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SATELLITE-BASED REMOTE SENSING TECHNIQUE AS A TOOL FOR REAL TIME MONITORING OF LEAF RETENTION IN NATURAL RUBBER PLANTATIONS AFFECTED BY ABNORMAL LEAF FALL DISEASE

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Most parts of the traditional natural rubber growing regions of India, extending from Kanyakumari district in the south to Kasaragod district in the north received excess and prolonged rains during 2013. This led to severe incidence of Abnormal Leaf Fall (ALF) disease caused by the fungus, *Phytophthora* sp. We demonstrate here for the first time the use of satellite-based remote sensing technique to monitor LAI in natural rubber holdings in real time. Leaf retention was monitored every month between April and December 2013 using real time satellite-based remote sensing measurements from rubber holdings spread across all districts in the traditional rubber growing region of the country that were earlier mapped using satellite imageries. Corresponding LAI data for 2012 was also similarly estimated from satellite data. It was found that as the monsoon advanced, LAI decreased substantially in both years, but the reduction was much more substantial and prolonged in many districts during 2013 than 2012, reflecting increased leaf fall due to ALF disease in 2013. The decline was more pronounced in central and northern Kerala than in the south. Kanyakumari district is generally known to be free from ALF disease, but there was considerable leaf loss due to ALF in June 2012 and June and July 2013 even as the monsoon was unusually severe in 2013. Weighted mean LAI for the entire period of April to December was estimated based on LAI and per cent of total area under rubber in each district for the two years. This was markedly less in 2013 than 2012. The implications of poor leaf retention for biomass production (net primary productivity), carbon sequestration and rubber yield are discussed.

Keywords: Abnormal leaf fall, Leaf area index, MODIS, Remote sensing

INTRODUCTION

Almost 90 per cent of India's natural rubber is produced from the traditional rubber growing regions that stretche from Kanyakumari in the south to Kasaragodu in the north (IRS, 2012). This part of the country has been witnessing marked rise in temperature in recent years and decades (Jacob and Satheesh, 2010; Raj *et al*., 2011; Satheesh, 2014). Earlier analyses have shown that for a unit concomitant rise in maximum

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and minimum temperatures, productivity of natural rubber can be reduced by almost 9-16 per cent. However, in North East India, climate warming will have little inhibitory effect on rubber yield, if not a likely stimulation (Satheesh and Jacob, 2011; Satheesh, 2014). Since North East India supplies only 4 per cent of the country's total natural rubber, climate warming in this part will not have any significant immediate impact on the total natural rubber production. On the contrary, warming conditions in traditional regions where bulk of the natural rubber is produced can have immediate negative impact on the total rubber production in India (Satheesh, 2014).

Impact of climate change on natural rubber is not limited to the direct inhibitory effect of climate warming on rubber yield which can be substantial in the traditional rubber growing regions (Satheesh and Jacob, 2011). More complex and difficult to predict than the effects of climate warming are changes associated with cloud formation, rainfall distribution, occurrence of extreme weather events *etc.* and their impacts on incidence of pests and diseases which can have direct or indirect effects on growth and productivity of natural rubber. The year 2013 witnessed unusually intense and prolonged monsoon leading to serious outbreak of Abnormal Leaf Fall (ALF) disease resulting in extensive leaf loss for most part of the year (RRII unpublished).

In the present study, satellite data was used to estimate leaf retention in real time based on Leaf Area Index (LAI) in rubber holdings in the different districts in the traditional rubber growing regions of India from April to December 2012 and 2013. The technique described in this study gives the ability for remotely monitoring LAI in rubber holdings in any part of the world at any time (Provided good quality satellite data are available). Implications of LAI for primary productivity and likely impact of poor leaf retention during 2013 on rubber yield are discussed.

MATERIALS AND METHODS

Rubber distribution across the entire traditional region has been recently mapped using satellite images (RRII, 2014). LAI, ratio of leaf area to land area was estimated using data from MODIS Terra satellites. Monthly composite 1km LAI tile data (MOD15A2) covering the study area (Kanyakumari district of Tamil Nadu in the south to Kasargod district of Kerala in the north) for the period April to December 2012 and 2013 were downloaded from the USGS site (http://glovis.usgs.gov). MODIS Hierarchical Data Format (HDF) was converted using MODIS tool. All tiles were reprojected and mosaicked using Geomatica v 10.3.1 image processing software. The study area was clipped and scale factor was applied to MODIS data sets for generating LAI values. Missing values and noise due to clouds *etc.* were removed from MODIS tiles and uniform rubber area was taken for analysis. Rubber area distribution map developed earlier using satellite imageries (RRII, 2014) was overlaid over the LAI raster images and LAI quality parameters of rubber growing areas were extracted. District-wise LAI images were generated and monthly district mean LAI was calculated. LAI during April/May coincides with the phenological stage of mature refoliated leaves (maximum foliage retention) and normally, June/July coincides with peak incidence of abnormal leaf fall disease (least foliage retention). During 2013, monsoon was prolonged causing serious defoliation due to ALF in several districts which was monitored using monthly LAI data from April to December 2013 and compared with the LAI data for

the same period in 2012 when the monsoon was much less aggressive. A weighted mean LAI for the entire period of April to December was calculated for 2012 and 2013. This was done by multiplying the mean LAI for each district for the year with the per cent of total area under rubber in the respective district. This ensured that LAI for each district had different weightage according to the extent of rubber area in each district.

RESULTS AND DISCUSSION

LAI ie the ratio of leaf area to land area or the number of layers of leaves present above the ground (Chen and Black, 1992) has a direct bearing on light interception by the canopy and biomass productivity in any crop (Tianxiang *et al*., 2002; Heiskanen, 2006). In the present study, the use of satellite-based remote sensing technique as an easy, fast and powerful tool to monitor leaf retention by rubber plantations is demonstrated for the first time.

This technique was employed to monitor leaf retention by rubber plantations in the traditional rubber growing regions of India from April to December 2012 and 2013. The year 2013 had unusually intense and long monsoon causing severe incidence of ALF disease (data not shown) leading to poor leaf retention after the onset of the rains in June compared to 2012 when the monsoon was less intense (Fig. 1).

April/May is the time when LAI is generally high. This is because after the natural leaf fall in January/February (wintering), the new foliage will be fully formed by March/April. Until the beginning of monsoon in June, there was little difference in LAI among most of the rubber-growing districts. As the monsoon advanced, there was marked loss of foliage (Fig. 1) (as a result of severe incidence of ALF which was corroborated through field reconnaissance of the disease; data not shown). The first sharp decline in LAI was observed in all other districts in June/July in both years which is the time when monsoon reaches a peak in this part of the country. Thus, variations in LAI were observed across the region and time of the year in both years, but the decline in LAI was more sharp and prolonged during 2013 than 2012 (Fig. 1). In general, decline in LAI was quicker, more pronounced and prolonged in the central and northern parts than in the Southern region. Kanyakumari and Trivandrum districts maintained better leaf retention throughout most of the study period in both years. It is generally known that ALF incidence is relatively absent in district compared to the rest of the traditional areas (Mathew *et al*., 2010). However, due the severity of the monsoon, even in this district there was some leaf loss due to ALF, *albeit* for a short period of two months (June and July) during 2013. Which recovered taster than the other districts.

Leaves are the only source where carbohydrates, the precursors for making latex are synthesized in rubber trees. There is a direct and immediate association between current carbohydrate synthesis and yield in annual grain crops such as wheat and rice (Setter *et al*., 1994; Kumura, 1995; Asseng and Herwaarden, 2003; Xue *et al*., 2008). However in rubber, the economic yield is not a reproductive organ, located close to the source of production of carbohydrates. Rubber is a secondary metabolite produced through complex and highly specialized biochemical processes in the designated laticiferous cells present in the soft bark tissues far away from the source of carbohydrate production. The relationship between current year's carbohydrate production (which depends on LAI) and that year's rubber yield is difficult to quantify. However, it is only

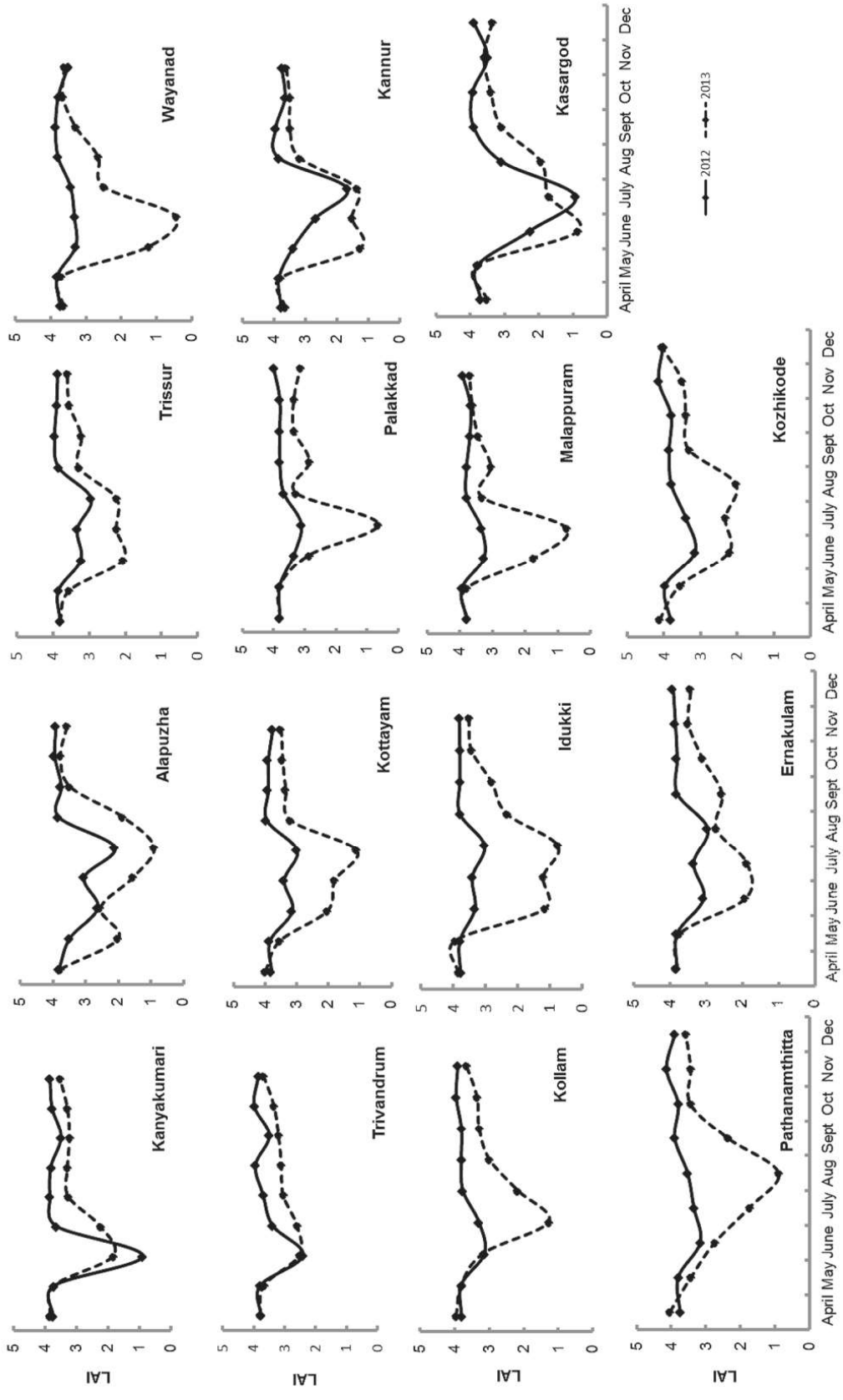

Fig. 1.Leaf Area Index (LAI) of NR plantations of Kerala and Kanyakumari estimated from satellite data during 2012 and 2013

natural that large loss of leaves will markedly reduce rubber yield, but there is no accepted methodology as such to quantify how far reduced leaf retention during 2013 might impact rubber yield.

In the present study, we addressed this issue by giving different weightage to LAI in each district according to the relative extent of area under rubber. LAI varied between months and districts which had different extents of rubber cultivation. The mean LAI that prevailed between April and December (2012 and 2013) in a given district was multiplied with the per cent of area cultivated under rubber in the same district to obtain an estimate of the area-weighted LAI in these districts (Fig. 2). This ensured that a district with more rubber area had a greater weightage attached to its mean LAI for the period from April to December and *vice versa*. Thus, districts of Kottayam, Ernakulam and Pathanamthitta which had relatively more share of rubber area also had higher area-weighted LAI (Fig. 2). Similarly, districts such as Alapuzha and Idukki which had only very small area under rubber also had small area-weighted LAI (Fig. 2). The sum of the area-weighted LAIs from all districts was as high as 358 during April to December 2012. This declined to 293 during the corresponding period in 2013 which is a 22 per cent reduction from 2012 (Fig. 2 inset). It is unlikely that there will be a one-to-one correspondence between reduction in the sum of area-weighted LAI and loss in rubber yield. Considering the importance of leaf retention for rubber yield as

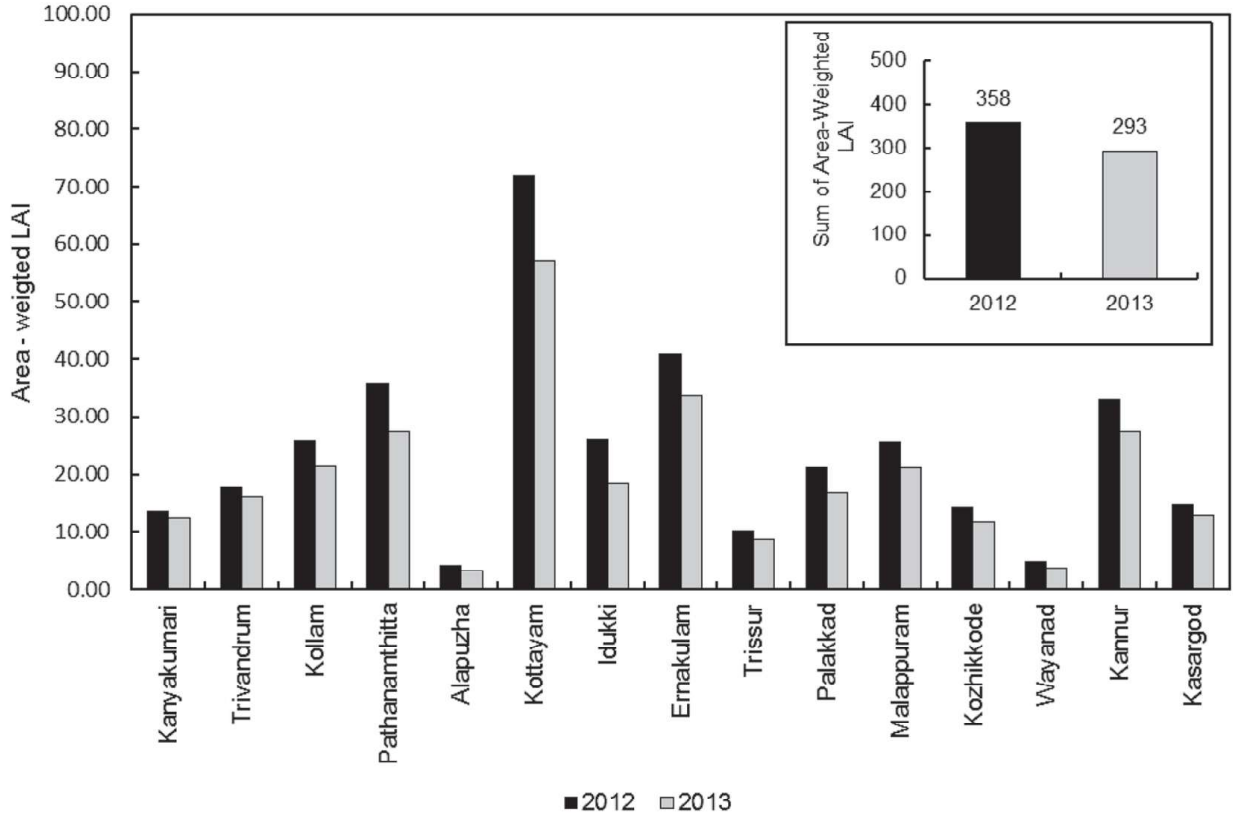

Fig. 2. Area-weighted LAI between April and December in different districts during- 2012 and 2013. Sum of area-weighted LAI for the same period is given in the inset.

explained above, it will not be surprising if a substantial extent of loss in area-weighted LAI is reflected as lost yield which we expect could be in the range of 10-15 per cent reduction in yield in 2013 compared to 2012.

LAI, amount of light intercepted by the canopy and efficiency of conversion of absorbed light into biomass are the major determinants of net primary productivity (Luo, 1996; Hirose *et al*., 1997; Luo *et al*., 2004) which results in net sequestration of CO_2 from the atmosphere. Net primary productivity in terms of biomass production (or CO_2 sequestration) is an important trait determining the yield of a rubber tree, because the larger the trunk size, the longer the tapping cut and thus the more the latex yield in a given clone (Sethuraj, 1981). Studies are on to monitor LAI using satellite-based remote sensing techniques and relate the same to net primary productivity (biomass production and CO_2 sequestration) and rubber yield with the ultimate objective of predicting potential rubber production in different rubber growing regions using satellite-based LAI data.

REFERENCES

Asseng, S. and Herwaarden A.F.V. (2003). Analysis of the benefits to wheat yield from assimilates stored prior to grain filling in a range of environments. *Plant Soil,* **256**: 217-229.

Chen, J.M. and Black, T. A. (1992). Defining Leaf Area Index for non-flat leaves. *Plant Cell and Environment,* **15**: 421-429.

Heiskanen, J. (2006). Estimating above ground tree biomass and leaf area index in a mountain birch forest using ASTER satellite data. *International Journal of Remote Sensing*, **27** (6): 1135-1158.

Hirose, T., Ackerly, D.D., Traw, M.B., Ramseier, D. and Bazzaz, F.A. (1997). CO_2 elevation, canopy photosynthesis and optimal leaf area index. *Ecology*, **78**: 2339-2350.

Indian Rubber Statistics (2012). Compiled by: Statistics and Planning Department. The Rubber Board, Kerala, Ministry of Commerce & Industry, Govt. of India. **34:** 7-8.

Jacob, J. and Satheesh, P.R. (2010). Impact of climate change on natural rubber productivity in different agro-climatic regions in India. *International workshop on climate change and rubber cultivation: R & D priorities*. Rubber Research Institute of India, Kottayam-686 009, India.

Kumura, A. (1995). Physiology of high yielding rice plants from the viewpoint of dry matter production and its partitioning. **In:** (Eds. Matsuo, M. *et al.). Science of the rice plant*, Food Agriculture Policy Research Centre, Tokyo, Japan, **2**: 704–736.

Luo, T. (1996). *Pattern of net primary productivity for Chinese major forest types and their mathematical models.* Ph.D. thesis. Commission for Integrated survey of Natural resources, Chinese Academy of Sciences, Beijing, China.

Luo, T., Pan, Y., Ouyang, H., Shi, P., Lou, J., Yu, Z. and Lu, Q. (2004). Leaf area index and net primary productivity along subtropical to alpine gradients in the Tibetan plateau. *Global Ecology and biogeography*, **13**: 345-358.

Mathew, J., Abraham, T., Jose, V. T., Mondal, G.C., Raj, S. and Sailajadevi, T. (2010). Prevalence of pests and diseases of *Hevea brasiliensis* in India - past and present. *International workshop on climate change and rubber cultivation: R & D priorities.* Rubber Research Institute of India, Kottayam, India.

NMCE (2012). Published by National Multi Commodity Exchange, of India Ltd. *Natural Rubber.* pp. 3-23.

Raj, S., Satheesh, P.R. and Jacob, J. (2011). Evidence for climate warming in some natural rubber growing regions of south India. *Natural Rubber Research*, **24** (1): 10-17.

RRII (2014). Satellite survey of natural rubber plantations in Kerala, Tamil Nadu and Karnataka. Consultancy project for Automative Tyre Maufacturers' Association (ATMA), New Delhi. Rubber Board, Kottayam, Kerala.

Satheesh, P.R. (2014). *Impact of climate change on Indian plantation sector with special reference to natural rubber.* Ph.D. Thesis. Submitted to

Mahatma Gandhi University, Kottayam, Kerala. pp. 106-139.

Satheesh, P.R. and Jacob, J. (2011). Impact of climate warming on natural rubber productivity in different agro-climatic regions of India. *Natural Rubber Research*, **24** (1): 1-9.

Setter, T.L., Peng, S., Kirk, G.J.D., Virmani, S.S., Kropff, M.J. and Kasman, K.G. (1994). Physiological consideration and hybrid rice. *Proceedings on rice yield potential in favourable environments*, IRRI. pp. 39-57.

Sethuraj, M. R. (1981). Yield components in *Hevea brasiliensis*. *Plant Cell and Environment*, **4**: 81-83.

Tianxiang, L., Ronald, N.P., Hanqin, T., Charles, V.J., Huazhong, Z. and Shirong, L. (2002). A model for seasonality and distribution of leaf area index of forests and its application to China. *Journal of Vegetation Science*, **13**: 817-830.

Xue, G.P., McIntyre, C.L., Jenkins, C.L.D., Glassop, D., Herwaarden A.F.V. and Shorter, R. (2008). Molecular dissection of variation in carbohydrate metabolism related to water soluble carbohydrate accumulation in stems of wheat (*Triticum aestivam* L.). *Plant Physiology*, **146**: 441-454.