Temporal Assessment Of Forest Canopy Density Around Hojai-Diphu Railway Line In Assam, India

Rekib Ahmed

Abstract: We are living in the most explosive era of transportation infrastructure expansion in anthropogenic history. Nine-tenths of all new transportation infrastructures will be in developing countries, particularly in subtropical and tropical regions that contain earth’s richest biodiversity. In the light of the distress around the transportation infrastructures, monitoring forest canopy density is an indispensable tool for sustainable management of forest resources. This research assessed forest canopy density within 9 km buffer of Hojai-Diphu railway stretch in Assam, India using the forest canopy density (FCD) model. Statistics derived through FCD model revealed that most of the changes in forest canopy density occurred in 41-70% and >71% FCD categories during 1988–2018. A sharp decline in area of >70% (dense canopy forest) FCD category was observed after gauge conversion period of the railway track with an average rate of deforestation of -1072 ha/year⁻¹. Restoring the integrity of dwindling dense canopy forest is being an urgent priority for current conservation efforts to halt the ongoing biodiversity crisis and achieve sustainability goals.

Key words: forest canopy density, dense canopy forest, railway line, gauge conversion.

I. INTRODUCTION

Transportation infrastructures are growing across the world at an unprecedented rate. Nine-tenths of all new transportation infrastructures will be in developing countries, particularly in subtropical and tropical regions that contain earth’s richest biodiversity (Sperling & Gordon, 2009). Further China, India, and Russia have an extensive railway networks, and where associated environmental impacts are likely to be important. Railways building in forested habitats can affect biodiversity both directly, as an immediate repercussion of construction of railway lines; or indirectly, as a result of human activities that are facilitated by enhanced such infrastructures. Examples of direct effects include wildlife-train collisions, reduced reproductive capacity of various species as a result of chronic train noise and behavioural avoidance of railways (Borda-da-Água, Barrientos, Beja & Pereira, 2017). Moreover, tropical forests have a uniquely complex canopy structure and humid and dark microclimate that sustain a huge number of endemic species. Many of these avoid altered habitats near railway lines and cannot traverse even narrow clearings. Others run the risk of being hit by trains or killed by people hunting near railway lines. This can result in diminished or fragmented wildlife populations, and can lead to local extinctions. Moreover habitat loss and fragmentation caused by road and railways have long been considered the primary cause for biodiversity loss and ecosystem degradation worldwide. As the pressures mount, it is vital to know whether existing forest covers can sustain their biodiversity. To appraise both the ecological integrity and threats for intact forest areas around railway lines, I conducted a systematic and uniquely comprehensive assessment of long-term forest canopy density change within 9 km buffer of the Hojai-Diphu railway line. The objective of this study was to assess temporal patterns of forest canopy density change around the study railway line during the period from 1988 to 2018.

II. STUDY AREA

The study was conducted along 58km long railway line between the Hojai railway station (latitude 26˚9˚37ˮN, longitude 92˚39˚28ˮE) and Diphu railway station (latitude 25˚57˚9ˮN, longitude 93˚45˚16ˮE) in Karbi Anglong, a hilly district of Assam. Given the increasing demand to enhance connectivity with north-eastern region of India, this railway section was converted from meter gauge to broad gauge (the distance between two rails is 1676 mm) in 1997 (North East Frontier Railway, 2019). The railway line dissects Dhansiri-Lungding elephant reserve, one of the prime habitats of Asian elephant (Elephas maximus) in India, and passes through other elephant ranges and corridors in the districts of Karbi Anglong in Assam. Three reserved forest (Lumding, Langting Mupa and Dhansiri) and a wildlife sanctuary (Morat Longri) are encompassed around the study railway section. These forested areas provide the living space and resources to the numerous wildlife species for their survival around the track. The wildlife habitats around the track are characterized by tropical moist deciduous forest and tropical semi-evergreen (Choudhury, 1999).

Figure 1. The location of the study area
III. DATA AND METHODS
Landsat 5 TM (thematic mapper) and Landsat 8 OLI (operational land imager) satellite imagery for the year 1988, 1997, 2007 and 2018 were selected for forest canopy density (FCD) classification of the study area. Selection of the dates for this imagery was based on minimal cloud cover, time of year, and the time frame in which forest change could be monitored. FCD Mapper V2 (ITTO/JOFCA, 2003) was used to examine the temporal change in FCD around the railway section. The FCD model comprises bio-physical phenomenon modelling and analysis utilizing data derived from four (4) indices: Advanced Vegetation Index (AVI), Bare Soil Index (BI), Shadow Index or Scaled Shadow Index (SI, SSI) and Thermal Index (TI) (Rikimaru, Roy & Miyatake, 2002). It determines FCD by modelling operation and obtaining from these indices. To assess the vegetation status of forests, the characteristics of chlorophyll were first examined using the Advanced Vegetation Index (AVI) that is calculated with the following formula (Eq.1).

\[
AVI = [(B4 + 1) \times (256 - B3) \times B43]^{1/3}
\]

where B3 and B4 are correspond to red and near infrared bands of Landsat TM/OLI imagery. For more reliable estimation of the vegetation status, a bare soil index (BI) which is formulated with the following formula (Eq.2).

\[
BI = \frac{(B5 + B3) - (B4 + B1)}{(B5 + B3) + (B5 + B1)} \times 100 + 100
\]

where B1, B2 and B5 are correspond to blue, green and short-wave infrared bands. By combining both vegetation and bare soil indices in the analysis, one may assess the status of forest lands on a continuum ranging from high vegetation conditions to exposed soil conditions. One unique characteristic of a forest is its three dimensional structure To extract information on the forest structure from remote sensing data, the Shadow Index (SI) examine the characteristics of shadow by utilizing (a) spectral information on the forest shadow itself and (b) thermal information on the forest influenced by shadow. The shadow index is formulated through extraction of the low radiance of visible bands (Eq.3).

\[
SI = [(256 - B1) \times (256 - B2) \times (256 - B3)]^{1/3}
\]

Two factors account for the relatively cool temperature inside a forest. One is the shielding effect of the forest canopy which blocks and absorbs energy from the sun. The other is evaporation from the leaf surface which mitigates warming. The source of thermal information is the thermal infrared band of TM/OLI data. Further, Vegetation Density (VD) is the procedure to synthesize AVI and BI by using principal component analysis. Since, AVI and BI have high negative correlation. Then it is scaled between zero to hundred percent (Rikimaru, 1996). On the other hand, the shadow index (SI) is a relative value. Its normalized value can be utilized for calculation with other parameters. The Scaled Shadow Index (SSI) was developed in order to integrate AVI values and SI values. In areas where the SSI value is zero, this corresponds with forests that have the lowest shadow value (0%). In areas were the SSI value is 100, this corresponds with forests that have the highest possible shadow value (100%). SSI is obtained by linear transformation of SI. Integration of VD and SSI means transformation for forest canopy density (FCD) value. Both parameter has no dimension and has percentage scale unit of density. It is possible to synthesize both indices safely by means of corresponding scale and units of each. The FCD is finally obtained for each pixel of forested land by integrating the values of VD and the SSI using following equation (Eq.4).

\[
FCD = (VD \times SSI + 1)^{1/2} - 1
\]

To validate the FCD estimation by FCD Mapper for 2018 data, the canopy cover was measured on the ground using a convex spherical densiometer (Forestry Suppliers Inc., Jackson, MS, USA) during November and December 2018 to coincide with the time of year that the image was acquired to minimize possible errors. The sample plots (n = 114) were selected using stratified random sampling. The size of the sample plot applied was (7 × 7 m) with a minimum 500 m interval to sample each canopy density class in the study area. In each plot, canopy density was measured at five survey points (four corners and the centre of each plot) and average reading was calculated to get percentage of forest canopy density.

Table 1. Description of parameters.

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Parameters</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FCD 0%</td>
<td>Non-forest lands</td>
</tr>
<tr>
<td>2</td>
<td>FCD 1-10%</td>
<td>Scrublands</td>
</tr>
<tr>
<td>3</td>
<td>FCD 11-40%</td>
<td>Open forest</td>
</tr>
<tr>
<td>4</td>
<td>FCD 41-70%</td>
<td>Moderately dense forest</td>
</tr>
<tr>
<td>5</td>
<td>FCD &gt;70%</td>
<td>Dense forest</td>
</tr>
</tbody>
</table>

IV. RESULTS & DISCUSSION

A. Accuracy assessment
Accuracy is estimated from the error matrix over the training class, in terms of percentage of number of correctly classified category against the total number of classes, viz., class 1 (0 %), class 2 (1-10%), class 3 (11-40%), class 4 (41-70%) and class 5 (>70%). The error matrix of measured and estimated classes of forest cover (Table 2) shows the accuracy of the FCD Mapper in classifying forest cover, that is 102 of 114 observations were correctly classified with an overall accuracy of 89.47% and a kappa coefficient of 0.87.

B. Extent of forest canopy density change
Forest canopy densities (FCD) are expressed in percentages from 0% to 100% for each pixel. Five categories of canopy density were assessed based on the FSI (forest survey of India) classification for forest cover mapping (FSI, 2017). The five FCD classes were 0% which included pixel values of 0 (non-forest), 1-10% where pixels value ranged between 0–10% (scrub), 11–40% (open forest), 41–70% class (moderately dense forest) and FCD class above 70% (dense forest). Overall analysis of FCD indicates that most of the forest in the study area has canopy density of 41-70% in all the study years. Temporal variations of forest cover are apparent from the FCD maps of 1988, 1997, 2007 and 2018 where forest covers with
canopy density ranged between 41-70% and above 71% decreased substantially over year. On the other hand, the 11–40% and 0% canopy cover classes accrued significantly during the period 1988-2018. These categories were mostly the result of degradation of dense and moderately dense forest coupled with the regeneration of secondary forest in abandoned “jhum” lands. Moreover, shifting cultivation cycles have been reduced due to population pressure in the hilly districts of Assam. Although the causes of tropical deforestation vary between countries (Geist and Lambin 2002), most forest loss is associated with agricultural expansion (Benhin 2006). Although shifting cultivation is identified as a major factor behind forest canopy density change in the Karbi Anglong district, factors such as encroachment of forest areas, bamboo harvesting, illegal timber trade and consumption of fuelwood are also drivers of forest cover dynamics in that region.

Encroachment occurs in the forest areas that are perceived as being common resources. Poverty, landlessness and increasing population inflows from neighbouring areas, people displaced by floods or by ethnic conflicts are all contributing factors (Saikia, 2014). Encroachment and poaching by vested interests is occurring in National Parks such as Kaziranga (Das 2006). Within Assam, the Karbi Anglong district is the largest producer of bamboo and almost 40 % of bamboos at the Hindustan Paper Corporation Limited mill in Jagirroad are supplied by this district (Gogoi, 2015). However, suppliers mostly involved in indiscriminate felling of different bamboo species leading to a disruption in the regeneration process and the ecological balance of canopy density in the district. Further the region’s growing population has not helped as rising rural human population densities with low income levels have no option than to use timber resources as fuel wood.

**Figure 2.** FCD around Hojai-Diphu railway line for 1989, 2002, 2009 and 2016.

**C. Rate of forest canopy density change**

The detected changes represent either a loss or gain in the FCD classes in the two study periods, which categorised as before gauge conversion and after gauge conversion periods. It is apparent that the annual rates of loss/gain in FCD classes were significantly high after gauge conversion period (1997-2018), when compared against the period 1988-1997. More importantly, 0% (non-forest) FCD category registered an eleven-fold increase while above 71% (dense canopy forest) FCD category characterized by nine-fold decrease in the extent (ha/year⁻¹) after gauge conversion period. Improvement of transportation infrastructures in forested areas is particularly damaging because they tend to spawn networks of secondary and tertiary roads that can increase the spatial scale of their impact on forest covers. For example, the 2000-km-long Belem-Brasilia Highway, completed during the early 1970s, has now evolved into a 400-km-wide swath of forest destruction and secondary roads across the eastern Brazilian Amazon (Laurance, 1998). In the tropics, enhanced transportation infrastructures often greatly facilitate in influx of illegal migrants, hunters, miners and land speculators. In Brazilian Amazonia, for example, 95% of all deforestation occurs within 50 km of highways or railways (Laurance, 2001). Moreover the growing populations and aspirations of developing nations are justifiably creating a powerful impetus for improvement in road and railway infrastructures, yet the tropics also harbour much of the planet’s biodiversity.

**Figure 3.** Forest cover areas under different canopy density categories.
V. CONCLUSION

If nations build fewer new railway lines overall, but concentrate them in strategic locations, then they can provide better socioeconomic advantages as well as less environmental damage. There is emerging evidence that the remaining dense canopy forest cover supports an exceptional confluence of globally significant environmental values relative to degraded forests, including rich biodiversity, carbon sequestration and storage, water provision, indigenous culture and the maintenance of human health (Watson et al., 2018). Beyond outright forest clearance, forest degradation from different anthropogenic activities is the most pervasive threat facing species inhabiting dense canopy forests. It is evident that dense canopy forests around Hojai-Diphu railway line are under severe and rising pressure, and there is an urgent need for greater conservation efforts. Forest Canopy density is one of the most useful parameters to consider in the planning and implementation of afforestation, reforestation and rehabilitation of logged-over areas. Forest cover is of great interest to a variety of scientific and land management applications, many of which require not only information on forest categories, but also tree canopy density.

REFERENCES