Rubber Science, **28**(3): 227-236, 2015 RESEARCH ARTICLE

GEO-SPATIAL MAPPING AND TERRAIN CHARACTERIZATION OF NATURAL RUBBER PLANTATIONS IN KARNATAKA, MAHARASHTRA AND GOA

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Received: 12 May 2015 Accepted: 02 September 2015

Pradeep, B., Jacob, J. and Krishnakumar, R. (2015). Geo-spatial mapping and terrain characterization of natural rubber plantations in Karnataka, Maharashtra and Goa. *Rubber Science*, **28**(3): 227-236.

In recent years, consumption of natural rubber (NR) in India has been increasing and its production is on a declining trend. Therefore the supply of NR needs to be increased to meet its increasing industrial demand in the country. This can be achieved by expanding its cultivation to agro-climatically suitable areas and temporal monitoring of NR growing areas. Thus accurate, up to date and timely NR area statistics is essential for management of the Indian rubber plantation sector. Geo-spatial mapping of NR plantations was carried out in Karnataka, Maharashtra and Goa states using recent satellite data. Indian Remote Sensing Satellite Resourcesat I and II LISS III data for the year 2013 were used for estimating spatial extent of NR cultivation. Distribution pattern of rubber area across topographic variables was studied using ASTER digital elevation model (DEM). Area of NR estimated using satellite data was compared with traditional ground survey statistics of the Rubber Board. Area under NR above three years was estimated using satellite data for the year 2013-14. In Karnataka, NR area was 31,231 ha which was 4473.2 ha lower than official ground survey statistics of the Rubber Board (35704.2 ha). Negative deviation was attributed to large area under young plantations in Karnataka. NR plantations aged below three years couldn't be delineated using satellite data because of their sparse canopy. Nearly 1133 ha of rubber area was delineated from Maharashtra. This showed 157.8 ha deviation compared to Rubber Board statistics (975.4 ha). Rubber area statistics of Goa was 424 ha as against ground survey area of 696.3 ha. Characterization of rubber plantation distribution over terrain parameters showed that majority of NR plantations in Karnataka and Maharashtra were distributed over 100 to 300 m elevation, less than 25 per cent slope and North and South facing aspects, whereas in Goa, this was 0 to 100 m elevation, 5 to 25 per cent slope and North and South aspects occupies majority of rubber area. This was the first time mapping of NR plantations has been conducted in Karnataka, Maharashtra and Goa and therefore a temporal monitoring is required to update young plantations and to understand its spatio-temporal shift in cultivation. The geo-spatial database of NR area statistics and its characterization in relation to elevation, slope and aspect can be used as baseline information for planning sustainable NR cultivation in the study area. Moreover, this study shows effectiveness of LISS III satellite data for NR area estimation which is up to date, cost effective and quicker than the traditional survey method.

Keywords: DEM, Geo-spatial, GIS, Natural rubber, Remote sensing

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INTRODUCTION

The major natural rubber (NR) producing countries in the world are Thailand, Vietnam, Indonesia, Malaysia, India and China. India ranks fifth in area and fourth in production accounting 8 per cent of global NR production (NMCE, 2012). In India 90 per cent of the NR production is from Kerala and Kanyakumari district of Tamil Nadu which is considered as traditional NR growing areas. In recent past, expansion of NR cultivation in traditional belt has almost saturated and its cultivation has been expanding to non-traditional regions like Karnataka, Maharashtra, Goa and North-eastern states of India which are considered as future hub of rubber expansion. Total area under NR cultivation in India has extended up to 7,57,520 ha in 2012-2013 (Rubber Board).

In India, domestic NR production and consumption ratio is not in a balanced state (IRSG, 2012). Domestic consumption of NR is being increased year by year due to increased demand of NR in different sectors particularly in automobile industries. According to Rubber Board, India, domestic NR production during April 2013 to January 2014 was provisionally estimated as 7,23,000 tonnes against 8,11,110 tonnes of consumption in the same period. According to Automotive Tyre Manufacturers' Association (ATMA), 65 per cent of NR consumption is by tyre industry. The consumption ratio between NR and synthetic rubber in India is nearly 73:27 against the world ratio of 44:56 which shows over dependence on NR in India (AIRIA, 2013). India was second largest consumer of NR in 2010 after China (Indian Rubber Statistics, 2011). Thus demand of NR can be met by increasing area under NR cultivation by knowing the present extent and identifying suitable areas for its expansion.

Satellite remote sensing and geographical information system (GIS) are being used very effectively for retrieving real time information on crop acreage compared to traditional ground survey method. This technique is being used all over the world for mapping various agricultural crops. Under national crop forecast programmes, Ministry of Agriculture and Indian Space Research Organisation (ISRO) is providing pre-harvest production forecast for crops such as rice, wheat, mustard, jute *etc.* every year. Use of satellite images along with the ground truth information for accurate crop area estimation has been attempted in crops like arecanut (Hegde *et al.*, 1994), cassava (Eiumnoh and Sreestha, 1999), paddy (Sahoo *et al.*, 2005), oil palm (Wahid *et al.*, 2010), tea (Dutta, 2011), coffee (Ortega-Huerta *et al.*, 2012) and sugarcane (Yedage *et al.*, 2013).

Effectiveness of remote sensing technology for NR acreage estimation using medium and high spatial resolution Indian remote sensing satellite (IRS) images have been reported earlier (Gopinathan and Samad, 1989; Menon, 1991; Menon and Ranganath, 1992; Rao *et al.*, 2003). Earlier attempt to estimate NR growing areas in Kerala, Tamil Nadu and Tripura using IRS P6 was in good agreement with Rubber Board's ground survey statistics (Meti *et al.*, 2012; RRSC and RRII, 2012; RRII and ATMA, 2014). Therefore, spatial estimation of NR cultivable areas and its accurate area statistics are significant for formulating policies and programmes in NR sector for increasing domestic NR production and this can be achieved quickly through geo-spatial technology with accurate and up to date information. In this context, rubber distribution mapping was carried out in NR growing tracts of Karnataka, Maharashtra and Goa states in India using IRS

Resourcesat I and II LISS III data for the year 2013. Further GIS analyses was carried out for various terrain parameters to characterize rubber plantation distribution in relation to elevation, slope and aspect.

MATERIALS AND METHODS

Study area

Natural rubber growing tracts of Karnataka, Maharashtra and Goa were chosen for mapping (Fig.1). NR growing regions of Karnataka lies between East longitude 74.47°E to 77.64°E and North latitude 7.98°N to 14.90°N. Goa and Sindhudurg district in Maharashtra falls between 72.64°E to 74.33°E and 14.89° to 20.21°N. Western Ghats is situated on the eastern side of the study area, which is characterized by highly undulating topography and elevation ranging up to 1031 m above MSL. Foot hills of the Western Ghats of the three states received tropical climate influenced by seasonal heavy rainfall with an annual average rainfall of 3000 mm. Study area receives most of its rainfall during the South-west monsoon from June to September. Summer is extreme in Goa and Maharashtra compared to Karnataka. Other than rubber plantations, coconut, cashew, arecanut, tea and coffee are the major commercial crops cultivated in the study area. Major portion of the midland and mid-upland areas of Karnataka and Goa occupies laterite soils. Brick-red laterites are generally seen in NR growing areas of Maharashtra. Natural rubber growing districts in Karnataka, Goa and Maharashtra cover geographical area of about 27,542. 0, 3611.5 and 22361.5 km^2 respectively.

Input data and methodology

Natural rubber is a deciduous tree which sheds all leaves in December-January and refoliates within two to three weeks and produce lush green thick canopy when refoliates fully. All satellite scenes were coincided with refoliation period of NR (maximum foliage). Total of six cloud free LISS III scenes of Resourcesat I and II data with a spatial resolution of 23.5 m were procured from National Data Centre (NDC) of National Remote Sensing Centre (NRSC), ISRO, Hyderabad for the study (Table 1).

Table 1. **Details of satellite data used**

Satellite and sensor	Date of acquisition	Path-row
Resourcesat I		
LISS III	5th March 2013	98-65
	5th March 2013	98-64
	29th March2013	98-63
	28th February 2013	97-64
	24th March 2013	97-63
Resourcesat II		
LISS III	31st March 2013	96-62

Rolta Geomatica v 10.3.1 and ArcGIS v 10.1 were used for satellite image processing and analysis. Administrative boundaries of the study area were delineated from Survey of India (SOI) toposheets of 1:2,50,000 scale. Taluk level administrative boundaries were vectorized using geo-referenced toposheets. All satellite data were imported and layer stacking were carried out. Atmospheric correction was done to remove haze in the satellite data. Ortho-rectification was carried out to remove terrain distortions in satellite data. Then satellite scenes were mosaicked and district-wise images were clipped for further analysis. NR spectral signature was mixing with paddy areas. Hence, a vector layer was generated for rice growing regions using soil information, satellite data, toposheets and ground truth information.

This layer was used as bitmap mask during digital classification of satellite image.

Unsupervised classification with K-means cluster algorithm was used for classification of satellite data. District-wise images were taken for unsupervised classification. NR gives a unique spectral signature compared to other vegetations in February-March period. NR spectral signature was standardised prior to digital classification by using visual interpretation, ground truth information and temporal normalized difference vegetation index (NDVI) during October, January and March. Extensive field survey was conducted and 674 ground control points (GCPs) collected from NR growing areas of Karnataka, Goa and Maharashtra (Table 3). These GCPs were used for accuracy assessment of NR area classification. SOI toposheets and hand held Garmin GPS Oregon 550 were used for field survey. District-wise unsupervised classification was carried out and NR classes were aggregated and labelled using spectral signature, GCPs and ground truth information. Further raster NR classes were vectorized using raster to vector conversion tool. Randomly selected locations were

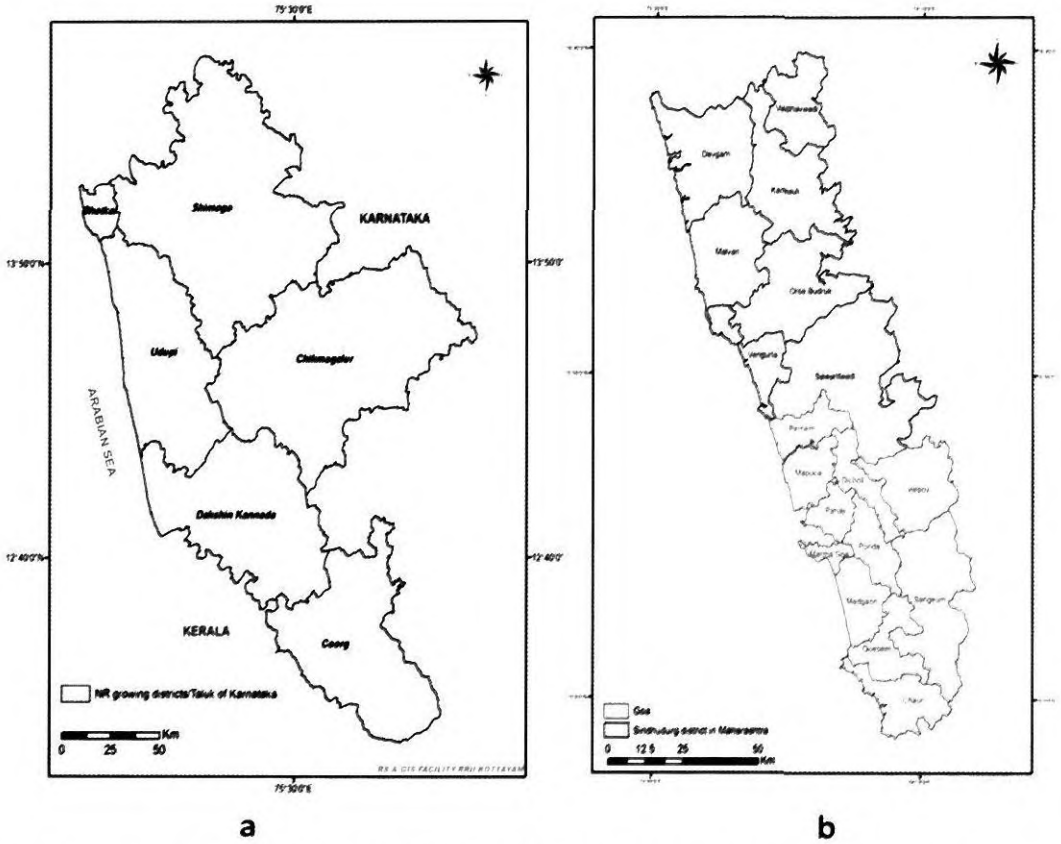

Fig. 1. Geographic position of study area (a) Karnataka and (b) Goa and (c) Sindudurg district (Maharashtra)

visited for post field verification using classified map. Then after the refinement of NR area, spatial distribution maps and statistics were generated. Finally, satellite based rubber area statistics were compared with official ground survey statistics of the Rubber Board. Advanced space-borne thermal emission and reflection radiometer (ASTER) digital elevation model (DEM) data with a resolution of 30 m was used to generate elevation slope and aspect map of study area. Study area was divided into three elevation classes (0-100, 100-300 and above 300 m), six slopes (0-5, 5-10, 10-15, 15-25, 25-33 and above 33 per cent) and five aspect classes (Flat, North, East, South and West). Area under rubber in each classes of terrain parameters have been calculated by using DEM data and raster overlay analysis technique.

RESULTS AND DISCUSSION

Spatial distribution of NR growing areas

NDVI profile of NR showed distinct spectral signature during February-March season compared to other vegetations (Fig. 2). Field survey and satellite image visual

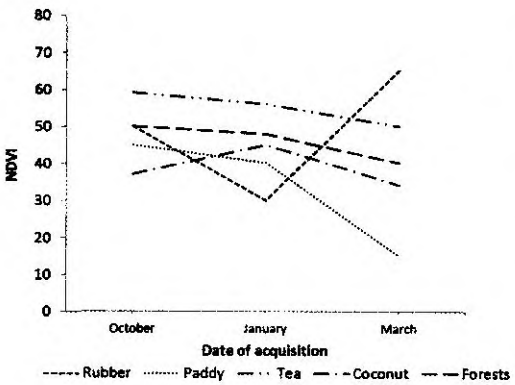

Fig. 2. NDVI profile of rubber and other vegetations during different seasons

interpretation revealed that NR plantations aged less than three years could not be delineated using LISS III satellite data because of poor development of their canopy and mixed spectral signature. Moreover, its spectral signature resembled fallow land and urban areas. Same observations were reported in earlier studies (RRII and ATMA, 2014; RRSC and RRII, 2012 and Meti, *et al.*, 2012 unpublished). Dakshin Kannada, Udupi, Chikamagalur, Shimoga and Coorg districts and Batkal taluk of Uttara Kannada have NR plantations in Karnataka (Fig. 3a). Out of these districts sixty five per cent of NR cultivation was from Dakshin Kannada district followed by Udupi (15%), Chikmagalur (8%), Coorg (7%) and Shimoga (5%) which is shown in Fig. 4. NR plantations were newly planted in large areas in Karnataka and Maharashtra during the year 2010-12. According to Rubber Production Department of the Rubber Board, 9195.8 ha area was newly planted with NR in Karnataka during 2010-12, and 1122.6 ha in Maharashtra (Table 2). More than 95 per cent of NR cultivation in Maharashtra was from Sindhudurg district (Fig. 3b). But, few NR patches were distributed at Thane, Ratnagiri and Raigad districts of Maharashtra. NR holdings were sparsely distributed in North and South Goa districts of Goa (Fig. 3c & Table 2). The Goa and Daman Diu Preservation of Trees Act, 1984 has restrictions on cutting of old/senile NR holdings in Goa. According to Sawantwady Regional Office, only 16.7 ha of NR was newly planted between 2010 to 2012 and no replantation has taken place in Goa during the period (Table 2). Therefore further scope for NR area expansion in Goa is limited.

Satellite based NR area statistics

Satellite based NR area statistics above three years in Karnataka during the year

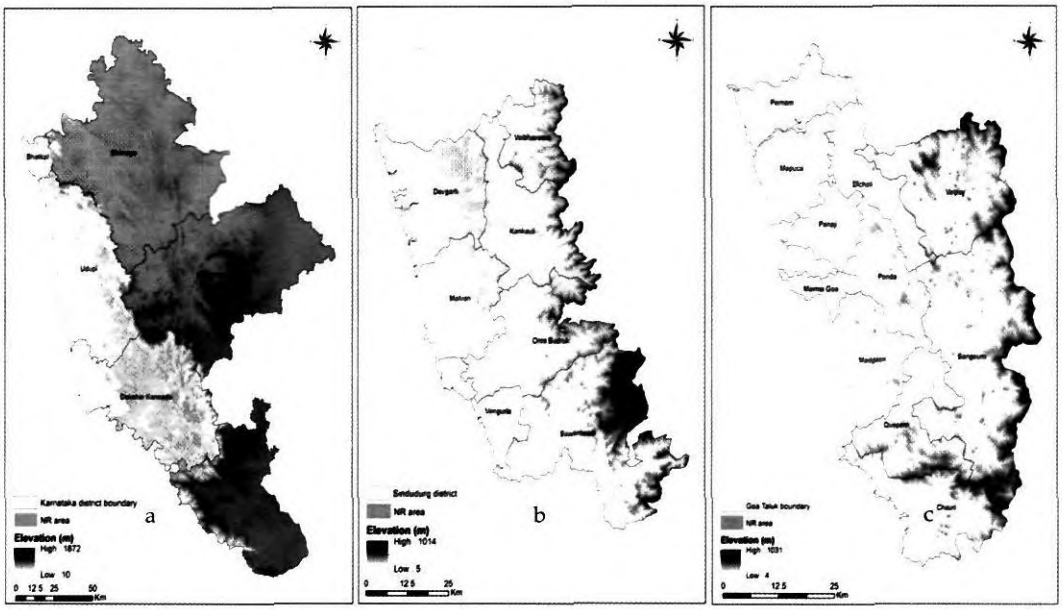

Fig. 3. Geo-spatial distribution of NR plantations in (a) Karnataka, (b) Sindhudurg district in Maharashtra and (c) Goa overlaid over digital elevation model

2013 was 31,231 ha (Table 2). This was negatively deviated compared to traditional ground survey statistics of the Rubber Board. A variation of -4473.2 ha area was estimated from Karnataka (Table 2). Young plantation area statistics (age below three years) in Karnataka for the past three years was 9195.8 ha. The negative deviation of area statistics was attributed by young plantation areas in Karnataka. Young NR plantations were planted more in Dakshin Kannada, Shimoga and Udupi districts in Karnataka. Thus temporal mapping of NR plantations in Karnataka is needed to update young plantation area statistics. NR area mapping accuracy of Karnataka was 88.5 per cent (Table 3).

Table 2. **Satellite based NR area statistics in comparison with ground survey statistics for the year 2013**

State	Remote sensing statistics (> three year old in ha)	Rubber Board statistics (> three year old in ha)	Variation (ha)	NR plantation less than three year old (ha)
Karnataka	31231	35704.2	-4473.2	9195.8
Maharashtra	1133.2	975.4	157.8	1122.6
Goa	424.0	696.3	-272.3	16.7
Total	32788.2	37375.9	-4903.3	10335.1

(Rubber Board Statistics: Rubber Production Department, Rubber Board, Kottayam
Regional Office, Sawantawady, Maharashtra)

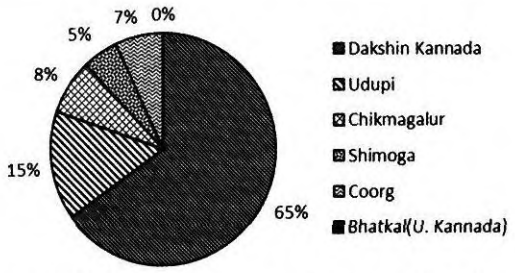

Fig. 4. District-wise per cent share of rubber cultivation in Karnataka

Satellite based NR area statistics above three year old in Sindhudurg district of Maharashtra for the year 2013 was 1133 ha (Table 2). This showed 157.8 ha deviation compared to official statistics of the Rubber Board, indicating good matching with ground survey statistics. During last three years 1122.6 ha of rubber was newly planted in Maharashtra. Ratio of the NR plantation below and above three years in Maharashtra was about 50:50 (Table 2). Therefore, regular mapping was required in Maharashtra to update young plantation area statistics. NR area classification accuracy was 82.4 per cent in Maharashtra (Table 3). Satellite based NR area statistics of Goa for the year 2013 was 424 ha (Table 2) and -273.3 ha variation was calculated compared to Rubber Board statistics and this was because of very sparse distribution of NR holdings in Goa. An accuracy of 86.1 per cent was estimated from Goa (Table 3). Ground truth information and satellite data interpretation showed there is no need to update young plantation area statistics in Goa since small area (16.7 ha) of rubber was newly planted in between 2010 to 2012 (Table 2).

Table 3. **GCPs used for estimating accuracy of rubber area class**

States	Reference points		
	No. of correctly interpreted GCPs	No. of GCPs fallen outside rubber class	Total
Karnataka	429	56	485
Maharashtra	89	19	108
Goa	70	11	81

Compared to ground survey statistics of the Rubber Board, satellite based estimation is faster with less man power involvement. Other advantages of satellite remote sensing statistics is geo-spatial distribution of NR areas which can be overlaid with various thematic layers of information such as elevation, slope, climatic parameters, soil characteristics *etc.* to derive useful information which can serve as a powerful geo-spatial decision making tool.

Distribution of rubber plantations in relation to terrain parameters

Characterization of NR plantations according to topographic variables such as elevation, slope and aspect classes have importance for selection of optimum set of terrain classes. This can be further used as baseline information for identifying potential lands for NR area expansion in the study area or elsewhere in the states, in general. Per cent area distribution of rubber plantations in relation to elevation, slope and aspect classes in Karnataka, Maharashtra and Goa are given in Fig. 5.

In Karnataka, 53 per cent of rubber area was in 100 to 300 m elevation followed by 32 per cent in 0 to 100 m and 15 per cent above 300 m elevation. It was reported that 70 per cent of rubber area in traditional belt of Kerala and Tamil Nadu falls under the elevation class 0 to 100 m (Meti *et al.*, 2012). Around 81 per cent of rubber area in

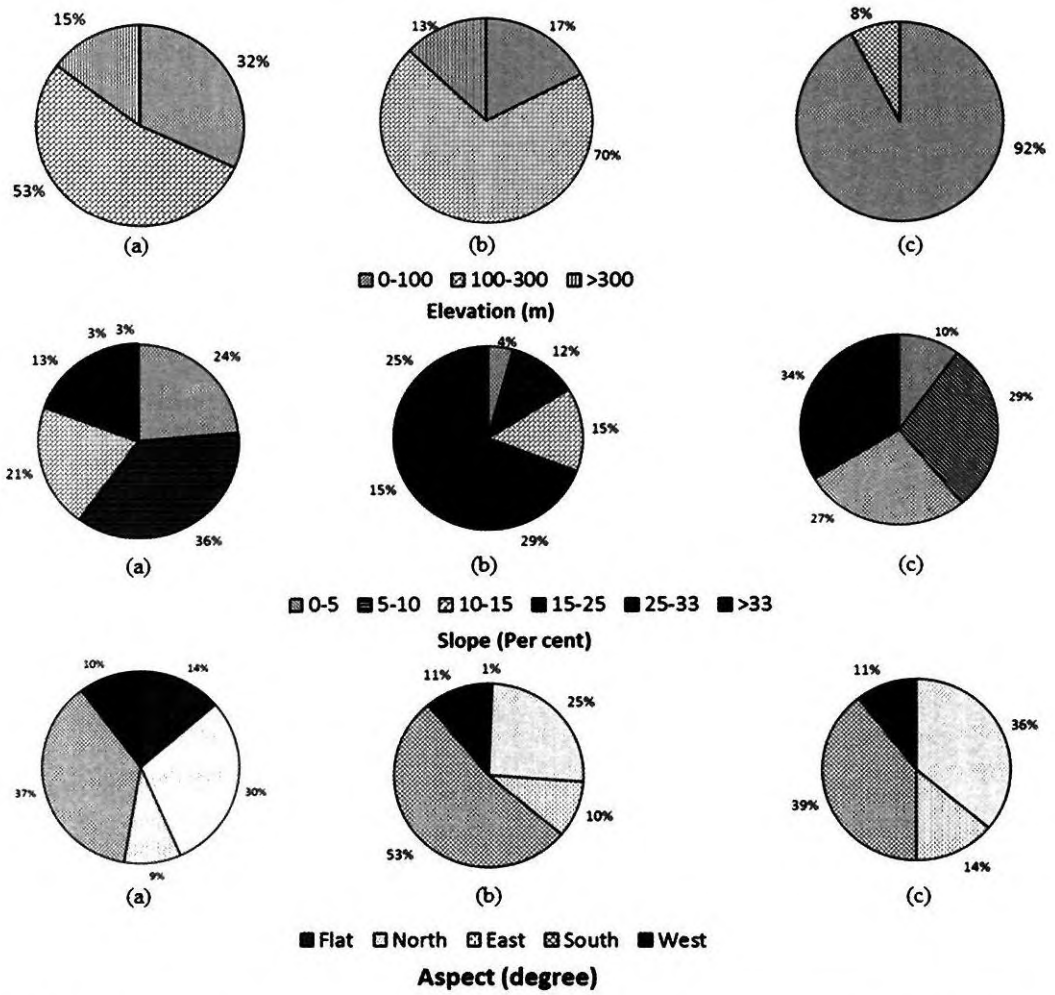

Fig. 5. Distribution of rubber plantations in relation to elevation, slope and aspect in (a) Karnataka, (b) Maharashtra and (c) Goa

Karnataka lies between 0 to 15 per cent slope and 13 per cent of rubber area falls between the slope per cent 15 to 25 (Fig. 5). Similar study in Kanyakumari district of Tamil Nadu has reported 77 per cent of rubber growing areas distributed under 5 to 10 per cent slope (Meti *et al.*, 2014). Sixty seven per cent of rubber plantations were distributed on North and South aspects followed by 14 per cent on flat aspect in Karnataka (Fig. 5). In Maharashtra, 70 per cent of rubber plantations were distributed on elevation class 100 to 300 m. Majority of rubber areas in the state were distributed on steep slopes, twenty nine per cent of rubber area was distributed on 15 to 25 per cent slope class

followed by 25 per cent on greater than 33 per cent slope. Seventy eight per cent of rubber areas of the state was distributed on North and South facing slopes (Fig. 5). In Goa, 92 per cent of NR holdings were distributed on 0 to 100 m elevation class. Ninety per cent of its distribution falls between the slope 5 to 25 per cent and aspect class North and South has highest rubber area distribution (Fig. 5). GIS database of terrain charcaterization is helpful for studying spatial variability of soil nutrients and climate across topographic variables.

CONCLUSION

Sustainable NR cultivation has to be promoted to increase the NR production to meet the domestic demand. Thus, the need for reliable and up to date information on NR acreage is significant and it is being achieved through traditional extensive surveys and are time consuming and expensive. Therefore, satellite remote sensing technology is a tool par excellence to get reliable NR area statistics with acceptable level of accuracy. This study showed the effectiveness of LISS III satellite data for NR area mapping in Karnataka, Maharashtra and Goa states in India for the first time. Deviation of NR area statistics in Karnataka and Goa were attributed to large area young plantations and very sparse distribution of NR holdings. NR cultivation in Karnataka and Maharashtra have been increasing in recent years and in future also new plantations will be expanding to these regions. Because of sparse canopy of young plantations a temporal mapping is required to update NR area statistics and to understand its expansion in Karnataka and Maharashtra. This can be achieved through space technology with less man power input and faster than traditional survey method. Moreover, the geo-spatial database of the present study (terrain characterization and rubber area distribution) can be used as baseline data for planning sustainable NR cultivation in the study area.

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