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Forest changes and fragmentation analysis of Hazaribagh district of Jharkhand, India using Geo-spatial technology

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Abstract
Forest cover and its fragmentation need to be assessed regularly for sustainable management of natural resources. In this study forest cover change and its fragmentation based on forest cover classifications derived from remotely sensed images. The study assesses the temporal changes of forest-cover maps from 1987 and 2019 using ArcGIS and FRAGSTATS. Visual interpretation technique involving on screen digitization was used for mapping and assesses the change statistics. In addition, FRAGSTAT was carried out to find the landscape matrix. Results showed that dense forest covers around 21.64% of study area in year 1987 which has decrease to become 18.90% in year 2019. It has also been observed that number of patches for dense forest increase from 116 to 226 and open forest increased from 161 to 446 between 1987 and 2019.This work demonstrates change in forest structure and pattern using geospatial technology which is cost effective and less time consuming.

Keywords: Forest cover, fragmentation, geospatial technology, landscape metrics

1. Introduction
Forest cover change and its fragmentation at landscape level in the tropical region draw an attention within the last few decades. The changes in forest pattern and structure have had direct effect on loss of biodiversity, climate change and soil conservation (Johnson *et al*.,1997; Park & Stenstrom,2008; Singh *et al*., 2016) [8, 16, 20]. The growth of population is directly linked to utilization of land which plays an important role in change in forest structure and pattern (Singh *et al.*, 2016; Kumar *et al*.2018) [20, 9]. As per report of Forest and Agriculture Organization (FAO) 13M ha of forest has been loosed between 1990 and 2000(FAO, 2010) [3]. Therefore, monitoring the change in forest cover and its dynamics required for research, management and planning purposes.

Forest degradation due to anthropogenic activity plays an important role in natural forest. Although, it is challenge to understand the natural forest degradation at landscape level. At present, geospatial technology facilitate data which can be use to assess the forest cover at regular interval and low cost (Burai *et al*., 2015) [2]. Change in forest area can be detected using different data and quantify the magnitude and pattern of change (Hang *et al*., 2014; Kumar M and N Kumar, 2011) [7, 10]. To understand and quantify changes in landscape structure, pattern and dynamics, it is important to have a clear understanding of landscape indices. These indices include area, patch density, size, edge, shape, nearest neighbour, diversity and interspersion, which have been developed in the past few decades to provide useful information about the composition and configuration of forest landscape (Li *et al*., 2000; Olsen *et al*., 2006; Paudel and yuan, 2012) [11, 15, 17]. Some spatial statistics programs like FRAGSTAT have been effectively used for landscape change analysis (Szabo *et al*.2012) [22]. Earlier works have demonstrated the applications of these tools to illustrate spatio temporal dynamics of forest change (Southworth *et al*., 2004; Singh *et al*., 2016; kumar *et al*., 2018; Gabril *et al*., 2019) [21, 20, 9, 4].

2. Material and Methods
2.1 Study area
Hazaribagh district is a part of Chotanagpur plateau consists of three natural divisions i.e Medium Plateau, Lower Plateau and Damodar Valley. The total geographical area of the district is 4313 km² lying between latitude 23°39'53.26"N to 23°57'58.797"N and longitude85°5'29.86"E to 85°55'41.565"E shown in figure-1.

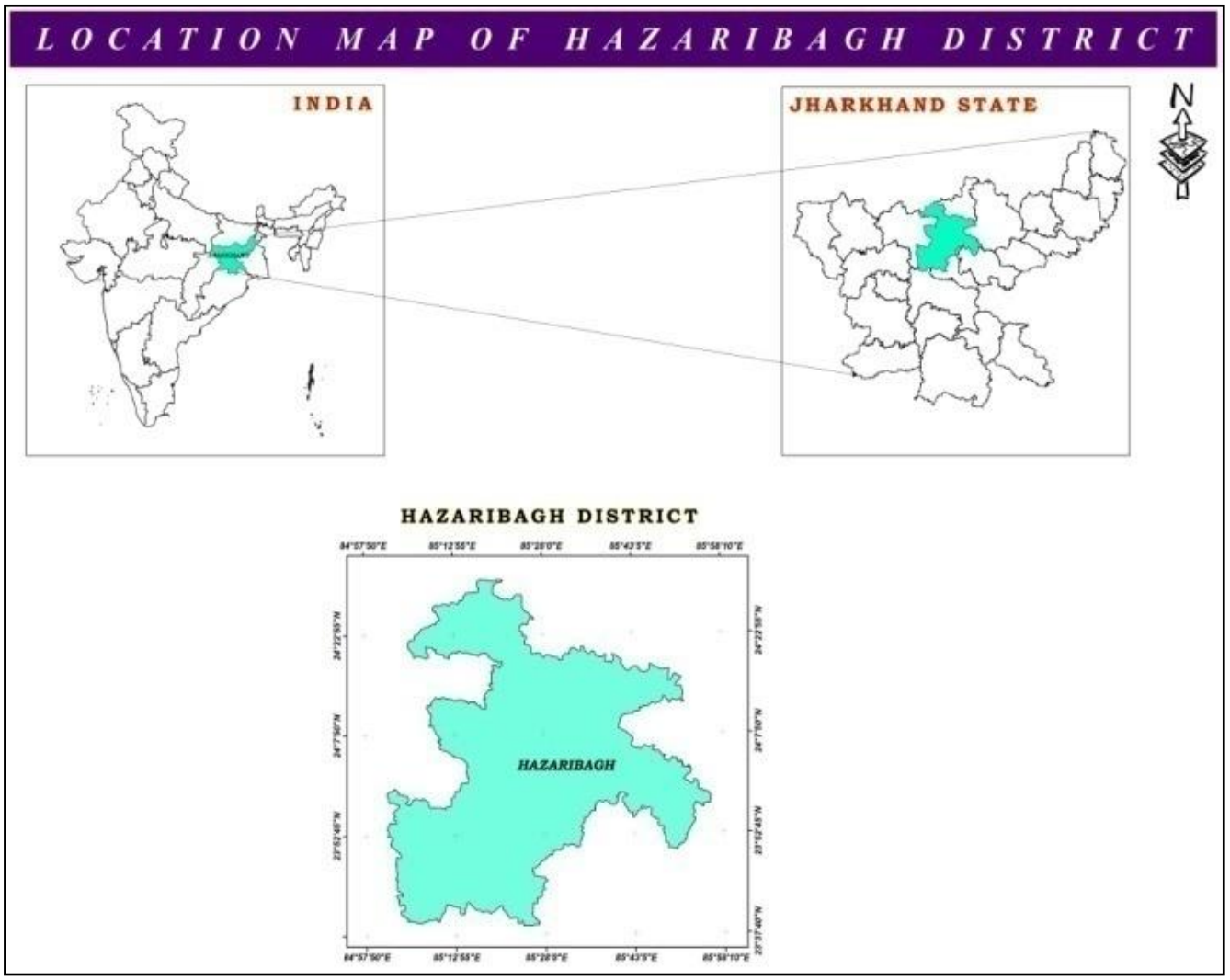

Fig 1: Hazaribagh district of state Jharkhand, India

Table 1: Population increase in Hazaribagh district

Year	Population	Population growth
1981	854377	+2.88
1991	1101171	+2.57
2001	1378881	+2.27
2011	1734495	+2.32

2.2 Data acquisition and pre-processing

Geometrically corrected Landsat satellite data for two time period i.e. December 1987 and July/August 2019 were downloaded from USGC website (USGS; http:// www.usgs.gov/in) [23] and details are given in Table 2. Also, Survey of India (SOI) topographic maps (Figure2) and the LULC map at the scale of 1:50,000 was used in this study (Table 3). LULC classified maps were downloaded from NRSC, Department of Space, Govt. of India website (http://bhuvan.nrsc.gov.in) [6]. The accurate boundary of the study area was used to subset the study area from the satellite scenes.

Table 2: Details of satellite images

Satellite/ Sensor	Year/date	Path/row	Bands used	Spatial Resolution(m)
Landsat5/TM	6th December 1987	140/43 140/44	1,2,3,4	30
Landsat 8/ OLI	1st August 2019 23rd July 2019	140/43 140/44	2,3,4,5	30

Table 3: Detail of topographic maps and the LULC map

Data	Year of publication	Topographic maps Number	Published Agency	Scale
Topographic maps	1977, 1978, 1981, 1982, 1983, 1984	72H/3; 72H/4; 72H/6; 72H/7; 72H/8; 72H/11; 72H/12; 72H/15; 72H/16; 73E/1; 73E/2; 73E/5; 73E/6; 73E/9; 73E/13.	Survey of India	1: 50,000
Topographic Maps	2009	G45T6; G45T7; G45T11; G45T15; G45T4; G45T8; G45T12; G45T16; F45B1; F45B2; F45B5-2009, F45B5, F45B9, F45B13.	Survey of India	1: 50,000
LULC classified map	2005–2006 and 2011–2012	-	NRSC, India	1: 50,000

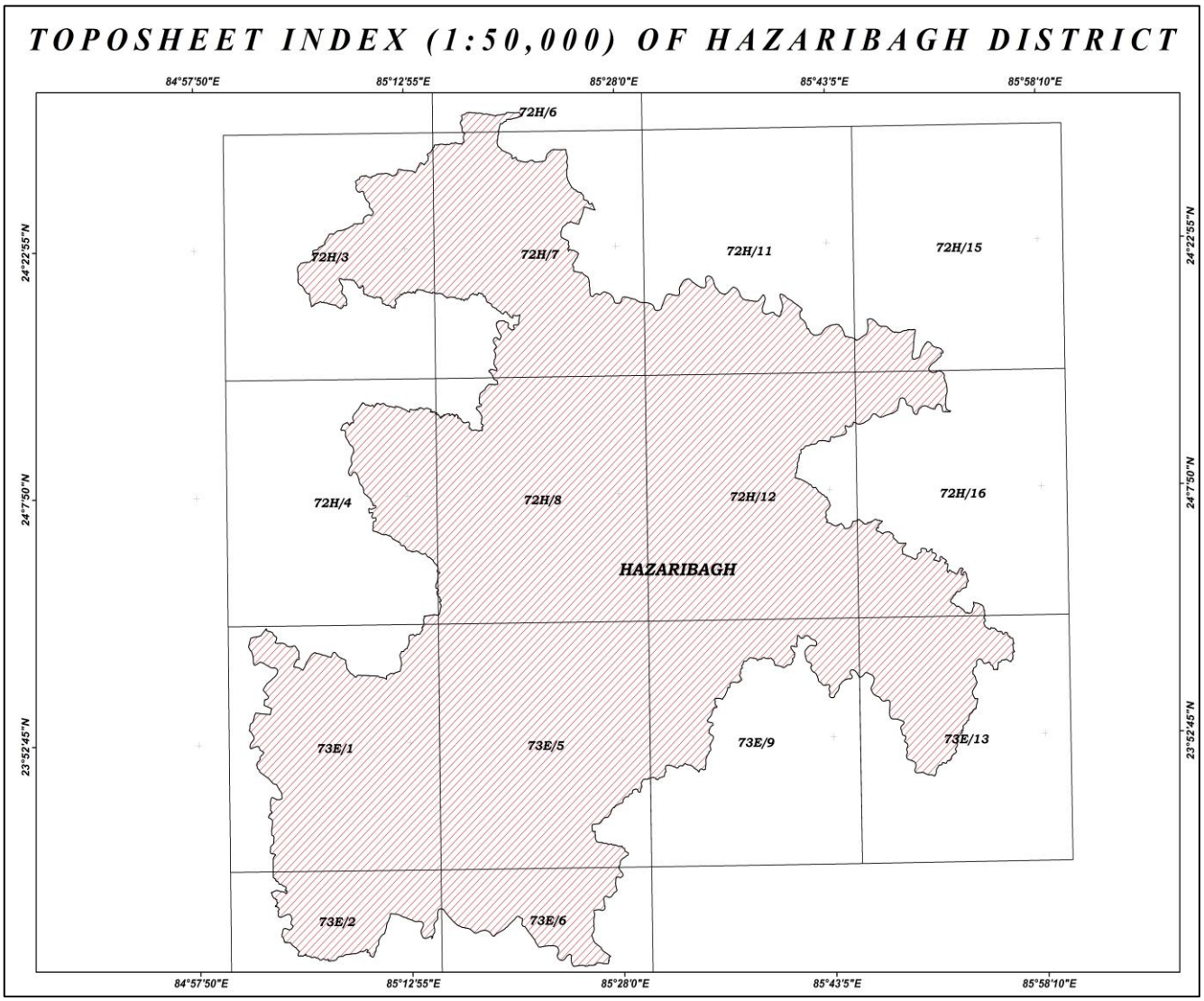

Fig 2: Toposheet Index Map of Hazaribagh district

2.3 Forest classification

The spatial and temporal analysis of landscape structure and changes was carried out systematically. First of all, Forest maps were prepared and changes were evaluated, secondly fragmentation of the study area was evaluated and lastly statistical analysis was applied in the study area.

Forest maps were prepared using on screen visual interpretation in ArcGIS software based on interpretation key i.e tone, texture, association shape, size, pattern, and shadow (Table.4). Landsat satellite data, toposheet, LULC classified maps with extensive field visits were used to derive the forest cover maps and its statistics of different date data. After the interpretation, topologies were prepared and cleaning is done. Finally, the attributes are given to define the classes i.e dense forest, open forest and non-forest area.

Table 4: Interpretation key for different forest cover classes:

S N	LU/LC Category	Tone	Size	Shape	Texture	Pattern	Association
1	Deciduous forest	Different tone of red	Varying in size	Irregular	Smooth to Medium depending on crown	Contiguous to non-contiguous	With different forest types and species in undulating areas
2	Forest Scrub	Red to Dark red	Varying in size	Regular to irregular	coarse	Contiguous to non-contiguous	Forest fringes and amidst forest areas

2.4 Landscape metrics analysis

In order to quantify changes in spatial and temporal patterns within the study area, landscape indices were calculated using FRAGSTATS (McGarigal and Marks, 1994) [13]. The advantage of using FRAGSTATS is that classified satellite images can be used directly (Rempal *et al*., 1999; Singh *et al*., 2014; McGarigal *et al*., 2002) [18, 19, 12]. In this study, landscape metrics at patch and class level were calculated for both date classified images. In this study only 8 matrices (Number of Patches–NP, Patch Density–PD, Largest Patch Index–LPI, Total Edge–TE, Edge Density–ED, Landscape shape index–LSI, Interspersion-Juxtaposition Index–IJI, Effective Mesh Size–MESH, Percentage of Landscape–PLAND) has been selected based on previous studies (Midha and Mathur, 2010; Gunlu *et al*., 2009; Singh *et al*., 2016) [14, 6, 20]. Table- 5 lists the set of eight metrics (8) were chosen in the present study.

Table 5: Metrics used at class level to quantify fragmentation **(**McGarigal and Marks, 1995; Kumar *et al*., 2018 Gabril *et al* 2019**)** [13, 9, 4]

Metrics and Units	
PLAND Percentage of land adjacencies as proportion of a given class type related to the total area.	PLAND = $P_i = \frac{\sum_{j=1}^{n} a_{ij}}{A}(100)$ P_i = proportion of the landscape occupied by patch type (class) i. a_{ij} = area (m^2) of patch ij. A = total landscape area (m^2)
NP Total number of patches in this class	NP = n_i n_i= number of patches in the landscape of patch type (class) i.
PD (per unit per ha) Ratio of number of patches and the area of investigated	PD = $\frac{n_i}{A}$(10,000) (100) n_i = number of patches in the landscape of patch type (class) i. A = total landscape area (m^2).
LPI – Ratio of largest patch area to investigated area	LPI = $\frac{\max_{j=1}^{n}(a_{ij})}{A}(100)$ a_{ij}= area (m^2) of patch ij. A =total landscape area (m^2)
TE (m) Sum of length of all edge segments for the class	TE = $\sum_{k=1}^{m} e_{ik}$ e_{ik} = total length (m) of edge in landscape involving patch type(class) i; includes landscape boundary and background segments involving patch type i.
ED - Edge Density , m/ha Total length of edge involving the corresponding land use land cover class divided by total area(ha).	ED = $\frac{\sum_{k=1}^{m} e_{ik}}{A}(10{,}000)$ e_{ik} = total length (m) of edge in landscape involving patch type (class) i; includes landscape boundary and background segments involving patch type i. A = total landscape area (m^2).
LSI- Landscape shape index average complexity of the landscape as a whole	LSI = $\frac{.25\sum_{k=1}^{m} e^*_{ik}}{\sqrt{A}}$ e^*_{ik} = total length (m) of edge in landscape between patch types (classes) i and k; includes the entire landscape boundary and some or all background edge segments involve class I
IJI- Interspersion-juxtaposition index Degree of interspersion of patches of this class, with all other classes.	

The indices of LPI, TE, ED, PD, NP and PLAND correspond to area metrics which provide indications of the degree of fragmentation for different land cover types and change images. Specifically, NP is an excellent measure of the fragmentation of a given class within the landscape since the landscape size is constant. IJI provide metrics of shape and interspersion.

3. Results and Discussion

3.1 Forest cover change

Forest area statistics of study area has been calculated for year 1987 and 2019 and presented in table 6. It was observed that the area of dense forest covers 21.64% of study area in year 1987 which has decrease to become 18.90% in year 2019. However, open forest showed increase in forest area from 23.25% to 29.68% in studied period. Most of the dense forest is converted into open forest. Main reason of increase in open forest is attributed to anthropogenic activities in the dense forest area. Increase in population and agriculture land cause the degradation of forest land which has been studied by many researchers (Southworth *et al*., 2004; Abdullah and Nakagoshi, 2007; Kumar *et al*.,2018) [21, 1, 9].

It was observed from figure 3a that northern part of study area is mostly dominated by the dense forest which gradually converted into open forest (figure 3b) and showing more fragmented in the studied period. Similar observation can be observed in centre part of study area. Many patches of forest land either converted into settlement or agriculture land. However, in the lower part of study area patches of open forest are converted into dense forest. Increase in forest area is mainly because of plantation activities in this part of study area.

Table 6: Area statistics of different land use classes of different years

Class	1985		2019	
	Area (Sq Km)	% Area	Area (Sq Km)	% Area
Dense forest	930.85	21.64	813.208	18.90
Open forest	1000.15	23.25	1224.82	29.86
Non forest area	2371.15	55.11	2064.39	50.32
Total area	4302.416	100	4302.416	100

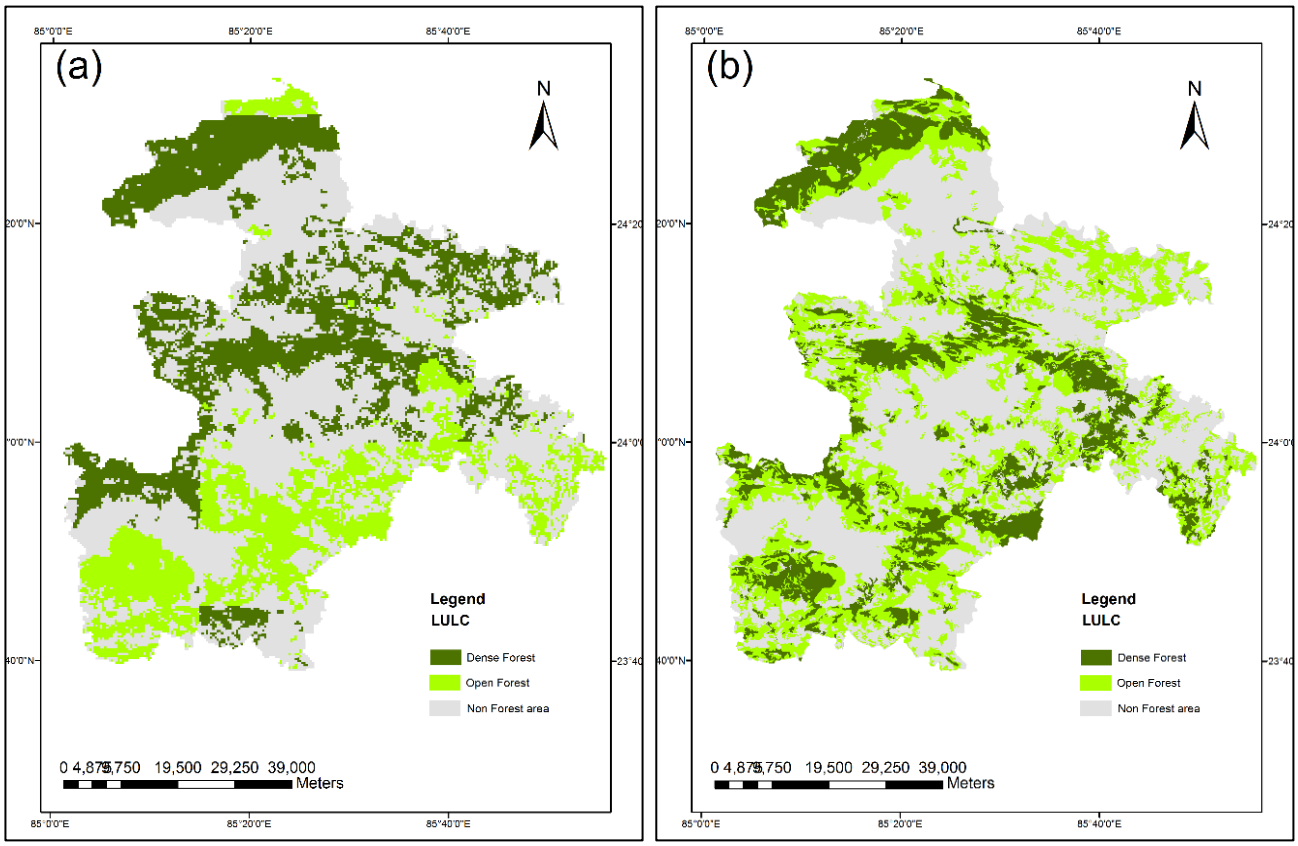

Fig 3: The classified forest cover maps of study area of years (a) 1987 (b) 2019

3.2 Fragmentation analysis

Forests fragmentation for the period of 1987 to 2019 has been shown in the table 7. Landscape metrics provided information regarding how patterns of forest cover changed over time. It has been observed that number of patches for dense forest increase from 116 to 226 and open forest increased from 161 to 446 between 1987 and 2019. The area statistics show that the area of dense forest decreases whereas open forests increase (Table 6) over time. Increase in number of forest patch indicates the forest fragmentation.

The patch density of the dense forest from 1987 to 2019 has increased from 0.0125 to 0.0243. Increase in patch density indicates that forest get disturbed or more fragmented. This may be due to rise in human population in the study area. In open forest patch density has also been increase from 0.0173 to 0.0479. The LPI of dense forest was drastically decreased from 6.351% to 2.0053% during study period. However, for open forest slightly decrease was observed. The open forest has been highly degraded by their increasing edge density. Whereas decrease in core area percentage (PLAND) in dense forest indicating high degradation of area. The increase of IJI in 2019 compared to 1987 for the dense and the open forest is from 38.6221 to 55.6898 and 39.0513 to 76.8345 respectively and indicating more uniform landscape configuration.

Table 7: Forest class-level landscape metrics

Date	Type	LULC	PLAND	NP	PD	LPI (%)	TE (m)	ED (m/ha)	LSI	IJI
1987	Dense forest	DF	13.7355	116	0.0125	6.351	2784620	2.993	19.4021	38.6221
1987	Open forest	OF	9.7735	161	0.0173	4.0517	2092350	2.2469	17.2561	39.0513
2019	Dense forest	DF	9.2912	226	0.0243	2.0053	2677690	2.8755	22.7673	55.6898
2019	Open forest	OF	15.3952	446	0.0479	4.0502	5619560	6.0347	37.0634	76.8345

4. Conclusion

The importance of this work is to apply the geospatial technology with FAGSTATE model to assess the forest changes and its fragmentation in cost effective method. The result revealed that Landsat satellite data can be used to find out the change in forest cover using different time data. FRAGSTATS analysis demonstrate that dense forest not only become less but also been fragmented. Loss of forest and its fragmentation not only affect the flora and fauna of this region but also promote the soil loss and animal movement. This work will be useful for policy maker as well as researcher to plan accordingly for protection of forest. Our future scope of the work will be to use high resolution satellite data, a greater number of land cover class and a greater number of landscape matrix.

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