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# CONSERVATION PRIORITIZATION AND PLANNING OF FOREST LAND: A RECIPROCAL APPROACH BY MEASURING FOREST DISTURBANCE USING GEOSPATIAL TECHNOLOGY

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**ABSTRACT**

Conservation of forestlands in West Singhbhum District of, Jharkhand State, is increasingly important because of enhanced pressure and deforestation. The present study was attempted to generate an accurate and reliable conservation prioritization map for restoration/ management activities by analyzing spatiotemporal patterns of landuse and land cover (LULC) change occurred in the part of Porahat forest division over the past three decades (1975 - 2015). Patterns of forest disturbance and the level of fragmentation were geospatially analyzed on the distance from roads, settlements, topography (slope, aspect, elevation).The results revealed that the forest cover was decreased from 60.5% (59,616 ha) in 1975 to 52% (51,257 ha) during 2015. However, there was an increase in non-forest and water bodies by 8.1% (8,045 ha) and 0.49% (314 ha), respectively compared to 1975 statistics. The prioritized conservation map was generated with an accuracy of 82 percent employing the GIS modeling. It was observed that about 22% of existing forest lands was highly disturbed. These disturbed patches need special attention/prioritization for conservation and management. The generated spatial pattern of conservation prioritization map of this study can be utilized in the regeneration of natural species and the sustainable development of forest lands.

**KEY WORDS**
Prioritization
Forest disturbance
Spatial modelling
Land use planning

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## INTRODUCTION

Natural resources, especially forestlands playing a critical role in the economic, social, and cultural development (Alberti *et al.,* 2003; DeFries, 2012). Forestlands are biologically rich and diverse ecosystems, significantly supporting in the stabilization of climate and carbon sinks (Houghton *et al.,* 2015). Most of the forestlands in India designated as protected forests. However, they are not free from various degrees of human interference. Therefore, it is essential to study landscape elements for their status, interactions, and importance. Forest disturbance (FD), a discrete event that modifies landscape, ecosystems, community and population structure along the passage of time (White and Pickett, 1985). The FD leads to processes like fragmentation, migration, local and regional extinction (Li and Reynolds, 1994; Roy and Behra, 2002; Bahamondez and Thompson, 2016). Forestlands are also experiencing temporary or permanent deterioration in their density/structure of vegetation cover and species composition (FAO, 2007). Of which, forest fragmentation is one of the key processes, that converts contiguous native forests into a set of small and isolated patches (Haila, 1999; Munguía-Rosas and Montiel, 2014).

The majority of disturbed and fragmented forests are the consequences of human interventions. The practices include forest clearance for agricultural production, regular or unsustainable logging practices (Houghton, 2005; FAO, 2007; Olagunju, 2015) and infrastructure development such as road networks and construction of dams. Also, the establishment of mines, industries, urbanization and other related entities played a major role in forest fragmentation and biodiversity loss. Hence, the quantification of FD and rate of forest fragmentation is essential. Spatial modeling is being widely used in the mapping of FD and involved as one of the key components in the procedures of forest conservation. Distrubed forestlands can be managed by adopting the efficient and sustainable forest management processes, such as regeneration of local or regional species (Roy and Tomar, 2000; Tamb *et al.*, 2011; Sharma *et al.,* 2016). For example, bamboo potentiality and its sustainability towards biomass enhancement have been discussed (Pathak *et al.,* 2015; Kumar and Kumari, 2010). Moreover, remote sensing and GIS techniques widely used in the assessment of forest disturbance, development of forest fragmentation and prioritization maps for the conservation of forests (Roy and Tomar, 2000;Martínez Ramos *et al.,* 2016; ). Several studies are taken up on forest disturbance, geospatial modeling and in the construction of conservation prioritization maps (Pressey and Bottrill, 2008; Nackoney and Williams, 2012).

Remote sensing and GIS techniques are widely used in modeling and monitoring of forest lands and other non-forest areas (Boori *et al.,* 2015; Ahmad and Goparaju, 2016 a, b ; Ahmad *et al.,* 2017 a, b) and for natural resource mapping for suitability/ vulnerability assessment (Boori and Amaro *et al.,* 2010 and Qayum *et al.,* 2015).

A reliable prioritization maps which developed based on the knowledge of distributed and fragmented forestlands are essential. Spatial modeling with the incorporation of critical data on anthropogenic activities, topography and land useland cover (LULC) may enhance the accuracy of the forest disturbance map (Brooks *et al.,* 2006; Mattson and Angermeier, 2007) and subsequently the accuracy of prioritization map (Paukert *et al.,* 2011; Martinez-Ramos *et al.,* 2016).Therefor this study was aimed to develop a reliable prioritized conservation map of Porahat forest division.

## MATERIALS AND METHODS

### Study area

A part of Porahat forest division (about 98,598 ha.), spread across Sonua, Bangaon, Goelkera, and Gudri blocks of West Singhbhum District of Jharkhand State, India, is considered for this study. Geographically, it is a rich biodiversity zone dominated by*' sal'* trees and is located between the latitudes 22º31' 32" N to 22º46'11" N and the longitudes 85º11'53" E to 85º32' 57" E (Fig. 1). The majority of the study area with undulating terrain represented by steep valleys and mountains with altitudes ranged between 199 m and 865 m from the mean sea level (MSL).

The forest area experienced tropical climates. The temperature varies from 16.6 (winter) to 44ºC (peak summer) with a mean of 27.2ºC. January is the coldest month with night temperatures falling below 10ºC, while May and June are the hottest months with a mean maximum temperature varies from 37 to 40ºC during the day and mean minimum temperature is 26ºC during the night. The average annual rainfall is about 1422±150 mm. Champion and Seth (1968) recognized the study site as Sal dominated forest and classified as Moist Peninsular Valley Sal [3C/C2e (iii)]. The natural regeneration of forest trees found to be excellent, and the composition of species varies across the moisture levels and fertile soil due to variation in aspect, the slope of the terrain/landscape. Most of the forestlands in the study characterized by *Shorea robusta* associated with *Terminalia tomentosa*, *Haldina cordifolia*, *Mangifera indica*, *Syzygium cuminii*, *Alstonia scholaris*, *Diospyros melanoxylon*, *Terminalia bellirica*, *Lagerstroemia parviflora*, *Anogeissus latifolia*, *Schleicher aoleosa*, etc. With its rich resources and diverse flora and fauna, identified as an elephant habitat. Moreover, the study site is habitat for the native tribal population.

### Data inputs

Cloud free Landsat-2 (MSS) and Landsat-8 (OLI) images downloaded from the USGS portal (Earth Explorer; http://earthexplorer.usgs.org) used in the mapping of conservation prioritization of Forest land. Initially, the images were geo-rectified to the Universal Transverse Mercator (UTM) map projection with World Geodetic System 84 (WGS84), the northern hemisphere of zone45. Subsequently, the geo-corrected images were processed for spectral radiance and transformed into Top-Of-Atmosphere (TOA) reflectance (Chander *et al.,* 2009 ; USGS, 2013). During the analysis, forest cover, land use and land cover change, topography, etc, generated as intermediate layers. The image analysis techniques and GIS modeling procedure used in this study are adopted as discussed by Qayum *et al.,* 2015 . The software's used in the analysis was ERDAS imagine (ver. 9.1) and ARCGIS (Ver. 10.1).

In addition to Landsat images, the Digital Elevation Data (ASTER DEM) of 30 m resolution was also downloaded and subsequently used in the extraction of the slope, aspect, elevation, and drainage layers the study area utilizing the spatial analyst tools of ArcGIS (Ver. 10.1) software. Ancillary data, such as village location points, road network were created through the digitization process with the assistance of Very High-Resolution Maps from the online Google maps and DIVA-GIS portal respectively.

### Land Use Land Cover (LULC) Mapping

Land use land cover (LULC) map of the study area was generated by applying the maximum likelihood classification-MLC (Supervised classification technique) algorithm. During the process, training sets (signatures) were assigned for each LULC class (forest, water, and non-forest) and obtained the spectral signature based on the spectral reflectance of Landsat data. Thus, the LULC map obtained for both the year 1976 and 2015. The identified LULC categories include forest lands, non-forest, and water spread areas. Forest lands further classified as dense (>70% of cover), medium (70-40% of cover) and open (< 40% of cover) forests. Area statistics for the study period (1976 and 2015) calculated and the extent of forest loss was estimated with the use of matrix tool in ERDAS Imagine software.

### Generation of topographic and human-made parameters

The topography, aspect, slope and elevation layers of the study area were generated from the ASTER DEM and utilized in the forest disturbance (FD) mapping (Fig. 2). Also, hydrological drainage lines, buffer areas of human-made structures such as approach roads, village/settlement were extracted with the help of Spatial Analyst tool of Arc GIS software.

### Forest Disturbance (FD) mapping

Forest disturbance (FD) is a manifestation of the impact of anthropogenic activities and natural disturbance on the forest lands. Hence, the FD mainly depends on the extent and the

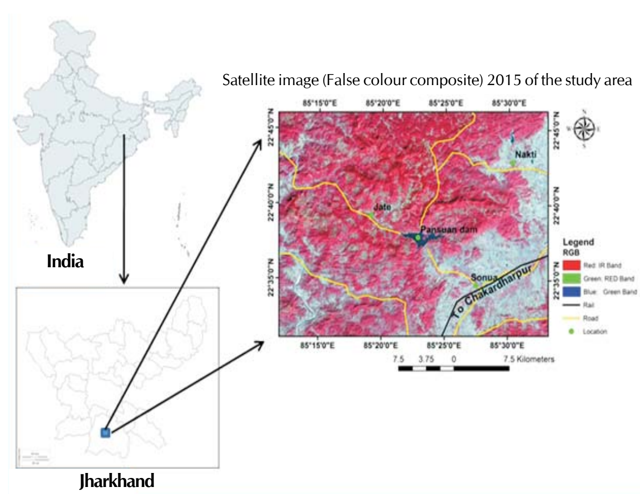


**Figure 1: Study area - part of Porahat forest division, Jharkhand State, India viewed by Landsat-8 (OLI sensor) on 19th December 2015**

density of forestlands along their ecological richness and species composition. In addition,topography (aspect, elevation, slope, drainage lines) and anthropogenic (village/ settlements and human-made structures) factors also influence the regeneration of forest cover.

As illustrated in Fig. 3, the geospatial model was executed and obtained the FD surface by integrating the LULC layer with thematic layers of influential factors for FD (Eq.1 to Eq. 3).

$$FD = (LULC * w) + TF + AF \quad ....................(1)$$

where, FD is the forest disturbance cover, LULC is the land use land cover, w is the weightage value, TF is the topographic factors and AF is the anthropogenic factors.

$$TF = \sum_{1}^{n} n = [(P_A * w) + (P_E * w) + (P_s * w) + (P_D * w)] \quad ....................(2)$$

$$AF = \sum_{1}^{n} n = [(P_V * W) + (P_R * W)] \quad ....................(3)$$

where $P_A$ is the aspect of forest land, $P_E$ is the elevation of the landscape, $P_S$ is the slope of the terrain, $P_D$ drainage buffer, $P_R$ is the road buffer, and $P_V$ buffer boundaries of villages located in the vicinity of forest lands.The factor wise weightage values of each thematic layer used in the study are given in Table 2.

Subsequently, the output of a grid cell of *30 x 30* m was obtained as a resultant of convolved layer with the spatial integration of LULC, TF and TA. About 50 iterations were repeated by moving the grid cell through the entire spatial layer. As a result, an output layer (i.e. FD) with the specific landscape metric value of a parameter was obtained. Subsequently, the associated look- up table (LUT) was generated and the data on the landscape metric values per cell was normalized to the range of 1 to 3 scale. The higher value of the zone (*i.e.* category 3) was attributed as highly disturbed forest, while the least disturbed forest was characterized as zone 1. LULC map of 2015 was finally used to mask the disturbance because our goal is to determine the disturbance within the existing forest.

## RESULTS AND DISCUSSION

### Land use land cover (LULC)

The obtained LULC layer was classified in to three distinct classes, namely forestlands, non-forest lands and water bodies (Fig. 4). The area statistics of obtained LULC classes for the year 1975 and 2015 provided in Table 3. The results revealed that the forest cover was decreased from 60.5% (59,616 ha) in 1975 to 52% (51,257 ha) during 2015. However, there was

**Table 1: Details of satellite datasets**

| Year | Date of pass | Sensor | Path/Row | Spatial Resolution (m) |
|---|---|---|---|---|
| 1975 | 8 Dec. 1975 | Landsat - 2 (MSS) | 151/44 | 60 |
| 2015 | 19 Dec. 2015 | Landsat - 8 (OLI) | 140/44 | 30 |

**Table 2: Weight table to each factor in a thematic layer based on forest disturbance**

| Thematic layer | Weight (%) | Value/Description | Rank | Category/zone |
|---|---|---|---|---|
| Land Use Land Cover($P_L$) | 10 | Dense forest | 2 | Low |
| | | Medium forest | 3 | Medium |
| | | Open forest | 4 | High |
| | | Water | 1 | Very low |
| | | Non-forest | 5 | Very high |
| Aspect($P_A$) | 10 | Non-shadow | 1 | Very low |
| | | Shadow | 3 | Medium |
| Elevation($P_E$) | 15 | 200- 400 meter | 4 | High |
| | | 400-600 meter | 3 | Medium |
| | | 600- 800 meter | 2 | Low |
| | | >= 800 meter | 1 | Very low |
| Slope ($P_S$) | 20 | <9 | 5 | Very high |
| | | 18-Sep | 3 | Medium |
| | | >= 18 | 2 | Low |
| Drainage buffer ($P_D$) | 15 | <250 meter | 5 | Very high |
| | | 250- 500 meter | 4 | High |
| | | 500-750 meter | 3 | Medium |
| | | 750- 1000 meter | 2 | Low |
| | | >= 1000 meter | 1 | Very low |
| Village buffer ($P_V$) | 15 | <1 Km | 4 | High |
| | | 1-2 Km | 3 | Medium |
| | | 2-3 Km | 2 | Low |
| | | >3 Km | 1 | Very low |
| Road buffer ($P_R$) | 15 | <1 Km | 4 | High |
| | | 1-2 Km | 3 | Medium |
| | | 2-3 Km | 2 | Low |
| | | >3 Km | 1 | Very low |

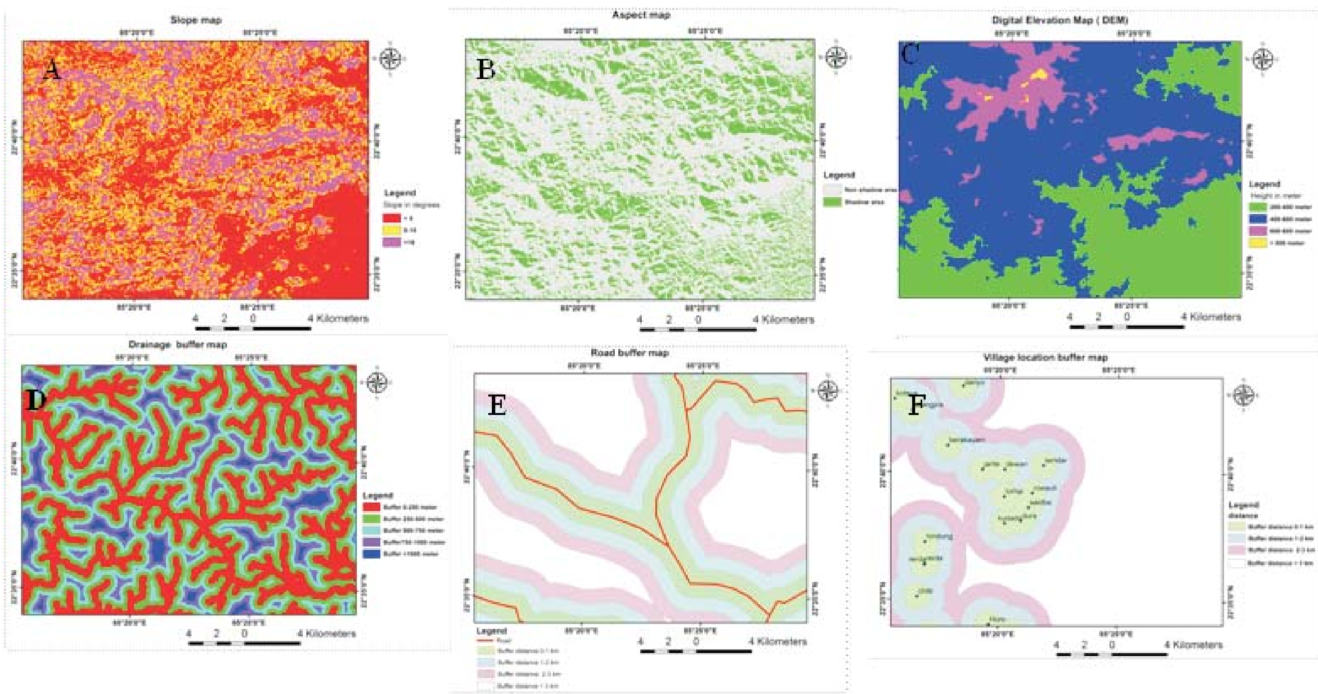


**Figure 2: Thematic layers used as for in forest disturbance mapping: A) Slope map, B) Aspect map, C) Digital elevation model - DEM and buffers of major drainage lines (D), road network (E) and settlements/village (F)**

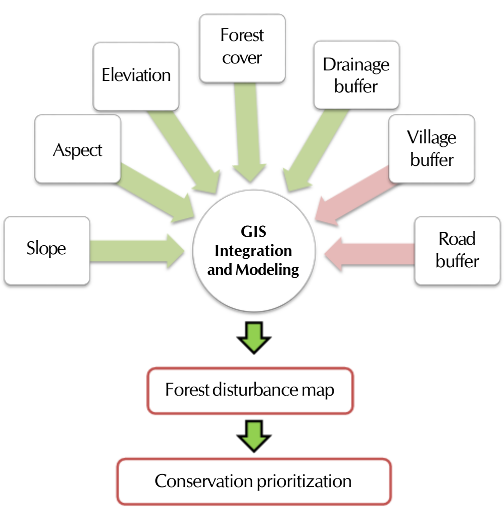


**Figure 3: Flowchart for forest land conservation prioritization**

an increase in non-forest and water bodies by 8.1% (8,045 ha) and 0.49% (314 ha), respectively compared to 1975 statistics. In the due course of developmental activities in the study area, a reservoir *"Pansuan dam,"* was constructed, which resulted in the increased area of water-bodies with respect to 2015 Landsat image.

The major reasons for the deteriorating condition of forests regarding quality and quantity are illegal felling as well as livelihood dependency on existing forest by villagers/farmer and inhabitants of the areas. Farmers tend to utilize the land near the drainage because of the high soil fertility and high moisture conditions. Cattle grazing is also frequently near the fringes of the forest. Extension of road networks through the forests by carving across the forestlands is one of the cause for further deterioration of the forests. Furthermore, demand for food, fuel, timber exploits the economically important tree species. Thus, the fringe of the forest, which is mainly open is always under such anthropogenic and biotic pressure.

**Status of forest disturbance**

The rate of forest disturbance (FD) over the study area between the year 1975 and 2015 was analyzed by integrating the LULC with the AF and TF factors. The FD map (Fig. 5) of the illustrated that the FD was more (21.6%) especially in the vicinity of the major villages/settlements with the well-connected road network and prevalent cultivation practices. Thus, the loss of forest cover (8.5%) can be accounted as the resultant of anthropogenic activities with the enhanced settlements/villages and the extended road networks compared to the year 1975.

Moreover, the computed disturbance index was obtained at a range of 1.3 to 4.14. The rate of forest disturbance was classified into three categories: low (1.2 to 2.85), medium (> 2.85 to < 3.49) and high (3.49 to 4.14). The mixed formation of forestlands has the highest area under low disturbance. Although, the disturbance mostly occurred in the degraded areas, however, most of the natural formations are relatively undisturbed. It was observed that about 21.6% (11,045 ha) of the forestland was categorized as highly disturbed, while about 47.6% (24,401 ha) was shown moderate and the rest of the 30.8 % (15,811 ha) of the forestland exhibited the least level of disturbance (Fig. 6). The accuracy of obtained forest disturbance map in this study was about 82% which is less

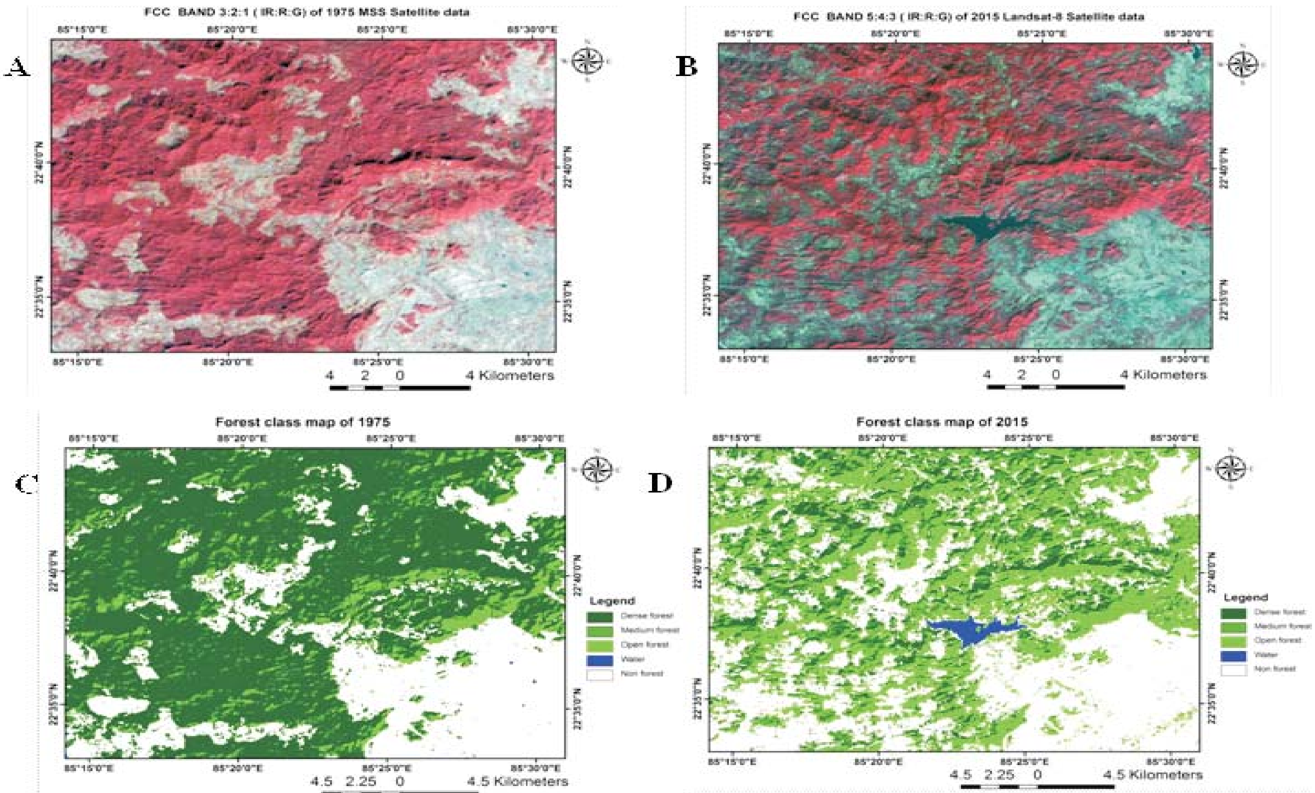


**Figure 4: False color composite (FCC) viewed by Landsat MSS on date: 8 Dec. 1975 (A), Landsat-8 on19 Dec. 2015 (B), land use land cover (LULC) maps of the study area for the year 1975 (C) and (D) 2015, respectively**

**Table 3: Land uses land cover statistics for the year 1975 and 2015**

| Land cover types | 1975 Area (Ha) | % | 2015 Area (Ha) | % |
|---|---|---|---|---|
| Water | 132 | 00.1 | 446.0 | 0.5 |
| Non Forest | 38850 | 39.4 | 46895 | 47.5 |
| Forest | 59616 | 60.5 | 51257 | 52.0 |
| Total | 98598 | 100 | 98598 | 100 |

than the reported accuracy of 90% by Zimmerman *et al*. (2013) and of 80-90% reported by Varjo (1997).

Most of the forestlands related to higher levels of disturbance occurred in the vicinity of the main villages. It also attributed that the developmental activities such as roads and other essential in fractural developments resulted in the disturbance of forest cover. Also, the low undulations (slope) of terrain facilitated easy access to reach forest lands for human interventions. Hence, the majority of forest lands in the vicinity of villages with streams and low undulations (slope) terrains are disturbed heavily. In the case of moderately disturbed forest lands, due to moderate to high undulated slopes, deep streams and hills with medium-dense vegetation are relatively inaccessible to anthropogenic activities. The areas of low disturbed forest lands identified in the localities far from the roads and rivers which are readily available for human activities. Dense vegetation mainly dominates theses localities with a terrain of deep valleys, mountains (northern aspect), high-to-very high slope and elevation were found highly inaccessible for anthropogenic activities.

**Influence of topographic parameters on forest disturbance:** The northern aspect (*i.e.* shadow area) of the forestlands influenced the level of forest disturbance. The forest lands located in the northern aspect from NW340º to NE70º was showed the least disturbance (25.3%). It can be attributed that due to higher moisture with fertile soil facilitated a better environment for the regeneration of forest cover compared to other aspects, *i.e.* non-shadow area. Similar results were reported by Jin *et al.* (2008), where the highest density ofproper moisture and fertile soils, there the regeneration of forest seedling and sapling densities was significantly greater in the north-facing forests. Therefore, the forestlands located in the southern aspect (non-shadow area) have degraded more (74.7%) when compared to the northern aspect forests. Given this, while assigning weightages for evaluating forest disturbance, higher values (*i.e.* 3) were assigned to non-shadow (*i.e.* Southern aspect) when compared to the northern aspect (*i.e.* 1). As described in Wachiye *et al.* (2013), anthropogenic

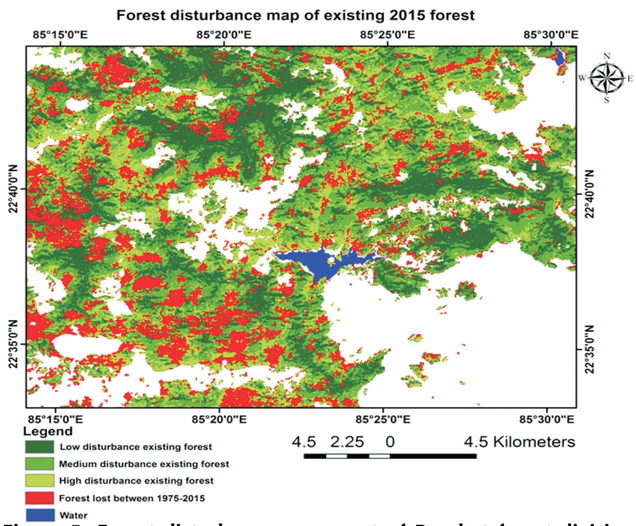


**Figure 5: Forest disturbance map, part of Porahat forest division area, Jharkhand, India**

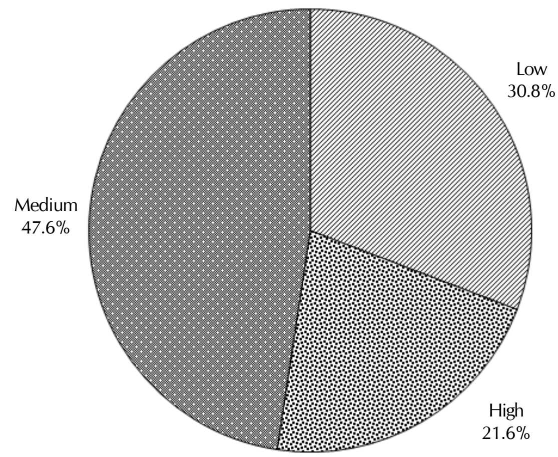


**Figure 6: Graphical representation of forest disturbance area in the part of Porahat forest division area, Jharkhand, India**

activities are more in forest lands with gentle slopes, relative flat terrains, lower elevation, close to roads and settlement-prone to a higher probability ofdisturbances compared to the forestlands with steep slopes, with high elevation and which are far from roads and settlement.

Accessibility of vegetation in steep slopes is highly impossible for anthropogenic interventions. Hence, while assigning the ranks for the slope component as 4, 3, and 2 for high (>=18°), moderate (9-18°), and low (<9°) level slopes respectively as per Saqui *et al*. (2011). In this study, it was observed that due to complex terrain and inaccessibility to steep slopes and deep valleys, the rate of forest disturbance is less and enhance the scope for sustainability of forest located at the relative degree of slopes.

Elevation played a major role in FD influence. The DEM (200 to >=800 m) was classified into four distinct zones with an equal interval of 200 m (Fig. 2).As the elevation increases, the rate of FD was less. It may be due to minimal accessible for anthropogenic activity. The level of FD was more at the lower elevations (*i.e.* 200-400 m) due to human activity such as settlement, cattle-grazing and illegal felling compared to higher elevations (>=800 m) similar finding was observed by Jain *et al*. (2016). Unfortunately, due to human interventions, under the forest developmental activities at higher elevations (400 to 600 m), thick and dense forests have been lost along the streams. As the soils, adjacent to river/streams are highly fertile, the majority of forest lands encroached gradually occupied, cleared and lifted for agriculture. Moreover, free grazing activities across the streams and rivers by livestock also heavily disturbed the riparian forests of this region.

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