR area. Acquisition date and row/path of IRS P 6 LISS III data is given in Table 1. Satellite acquisition dates were selected corresponding

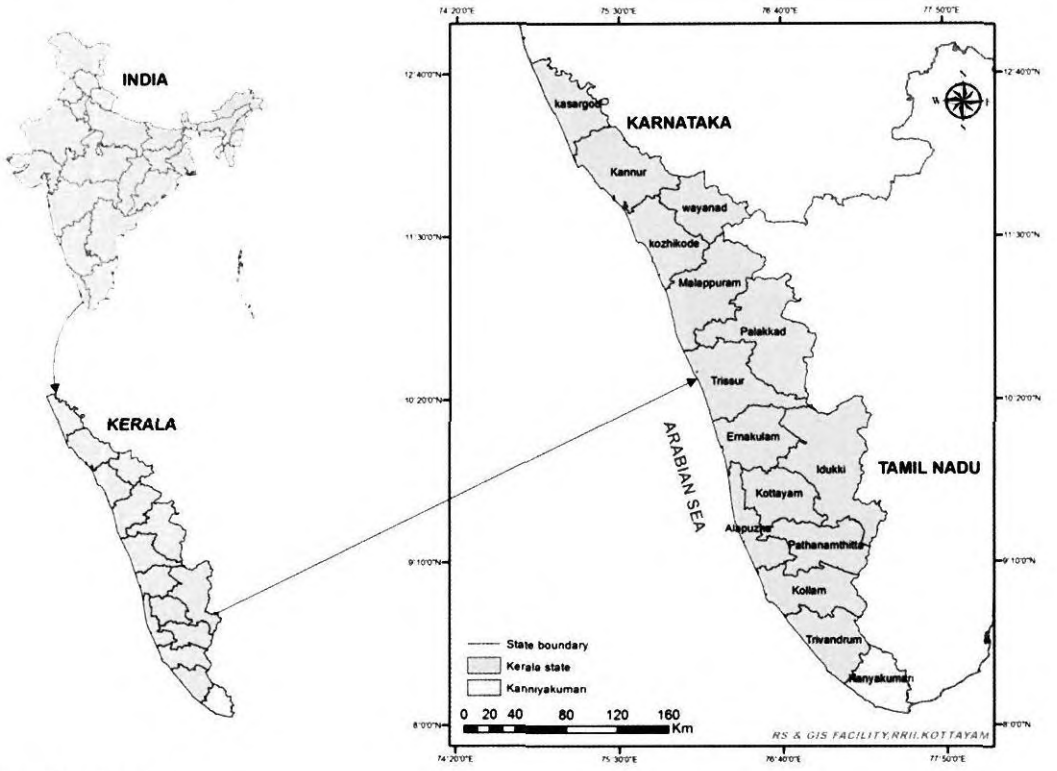

Fig. 1. Study area

to complete refoliation period of NR (February - March). Rubber tree being deciduous, sheds leaf and reflush immediately, whereas other deciduous trees do not. Hence NR during this period shows distinct signature particularly in infrared band compared to other vegetation. Satellite images were geo-referenced using Survey of India toposheets (1:50,000 scale).

Wherever district covers more than one satellite scenes then scenes were mosaic and clipped using district boundary. District satellite images were classified using K means clustering (minimum distance) algorithm in Geomatica software v.10.3.1. Four bands of IRS P6 LISS III and Normalized Difference Vegetation Index (NDVI) generated using band 2 and 3 were taken as inputs for image classification. Bitmap covering forests and low-lying areas was generated using toposheet and Google

Table 1. **Details of satellite data used in the study**

Sl. no.	Acquisition date	Path/Row
1	2nd March, 2011	100/68
2	2nd March, 2011	100/67
3	13th February, 2005	100/67
4	1st February, 2011	99/66
5	27th February, 2006	99/66
6	1st February, 2011	99/67
7	27th February, 2006	99/65
8	18th March, 2006	98/65
9	8th February, 2007	101/68

Table 2a. **Confusion matrix of image classification**

Class	Reference Class						
	Water	Mixed vegetation	Rubber	Town	Paddy	Null	Total
Water	293	0	1	0	0	0	294
Mixed vegetation	0	313	68	5	2	0	388
NR	0	7	785	0	0	0	792
Town	0	13	33	297	0	0	343
Paddy	0	2	7	0	96	0	105
Null	0	2	6	0	0	0	8
Total	293	337	900	302	98	0	1930

Table 2b. **Accuracy statistics of NR based area estimate**

District	Overall accuracy (%)	Overall Kappa statistics (%)
Thiruvananthapuram	90.40	0.87
Kollam	85.03	0.79
Pathanamthitta	90.17	0.85
Alapuzha	88.97	0.84
Kottayam	75.28	0.63
Idukki	94.11	0.91
Ernakulam	89.74	0.84
Trissur	94.73	0.93
Palakkad	96.68	0.94
Malappuram	88.49	0.85
Kozhikode	91.66	0.88
Waynad	96.07	0.95
Kannur	88.23	0.82
Kasaragod	85.00	0.78
Kanyakumari	91.25	0.87

Earth and used as mask during classification. Using the ground knowledge, GPS readings of major vegetation classes and unique signature of NR and other vegetation (Meti *et al.*, 2008), 16 different spectral classes were aggregated into NR, mixed vegetation, paddy, water body and town/built up area. GPS readings (Garmin-Oregon 550) collected from dominant land use classes in each district were used as test point for accuracy assessment of classified image and generated accuracy assessment report for each district. Total 900 test points were taken for ground truth information from NR plantations and other land use/land cover of the study area. Using raster to vector conversion tool, district-wise rubber area was extracted and further used for overlay analysis in GIS. Software used for image processing and analysis were ArcGIS v.10 and Rolta Geomatica v.10.3.1. For estimating the rubber area and its distribution over elevation, slope and SMU classes, thematic layers of elevation, slope and SMUs of Kerala and Kanyakumari were superimposed on NR distribution and NR area under each category was estimated. Advanced Space-born Thermal Emission and Reflection Radiometer (ASTER) Digital Elevation Model (DEM) data of 30m resolution was used for physiographic analysis. Elevation was grouped into three classes (0-100, 100-300 and >300m) and slope into seven classes (0-3, 3-5, 5-10, 10-15, 15-25, 25-33 and >33%).

National Bureau of Soil Survey and Land Use Planning (NBSS & LUP, 1999) has surveyed rubber growing regions of Kerala and Kanyakumari district of Tamil Nadu and grouped the whole area into seven SMU classes based on soil depth, gravel content and organic carbon status. According to this

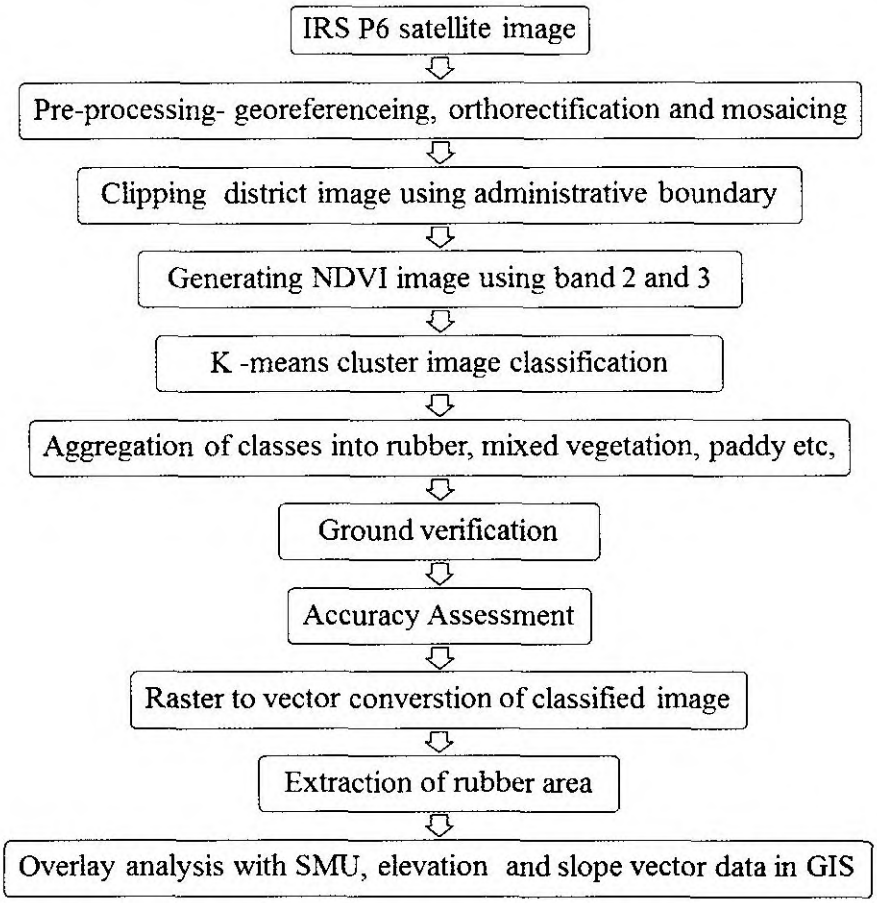

Fig. 2. Flow chart of satellite image processing and analysis

grouping, SMU 1 is with most desirable properties and SMU 7 is with least favourable properties with respect to NR cultivation. SMU maps of NR growing areas of Kerala and Kanyakumari district were vectorized and brought into GIS for overlay analysis.

RESULTS AND DISCUSSION

Image classification

Accuracy of the image classification is given in Table 2 (a & b). Confusion matrix shows that classification accuracy of NR was 87.2 per cent. Overlapping of NR classification was mainly with mixed vegetation and town/settlement (Table 2a). In Kerala small rubber growers are the dominant and a re-surrounded with many other trees and plantation crops. So edge pixels will be having mixed signature from other trees and hence more chance of miss classification. Except large estates, NR plantations are very much associated with human settlement/households. Apart from this homestead farming with perennial and annual crops is widely practiced in Kerala

Table 3. **District-wise NR area statistics of Kerala and Kanyakumari (2005-06*)**

District	Ground survey statistics (ha)	Satellite based NR area (ha)	Variation compared to ground survey statistics (ha)	District-wise geographical area (ha)	Geographical area under NR (%)
Thiruvanathapuram	30009	27527	-2482	218179	12.6
Kollam	35665	37272	1607	249049	14.9
Pathanamthitta	49551	51766	2215	251916	20.5
Alapuzha	3934	5771	1837	153906	3.7
Kottayam	111635	106793	-4842	221581	48.1
Idukki	38844	37103	-1741	501922	7.3
Ernakulam	58309	56654	-1655	240222	23.5
Trissur	14058	13927	-131	303360	4.5
Palakkad	31952	28421	-3531	448834	6.3
Malappuram	32588	36634	4046	355340	10.3
Kozhikode	18237	18752	515	235515	7.9
Waynad	7777	8977	1200	212887	4.2
Kannur	38366	49477	11111	295475	16.7
Kasaragod	25374	20053	-5321	198802	10.0
Kanyakumari	18225	20782	2557	168074	12.3
Total	514524	519909	5385 (1.04%)	4055064	12.2

*Area under three year old holdings are not included

household and because of this reason NR classification also showed overlapping with town/settlement (Table 2a). Overall accuracy of satellite image classification ranged from 75-97 per cent with Kappa coefficient varying from 0.63 to 0.95 (Table 2b).

Rubber area statistics

Total NR area distribution map is shown in Figure 3. Spatially, NR area is mainly distributed in the midlands of Kerala and Kanyakumari district. However, in Idukki, Waynad and Kasaragod districts, NR is cultivated in high lands also. Since no earlier published spatial distributed map of NR available, attempt has not been made to compare the spatial accuracy satellite based NR distribution. However, attempt has been made to compare the satellite based NR area with ground survey statistics and result is presented in Table 3. Total area under NR in Kerala and Kanyakumari district of Tamil Nadu (above three years) was 5,19,909 ha, accounting for 12.2 per cent of the total geographical area. Total NR area estimated based on satellite image deviated from ground survey data to the extent of just 5385 ha (1.04%), thus proving the potential utility of mapping NR area using satellite image.

Among the districts, large extent of NR area was seen in Kottayam district (48.1%) followed by Ernakulam district (23.5%) and Pathanamthitta district (20.5%) and the smallest area was in Alapuzha district (3.7%). District-wise deviation of satellite image based NR area from ground survey statistics showed higher positive deviation in Kannur district (11,111 ha) and negative deviation in Kasaragod (-5,321 ha) and Kottayam (-4,842 ha) while minimum difference was

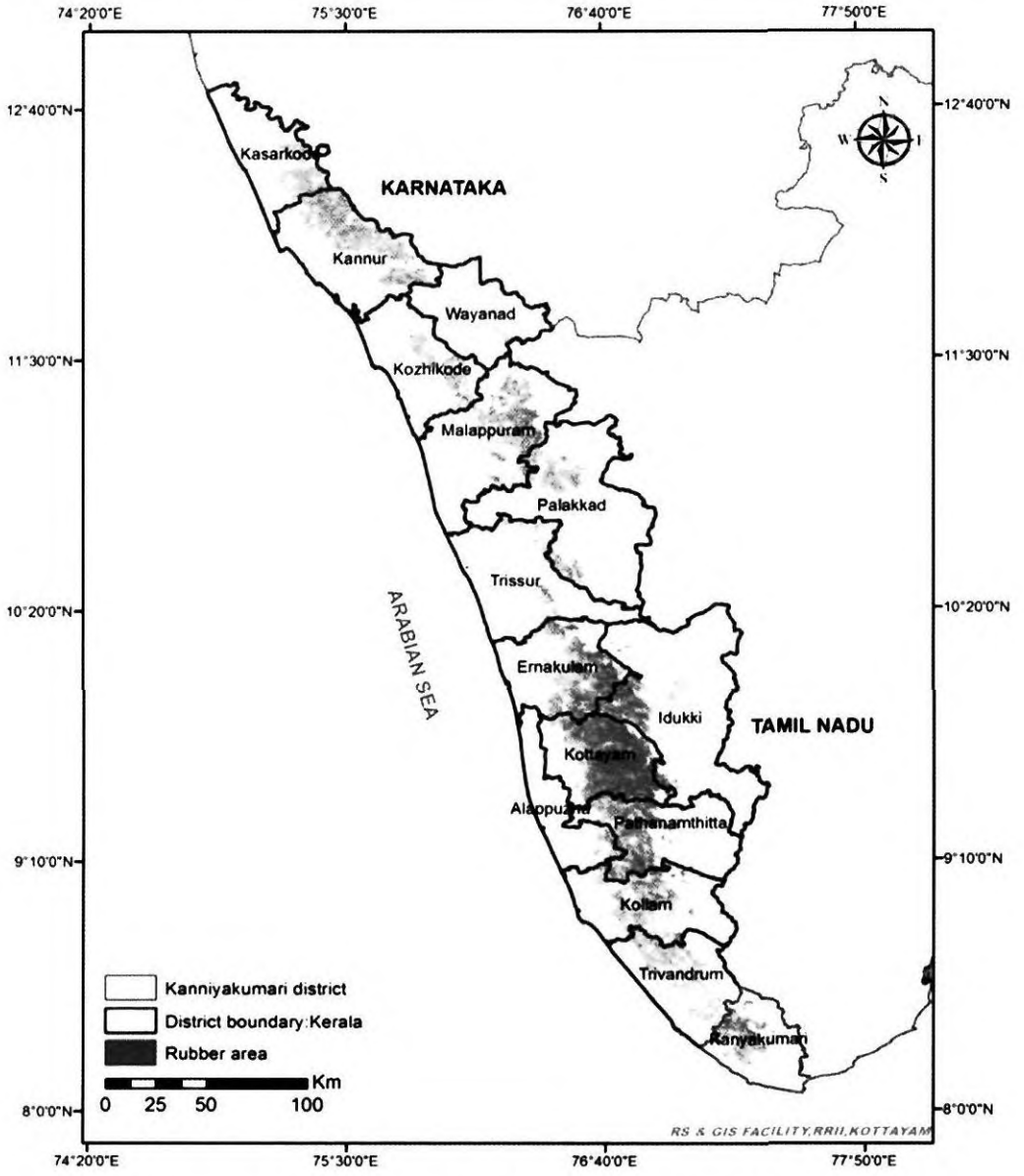

Fig. 3. Natural rubber area distribution in Kerala and Kanyakumari district of Tamil Nadu

observed in Thrissur district (-131 ha). No definite trend was observed in the extent of difference between the NR area estimated by ground survey method and satellite image based method. However, it should be considered that in the ground survey method also, area is estimated based on random sampling, and a possibility of error exists.

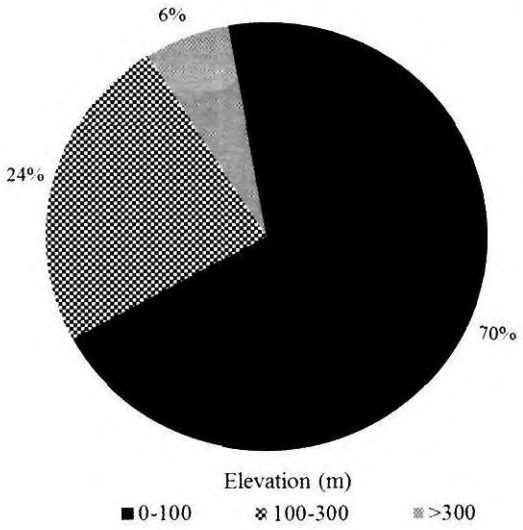

Fig. 4. Rubber distribution on different elevation classes

GIS and overlay analysis

GIS is the ideal platform for integrating spatial NR information with other geospatial information like elevation, soil, slope *etc.*, for better interpretation and visualization. Overlay analysis of NR area with land scape attributes provide important tool in the form of maps for planning and management of NR.

Distribution of natural rubber area according to elevation

NR distribution on different elevation classes in Kerala and Kanyakumari district is given in Figure 4. Kerala has a diverse physiography with elevation ranging between 0-2692 m and distinct lowlands, midlands and highlands. Majority of NR area (70%) in Kerala and Kanyakumarifalls under the elevation class 0-100 m and

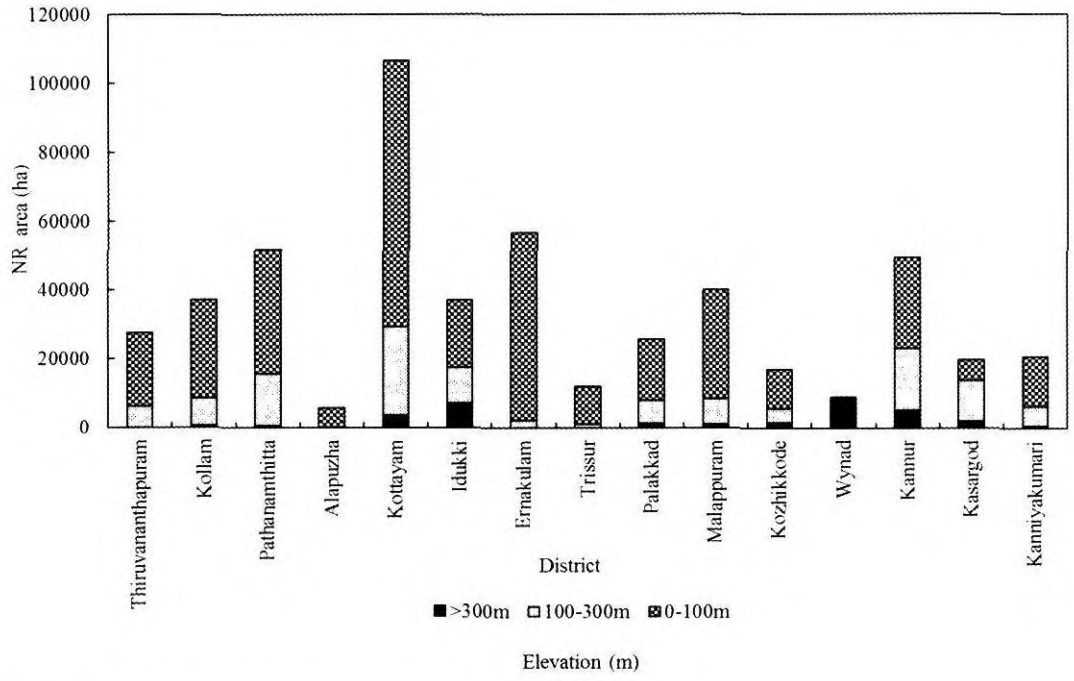

Fig. 5. District-wise distribution of natural rubber area according to different elevation classes

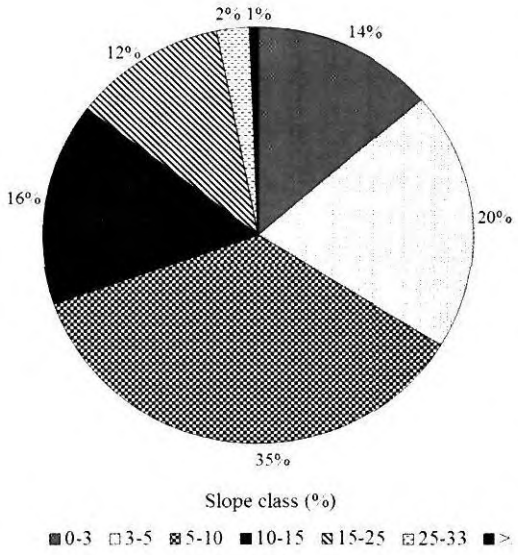

Fig. 6. Rubber distribution on different slope classes

least (6%) in >300 m elevation class (Fig. 4). In general, the district-wise distribution of NR area under different elevation classes also followed the same trend (Fig. 5). However in Waynad, 90 per cent of the total area under NR is situated in the elevation range 600-1000 m (Fig. 5). Among the physiographic features, elevation influences the growth of rubber. At high elevation, apart from low temperature, high humidity favours the incidence of powdery mildew disease in rubber resulting in retarded growth (Bansil, 1971). At high elevation, low temperature becomes unfavourable for the growth of rubber. Altitude increase brings in progressive decrease of atmospheric temperature and pressure and increase in solar radiation during clear sky (Ziello *et al.*, 2009). Elevation up to 450m MSL is found to be satisfactory for the growth of NR (Pushpadas and Karthikakuttyamma, 1980).

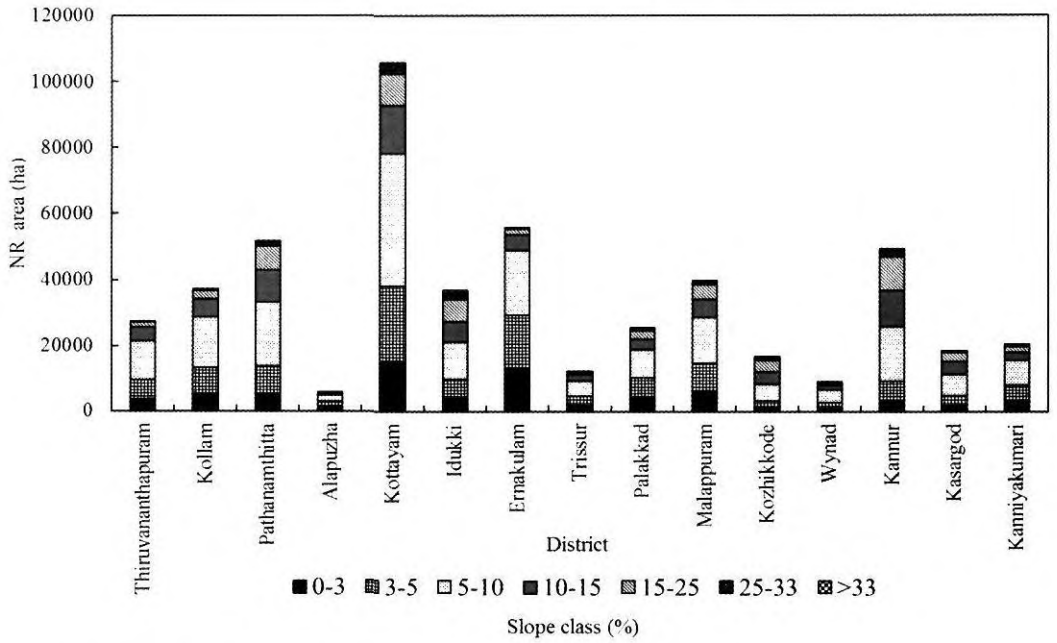

Fig.7. District-wise distribution of natural rubber area according to different slope classes

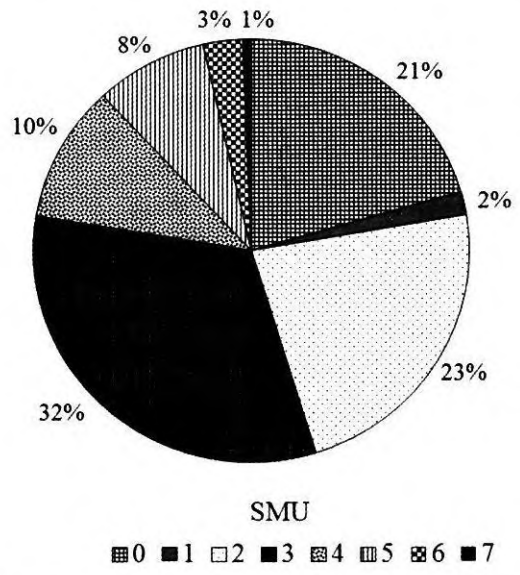

Fig. 8. Distribution of natural rubber area over different SMU classes

Increase in immaturity period by six months for every 100 m rise in altitude had been reported (Foth and Turk, 1973). This might be one of the reasons for the poor performance of NR plantations in Waynad district. In the recent past due to attractive price of rubber coupled with steady decline of price of other plantation crops, NR cultivation is being extended beyond 400m elevation. Considerable NR area is found above 300 m elevation in Waynad, Idukki and Kannur districts (Fig. 5). In the context of climate change, NR may perform well beyond 400 m elevation and hence there is a need to monitor the performance of NR cultivation extended beyond 400 m elevation.

Distribution of natural rubber area according to slope

Distribution of NR area over different slope classes in Kerala and Kanyakumari

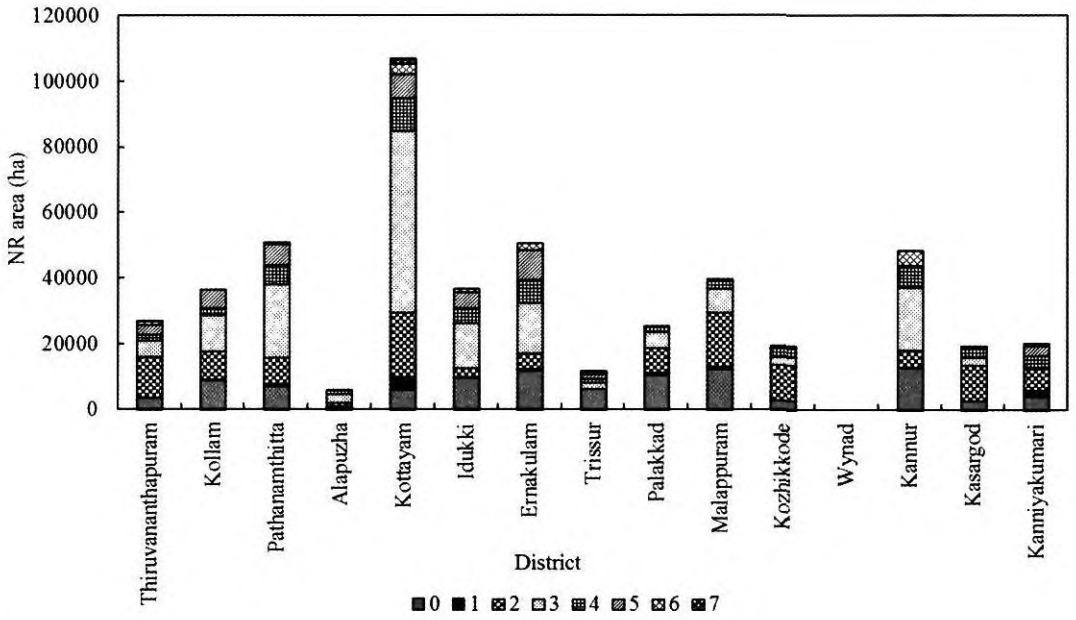

Fig. 9. District-wise distribution of natural rubber area according to different SMU classes

district is given in Figure 6. In Kerala and Kanyakumari, 35 per cent of the NR area is distributed on the 5-10 per cent slope class followed by 20 per cent on 3-5 per cent slope and16 per cent on 10-15 per cent slope. District-wise distribution of NR area in different slope classes is shown in Figure 7 and it follows the same trend. In general, 30-50 per cent of the NR area in all districts of Kerala and Kanyakumari district is distributed on the slope category 5-10 per cent slope (Fig. 7). However, 34 and 15 per cent of NR area in Kerala and Kanyakumari is distributed on level area (< 5% slope) and steep areas (> 25% slope), respectively. Rubber needs well drained soil for better growth and at the same time steep areas pose erosion and runoff problem. Chan *et al.* (1974) observed the increase in girth and yield with increase in slope up to 26 per cent due to better drainage. Most of the study area receives heavy rainfall during rainy season and slope of the area is an important factor which influences the extent of soil erosion. Delineation of NR plantations in the slope area is useful for planning management practices to reduce erosion. In an attempt to assess the soil-site characteristics and their limitation for NR cultivation in northern Mizoram, a non-traditional rubber growing area of India, Satisha *et al.* (2002) found soils of high elevation (>400 m) area are marginally suitable due to severe limitation of slope and coarse fragment. During initial stage of rubber growth and during new or replanting time, top soil will be exposed for erosion due to runoff and to protect the top soil, Rubber Board provides financial assistance to small growers to take up soil conservation measures like silt pits, terracing and bunding. At present this assistance is given for all regions and the present analysis helps to prioritise the assistance for erosion prone areas only.

Rubber distribution according to soil management units

Distribution of NR on different SMU classes is given in Figure 8. Waynad district has not been included in SMU overlay analysis because of the lack of SMU data for that district. Area unsurveyed by NBSS & LUP is shown as class 0 in Figures 8 & 9. Around 32 per cent of the NR area in Kerala and Kanyakumari is concentrated in SMU 3 followed by 23 per centin SMU 2 and 10 per cent in SMU 4. The least suitable SMU categories are 5, 6 and 7 and around 12 per cent of the total NR area distributed over these categories (Fig. 8). Natural rubber in these areas needs special management practices to improve soil organic carbon, moisture conservation *etc.*, for successful cultivation. District-wise distribution of NR area over SMU reveals that more than 50 per cent of the total NR area is in SMU 2, 3 and 4 (Fig. 9). In Kottayam district, major share of NR area (52%) is in SMU 3 while in Kanyakumari district 9 per cent of the NR area is in SMU 1 and 31 per cent in SMU 2. This overlay analysis is useful for estimating NR area in different suitability classes for identifying constraints and formulating site specific management practices. Yield reduction in shallow soil compared to soil with adequate depth has been reported (Dijkman, 1951). Rubber needs a minimum soil depth of 1m without hard pan (Pushpadas and Karthikakuttyamma, 1980). Chan *et al.* (1974) reported the positive effect of soil depth on girth and yield. Evaluating the soil-site suitability for NR in India, Karche *et al.* (1995) attempted to identify the kind and degree of major constraint for NR production. The most striking parameter influencing the NR yield was the period of moisture availability followed by soil depth, available water content, slope, winter

temperature and excess rains. So about 12 per cent of NR area is distributed on poor soil (SMU 5-7) needs to adopt suitable water conservation measures and nutrient management for better performance and enhance the NR yield. In this direction the present analysis gives guidelines for Rubber Board to take up suitable measures.

CONCLUSION

Mapping NR growing areas of Kerala and Kanyakumari district of Tamil Nadu using Remote Sensing and GIS showed the effective use of satellite image for NR area estimation. Natural rubber area estimates using satellite image was comparable to ground survey method which is time consuming and laborious. Additional advantage is that satellite based spatial distribution of NR can be integrated with any spatial data. Integrated analysis of NR area distribution with soil and physiographic features like slope and elevation revealed that significant extent of natural NR area is distributed over high elevation, slope and poor soil for which Rubber Board has to plan and formulate policy guidelines and research programmes for improving the overall productivity of the NR plantations.

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