IDENTIFICATION AND MAPPING OF NATURAL RUBBER PLANTATIONS AND POTENTIAL AREAS FOR ITS CULTIVATION IN ASSAM USING REMOTE SENSING TECHNOLOGY

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Received: 02 November 2017 Accepted: 28 November 2017

Pradeep, B., Jacob, J., Anand, S.S., Shebin, S.M., Meti, S. and Annamalainathan, K. (2017): Identification and mapping of natural rubber plantations and potential areas for its cultivation in Assam using remote sensing technology. *Rubber Science*, **30**(3): 244-254.

Present study utilized multi-resolution satellite images of Indian remote sensing (IRS) satellites for identification and estimation of spatial extent of NR and wastelands suitable for NR cultivation in the state of Assam in India. Temporal and multi-resolution satellite images of IRS R I and II L-3, L-4, Cartosat PAN were used for the study. We used Cartosat PAN merged L-4 data for mapping of areas under NR and wastelands suitable for its cultivation. Spectral signature, phenological characteristics and ground truth information were used to identify rubber holdings. Wastelands suitable for rubber cultivation were estimated from the high resolution satellite data using terrain conditions, land cover types *etc.* Mapping of the wastelands suitable for NR cultivation was carried out excluding the areas under food crops, forests, steep valleys and lands which are more suitable for food crop cultivation. Spatial extent of rubber plantation in Assam was 16,872 ha and about 24,783 ha of wastelands suitable for NR cultivation were estimated during 2011-2012. Karimkhanj district of Assam has the highest extent of wastelands (6,969 ha) followed by Karbi Anglong (6,052 ha), Kamrup (4,525 ha) and Goalpara (2,988 ha) districts. These four districts accounted for about 69.8 per cent of total rubber cultivation and 82.8 per cent of total wastelands estimated in the state. Other fairly suitable districts for NR cultivation are Dima Hasao, Hailakandi, Dhubri, Kokrajhar and Jorhat. These districts have 13 per cent of total wastelands suitable for NR. In general, spread and occurrences of NR and wastelands suitable for its cultivation are more in south-western and north-southern districts than in the north-eastern districts of the state. Estimated wastelands can be prioritized hierarchically for further analyses of suitability in terms of soil and climate variables. This study also serves as a GIS based decision support system for planners in NR sector.

Key words: Natural rubber, North-east India, Remote sensing, Satellite images, Spectral signature

INTRODUCTION

Natural rubber (NR) is one of the most important commercial plantation crops in India and it is a raw material for the fast growing rubber based manufacturing industry. Natural rubber consumption increases with industrial and economic growth of the country (RRII and RRSC, 2012).

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About 7,34,780 ha is under NR cultivation in India during 2011, of which 70 per cent lies in the traditional rubber cultivating regions in Kerala and Kanyakumari district of Tamil Nadu (IRS, 2013). The rest of the area is in the non-traditional areas like Karnataka, Goa and Maharashtra and a smaller extent in Andhra Pradesh, Odisha and North-eastern (NE) states like Assam, Tripura, Meghalaya, Mizoram, Manipur, Nagaland and Arunachal Pradesh. Total area under NR cultivation in NE India in 2011 was 1, 28,470 ha (IRS, 2013). Exploratory surveys conducted by the Rubber Board indicated that expansion of rubber cultivation in the non-traditional areas of NE region of India has the largest potential, with an area of two lakh ha in Assam (Maibangsa and Subramanian, 2000). Assam is the second largest NR cultivated area in NE India after Tripura. Generally, NE Indian regions are agro-climatically suitable for NR cultivation, however, its exact geographic locations are not identified or spatial extent is not estimated. Physiography and undulating terrain of NE is a limiting factor for physical identification of suitable lands for NR cultivation in these regions. Remote sensing has the potentiality in providing spatial information of natural resources and when integrated to GIS platform is a powerful tool to provide spatial information for decision making. Furthermore, through satellite remote sensing, land use dynamics pattern could be updated and monitored regularly. Earth observation satellite images along with ground truth information are used for studying agriculture, forest, water resources, disasters, soils, climate change, developmental planning and even in glacier monitoring (NRSC, 2010). Applications of remote sensing in rubber plantation monitoring in India was effectively explored during early 2010 and the technology was used successfully for mapping rubber plantations in different states of India (RRII and RRSC, 2012; RRII and ATMA, 2014; Pradeep *et al.*, 2015; Meti *et al.*, 2016). Other countries are also using satellite data for monitoring and mapping of rubber plantations for decision support system (Li and Fox, 2010; Dong *et al.*, 2012; Senf *et al.*, 2013; Kou *et al.*, 2015; Koedsin and Huete, 2015; Charoenjit, 2015; Chen *et al.*, 2016). Mapping and suitable area identification of different agricultural crops and plantations were studied by many researchers (Kokmila *et al.*, 2010; Elsebaie *et al.*, 2013; Lallianthanga *et al.*, 2014; Razali *et al.*, 2014; Rendana *et al.*, 2014; Mosleh *et al.*, 2015; Purohit *et al.*, 2015; Widiatmaka *et al.*, 2015; Pramanik, 2016). In 2012, RRII collaborated with Indian Space Research Organization (ISRO), Regional Remote Sensing Centre - South (RRSC-S) for identification and mapping of rubber and potential areas for its cultivation in Tripura state. An area of 22,947 ha of wastelands suitable for NR cultivation was estimated from Tripura using RS and GIS techniques (RRII and RRSC, 2012). Space technology based remote sensing applications are extended to mapping exercise in NR growing regions in NE India. The present study was conducted with an objective of geo-spatial estimation of NR holdings and identification of wastelands suitable for NR cultivation in Assam state excluding area under forests and food crops.

MATERIALS AND METHODS

The state of Assam is situated in NE part of India between longitudes 89°31'02.34"E to 96°03'41.23"E and latitudes 24°01'32.25"N-28°02'03.37"N with an area of 78,470.2 km^2 (Fig. 1). The state shares international borders with Bhutan and Bangladesh. The northern Himalayas (Eastern Hills), the northern plains (Brahmaputra plain) and Deccan plateau (Karbi Anglong) are the three physiographic divisions of Assam. The climate of Assam is

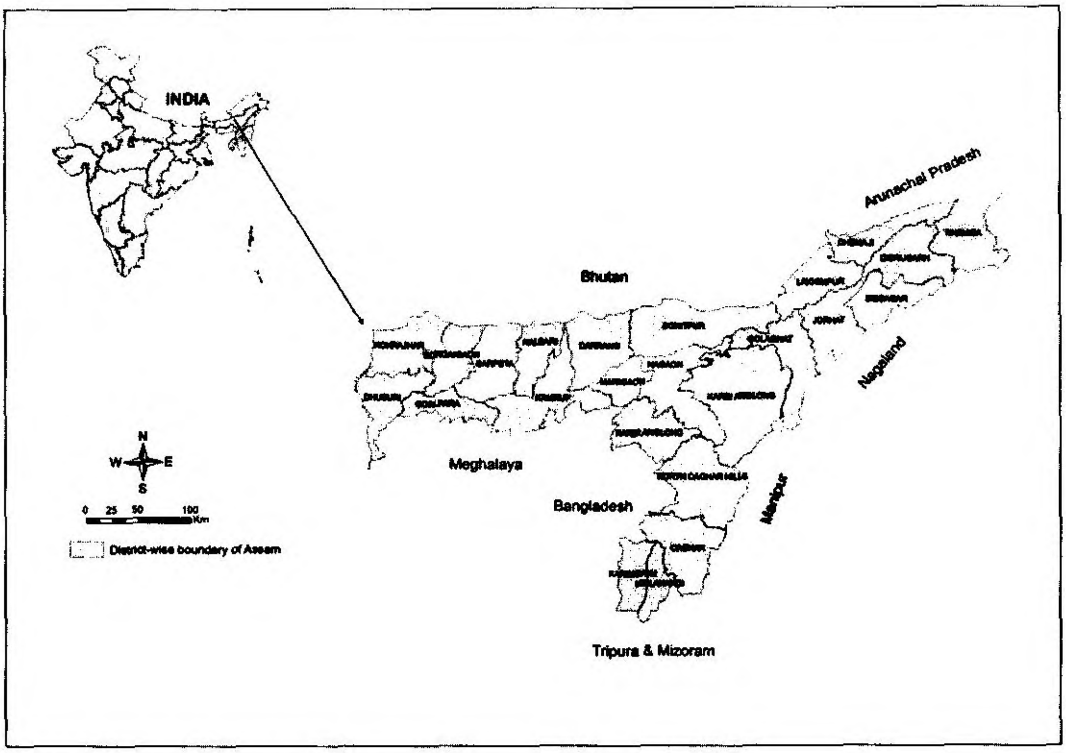

Fig. 1. Study area location in Assam

influenced by heavy rainfall in monsoon. The state's agriculture mainly depends on the south-west monsoon rains. Assam is one of the richest biodiversity zones in the world consisting of tropical rainforests, deciduous forests, riverine grasslands, bamboo, orchards and numerous wetland ecosystems. According to Forest Survey of India (FSI, 2013) the state has 35.2 per cent of forest cover. This constitutes 3.2 per cent of India's total forest cover. Rubber cultivation was started in Assam in 1950 on an experimental basis by the Soil Conservation Department of the Govt. of Assam. Now the state has good extent of NR holdings in almost all districts.

Temporal and multi-resolution satellite images were used for the study. Indian Remote Sensing Satellite (IRS) data of Resources at I & II L-3, L-4, and Cartosat PAN data were used for mapping of NR and identification of wastelands suitable for its cultivation (Table 1). Ancillary data such as Survey of India (SOI) toposheets, advanced space-borne thermal emission and reflection radiometer digital elevation model (ASTER DEM), global positioning system (GPS), forests map of Assam and ground truth information were also utilized. Satellite image processing and analyses were carried out using ArcGIS v10 and Rolta Geomatica v10.1.1 GIS softwares. Technical details of satellite data used in the study are given in Table 1.

Ortho-rectification, mosaicking, clipping, image fusion, NDVI generation and image

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

Sl. No.	Satellite	Sensor	Spatial resolution (m)	No. of scenes	Year of pass
1	Resourcesat-1	LISS III	23.5	37	2007-2012
2	Resourcesat-2	LISS III	23.5	6	2011-2012
3	Resourcesat-1	LISS IV	5.8	93	2006-2010
4	Resourcesat-2	LISS IV	5.8	22	2011-2012
5	Cartosat-1	Mono	2.5	266	2005-2013

classification of the satellite data were carried out before the interpretation and analyses. Ortho-corrected images were used for interpretation, vectorization and analyses. Vectorization and mapping were carried out using Cartosat PAN merged LISS IV data at 1:10,000 scale. Preliminary interpretation of satellite images was carried out using visual interpretation elements such as colour, tone, texture, pattern and terrain conditions. Multi-temporal remote sensing data was used to separate the spectral signature of rubber trees. Spectral signature changes during defoliation and refoliation periods of

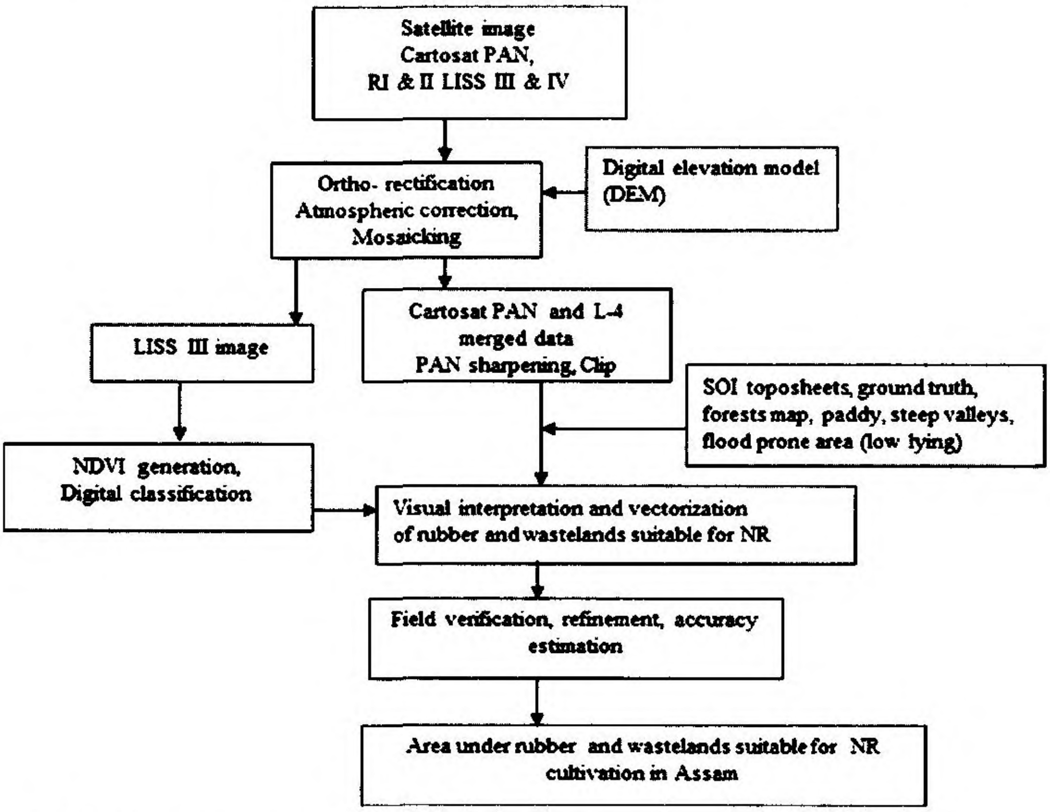

Fig. 2. Methodology of delineation of NR and wastelands suitable for its cultivation

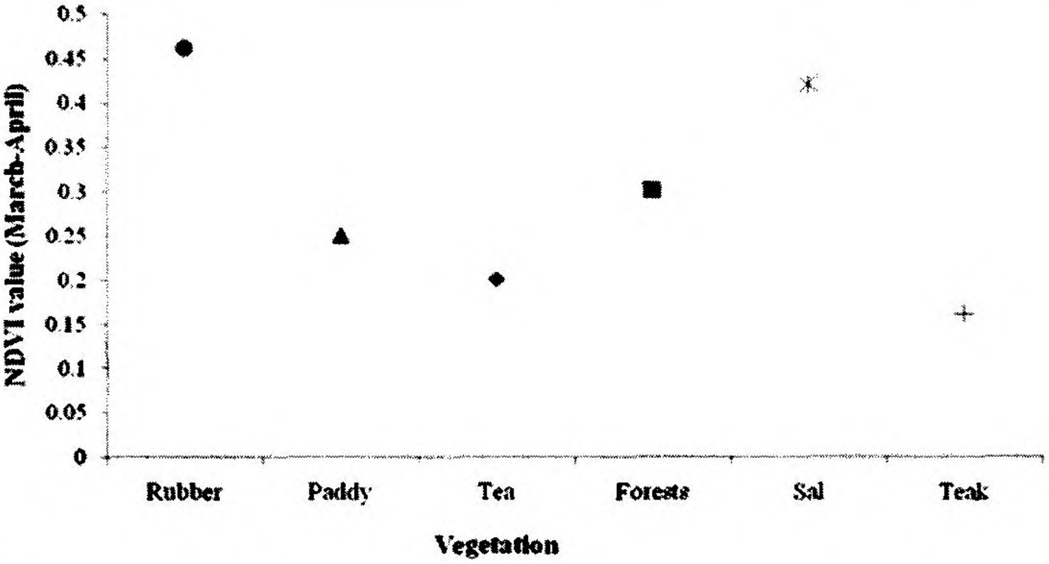

Fig. 3. Comparison of NDVI values of dominant vegetations present in Assam with NR during March-April season

NR were noticed by generating Normalized Differential Vegetation Index (NDVI) of dominant vegetations (Fig. 3). Using these spectral signature variation, NR area delineation was carried out using LISS III and finalized with LISS IV merged Cartosat satellite image.

The spectral signature of wastelands such as scrubland, denuded lands, lands with grass or weed, jhum lands *etc.* and their terrain characteristics were interpreted while vectorization of wastelands suitable for NR cultivation was carried out. Terrain conditions with fallow lands, forests, lands vulnerable to flood, steep valleys, and food crops present in the study area were excluded. LISS IV and Carto PAN sharpened satellite images were used for delineation of wastelands suitable for NR cultivation. Grid-wise interpretation was carried out to delineate rubber and wastelands. Accuracy of NR area estimation was done using ground verification. Detailed field survey and analyses of satellite images for delineation of NR and its wastelands were conducted. Ground truth information was collected using GPS (Global Positioning System) from rubber holdings, wastelands suitable for NR, food crops and other dominant plantations and vegetations from the study area. Total 1,074 ground reference points were collected from the study area. Mapping accuracy (NR) was calculated using correctly interpreted points and total number of points of rubber. Methodology of NR and suitable wastelands delineation used in the study is given in Figure 2.

RESULTS AND DISCUSSION

Spectral characteristics and distribution of NR in Assam

Preliminary classification of NR was done by analysing LISS III satellite image in

Table 2. **Satellite-based area under NR and wastelands suitable for its cultivation in Assam during 2011-2012 period**

Sl. No.	District	Rubber area (ha)	Wastelands suitable for NR cultivation (ha)	District-wise % of total NR	District-wise % of total wastelands suitable for NR
1	Goalpara	3388	2988	20.1	12.1
2	Kamrup	1063	4525	6.3	18.3
3	Karimganj	3453	6969	20.5	28.1
4	Cachar	167	128	1.0	0.5
5	Dima Hasao (N.C. Hills)	732	1010	4.3	4.1
6	Hailakandi	293	619	1.7	2.5
7	Karbi Angong	3872	6052	22.9	24.4
8	Golaghat	500	98	3.0	0.4
9	Nagaon	166	39	1.0	0.2
10	Morigaon	70	39	0.4	0.2
11	Darrang	588	208	3.5	0.8
12	Bongaigaon	688	195	4.1	0.8
13	Dhubri	540	837	3.2	3.4
14	Kokrajhar	419	178	2.5	0.7
15	Barpeta	19	7	0.1	0.0
16	Nalabari	7	14	0.0	0.1
17	Sonitpur	93	19	0.6	0.1
18	Jorhat	564	561	3.3	2.3
19	Lakhimpur	19	0	0.1	0.0
20	Sivasagar	188	157	1.1	0.6
21	Dhemaji	13	30	0.1	0.1
22	Dibrugarh	0	2	0	0
23	Tinsukia	30	108	0.2	0.4
	Total area	16872	24783		

relation to phenology of NR. In LISS III data, NR showed a unique red tone during March-April months. Distinct tonal difference (spectral signature) was observed for NR compared to other dominant vegetations in the study area (Fig. 3). Due to its deciduous nature, the spectral signature was not distinct during the months of December-January compared to other vegetations. The deep red tone was discriminated only for NR plantation with age three years and above (Fig. 4 a, b and c). Young plantations less than three years old were not clearly discriminated using LISS III image due to its underdeveloped canopy with other land cover such as fallow lands, scrub lands, cover crops and intercrops with ash or greyish in appearance. Remote sensing studies conducted by RRII reported

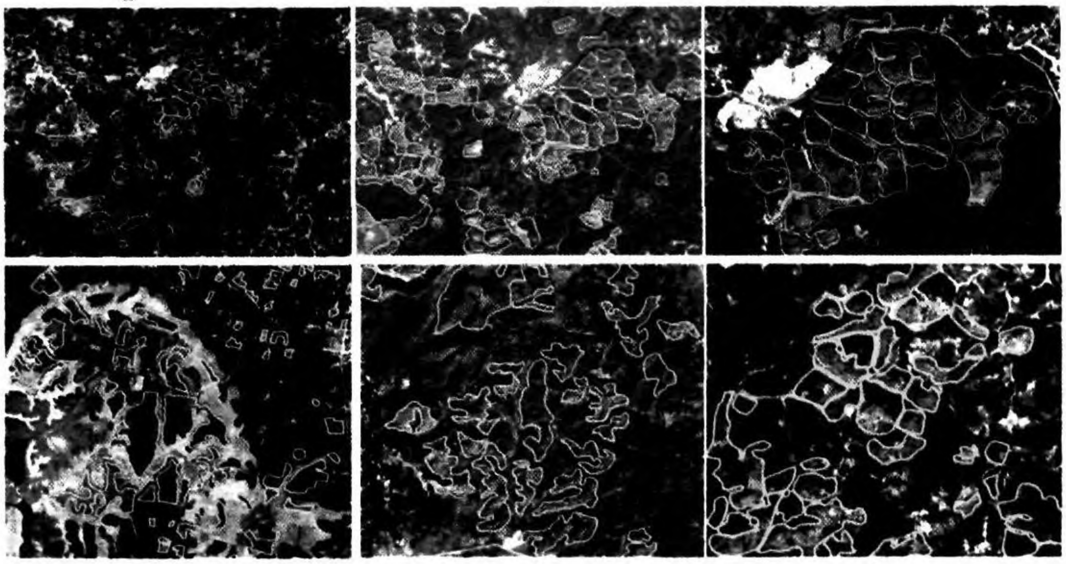

Fig. 5. (a, b and c). Spectral signature characteristics of different types of wastelands suitable for NR cultivation in Assam as seen in LISS IV merged Cartosat

similar results (RRII and RRSC, 2012; Pradeep *et al.*, 2015; Meti *et al.*, 2016). NDVI values of forests, tea, teak, paddy and sal plantations with NR during the months of March-April are given in Figure 3. As compared to other vegetations, distinct NDVI value of NR was noticed which was highest in March-April because of complete re-foliation. NDVI value of sal plantation was often mixed with NR but tonal difference, canopy structure and plantation pattern were different. Hence, these areas were manually eliminated during vectorization stages. Later NR was interpreted and finalized with LISS IV merged Cartosat satellite image which gave a mapping accuracy of 95.2 per cent.

The total estimate of spatial extent of NR plantations (>3years) in Assam during 2011-2012 was 16,872 ha (Table 2) as compared to Rubber Board's survey statistics record of 18,753 ha. Natural rubber area distribution in Assam is given in Figue 6. Natural rubber plantations are densely cultivated only in few districts of Assam which are spread in low elevated regions (generally less than 100 m above MSL). Satellite image based district-wise rubber area in Assam is shown in Table 2. Area under NR cultivation was highest in Karbi Anglong district (3,872 ha). Goalpara, Kamrup, Karimkhanj and Karbi Anglong are major rubber growing districts with 69.8 per cent of NR cultivation in Assam (Table 2). Dima Hasao (N.C. Hills), Golaghat, Darrang, Bongaigaon, Dhubri, Kokrajhar and Jorhat districts have a share of 23.9 per cent of total rubber cultivation. Remaining 6.3 per cent of total rubber area (1063 ha) was distributed in other thirteen districts of Assam. Rice is the major food crop cultivated in Assam. Other major plantation crops cultivated in the state are tea, sal, teak, arecanut, banana, mustard, orange, bamboo, pineapple, coconut

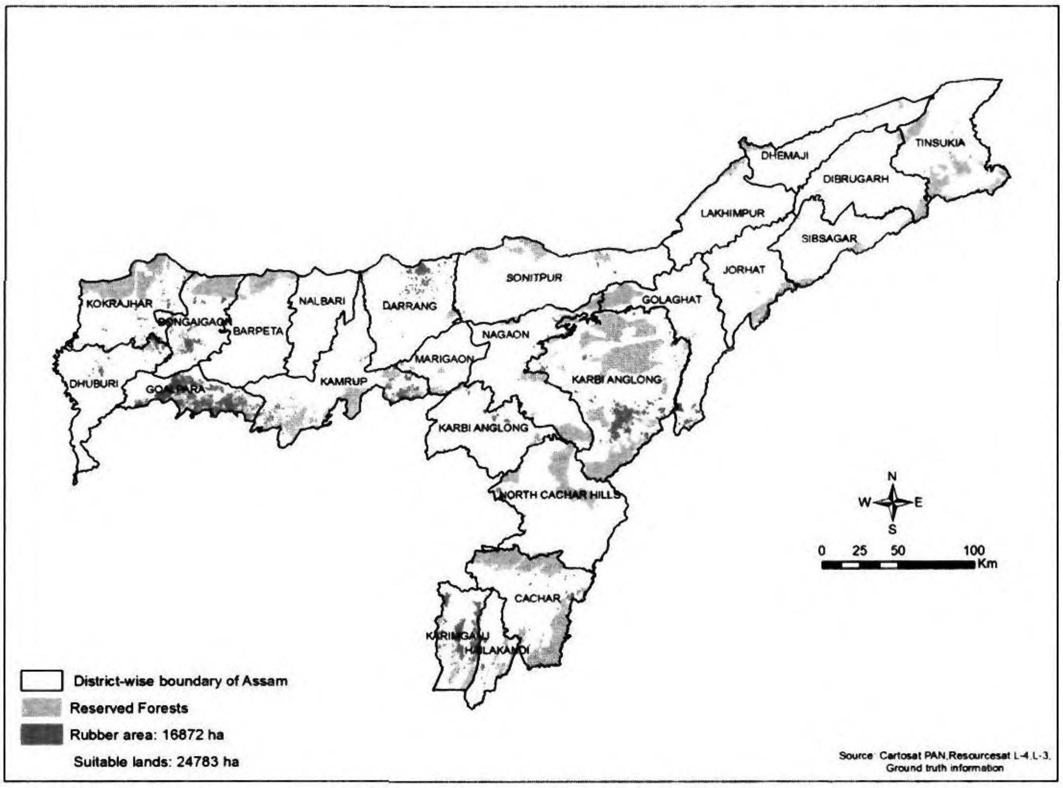

Fig. 6. Geo-spatial distribution of NR plantations and wastelands suitable for its cultivation in Assam during 2011-2012

etc. Terrain characteristics of NR cultivation were restricted to hilly, undulating and sloping terrain. Very few NR holdings were present in the eastern districts of the state such as Dhemaji, Lakhimpur and Tinsukia (Table 2 and Fig. 6). In Karbi Anglong district, large tract of new lands were being prepared for cultivation of NR plantations. Therefore current extent of area under NR in Assam would be more than the estimate of present study. Natural rubber plantations are also present in Jhum lands. Prediction modelling of *Hevea* species in north-east India indicated upper Brahmaputra valley has good potential for expansion of NR plantation till the year 2020 (Ray *et al.*, 2014). Results of high resolution satellite image analyses of Assam showed that only 0.2 per cent of total geographical area of the state is under NR plantations during 2011-2012.

Spectral characteristics and distribution of wastelands suitable for NR cultivation in Assam

Generally most parts of western districts in Assam are below 100 m elevation whereas most parts of north east districts of the state are situated less than 100 m and ranging up to 300 m elevation. Elevations of Karbi Anglong, Dimo Hasao districts and NR growing regions of Golaghat and Jorhat districts are ranging from 100-300 m and above. The districts in southern tip of the state are with below 100 m elevation. Spectral signature of wastelands suitable for NR cultivation and its distribution in the state were changing according to terrain situations. Typical spectral signature characteristics of suitable wastelands for NR cultivation are shown in Figure 5 (a, b, c).

Satellite image interpretation and ground truth verification showed that wastelands suitable for NR cultivation is distributed all over in Assam. Spectral signature of wasteland was cyan and reddish color in L-4 merged cartosat image but its tonal variation differed in relation to topography and land cover types (Fig. 5 a, b and c). Predominantly rice and tea gardens were present all over the state. Wastelands suitable for NR cultivation in western districts mainly Goalpara, Kamrup, Dubri, Bongaigaon, Kokhrajhar and Darrang were generally distributed at low elevated regions. Suitable wastelands present in NE districts of Assam were found mainly in Jorhat and Golaghat districts which spread across moderately hilly areas. In Karbi Anglong and Dimo Hasao districts, the wastelands suitable for NR cultivation occurred in hilly areas while in southern districts such as Karimghanj, Hailakandi and Cachar, in low elevated regions. Satellite-based estimation of wastelands suitable for rubber cultivation during 2011-2012 in Assam was about 24,783 ha (Table 2). The area of wastelands estimated for NR cultivation is more than the total area of rubber plantations in Assam. Spatial distribution of wastelands suitable for NR cultivation in Assam is shown in Figure 6. Satellite image interpretation and estimation of the suitable wastelands were carried out after excluding areas under major vegetation, food crops, steep valleys and areas vulnerable to flood in Assam. Thus expanding NR cultivation to the proposed wastelands may have no impact on food crops, forests and dominant vegetation present in the state. Large area of wastelands suitable for NR were present in Karimghanj district (6,969 ha) followed by Karbi Anglong (6,052 ha), Kamrup (4,525 ha), Goalpara (2,988 ha) and Dima Hasao (1,010 ha) districts (Table 2). Considerable extent of wastelands suitable for NR was also present in Hailakandi, Dubri and Jorhat districts of Assam. These three districts together accounted for about 2,017 ha of wasteland. Present study used terrain condition and land cover types for identifying wastelands suitable for NR cultivation from satellite images. Therefore, estimated wastelands are to be further prioritized by integrating pedo-climatic variables to know the extent of suitability for rubber cultivation.

CONCLUSION

The study utilized satellite remote sensing technology to estimate area under NR plantations and wastelands suitable for NR cultivation in Assam using temporal and multi-resolution satellite images. Present study estimated an area about 16,872 ha of NR plantations and 24,783 ha of wastelands suitable for NR cultivation in Assam using high resolution satellite image during 2011-2012 with very high mapping accuracy. Estimated wastelands need to be further prioritized based on pedo-climatic variables for determining hierarchical extent of suitability for rubber cultivation. Geo-spatial information of the study offers a decision support platform for policy makers and planners to decide on NR cultivation in a sustainable way by protecting food crops, forests, other vegetation and biodiversity in Assam.

ACKNOWLEDGEMENT

Authors express sincere thanks to Dr. Dhurjati Chowdhury (Project Co-ordinator for NE (Retired) and Dr. Mrinal Chowdhury (former Scientist of Rubber Board's Regional Research Station, Guwahati, Assam) for their help during field visit and ground truth collection from the study area.

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