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Persistent negative changes in seasonal greenness over different forest types of India using MODIS time series NDVI data (2001–2014)

Abhishek Chakraborty*, M.V.R. Seshasai, C. Sudhakar Reddy, V.K. Dadhwal

National Remote Sensing Centre, Indian Space Research Organisation, Balanagar, Hyderabad, 500 037, India

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ABSTRACT

This study assessed the spatial patterns of significant negative trend of forest seasonal greenness over the different forest types of India using 8-day composite MODIS NDVI (500 m) time series data (2001–2014). It was further analyzed to quantify the negative changes in the core forest areas and to indentify hotspots of it over the large protected forest areas. Significant negative changes in the seasonal greenness were found to be highest over tropical moist deciduous forest (2067.35 thousand ha) followed by tropical dry deciduous (1407.73 thousand ha), tropical wet evergreen (577.43 thousand ha), tropical semi evergreen (442.58 thousand ha), subtropical broad leaved (321.13 thousand ha) and Himalayan moist temperate forest (293.80 thousand ha). Mangroves forest also showed decrease in its greenness over 15.6% of its total area. Interestingly, most of the observed negative changes of high to medium magnitude were found in the core areas of the forest types. Hotspots analysis revealed spatially coherent significant negative changes of seasonal greenness over the large protected areas i.e. Similipal wildlife sanctuary of Odisha, Rajaji national park of Uttarakhand, Achanakmar wildlife sanctuary of Chhattisgarh and Sundarban of West Bengal. The outcomes of the present study would help in the prioritization of the forest types and protected forest areas for biodiversity conservation and climate change mitigation programmes.

1. Introduction

There is an increasing scientific consensus that natural vegetation systems are facing unprecedented risk due to anthropogenic activities and climatic change (Midha and Mathur, 2010). Negative changes in forest vigour and deforestation has huge ramifications on carbon stocks, biodiversity, ecosystem services and livelihoods of dependent people. According to the IPCC AR5 report, the net annual carbon emission was estimated to be 3.3 billion tonnes of CO_2 from deforestation during the past decade (http://www.ipcc.ch). The loss of ecosystem services has been identified by the United Nations as the greatest challenge to the humankind as it slows down the economic development of a nation, thus intricately linked to poverty (Díaz et al., 2006). The entities at threat include ecosystem, population, physical and biological processes (Kaly et al., 2002). Thus to mitigate the menace of climate change, the Reducing Emissions from Deforestation and forest Degradation (REDD +) has gained importance as a implementable strategy at multiple scales (Lin et al., 2014).

As per the definition of the Food and Agricultural Organization of the United Nations, forest degradation is a process that leads to temporary or permanent deterioration in the density, structure of vegetation or its species composition, and thus to a lower productive capacity of forest (FAO, 2011). The different indicators of forest degradation include: high fragmentation, negative change in forest canopy cover, reduction of biomass, shifting cultivation, unsustainable logging, frequent fires, decline in species population, invasion of alien species and loss of soil fertility. Subtle changes in forest vigour can be identified by analysing changes in its seasonal greenness using vegetation phenology. Vegetation phenology is a study of recurring patterns of vegetation growth and development. The impact of climate change on ecosystem can be successfully assessed by the changes of vegetation phenology (White et al., 1997). Variations in vegetation phenology alter global carbon, water and nitrogen cycles, crop production, duration of pollination season and distribution of diseases and pests, thus has broad impact on terrestrial ecosystems and human societies (Penuelas and Fiella, 2001; Soudani et al., 2008). Therefore, the ecological and climatic research has given special emphasis to the study of phenological changes of vegetation (Menzel et al., 2001; Cleland et al., 2007). There are three possible ways to assess vegetation phenological events *i.e.* '*in situ*' observations, bioclimatic models and remote sensing techniques (Schaber and Badeck, 2003; Fisher et al., 2007). The *in situ* observations are expensive, time consuming, subjected to operators bias

* Corresponding author.
E-mail address: jeet.abhishek@gmail.com (A. Chakraborty).

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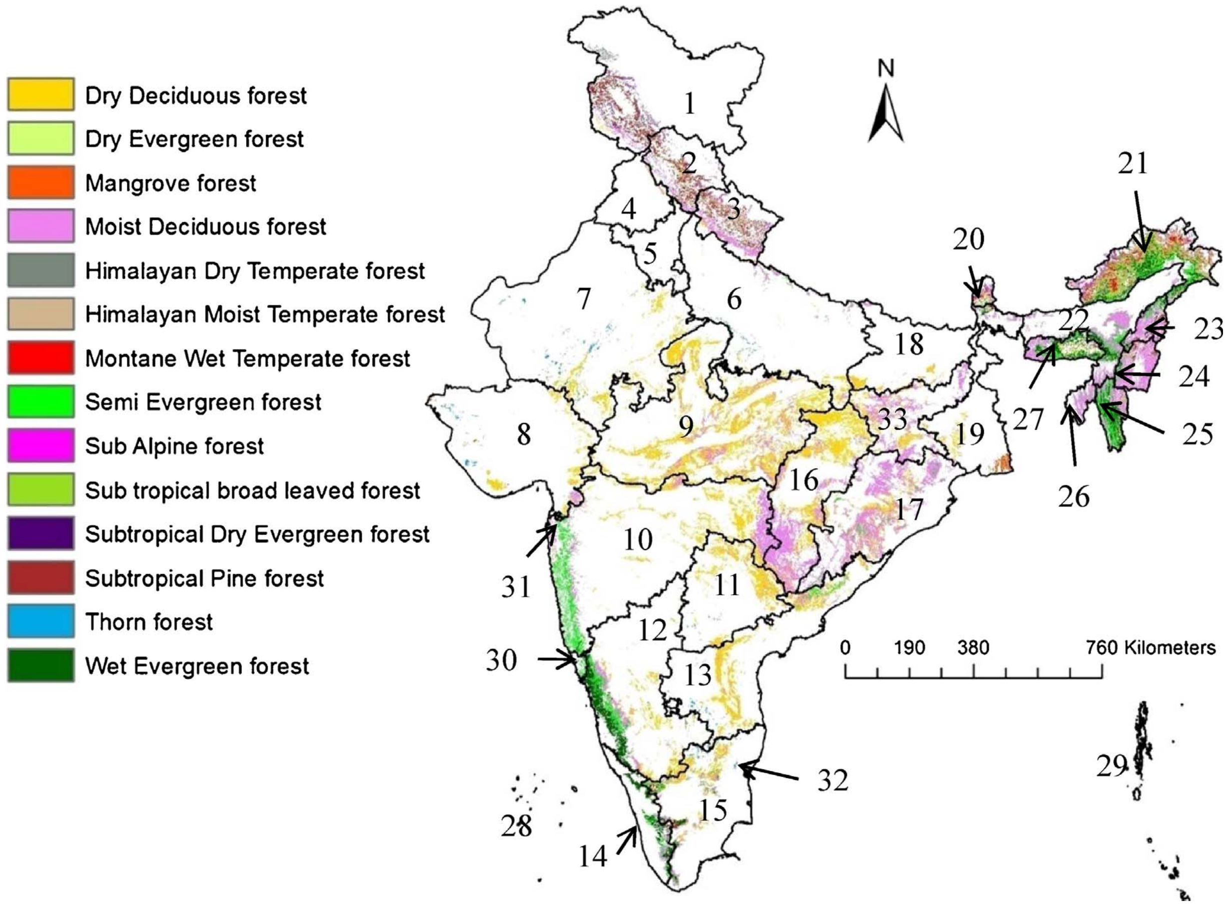

Fig. 1. Forest types of India (Reddy et al., 2015). Selected Indian states and union territories of the present study: 1 Jammu & Kashmir, 2. Himalchal Pradesh, 3. Uttarakhand, 4. Punjab, 5. Haryana, 6. Uttar Pradesh, 7. Rajasthan, 8 Gujarat, 9. Madhya Pradesh, 10. Maharashtra, 11. Telangana, 12. Karnataka, 13. Andhra Pradesh, 14. Kerala, 15. Tamil Nadu, 16. Chhatisgarh, 17. Odissa, 18. Bihar, 19. West Bengal, 20. Sikkim, 21. Arunachal Pradesh, 22. Assam, 23. Nagaland, 24 Manipur, 25. Mizoram, 26 tripura, 27. Meghalaya, 28. Lakshadweep, 29. Andaman & Nicobar island, 30. Goa, 31. Dadra & Nagar Haveli, 32. Pondicherry, 33. Jharkhand.

and thus difficult to extent to large geographical areas. Bioclimatic models require accurate and exhaustive vegetation and climatic data specific to forest species along with local calibration to extend it over large scales. Satellite remote sensing is a proven viable alternative which could provide regular, even daily, monitoring of the entire global land surface. The satellite gather data about entire ecosystems or regions rather than individual species over its footprint, thus could provide a unique perspective of earth surface. Satellite remote sensing can reveal broad-scale phenological changes that would be difficult, if not impossible, to detect from the field survey. Satellite data can be standardized and calibrated across the sensor to provide continuous information over large temporal span. Thus satellite remote sensing technique has emerged as a cost effective alternative of phenological study with good temporal repeatability over large and inaccessible regions.

There have been many studies of changes in vegetation phenology in different parts of the globe using *in situ* observations. The advancement of spring phenophages and significant increase in the length of growing season of deciduous tree over Germany during the period of 1951–1996 was reported by Menzel et al., 2001. The phenological data of six major phenophases of 29 species over Spain for the period of 1943–2003 were analyzed by Gordo and Sanz 2009, and found advancement of the dates of leaf folding, flowering, and fruiting in few species. They have also reported that wind pollinated species have advanced their flowering more than the insect and animal pollinated plants.

Extensive research works were conducted to find out the changes in vegetation phenology using remote sensing techniques. Vegetation phenology is usually addressed through temporal monitoring of the satellite derived Normalized Difference Vegetation Index (NDVI) time series. The NDVI is calculated as the normalized relative difference between near-infrared and red bands. The NDVI quantifies the photosynthetic capacity of plant canopies, thus represents the amount of vegetation present in one place. Moderate to coarse resolution satellite sensor, which is generally preferred in phenological studies for its high repeativity, cannot provide the phenological events directly, rather different phenology analogues such as start of the growing season (SGS), end of the growing season (EGS), length of the growing season (LGS), seasonal NDVI amplitude (AMP), seasonally integrated NDVI etc could be derived. Time series NDVI had been used to detect positive trends of LGS over North America and Eurasia (Zhou et al., 2001), changes of vegetation activities over Europe (Stockli and Vidale, 2004), Central Asia (De Beur and Henebry, 2004), Inner Mongolian steppe (Lee et al., 2002), Sahel & Soudan (Heumann et al., 2007), China (Piao et al., 2006; Fang et al., 2003), and India (Chakraborty et al., 2014).

India is one of the mega-biodiversity countries having an area of 328.72 Mha. Reddy et al. (2013a) has reviewed the works on the forest cover changes in India. The study has contributed to the understanding of spatial patterns of forest fragmentation in India (Reddy et al., 2013b). Reddy et al. (2016) has carried out quantitative analysis of deforestation in India over eight decades (1930–2013). Single or two date mapping of forest degradation is not meaningful for the evaluation of status of forest without having continual time series information. All the previous studies on the forest cover change mainly involved in analysis of changes between two or more time epoch. The continuous process of changes in the forest greenness using time series satellite