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# Landscape Fragmentation Analysis in and around Rajaji National Park, Uttarakhand, India

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***Abstract*:** The study was conducted to figure out the landscape fragmentation in and around Rajaji National Park using landscape indices viz., total Class area (CA), number of patches (NP), patch density (PD), interspersion and juxtaposition Index (IJI) and largest patch index (LPI) over the classified LULC map of the study area during 1993 and 2015. Landsat imageries through spatial analyst programme FRAGSTATS 4.2.Comparative study of the landscape indices inside the protected area (2000 m buffer) and innermost protected area (excluding 2000 m buffer area) during 1993 and 2015 indices such as NP, PD, LPI decreased over time while, IJI got increased with respect to forest patch, which means interspersion is more and patch adjacency is getting increased during the analyzed period, which means inside the protected area fewer disturbances were observed. Meanwhile, comparison of landscape indices outside protected area (2000 m buffer outside PA) during 1993 and 2015 revealed that NP, PD increased overtime while, LPI and IJI decreased over time. Lower values of IJI characterize landscapes in which the patch types are poorly interspersed, means the outer side of protected area are more fragmented with respect to the inside boundary.

***Keywords***: Landscape fragmentation, Digital image processing, Patch density, Largest Patch Index

In global scale, land use changes are cumulatively transforming land/ forest cover at an alarming and accelerating pace, especially in the tropical region. So, the time demands a quick and accurate assessment of the changes happening or happened to the natural resources like forest both in present as well as past respectively. Vegetation is an essential and fundamental aspect of general biodiversity, hence knowledge of its spatial distribution patterns can help in conservation (Rashid et al 2013). Moreover, forest cover changes have an impact on the supply of crucial ecosystem services such as biodiversity, climate control, carbon storage, and water supplies (Hansen et al 2013). Landscape structure and composition can also use to analyze ecological processes, which aids in landscape management (Reddy et al 2013a). Deforestation, commercial logging, and other human effects have all been monitored and assessed via geospatial analysis, which is frequently employed in the area of ecology (Wang et al 2010, Hou et al 2013). Due to the wide availability of Landsat satellite data, it has also received attention in detecting land use change and forest fragmentation (Rajani and Smitha 2017). Remotely sensed data, also with GIS tools and ground observations, is essential for cost-effective monitoring, and the generated information aids in smart planning and decision-making (DeFries et al 2007, Carranza et al 2014). Landscape ecology is largely founded on the notion that environmental patterns strongly influence ecological processes. A disruption in landscape patterns may therefore compromise its functional integrity by interfering with critical ecological processes necessary for population persistence and the maintenance of biodiversity and ecosystem health. For these and other reasons, much emphasis has been placed on developing methods to quantify landscape patterns, which is considered a prerequisite to the study of pattern-process relationships. The landscape consists of patches of different land covers. Patch characterization is the best method to analyses patch size, shape, and arrangement. The patches are the representation of past and present environmental conditions and human dimensions. Disturbance zones have also been investigated using factors such as patch density, porosity, fragmentation, and juxtaposition (Reddy et al 2013b). The present study aims at evaluating the landscape in and around the protected area. Spatial pattern analysis program FRAGSTATS 4.2 is used here for quantifying the structure (i.e., composition and configuration) of landscapes (Mcgarigal 2015).

## MATERIAL AND METHODS

**Study area:** Rajaji National Park is situated in the state of

Uttarakhand. In the year 1983, Rajaji Wildlife Sanctuary of Uttaranchal was merged with Motichur and Chilla wildlife sanctuaries and made into Rajaji National Park is situated along the hills and foothills of Shiwalik ranges in the Himalayan foothills and represent the Shiwalik eco-system (Fig. 1). Combining three sanctuaries viz. Chilla, Motichur and Rajaji National Park is spread over the Pauri Garhwal, Dehradun, and Saharanpur districts of Uttarakhand. The Motichur and Rajaji sanctuaries are contiguous and are separated from the Chilla Sanctuary to the south-east by the Ganges River and the Chilla River. Motichur and Rajaji wildlife sanctuaries lie to the north and south of the Siwalik Ridge and are dissected by many ravines carrying water which descend from the main ridge, becoming broad pebble/boulder filled streams in the plains. These streams remain dry for most of the year but become raging torrents during the monsoon. The area is covered with diverse forest types ranging from semi-evergreen to deciduous and from mixed broad-leaved to Terai grassland and has been classified as Indus-Ganges Monsoon Forest type. Lofty strands of sal dominate in many parts. The study area falls in the following forest ranges of Rajaji National Park division viz., Dholkhand West, Dholkhand East, Chillawali and Haridwar ranges.

**Methodology:** Monitoring and evaluating the land cover change in and around protected area (Rajaji National Park) via bi-temporal change analysis of the study area within the addressed periods of 1993 and 2013, inside protected area (in 2000 m buffer inside PA), outside protected area (in 2000 m buffer outside PA) and innermost protected area (excluding 2000 m buffer area) using 1993 and 2015 datasets. Firstly, Acquisition of bi-temporal imageries (1993 and 2015) from USGS Earth Explorer web portal (https://earthexplorer.usgs.gov/) were made (Fig. 3). The entire image related activities viz. processing, analysis and extraction etc. has been done using ERDAS 2014 software and Arc Map 10.3.1. Digital image processing includes procedures for pre-processing, enhancement, and information extraction. Layers import and Layer stacking were the first step which were done after the data acquisition. Image processing requires several steps for the better identification of the image features. It is a kind of numerical manipulation of digital images including the procedures for image enhancement and information extraction. Spectral enhancement has been performed on both the images studied during the classification and interpretation steps. Layer stacking, FCC creation and image enhancement was done (Fig. 4). Supervised classification involves on-screen digitizing of polygons on training sites. Google earth synchronized training areas for Landsat TM 2015 data were used to develop signatures for different classes in the region of interest. Buffer creation and extraction (2000 m) both inside and outside the study area. Flow chart of the methodology adopted for the study are shown below (Fig. 2)

**Fragmentation analysis using fragstats:** A spatial pattern analysis programme for categorical maps developed by Kevin Mcgarigal and Eduard ENE (McGarigal and Marks, 1995). Through this programme, landscapes subjected to analysis are user defined and can represent any spatial phenomenon. FRAGSTATS version 4.2simply quantifies the areal extent and spatial configuration of patches within a

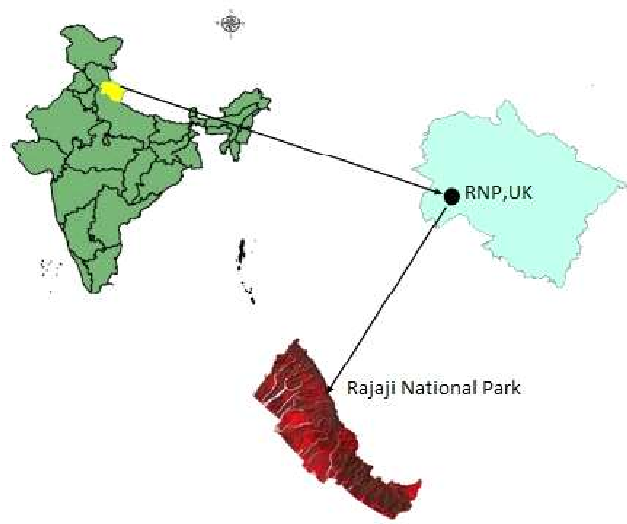


**Fig. 1.** Study area (30˚3' 29" N, 78˚10' 22" E)

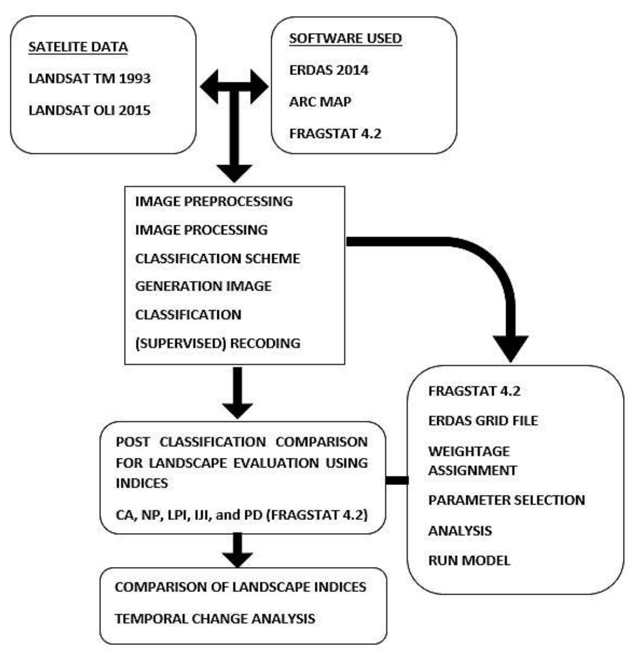


**Fig. 2.** Flowchart of methodology

landscape; it is incumbent upon the user to establish a sound basis for defining and scaling the landscape, including the extent and grain of the landscape and the scheme upon which patches are classified and delineated. FRAGSTATS computes 3 groups of metrics viz., *patch-level* – nature of patches - average size, size of core area, *class-level* – nature of each type - amount and distribution of each type and *landscape-level* – nature of the landscape - pattern, configuration of entire mosaic, landscape diversity and heterogeneity (Mcgarigal 2015). In this study, landscape evaluation was conducted using indices like CA (Class Area), NP (Number of Patches), PD (Patch Density), LPI (Largest Patch Index) and IJI (Interspersion and Juxtaposition Index) through FRAGSTATS version 4.2 spatial analyst programme.

**Indices Used for the Present Study**

**Total classarea (Hectares):** CA equals the sum of the areas ($m^2$) of all patches of the corresponding patch type, divided by 10,000 (to convert to hectares); that is, total class area.

**Number of patches (unit-none):** NP equals the number of patches of the corresponding patch type (class). Number of patches of a particular patch type is a simple measure of the extent of subdivision or fragmentation of the patch type. Of course, if total landscape area and class area are held constant, then number of patches conveys the same information as patch density or mean patch size and may be a useful index to interpret. Number of patches is probably most valuable, however, as the basis for computing other, more interpretable, metrics. Note that the choice of the 4-neighbor or 8-neighbor rule for delineating patches will have an impact on this metric.

**Patch density (Number per 100 hectares):** PD equals the number of patches of the corresponding patch type divided by total landscape area ($m^2$), multiplied by 10,000 and 100 (to convert to 100 hectares). If total landscape area is held constant, then PD and NP convey the same information. Like NP, PD often has limited interpretive value by itself because it conveys no information about the sizes and spatial distribution of patches. Note that the choice of the 4-neighbor or 8-neighbor rule for delineating patches will have an impact on this metric

**Largest patch index (percent)**: LPI equals the area ($m^2$) of the largest patch of the corresponding patch type divided by total landscape area ($m^2$), multiplied by 100 (to convert to a percentage); in other words, LPI equals the percentage of the landscape comprised by the largest patch. Total landscape area (A) includes any internal background present. Largest patch index at the class level quantifies the percentage of total landscape area comprised by the largest patch. As such, it is a simple measure of dominance.

**Interspersion and juxtaposition index (percent):** IJI equals minus the sum of the length (m) of each unique edge type involving the corresponding patch type divided by the total length (m) of edge (m) involving the same type, multiplied by the logarithm of the same quantity, summed over each unique edge type; divided by the logarithm of the number of patch types minus 1; multiplied by 100 (to convert to percentage). Consequently, a landscape containing 4 large patches, each a different patch type and a landscape of the same extent containing 100 small patches of 4 patch types will have the same index value if the patch types are equally interspersed (or adjacent to each other based on the proportion of total edge length in each edge type).

## RESULTS AND DISCUSSION

The NP, PD, LPI decreased overtime while IJI got increased, which means interspersion was more and patch adjacency was getting increased. Inside the protected area (2000m buffer) during the study period from 1993 to 2015, there was an increase of 2355 ha in the total class area of forest class type and shown a considerable decrease in agriculture and habitation.

Moreover, there is less disturbance or fragmentation in the innermost area of the National Park. Number of Patches (NP), Patch Density (PD) and Largest Patch Index (LPI) were decreased in 2015 when compared to 1993 imagery studied (Table 1 and Fig. 5). Interspersion and Juxtaposition Index (IJI) was more with respect to forest class type which means,

**Table 1.** Landscape indices inside protected area (2000 m buffer) during 1993 and 2015

| Class types | Total class area (Hectares) | | Number of patches | | Patch density (Number per 100 hectares) | | Largest patch index (Percent) | | Interspersion and juxtaposition index | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1993 | 2015 | 1993 | 2015 | 1993 | 2015 | 1993 | 2015 | 1993 | 2015 |
| Forest | 11058.66 | 13413.67 | 1796 | 1278 | 1.78 | 1.27 | 7.69 | 7.64 | 39.50 | 55.94 |
| Agriculture + Habitation | 6142.77 | 3976.31 | 3549 | 5186 | 3.51 | 5.14 | 0.90 | 0.20 | 42.19 | 27.09 |
| Dry river bed | 898.29 | 239.02 | 1127 | 227 | 1.12 | 0.22 | 0.10 | 0.04 | 44.05 | 0.13 |
| Open scrub | 844.02 | 1182.91 | 1233 | 3154 | 1.22 | 3.13 | 0.18 | 0.20 | 48.88 | 17.45 |
| Water | 1.44 | 0 | 14 | 0 | 0.01 | 0 | 0 | 0 | 18.10 | 0 |

interspersion is more, and patch adjacency is getting increased.

Mean while, studied landscape indices outside the protected area viz. NP, PD were increased overtime and LPI decreased overtime; IJI was less which means interspersion was less and patch adjacency was getting decreased, that is more fragmented outside. Here, along with forest class type, agriculture and habitation also show a considerable increase in the total class area (Table 2).

It was quite evident that, there was more disturbance or fragmentation in the outermost buffer area of the National Park. Number of Patches (NP), Patch Density (PD) got increased in recent imagery. Largest Patch Index (LPI) and Interspersion and Juxtaposition Index (IJI) decreased in 2015 when compared to 1993 imagery (Table 2 and Fig. 6). IJI with lower values characterize landscapes in which the patch types are poorly interspersed (i.e., disproportionate distribution of patch type adjacencies).On the contrary, studied landscape indices of innermost protected area viz., NP, PD, LPI decreased overtime; while IJI was more, which means interspersion was more and patch adjacency was getting increased. In the inner most region of the protected area, agriculture and habitation decreased to a great extent and total forest class area increased (Table 3).

There was less disturbance or fragmentation in the innermost area of the National Park. Number of Patches (NP), Patch Density (PD) and Largest Patch Index (LPI) were decreased in 2015 when compared to 1993 imagery. Interspersion and Juxtaposition Index (IJI) was more with respect to forest class type which means, interspersion was more, and patch adjacency was getting increased (Table 3 and Fig. 7). The rate and extent of forest fragmentation both inside and outside of the National Park during the mentioned study period revealed that declaration and merging of Rajaji, Motichur and Chilla Wildlife Sanctuaries into National Park quite evidently helped in reducing fragmentation and augmenting vegetation cover. Increased disturbances caused by anthropogenic activities will increase fragmentation and thus indirectly decrease forest cover of the area (Aditya et al 2018). Outside the National Park clearly indicates a patch type of increased fragmentation. Similar approaches were also been adopted by several authors all over the world (Midha and Mathur 2010, Lamine et al 2018).

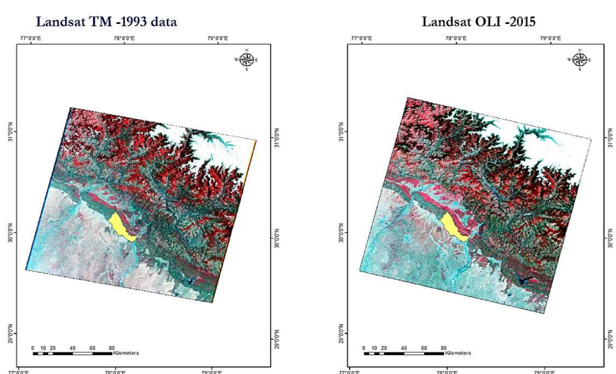


**Fig. 3.** Acquired Landsat Imageries of study area (Path 146, Row 039)

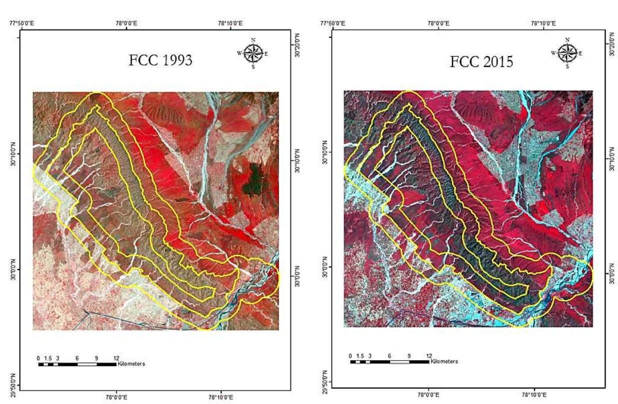


**Fig. 4.** FCC and image enhancement of study area

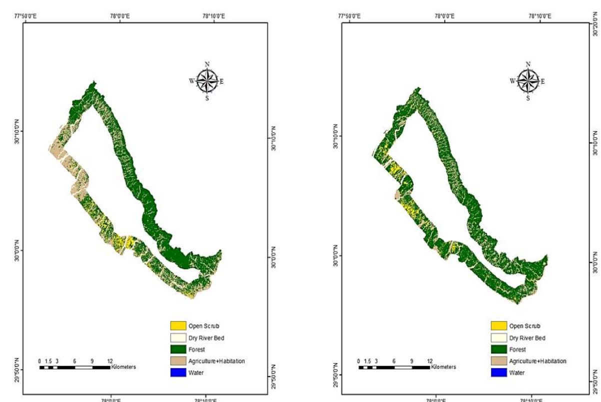


**Fig. 5.** Comparison of classified buffer area of 2000 m (Inside protected area)

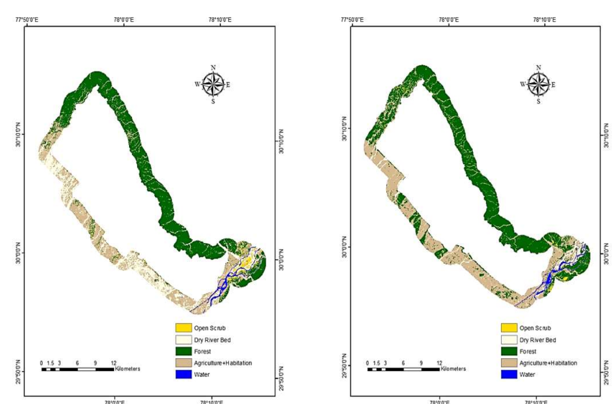


**Fig. 6.** Comparison of classified buffer area of 2000 m (Outside protected area)

**Table 2.** Comparison of landscape indices of outside the protected area (2000 m buffer) (1993 and 2015)

| Class types | Total class area (Hectares) | | Number of patches | | Patch density (Number per 100 hectares) | | Largest patch index (Percent) | | Interspersion and juxtaposition index (Percent) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1993 | 2015 | 1993 | 2015 | 1993 | 2015 | 1993 | 2015 | 1993 | 2015 |
| Forest | 11460.96 | 12691.64 | 1376 | 1768 | 0.96 | 1.23 | 6.50 | 5.93 | 41.88 | 33.92 |
| Agriculture + habitation | 8063.01 | 10443.06 | 3004 | 3639 | 2.09 | 2.53 | 0.97 | 3.49 | 71.50 | 55.72 |
| Dry river bed | 4524.39 | 848.52 | 1759 | 915 | 1.22 | 0.64 | 0.93 | 0.04 | 31.32 | 2.83 |
| Open scrub | 405.36 | 320.60 | 579 | 1630 | 0.40 | 1.13 | 0.04 | 0.02 | 62.60 | 13.01 |
| Water | 441 | 452.14 | 34 | 180 | 0.02 | 0.13 | 0.25 | 0.27 | 37.20 | 12.60 |

**Table 3.** Comparison of landscape indices of innermost protected area (excluding 2000 m buffer area) during 1993 and 2015

| Class types | Total class area (Hectares) | | Number of patches | | Patch density (Number per 100 hectares) | | Largest patch index (Percent) | | Interspersion and juxtaposition index (Percent) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1993 | 2015 | 1993 | 2015 | 1993 | 2015 | 1993 | 2015 | 1993 | 2015 |
| Forest | 8125.11 | 10030.43 | 1544 | 1124 | 2.35 | 1.72 | 4.54 | 3.61 | 31.76 | 57.40 |
| Agriculture + Habitation | 4977.18 | 2963.07 | 2646 | 3854 | 4.04 | 5.89 | 3.07 | 0.74 | 35.17 | 35.91 |
| Dry river bed | 754.92 | 225.9 | 581 | 240 | 0.89 | 0.37 | 0.25 | 0.11 | 35.17 | 0 |
| Open scrub | 3.24 | 0 | 18 | 0 | 0.03 | 0 | 0 | 0 | 49.18 | 0 |
| Water | 433.44 | 1023.97 | 806 | 2496 | 1.23 | 3.82 | 0.29 | 0.15 | 41.89 | 22.57 |

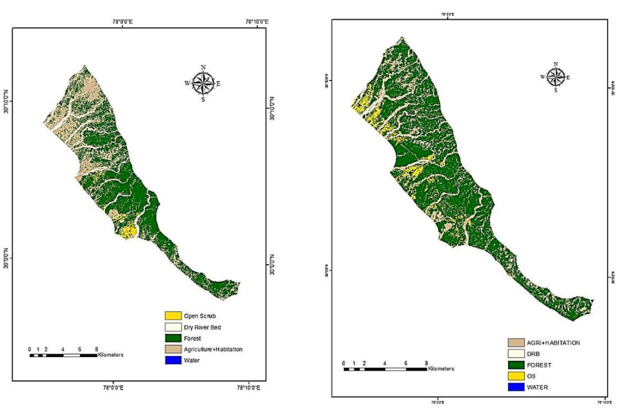

**Fig. 7.** Comparison of classified innermost protected area (Excluding buffer)

## CONCLUSION

Landscape evaluation via bi-temporal image analysis revealed that there was considerable fragmentation in adjacent landscapes outside the protected area in the recent image when compared to historical image. While comparing landscape indices inside protected area (2000 m buffer) and innermost protected area (excluding 2000 m buffer area) during the study period (1993 and 2015). landscape indices such as NP, PD, LPI decreased over time while, IJI got increased with respect to forest patch, which means interspersion was more and patch adjacency got increased during the analyzed period. On the other hand, Comparison of landscape indices outside the protected area (2000 m buffer) during 1993 and 2015 revealed that NP, PD increased overtime while, LPI and IJI decreased over time. Lower values of IJI characterize landscapes in which the patch types are poorly interspersed (i.e., disproportionate distribution of patch type adjacencies) which means the outer side of protected area are more fragmented with respect to the inner boundary. This kind of studies figures out the significance of maintaining protected area network, especially National Parks. More studies in similar lines will surely facilitate better conservation and management of the protected area networks of the country.

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