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Mapping and monitoring landuse / landcover change of Doloo tea estate, Barak Valley, Assam using multi - temporal satellite data

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Abstract:

One of the most important problems facing in the tea gardens of Barak Valley, Assam is infestation of diseases and pests. Tea plants are highly susceptible to red spider mite attack in Barak Valley. Once the outbreak occurs it becomes difficult to control it as it spreads rapidly. Remotely sensed data helps in identifying the status of the crop and allow the user to take appropriate action at the appropriate time. In the present study an attempt has been made to identify the affected tea patches in Barak Valley using multi-temporal data. Unsupervised digital classification was used for identification of major land use/ land cover classes. It categorized the images into six classes which include healthy tea patches, affected tea patches, young tea patches, water, built up and marginal land. The overall accuracy for 2007 and 2011 classified maps were 93.81 % and 91.58 % respectively. The trend of change (2007-2011) of healthy tea areas was found to be 11.57 % while affected tea area was found to be 22.7 %.

Key words: Tea, Red spider mite, Barak Valley, Remote sensing, Unsupervised classification, trend of change

Introduction

Tea yield depends on health of the shoots of tea plants. The healthy tea bush is considered to be productive, and affected tea bush is considered to be unproductive or not having any contribution towards the gross annual yield. The disease or pest infestation in the tea gardens occurred mostly during the monsoon season (March - November) when there is severe and incessant rainfall (Banerjee, 2012). During this time the humidity as well as the temperature is also quit high which is favorable for red spider attack. Red spider mite (*Oligonychus coffeae*) affects green leaf and the maintenance foliage, which sustains the health of tea bush. Once the tea bush gets affected by mites, it spreads rapidly and becomes difficult to control. It leads to a decline in the health of the tea bush, thereby bringing down production. Assessment of tea health, as well as early detection of the crop infestations, is critical in ensuring better productivity of tea. One of the advantages of optical remote sensing is that it can see beyond the visible wavelengths into the infra-red, where wavelengths are highly sensitive to crop vigor as well as crop stress and crop damage. Remote sensing technology is principally appropriate for mapping land use and land cover as field-based mapping is practically difficult. Mapping of land use classes were carried out using digital image processing on IRS- 1C-data (Kumar *et al.*, 2004, Pandey & Nathawat, 2002). Some research works have also been carried out in the agricultural sector from crop monitoring to damage assessment (Chen *et al.*, 2007, Huang *et al.*, 2003, and Wu *et al.*, 2002). Some studies on tea plantation have also been carried out using remote sensing data which aimed at identification of crop, area estimation, condition assessment and yield prediction (Maruthachalam *et al.*, 1993, Pal *et al.*, 1993 & Rao *et al.*, 2007). A study has been carried out in Sonitpur area, Tezpur for the delineation of diseased tea patches using LANDSAT, LISS III and ASTER images. The classification method followed was both supervised and unsupervised (Dutta, 2006). Study was also conducted in the tea gardens of the Terai region by Barman (2008) where the assessment of tea bush health was done using Landsat image of the year 1990 and 1999. Unsupervised classification method was used for landuse classification. The changing trends and pattern of land use in Baragaon Block, Varanasi District was highlighted using two time frame Satellite data (IRS P-6 LISS III, Standard FCC) of Rabi cropping season. The study was based on standard digital classification techniques and its accuracy assessment (Jaiswal & Verma, 2013). Study also demonstrated the use of multiyear multi-date WiFS data for monitoring changes in cropping pattern in Kota-Baran districts in Rajasthan from 1997-98 to 1999-2000 (Rajak *et al.*, 2002). Mapping and monitoring landcover change in an urban wetland in China was carried out between June 2003 and January 2006 using an optimal iterative unsupervised classification (Zhou *et al.*, 2010). An attempt was made to study the changes in landuse and landcover in Indra river watershed located in Hoshangabad distrct, M. P. using Landsat imageries of 1992 and 2006. The landuse/landcover change detection was also done between the year 2005 and 2010 in Achanakmar-Amarkantak Biosphere Reserve, Central India (Gajbhiye & Sharma, 2012). Landsat TM satellite imageries for the years 2005 and 2010 was made use to identify the land use/land cover categories in Achanakmar- Amarkantak Biosphere Reserve (Maurya *et al.*, 2013). The potential of satellite remote sensing technology for detection, mapping and monitoring of diseased rubber plantation affected by Corynespora and Gloeosporium fungi, which causes leaf spot and leaf fall was evaluated. Multi-date satellite data of IRS-1C have been analyzed adopting enhancement and classification techniques to identify and extract information on the spatial extent and distribution of healthy and diseased rubber plants with an accuracy of 90% (Ranganathan *et al.*, 2004).

Study area

Doloo tea garden is one of the biggest tea plantations in Barak Valley, Assam. It lies between 24˚ 54' 58" N- 24˚ 56' 21" N latitude and 92˚ 49' 17" N- 92˚ 47' 57 " E longitude. It covers a geographical area of 1682 ha. The area has an altitude of 151 ft. above mean sea level. This study is a pilot study in this region where only a single garden has been studied using LISS III imagery since most of the tea gardens in this region are of relatively small size and cannot be studied in detail using LISS III imageries which have moderate resolution. The study area map is shown in Fig. 1.

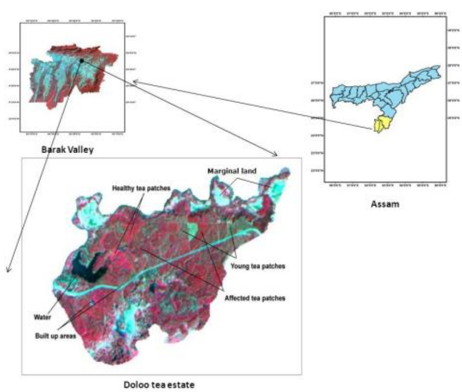

Fig. 1 Location of Doloo tea estate in Barak Valley, Assam

Materials and methods

Earth Resources Data Analysis System (ERDAS) 9.1 Software was used for radiometric corrections, georeferencing and classification of the image. Linear Imaging Self Scanning Sensor (LISS III) images were acquired for two dates i.e., January 2007 and April 2011, for the mapping of Doloo tea estate. IRS P6-LISS III has a spatial resolution of 23.5 m, four spectral channels and a temporal resolution of 25 days with 127 Km swath width. The study area falls under path - row 112-54 according to the IRS P6-LISS III image acquisition referencing scheme. The study was carried out using multi-temporal images of LISS III of 2007 and 2011. The LISS III image of 2007 was georeferenced to LISS III image of 2011 using adequate ground control points at first order polynomial transformation fit and the sub-pixel Root Mean Square (RMS) error was within the acceptable limit (0.03). Latitude and longitude coordinates in the files were converted into Universal Transverse Mercator (UTM) co-ordinates, World Geodetic System 1984 (WGS-84) zone 46 in northern hemisphere. Ground truth data were collected by integrated use of GPS in the intensive study site and geocoded False Colour Composite (FCC) of LISS III imagery and Google earth image. The field survey was carried out for ground verification of the affected patches that were identified in the imagery. GPS points were taken for the infested tea patches. The study area map was taken from the Doloo tea estate management. The map was digitally scanned and geometrically rectified with LISS III data. The boundary of the map was delineated by onscreen digitization. The study area was extracted from the satellite imagery using the digitized boundary of the garden. Subsequently, classification was carried out. Unsupervised classification technique was adopted based on spectral reflectance for the preparation of the map of Doloo Tea Estates using multi-temporal data of LISS III 2007 and 2011 images in which Iterative Self-Organizing Data Analysis Technique (ISODATA) classification algorithm was followed with 20 iterations. The unsupervised classification was adapted to minimize the effect of subjectivity (Soares *et al.*, 2008). For a more detailed verification of the results, the ground reference data were compared with the classified images and the accuracy of each classifier was quantitatively assessed using four statistics: producers' accuracy, users' accuracy, overall accuracy (OA), and Kappa coefficient based on the confusion matrix (Lillisand & Keifer, 2000).

Land use land cover change

The comparison of the land use land cover statistics assisted in identifying the percentage change (trend) from 2007 to 2011. Percentage change to determine the trend of change was then calculated by dividing observed change by sum of changes multiplied by 100 (Gajbhiye & Sharma, 2012).

Results and discussion

In the present study, unsupervised classification categorized the LISS III 2007 and LISS III 2011 images into six classes namely healthy tea patches, affected tea patches, young/ pruned tea patches, water and marginal land. The overall classification accuracies for 2007 and 2011 were 93.81 % and 91.58 %, with Kappa statistics of 0.93 and 0.91. The accuracy evaluation of landuse/ landcover maps of Doloo tea estate of 2007 and 2011 are shown in Table1. Landuse/ landcover distribution in 2007 (Fig. 2) shows Healthy tea area occupies a major portion of the total area (61.34%) followed by affected tea areas (5.72 %). Young tea occupies 18.06 %, marginal land areas occupy 8.30 % and water occupies 3.85 % out of the total area. Built up areas maintains the least portion out of the total area i.e., 3.83 % only whereas landuse/ landcover distribution in 2011 (Fig. 3) shows Healthy tea area occupies a major portion of the total area (63.83 %) followed by affected tea areas (10.55 %). Young tea occupies 7.87 %, built up areas occupies 3.85 % and marginal land areas occupy 10.06 % out of the total area. Water maintains the least portion out of the total area i.e., 3.83 %

only. Area statistics of landuse/ landcover classes of 2007 and 2011 are shown in Table 2.

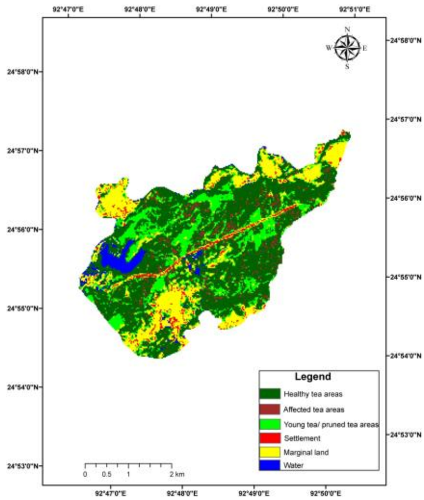

Fig. 2 Landuse/ landcover map of Doloo tea estate in 2007

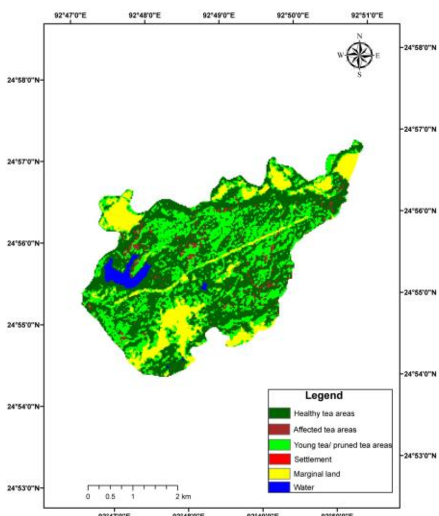

Fig. 3 Landuse/ landcover map of Doloo tea estate in 2011

Table 1. Accuracy evaluation of landuse/ landcover map of Doloo tea estate in 2007 and 2011

Class name	LISS III 2007		LISS III 2011	
	Producers Accuracy (%)	Users Accuracy (%)	Producers Accuracy (%)	Users Accuracy (%)
Healthy tea areas	93.52	92.23	93.64	94.27
Affected tea areas	95.71	94.46	95.32	95.41
Young/ pruned tea areas	93.47	91.42	94.17	91.82
Settlement	98.73	97.38	97.51	97.55
Water	89.31	85.15	83.58	81.14
Marginal land	85.29	83.82	87.26	85.32
Total	92.67	91.58	91.91	90.92

Table 2. Area statistics of landuse/ landcover classes of Doloo tea estate in 2007 and 2011

Landuse classes	LISS III 2007		LISS III 2011	
	Area in ha	Percentage (%)	Area in ha	Percentage (%)
Healthy tea areas	1031.76	61.34	1073.78	63.84
Affected tea areas	96.25	5.72	177.47	10.55
Young/ pruned tea areas	303.72	18.06	132.36	7.87
Built up	51.38	3.05	64.74	3.85
Water	59.32	3.53	64.51	3.83
Marginal land	139.57	8.30	169.14	10.06
Total	1682	100	1682	100

Land use land cover change in Doloo tea estate from 2007 to 2011

Landuse landcover change of Doloo tea estate of 2007 and 2011 showed the trend of change (2007-2011) of healthy tea areas was found to be 11.57 % while affected tea area was found to be 22.7 %. In case of young/ pruned tea areas, there seems to be a negative change (-52.10 %) i.e., reduction young/ pruned tea areas in 2011 as compared with 2007 classified map. Built up area trend of change % was 3.76 %, water was 1.50 % and marginal land area was 8.27 % as shown in Table 3. A comparative change in area (%) of the temporal images is shown in Fig. 4.

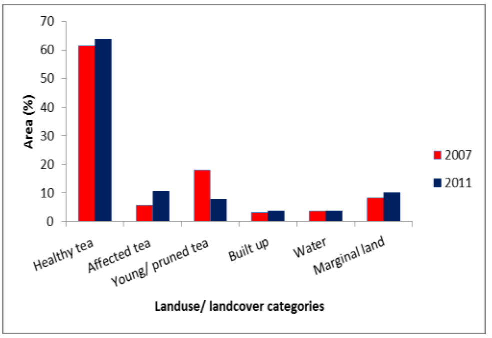

Fig. 4 Area in percentage under different landuse/ landcover categories of Doloo tea estate in 2007 and 2011

Table 3. Landuse/ landcover change of Doloo tea estate from 2007 to 2011

Land use/ land cover categories	Observed change in percentage (2011 – 2007)	Trend of change in percentage (2007 - 2011)
Healthy tea	2.50	11.75
Affected tea	4.83	22.71
Young/ pruned tea	- 11.06	- 52.10
Built up	0.80	3.76
Water	0.32	1.50
Marginal land	1.76	8.27
Total	21.27	

From the study of landuse/ landcover change of Doloo Tea Estate, it was observed that the healthy tea areas were found to increase in the LISS III 2011 image as compared to LISS III 2007 image while young/ pruned tea areas were found to have negative change. The reason is that young tea plants become mature in five – six years and were considered to be productive. Within six years it branches out and imageries of this period are observed to have a healthy spectral reflectance. This also indicates that new areas were not brought under plantation in the period of study and the young tea areas of 2007 had converted into matured tea areas by 2011. Affected areas under cultivation were more in 2011 than 2007 image due to the outbreak of the disease and pest from March to November. The built up areas also increased considerably from 2007 to 2011 indicating an increase in the construction of buildings etc. within the study area. Marginal land areas were more in 2007 image as the image was of January month i.e., dry season. Water areas did not change considerably in the temporal images.

Tea plants are highly susceptible to red spider attack. Once the outbreak occurs it becomes difficult to control it as it spreads rapidly. Remote sensing plays an important role in assessing the health of the vegetation. Once the stress area is identified precautionary measures can be taken at the very initial stages. Using the optical remotely sensed data i.e., LISS III it is possible to observe the affected tea patches. False colour composite image was analyzed to assess the affected and non-affected tea patches. The healthy patches were seen as bright red colour while the affected patches were seen as brownish red or dark brown in colour.

Remote sensing imagery should be provided on a frequent basis. LISS III has a rapidity of 24 days, so satellite imagery can be procured every month and the shift in the disease can be noticed. The spatial distribution of affected tea patches will help the tea management authorities to identify their area of interest and take necessary measures. These images can also help in regular monitoring of the shifts in the spread of the infected patches. This could thus facilitate timely intervention by the authorities to counteract the pest.

Conclusion

The potential of satellite remote sensing technology for detection, mapping and monitoring can be evaluated using LISS III imagery. Multi date satellite imagery has been analyzed to identify and extract information on the spatial extent and distribution. The spatial distribution of affected tea patches can help the tea management authorities to identify their area of interest and take necessary measures. These images can also help in regular monitoring of the shifts in the spread of the affected tea patches. This could facilitate timely intervention by the authorities to counteract the pest. Using these images the management can monitor the shift in the disease patches saving time and labour. Crop yield estimation in many countries is based on conventional techniques of data collection for crop and yield estimation based on ground-based field visits and reports. Such reports are often subjective, costly, time consuming and are prone to large errors, leading to poor crop yield assessment and crop area estimation.

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