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Earth observation data for habitat monitoring in protected areas of India

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ABSTRACT

The role of protected areas in biodiversity conservation was recognised in a globally agreed target to be achieved by 2020. Increasing concerns on biodiversity and ecosystem services have led to rising in the number and extent of protected areas. Evaluating the conservation effectiveness of protected areas is difficult, especially due to the paucity of data on long-term changes in forest cover. In order to understand the impact and efficacy of protected area it is highly desirable to monitor the habitat for assessing the conservation status. Earth observation data is useful to monitor the changing extent of habitats and threats over time. The present work has considered the forest cover change and fragmentation (1930–1975–1985–1995–2005–2013) as the potential indicators to evaluate the conservation effectiveness for 175 protected areas of India. Spatial pattern processes of fragmentation analysed within the current study were core forest loss and other fragmentation classes. Historically 7.3% of the reduction was observed in large core forests from 1930 to 2013. This study reveals that protected areas of India are effective in controlling deforestation and consequently fragmentation. High resolution satellite data based information is needed for analyzing degradation in protected areas including invasion of alien species, forest fires, grazing pressure, selective logging and small scale agricultural encroachments towards continuing conservation of biodiversity and improving carbon stocks.

1. Introduction

Habitat monitoring is an important tool for assessing the conservation status of species and protected areas. Growing concerns about the impacts of anthropogenic pressures on biodiversity and ecosystem services have led to increasing in the number and extent of protected areas across the tropics (Laurance et al., 2012). Land use and land cover changes occurring at a rapid rate even in protected areas and many areas of substantial conservation value (Ramesh et al., 1997). In general, it is agreed that deforestation of tropical forests has increased markedly since the early 1930s. Tropical forests are being cleared, burned, logged, fragmented, and over hunted on scales that lack historical precedent (Laurance and Bierregaard, 1997). Emission of greenhouse gases and the loss of biodiversity are the two most serious consequences of deforestation. Yet, the estimates are uncertain which is why it is important to regularly monitor the forest resources around the globe with a more practical approach (Menon and Bawa, 1997). So, evaluations of the effectiveness of past conservation efforts can inform the design of interventions to promote REDD (Reduced Emissions from Deforestation and Degradation) agenda (Nelson and Chomitz, 2011). Aichi Target 5 on habitat loss, fragmentation and degradation indicates that by 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced. Ensured long-term (decadal) continuity of earth observations is a key requirement for understanding biodiversity change. A major requirement of the conservation community is for long-term land cover change products (Secades et al., 2014).

The seventh largest in the world, India is one of the mega-biodiversity nations and has about 17,527 species of flowering plants out of which 5400 species are endemic (Hajra and Mudgal, 1997; Karthikeyan, 2009). The major drivers of deforestation in India are shifting cultivation along with encroachment for agricultural land, mining, quarrying, expansion of settlements, dam construction, illegal logging (Reddy et al., 2013). Protected areas are notified to conserve biodiversity from anthropogenic activities and recognised as core 'units' for in situ conservation. The IUCN and the WCPA have been instrumental in guiding this paradigm shift, and have defined a protected area as: An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means (Hockings and Phillips, 1999).

The Protected areas (PAs) are constituted and governed by the provisions of the Wild Life (Protection) Act, 1972, which has been

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amended from time to time, with the changing ground realities concerning wildlife crime control and PAs management. Implementation of this Act is further complemented by other Acts viz. Indian Forest Act, 1927, Forest (Conservation) Act, 1980, Environment (Protection) Act, 1986, Biological Diversity Act, 2002 and the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006. The Supreme Court of India has banned all kinds of clear-felling in the forests of India from 1996 which has resulted in more protection. National Environment Policy, 2006 addressed the issue of empowerment of the local communities to avoid forests from becoming open access in nature and degrading gradually (http://www.conservationindia.org). Evaluating the effectiveness of protected areas is difficult, especially given the poor availability of data on ecological and social conditions and their change over time (Naughton-Treves et al., 2005). Environmental degradation occurring around a protected area could affect biodiversity in many ways.

As the human population increases, pressures on habitats are intensifying with unknown consequences on protected area effectiveness (Curran et al., 2004). The significance of protected areas in the conservation of biodiversity is now enshrined in Aichi Target 11 that forms part of the Strategic Plan for Biodiversity 2011–2020 of the Convention on Biological Diversity (CBD, 2010). Target 11 states that, by 2020, at least 17% of terrestrial and inland water habitat should be conserved effectively by protected areas or other similar area-based conservation measures.

Very few studies have addressed the land cover change before and after the establishment of protected areas that can help to evaluate the impact of the management regimes over time (Sader et al., 2001). There is an argument over the effectiveness of PAs in reducing deforestation, especially when local people have rights to use the forest (Nelson and Chomitz, 2011). Since protected areas are considered as the most important core units of conservation, management effectiveness is the key towards achieving and sustaining biodiversity.

Remote sensing provides a reliable and robust means for obtaining a synoptic view of the status of forest cover condition on near real time basis. Remote sensing data enable evaluation of rates of land-cover change at a landscape scale in a relatively unbiased manner compared to expensive assessments based on field interpretation (Jensen, 2000). It can be applied to monitor the status of conservation targets and to evaluate the conservation effectiveness. The results obtained through remote sensing change detection quantifies the effects of humans on a landscape scale which can be used for efficient conservation management (Willis, 2015). The combination of remote sensing, as well as GIS techniques with ground surveys, can go a long way in the management of critical areas and contribute to the ecological interpretation of remote sensing data. Remote sensing as state of art technology supports establishing a spatially explicit monitoring system at ecosystem to species level. Remote sensing still has the limitation of mapping individual tree species especially in a tropical forest with layers of species within a few meters (Turner et al., 2003). Li et al. (2014) had reviewed opportunities, challenges and future perspectives using remotely sensed data to retrieve a variety of ecosystem health indicators. The study in South Asia using coarse-scale data shows that the habitat loss does not decline following gazettement of a protected area (Clark et al., 2013). There is a debate over the overall effectiveness of protected areas. Yet, there is no consistent long-term study at the global level to regional level using high to moderate resolution temporal satellite data.

A network of 733 Protected Areas has been established, extending over 1,60,901.74 km^2 (4.89% of total geographic area), comprising 103 national parks, 537 wildlife sanctuaries, 67 conservation reserves and 26 community reserves (Fig. 1; http://www.wiienvis.nic.in/Database/Protected_Area_854.aspx.). 39 Tiger Reserves and 28 Elephant Reserves have been designated for the species-specific management of tiger and elephant habitats. Wildlife sanctuaries referred to as category IV protected areas (Habitat/Species Management Area). National parks in India are IUCN category II protected areas (Category II protected areas are large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities). Large protected areas maintain viable populations of many species within their bounds and perform vital functions for biodiversity conservation.

To overcome the paucity of studies, this work brings out a spatial analysis of the long-term forest cover change and the extent of forest fragmentation as potential indicators and the basis for determining of conservation effectiveness at landscape level in the protected areas of India.

2. Materials and methods

This study has utilized spatial data prepared as part of national carbon project of India. To generate maps of forest cover the topographical maps on 1:250,000 scale (1930's period), remote sensing data pertains to Landsat MSS (1975 and 1985), IRS 1A/IB LISS I (1995), IRS P6 AWiFS (2005) and Resourcesat-2 AWiFS (2013) were used (Reddy et al., 2016).

$$r = \frac{1}{(t_2 - t_1)} \times \ln \frac{a_2}{a_1}$$

Where r is the annual rate of change (percentage per year), a_1 and a_2 are the forest cover estimates at time t_1 and t_2 respectively.

2.1. Forest cover change

Historical forest cover dataset provides estimates of forest cover for 1930, 1975, 1985, 1995, 2005 and 2013. The spatial layers of protected area boundaries were obtained from a database on protected areas from Wildlife Institute of India. We extracted the protected areas in mainland India that were representing forest area more than 100 km^2. The time series forest cover information provides valuable insight on the condition of forests in the PAs. A statistical evaluation of forest cover change and annual net deforestation rates were carried out using the compound interest formula (Puyravaud, 2003).

2.2. Fragmentation modeling

Landscape level fragmentation maps of 1930, 1975, 1985, 1995, 2005 and 2013 were prepared using Landscape Fragmentation Tool v2.0 (Vogt et al., 2007). Forest cover is classified into four main categories - patch, edge, perforated and core - based on a specified edge width. An edge width of 100 m was assumed. The study of Broadbent et al. (2008) had found edge distance as 100 m in several tropical forest sites. The core pixels are outside the "edge effect" and thus are not degraded from proximity to other land cover types. Core pixels are subclassified into 3 categories based on the area of a given core patch - small core / core 1 (< 101 ha), medium core / core 2 (101 ha to 202 ha) and large core / core 3 (> 202 ha). Edge and perforated pixels occur along the periphery of tracts containing core pixels. Edge pixels make up the exterior peripheries of the tracts whereas perforated pixels make up the interior edges along small gaps in the tracts. Patch pixels make up small fragments that are completely degraded by the edge effect (Vogt et al., 2007).

3. Results and discussion

Among the protected areas analysed, majority are belonging to the status of wildlife sanctuary. In many cases, national parks are part of core area in wildlife sanctuaries. In this study, national park boundaries were used for Anshi, Bandipur, Dudhwa, Kanha, Madhav, Mouling, Namdapha, Panna, Rajaji, Satpura, Silent Valley and Tadoba. Spatial

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