INVENTORY OF RUBBER PLANTATIONS AND IDENTIFICATION OF POTENTIAL AREAS FOR ITS CULTIVATION IN ASSAM USING HIGH RESOLUTION IRS DATA

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ABSTRACT: To some extent climate, topography and soil of north-eastern states of India are fully or marginally favourable for natural rubber (NR) cultivation but exact geo-spatial locations of these areas under NR cultivation are unknown yet. Geo-spatial technology based identification of NR and potential areas for its cultivation are relevant to find these lands for further expansion of NR plantations to suitable agro-climatic regions to increase domestic NR production. Present study utilized temporal and multi-resolution satellite data (Cartosat merged LISS IV) of Indian Remote Sensing Satellites (IRS) for identification and estimation of spatial extent of NR and wastelands suitable for its cultivation in Assam state of India. Mapping of the wastelands was carried out without interfering areas under food crops, forests, steep valleys and lands which are more suitable for cultivation of food crops. Spatial extent of rubber plantation distribution of Assam was 16872 ha and additionally areas of about 24783 ha of wastelands suitable for NR cultivation have been estimated. Karimkhanj district of Assam has the highest extent of wastelands suitable for NR followed by Karbi Anglong, Kamrup and Goalpara districts. These four districts alone accounted for about 63.5 % of total rubber cultivation and 82.8 % of total wastelands estimated from the state. In general, spread and occurrences of NR and wastelands suitable for its cultivation are more in south-western and north-southern districts whereas north-eastern districts of the state are found less areas of wastelands. The study showed usefulness of high resolution satellite data for accurate mapping and estimation of rubber holdings and wastelands suitable for NR cultivation to increase the extent of NR in Assam without conversion of food crops, forests *etc*. Estimated wastelands can be prioritized in terms of pedo-climatic variables which can serve as a geo-spatial decision support system for planners in NR sector.

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 goods manufacturing industry. Therefore, NR consumption increases with growth in industrial activity and economic growth of the country (RRSC and RRII, 2012). About 734780 ha is under NR cultivation in India during 2011, in which a 70% of its area lies in the traditional rubber cultivating regions of 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.

As per Rubber Board's statistics total extent of area under rubber in NE India as of the year 2011 was 1,28,470 ha (IRS, 2013). Exploratory surveys conducted by the Rubber Board indicated that expansion of rubber cultivation can take place in the non- traditional areas of which the North Eastern region of India has the largest potential area of 2 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 yet. Physiography and undulating terrain of NE is a limiting factor for identification of suitable lands for NR cultivation in these regions. Nowadays role of remote sensing (RS) and GIS (Geographic information system) are very crucial for managing natural resources. RS has the potentiality in providing spatial information of natural resources and when it integrates to GIS platform will help in providing spatial decision supporting system and it is a powerful tool for providing spatial information towards decision making. Furthermore, through satellite remote sensing, land use dynamics pattern could be updated and monitored regularly. Recent times the availability of high spatial resolution satellite images has eased the task of managing natural resources at local or regional level. Earth observation satellite images along with ground truth information are used for studying agriculture, forest, water resources, disasters, soils, climate change, and developmental planning and even in glacier monitoring (NRSC, 2010). Applications of remote sensing in rubber plantation monitoring in India was effectively explored early 2010 and successfully used the technology for mapping of rubber plantations in different states of India (Meti *et al*., 2016, Pradeep *et al*., 2015, RRII and ATMA, 2014, RRSC and RRII, 2012). Other countries are also using satellite data for monitoring and mapping of rubber plantations for decision support system (Chen *et al*., 2016, Charoenjit, 2015, Koedsin and Huete, 2015, Kou *et al*., 2015, Senf *et al*., 2013, Dong *et al*., 2012 and Li and Fox, 2010). 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 and Widiatmaka *et al*., 2015., Pramanik, 2016). In 2012, RRII could collaborate 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. According to RRSC's result an area extent of 22947 ha of wastelands suitable for NR cultivation was estimated using remote sensing and GIS techniques (RRSC and RRII, 2012). With the aim of effective utilization of space technology based remote sensing applications we extend the mapping exercise to other NR growing states of NE India. The present study is conducted with an objective of geo-spatial estimation of spatial extent of rubber holdings and identification of wastelands suitable for NR cultivation in Assam state without conversion of forests, food crops and biodiversity present in the state.

MATERIALS AND METHODS

Study area

The state Assam is situated in north-eastern part of India between east longitudes 89^{o}31'02.34"E to 96^{o}03'41.23"E and north latitudes 24^{o}01'32.25"N-28^{o}02'03.37"N with an area extent of 78470.2 Sq.km (Figure 1). The state shares an international border with Bhutan and Bangladesh. The northern Himalayas (Eastern Hills), the northern Plains (Brahmaputra plain) and Deccan Plateau (Karbi Anglong) are three physiographic divisions of Assam. The topography is with plains and hills in Assam. The Brahmaputra and Barak valleys are two major valleys of Assam separated by the hills. The area covered by Brahmaputra valley is rich in alluvial land. The Barak valley is mainly plain land. The hills Karbi Anglong and North Cachar hills are in central Assam range. The climate of Assam is influenced by heavy rainfall in monsoon. The state experiences flood almost every year and the Brahmaputra and other rivers deluges surrounding places. The state's agriculture usually depends on the south-west monsoon rains. Assam is one of the richest biodiversity zones in the world consists 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 to total geographical area. This constitutes 3.2% of India's total forest cover. The state's economy is mainly based on agriculture in which major contribution to the world is tea. The state also produces rice, mustard, jute, banana, arecanut, sugarcane etc. The major food crop rice is cultivated in the valleys and low lying regions however, the elevated terrains are ideal for rain fed and plantations crops. Sal forest, teak, and mangium plantations are also found in this state. The major soils of Assam belong to inceptisols, entisols, alfisols and ultisols. Long before 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 rubber holdings in almost all districts.

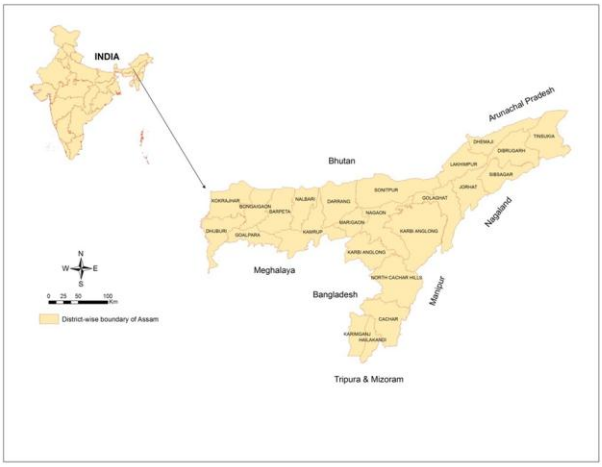


Figure 1. Study area location in Assam

Methodology

Temporal and multi resolution satellite images were used for the study. Indian remote sensing satellite (IRS) data of Resourcesat I & II L-3, L-4, and Cartosat PAN data have been used for mapping of NR and wastelands suitable for its cultivation (Table 1). Ancillary data like 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 used. Satellite image processing and analyses were carried out in ArcGIS v10 and Rolta Geomatica v 10.1.1 GIS softwares. Technical detail of satellite data used in the study is given in Table 1.

Table 1. Details of satellite data used in the study

Sl no	Satellite	Sensor	Spatial resolution(m)	No. of scenes	Date 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

Satellite data pre-processing such as ortho-rectification (removing of geometric distortions), mosaicking, clipping, image fusion, NDVI generation, image classification, etc were carried out before the interpretation and analyses. Ortho-corrected images were used for interpretation, vectorization and analyses of NR and its wastelands. Vectorization and mapping of rubber and suitable wastelands 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 and its spectral signature varies according to season. Major spectral changes of NR happen during December to March wintering mediated defoliation of NR is in December-January and fully refoliates in March-April period, this could be noticed by generating normalized differential vegetation index (NDVI) of NR and other dominant vegetations present in Assam (Figure 3). Using these spectral signature variation, NR area delineation was carried out using LISS III and finalized with LISS IV merged Cartosat satellite image.

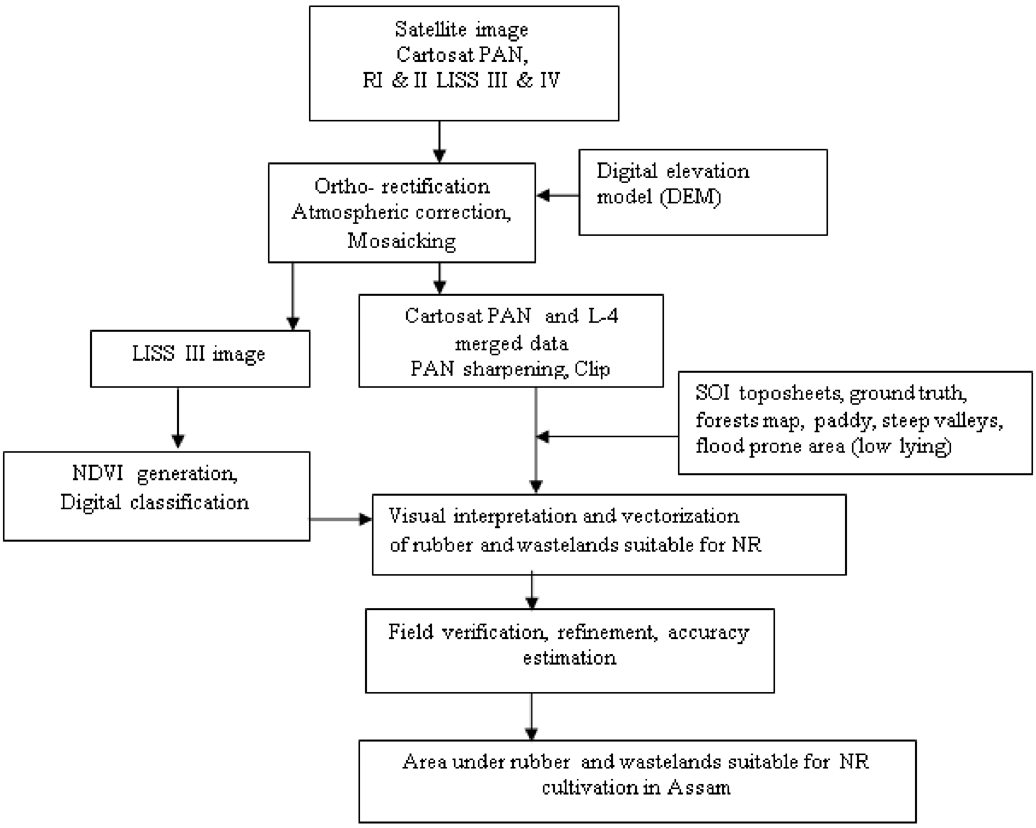


Figure 2. Methodology of delineation of NR and wastelands suitable for its cultivation

The spectral signature of wastelands such as scrubland, denuded lands, lands with grass or weed, jhum lands *etc.* and their terrain characteristics are interpreted while vectorization of wastelands suitable for NR cultivation. Importance was given on the terrain conditions to exclude fallow lands, forests, lands vulnerable to flood, steep valleys, and food crops present in the study area. LISS IV and Carto PAN sharpened satellite images were used for delineation of wastelands suitable for rubber cultivation. Grid-wise interpretation was carried out to delineate rubber and waste- lands. Afterwards accuracy assessment and acreage estimation of rubber was done using ground truth points. We have conducted detailed field survey and analyses of satellite images for delineation of NR and its wastelands. 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. Ground reference points were collected from almost all rubber growing districts of Assam. Total 1074 ground reference points were collected from the study area. Mapping accuracy of 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.

RESULT AND DISCUSSION

Spectral characteristics and distribution of NR in Assam

Preliminary classification of NR was done by analysing LISS III satellite image in relation to phenology of NR. In LISS III data NR showing a typical unique red tone during March-April months. Distinct tonal difference (spectral signature) was observed as compared to other dominant vegetations seen in the study area (Figure 3). Due to its deciduous nature, the spectral signature is not distinct during the months of December- January compared to other vegetations. The deep red tone was discriminated only for NR plantation age three years and above old (Figure 4a). Young plantations age less than three years old wasn't clearly discriminated using LISS III image due to its underdeveloped canopy which was mixing with other land cover such as fallow lands, scrub lands, cover crops and intercrops with ash or greyish in appearance. Recent remote sensing studies conducted by RRII have been reported the same results (Meti *et al*, 2016, Pradeep *et al*., 2015 and RRSC and RRII, 2012). Comparison of NDVI values of forests, tea, teak, paddy and sal plantations with NR during the months of March-April seasons 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 it distinguishes NR's spectral signature from other vegetations. NDVI value of sal plantation was often mixed with NR but tonal difference, canopy structure and pattern of the plantation was entirely dissimilar from rubber tree. Therefore, 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 95.24 per cent.

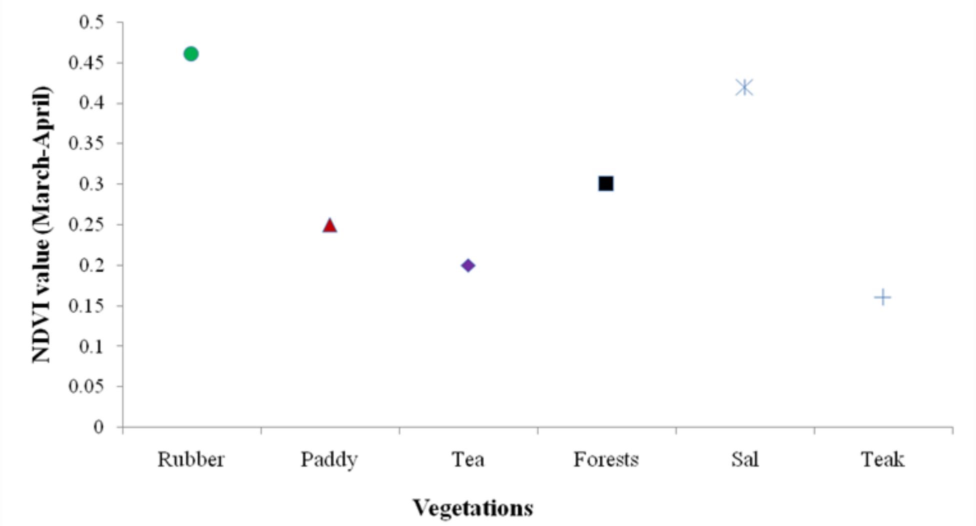


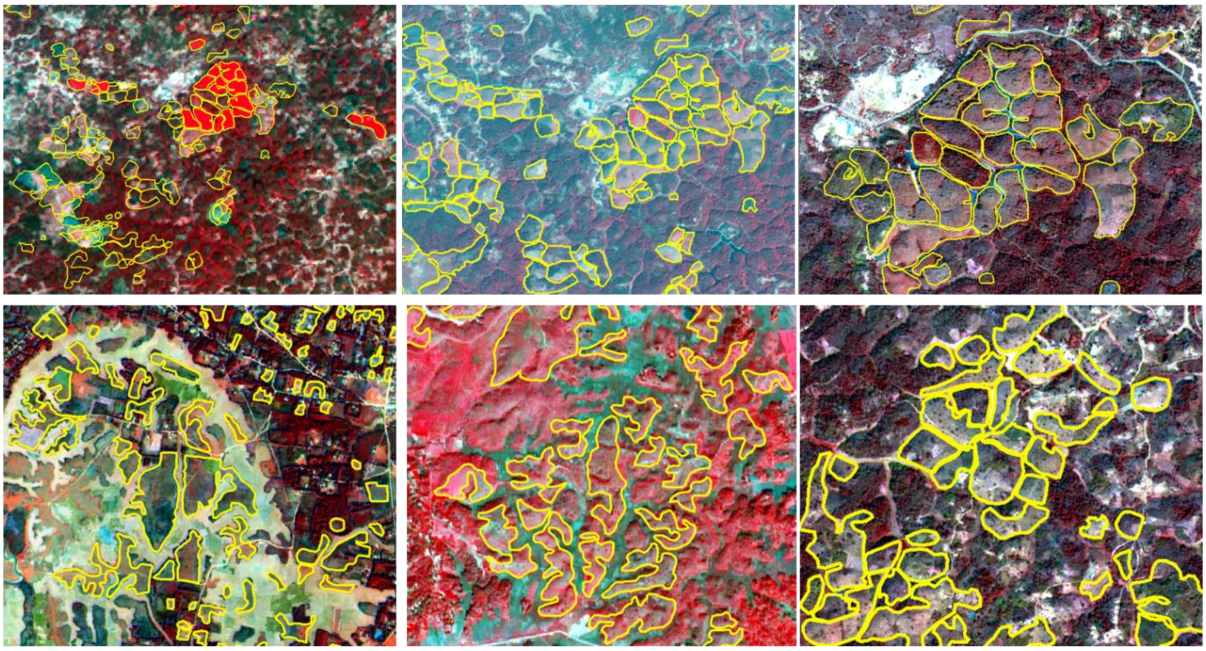
Figure 3. Comparison of NDVI values of dominant vegetations present in Assam with NR during March-April season.

The total estimate of spatial extent of NR plantations three and above years old in Assam for year 2011- 2012 was 16872 ha (Table 2) as compared to Rubber Board's survey statistics record of 18753 ha. NR area distribution of Assam is given in Figure 5. NR 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 acreage in Assam is shown in Table 2. Area under NR cultivation was the highest in Karbi Anglong district (3872 ha). Goalpara, Kamrup, Karimkhanj and Karbi Anglong are major rubber growing districts which shared 69.8 per cent of NR cultivation in Assam (Table 2). Dima Hasao (N.C. Hills), Golaghat, Darrang, Bongaigaon, Dhubri, Kokrajhar and Jorhat ditrics have a share of 23.9 per cent of total rubber cultivation. Remaining 6.3 per cent share of total rubber area was distributed in other thirteen districts of Assam. These districts have accounted 1065 ha of total rubber area. During field visits it was noticed that rice was the major food crop cultivated in Assam. Other major plantations cultivated in the state are tea, sal, teak, arecanut, banana, mustard, orange, bamboo, pineapple, coconut *etc.* Terrain characteristics of NR cultivation were restricted to hilly, undulating and sloping terrain. Distribution of NR was more or less absent in eastern districts of the state such as Dhemaji, Lakhimpur, Dibrugarh and Tinsukia (Table 2 and Figure 5). In Karbi Anglong district, large tract of new lands were being prepared for cultivation of rubber plantations. Therefore current extent of area under rubber in Assam would be more than the estimate of present study. NR plantations are also present in Jhum lands. Recent studies of 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 in Assam showed only 0.21 per cent to total geographical area of the state is under NR plantations as of the year 2011-2012.

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

Generally most parts of Western districts in Assam are below 100m elevation whereas most parts of North-eastern districts of the state are situated less than 100 m and ranging up to 300 m elevation but elevations of Karbi-Anglong, Dimo Hasao districts and NR growing regions of Golaghat and Jorhat districts are ranging from 100-300 and beyond 300m. The districts present in southern tip of the state are below 100 m elevation. Spectral signature of wastelands suitable for NR and its distribution in the state are changing according to terrain situation. Typical spectral signature characteristics of suitable wastelands for NR are shown in Figure 4 (d-f).

a) b) c)



d) e) f)

Figure 4. Spectral signature characteristics of rubber plantations in multi resolution satellite images of a) LISS III b) LISS IV) and c) LISS IV merged Cartosat. Figure d-f shows different types of wastelands suitable for NR cultivation in Assam as seen in LISS IV merged Cartosat.

Satellite image interpretation and ground truth information have been shown that distribution of wastelands suitable for NR cultivation occurred all over in Assam. Wasteland's spectral signature seen as cyan and reddish color in L-4 merged cartosat image but its tonal variation was differed in relation to topography and land cover types. 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 north-eastern 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 whereas in southern districts such as Karimghanj, Hailakandi and Cachar have these areas in low elevated regions. Satellite-based total extent of wastelands suitable for rubber cultivation estimated as of the year 2011-2012 in Assam was about 24783 ha (Table 2). The extent of wastelands estimated for rubber cultivation is more than the total extent of rubber plantations in Assam. Substantial amount of suitable wastelands (22,947 ha) were also estimated in North-eastern state of Tripura by RRSC and RRII in 2012. Spatial distribution of wastelands suitable for NR cultivation in Assam is shown in Figure 5. Satellite image interpretation and estimation of the suitable wastelands have done by excluding major vegetations, food crops, steep valleys and areas vulnerable to flood in Assam. Thus expanding rubber cultivation to these areas has no impact on food crops, forests and dominant vegetations present in the state. Highest area of wastelands suitable for NR were present in Karimghanj district (6969 ha) followed by Karbi Anglong (6052 ha), Kamrup (4525 ha), Goalpara (2988 ha) and Dima Hasao (1010 ha) districts respectively (Table 2). Among the total estimates of wastelands suitable for rubber cultivation about 52.5 per cent of its distribution was from Karimkhanj and Karbi Anglong ditricts. Considerable extent of wastelands suitable for NR was also present in Hailakandi, Dubri and Jorhat districts of Assam. These three districts together accounted wasteland area of about 2017 ha. Present study is 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.

Table 2. Satellite-based area under NR and wastelands suitable for its cultivation in Assam as of the year 2011-2012

Sl no	Districts	Rubber area (ha)	Wastelands suitable for NR cultivation (ha)	% of total NR	% 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		

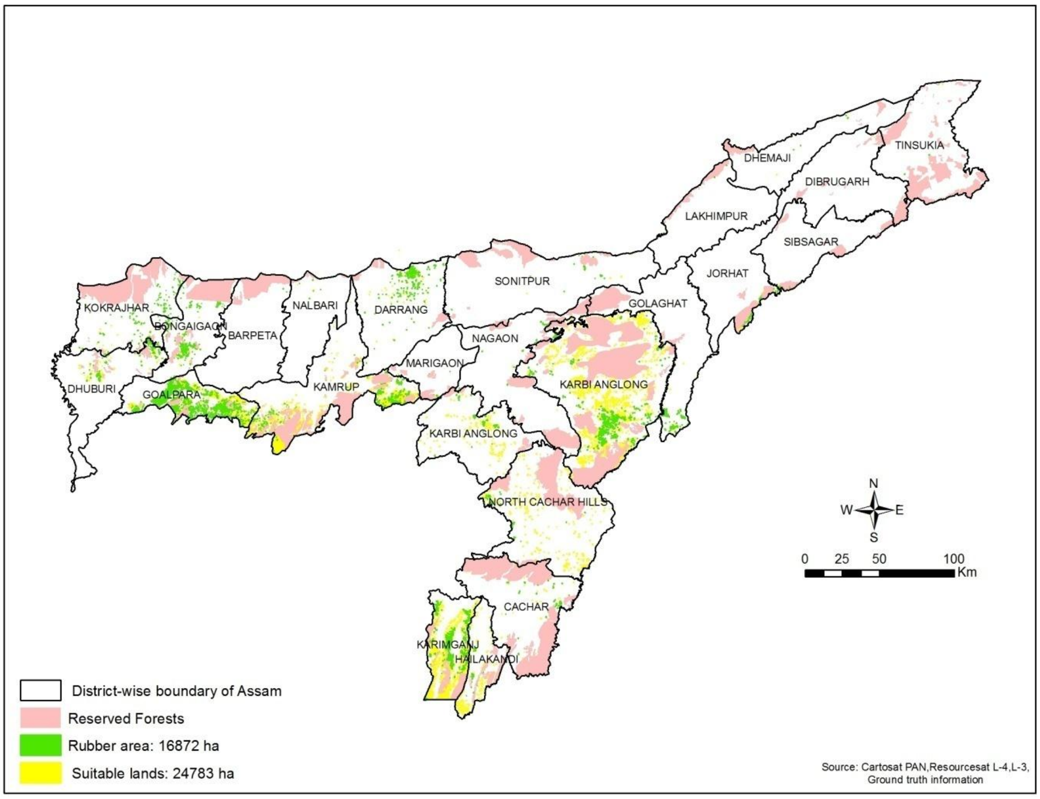


Figure 5. Geo-spatial distribution of NR plantations and wastelands suitable for its cultivation in Assam

Conclusion

The study highlighted the utility of satellite remote sensing technology to estimate NR plantations and wastelands suitable for its cultivation in Assam using temporal and multi resolution satellite images. Previous empirical estimates showed that North-eastern states of India are agro-climatically suitable for NR cultivation however its exact locations and extent of suitability are yet to be carried out. There is a need for increasing NR production in the country by extension of NR plantation to likely suitable areas. Therefore, identification and estimation of suitable geo-spatial locations and extent of availability of potential lands are important to increase the domestic NR production without converting forest, food crops and major vegetated areas into NR plantations. Present study estimated an area about 16872 ha of NR plantations and 24783 ha of wastelands suitable for NR cultivation in Assam using high resolution satellite image as of the year 2011-2012 with very high mapping accuracy. Estimated wastelands will be further prioritized based on soil fertility, climate *etc* for determining hierarchical extent of suitability for rubber cultivation. Promoting NR cultivation in NE India is one way associated with improving the socio-economic and livelihood status of the people in these regions. The present study analysed the use of satellite-based remote sensing technology to promote sustainable NR cultivation in Assam in order to improve the socio-economic conditions of people. Geo-spatial information of the study definitely a decision support platform for policy makers and planners to promote NR cultivation in a sustainable way by protecting food crops, forests, other vegetations and biodiversity.

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