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RESEARCH ARTICLE

Assessment of Forest Fragmentation in the Conservation Priority Dudhwa Landscape, India using FRAGSTATS Computed Class Level Metrics

N. Midha • P.K. Mathur

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Abstract The Dudhwa landscape, a priority conservation area representing Terai ecosystem (woodland-grassland-wetland complex) has witnessed a sea change in past 150 years or so on account of long history of forest management, changes in land use, and rapid economic development. We assessed fragmentation in two constituent protected areas (Dudhwa National Park-DNP and Katerniaghat Wildlife Sanctuary-KAT) of the landscape due to forest management activities (clear cutting, development of rail and road network, and plantations) and compared the magnitude among them using select metrics at the forest class level. We applied FRAGSTATS spatial pattern analysis software (ver.3.3) on different forest classes deciphered by land use/ cover maps generated using IRS P6 LISS IV digital data. Study amply revealed that the forests in DNP are less fragmented and of better habitat quality than forests of KAT. The set of seven metrics (patch density, mean patch size, edge density, mean shape index, mean core area, mean nearest neighbour, and interspersion and juxtaposition index) at the class level quantified in the present study are simple and proved useful for quantifying complex spatial processes and can be used as an effective means of monitoring in Dudhwa landscape.

N. Midha. P.K. Mathur (✉)

Wildlife Institute of India
Post Box #18, Chandrabani
Dehra Dun, 248 001, Uttarakhand, India

email : mathurpk@wii.gov.in, mathurpk@yahoo.com

Introduction

World over, habitat loss and fragmentation has been recognized as a key issue facing the conservation of biological diversity. Human activities have modified the environment to the extent that most common landscape patterns portray mosaic of human settlements, agricultural land, and scattered fragments of natural ecosystems. Most conservation reserves, even large reserves, are becoming increasingly surrounded by intensively modified environment and in the long term appear destined to function as isolated natural ecosystems (Bennett, 2003).

Fragmentation is a dynamic process that results in marked changes to the pattern of habitat in a landscape through time. The term 'fragmentation' has been defined as simultaneous reduction of forest area, increase in forest edge, and subdivision of large forest areas into smaller non-contiguous fragments (Laurance, 2000). The consequences of fragmentation include habitat loss for some plant and animal species, habitat creation for others, decreased connectivity of the remaining vegetation, decreased patch size, increased distance between patches, and an increased in edge at the expense of interior habitat (Reed *et al*., 1996).

The Dudhwa landscape in Uttar Pradesh state of India is one such example where spatial and temporal changes of land use have played a major role in promoting forest fragmentation. The landscape witnessed a sea change during past 150 years or so on account of long history of forest management, changes in land use, and rapid economic development. Forest reserves were carved out as early as 1880s and were subjected to extensive working which included extensive clear felling of natural forests and raising of monoculture plantations of exotics viz., teak (*Tectona grandis*) and eucalyptus (*Eucalyptus citridora*). This fostered the establishment of a massive rail and road infrastructure in Dudhwa landscape. The landscape severely got influenced during the country's post independence era of 1950s due to abrupt changes in land use policy, settlement of refugees, expansion of agriculture and large scale conversion of grassland and swamp habitats into agriculture land (De, 2001; Mathur and Midha, 2008). All these factors worked against conservation, resulting once extensive wilderness into smaller forest fragments. Today, the Dudhwa landscape harbours three large forest fragments, now each serving as a protected area i.e. Dudhwa National Park (DNP), Katerniaghat Wildlife Sanctuary (KAT) and Kishanpur Wildlife Sanctuary besides several small, scattered forest fragments separated spatially amidst human dominated matrix (Fig. 1).

Over recent decades, many authors have raised concern about conservation implications of such large scale alterations on wildlife flora and fauna. Incessant increase in anthropogenic pressure has resulted into local extinction of some species such as Indian great one-horned rhinoceros (*Rhinoceros unicornis*), swamp deer (*Cervus duvauceli duvauceli*) and hog deer (*Axis porcinus*) from these areas (Holloway, 1973; Qureshi *et al*., 2004; De, 2001; Kumar *et al*., 2002; Jonhsingh *et al*., 2004; Midha and Mathur, 2010). Islam and Rahmani (2004) have also drawn attention to the problem of large-scale conversion of natural grasslands into croplands and plantations outside as well as inside the protected areas and has worriedly voiced that it is impeding the survival of key and threatened grassland bird species like swamp francolin (*Francolinus gularis*) and Bengal florican (*Houbaropsis bengalensis*).

Recognition of above alterations leading to fragmentation in Dudhwa landscape has driven land managers to consider and adopt a landscape perspective for management. Pre-requisit to this is an adequate quantitative understanding of how the landscape has been transformed by fragmentation and how it will affect landscape characteristics in the future (Reed *et al*., 1996). The degree of fragmentation has been described as a function of the varying size, shape, spatial distribution, and density of patches (Jorge and Garcia, 1997). Scientists have been using metrics for assessing fragmentation and its impact (Mladenoff *et al*., 1993; Reed *et al*., 1996; Lele *et al.*, 2008). The present study specifically aimed to understand and compare the magnitude of forest fragmentation in two protected areas of the Dudhwa landscape i.e., DNP and KAT due to the influence of forest management and changes in land use.

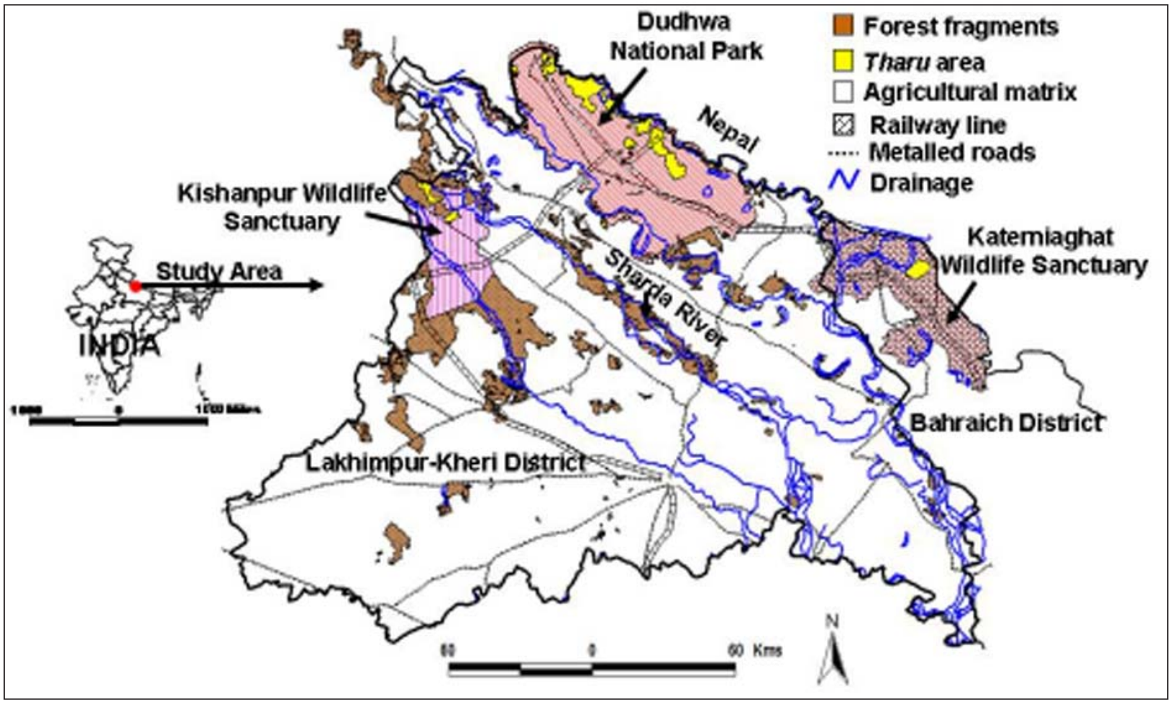

Fig.1 Location of the study area - Dudhwa landscape which includes Dudhwa National Park and Katerniaghat Wildlife Sanctuary

Study Area

The study area 'Dudhwa landscape' stretches across Lakhimpur Kheri and Bahraich districts of state Uttar Pradesh in India. It lies between latitude N 28^0 15' 44.7" and 28^0 17' 13.4" and longitude E 81^0 10' 38.7" and 81^0 15' 17.2" (Fig.1). It includes DNP and KAT. The DNP was established in 1977 and covers an area of 680.3 km^2 while KAT was designated as a wildlife sanctuary in 1976 and encompasses an area of 400.6 km^2. The tract experiences very gentle slopes towards the south-east. The average elevation is 160 m above mean sea level. The soil consists of Gangetic alluvial formations. The moist deciduous forests in the tract dominated by valuable Sal (*Shorea robusta*) have well interspersed tall grasslands and swamps (Jha, 2000; De, 2001; Mathur *et al*., 2010). Unique complex of woodland-grassland-wetland ecosystem harbours a variety of floral and faunal life, including several charismatic and obligate species viz., tiger (*Panthera tigris*), Asian elephant (*Elephas maximum*), Indian great one-horned rhinoceros, swamp deer, and pygmy hog (*Sus salvanicus*) (Mathur *et al*., 2010). Undoubtedly, the landscape has undergone irreparable changes due to past intensive forest management, changes in land use, and developmental activities inside as well as outside the two protected areas under consideration.

Methodology

Landscapes often depict a mosaic of different patches. Thus, landscapes are usually characterized by the structure and composition of constituent patches besides their spatial pattern or configuration. Information on the structure, composition and configuration of patches and spatial pattern of varied landscapes has been widely assessed using software FRAGSTATS, a spatial pattern analysis programme for quantifying landscape features (McGarigal and Marks, 1994). Indices computed by FRAGSTATS characterize each patch in the mosaic, each patch class (class) in the mosaic, and the landscape mosaic as a whole. McGarigal and Marks (1994) suggested that class indices can be used as indicator for fragmentation as these separately quantify the amount and distribution of each class or forest class and thus measure the fragmentation of particular forest class. Details of dataset and software used for computation of select metrics at the class level to quantify fragmentation in two protected areas in the present study are given below:

Dataset: We used land use/cover maps for DNP and KAT generated during the Ministry of Environment and Forests sponsored project 'Mapping of National Parks and Wildlife Sanctuaries' using IRS P6 LISS IV digital data (Mathur and Midha, 2008). The maps included 16 land use/ cover (forest and non-forest) categories in case of DNP (Fig. 2) and 20 for KAT (Fig. 3). However, for the purpose of present study on fragmentation, we considered, evaluated and interpreted only 9 forest classes out of altogether 16 land use/cover classes in case of DNP and 12 forest classes in KAT out of total 20 classes mapped for explaining fragmentation. We converted polygon layers (vector format) developed for preparing land use/ cover maps into raster format with a pixel size of 100 m.

Computation of Metrics: We used raster version of FRAGSTATS spatial pattern analysis software (ver.3.3) developed by McGarigal *et al.* (2002) to assess different metrics. As stated above, we selected seven metrics at class level based on several similar studies (Hargis *et al.*, 1998; Tinker *et al.*, 1998; Botequilha and Ahern, 2002; Corry and Nassauer, 2005; Miyamoto and Sano, 2008). An eight-neighbourhood criterion for the definition of patches was adopted. As adopted by Tinker *et al*. (1998), we selected those metrics which were standardized per unit area to carry out comparison of metrics between two PAs. We have chosen 100 m edge influence to assess mean core area (Laurance, 2000; Kumar *et al*., 2002). Table 1 lists the set of seven metrics (patch density - PD, mean patch size-MPS, edge density - ED, mean shape index-MSI, mean core area-MCA, mean nearest-neighbor distance-MNN, and interspersion and juxtaposition index-IJI) chosen in the present study. Accordingly, a forest class with greater density of patches indicate more fragmentation. Smaller MPS of similar patches in a forest class also indicates greater fragmentation. Amount of edge is expected to increase in fragmented forest class. Fragmentation results into decreased core area available in patches of a forest class. Managed forests are expected to have less geometrically complex patches in terms of shape. The mean nearest-neighbor distance is expected to decrease as patches become smaller and more isolated, indicating greater fragmentation. The percentage values of IJI will indicate the adjacency of each patch with all other forest classes.

Results

The results on the assessment of fragmentation in two protected areas – DNP and KAT and their indicators and magnitude are presented below.

Forest fragmentation

Patch density and mean patch size: The values of MPS for 12 different forest classes in KAT ranged from 9.5 ha to 360 ha while these values for nine forest classes considered in case of DNP ranged from as low as 6.1 ha to as high as 1,256.8 ha (Table 2). Explicitly, with low patch density, open sal forest in KAT obtained highest and significantly large average patch size of 360 ha. Moderately dense sal and *Terminalia alata* forest classes in KAT obtained next highest values of MPS (Table 2). Thus, in terms of fragmentation, open sal, moderately dense sal, and *Terminalia alata* forest classes in KAT were found to be least fragmented. Interestingly, with lower values of patch density, all different sal forest classes registered the higher range of average patch size

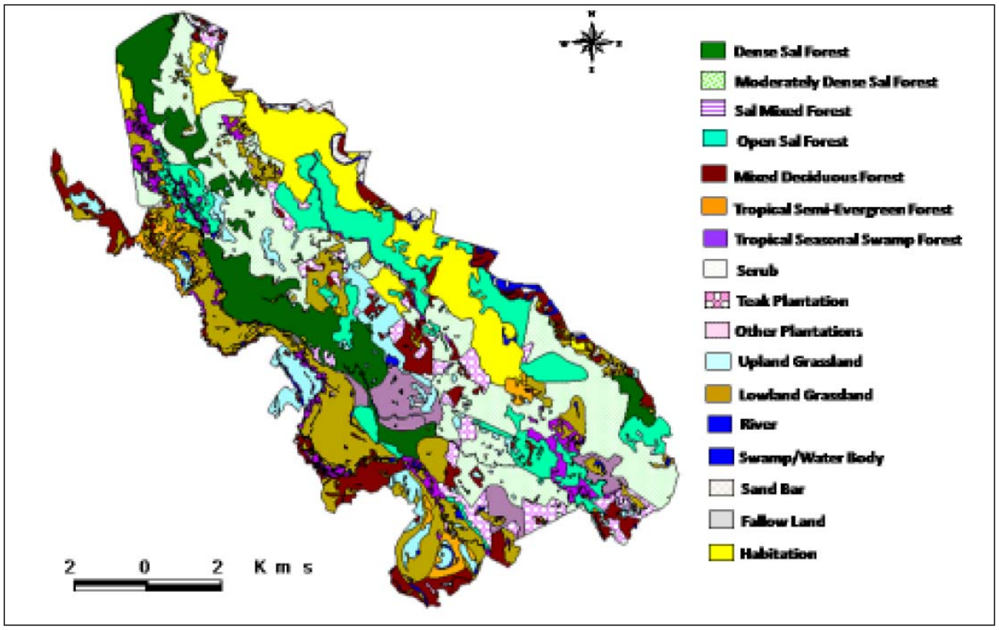

Fig. 2 Land use/land cover of DNP developed from IRS P-6 LISS IV at the scale of 1:25,000

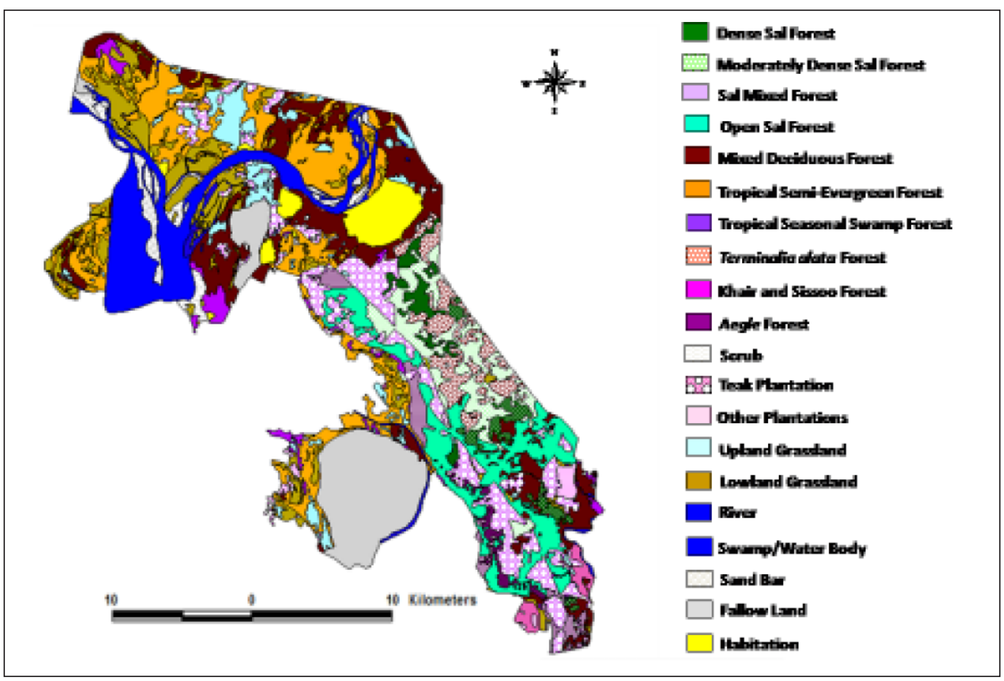

Fig. 3 Land use/land cover of KAT developed from IRS P-6 LISS IV at the scale of 1:25,000

Table 1 Metrics used at class level to quantify fragmentation in KAT and DNP

Metrics and units	Description
Patch Density- PD (patches/100 ha)	The number of patches of corresponding forest type divided by total area* (ha) multiplied by 100 ➢ A class with greater density of patches indicate that it is subdivided into many patches and thus could be considered more fragmented
Mean Patch Size – MPS (ha)	The average size of the patches of the corresponding forest type ➢ Smaller mean patch size indicates more fragmented forest
Edge Density – ED (m/ha)	Total length of edge involving the corresponding forest type divided by total area (ha) ➢ Amount of edge relative to total area is expected to increase in initial stages of fragmentation
Mean Shape Index – MSI (None)	The average shape index of patches of corresponding forest type, adjusted by a constant for a square standard (raster) ➢ Patches are expected to become less geometrically complex in managed forest
Mean Core Area – MCA (ha)	The average core area of the patches of the corresponding forest type ➢ One of the main effects of fragmentation is the conversion of interior habitat to edge habitat. It is expected that the amount of core area will decrease as a result of fragmentation
Mean Nearest- Neighbor Distance - MNN (m)	The average distance between patches of corresponding forest type, based on edge to edge distance ➢ It is expected to decrease as patches become smaller and more isolated. It affects the movement and dispersal of species
Interspersion and Juxtaposition Index - IJI (%)	The adjacency of each patch with all other forest types ➢ It is expected to increase

* *Total area of respective study site (DNP or KAT)*

(Table 2). Hence, they were found to be least fragmented forests in DNP.

Edge density, mean shape index, and mean core area: The values of edge density in case of 12 different forest classes in KAT ranged from 0.6 m/ha to 12.1 m/ha. The lowest value was registered in case of khair and sissoo (*Acacia catechu and Dalbergia sissoo*) forest while highest value was obtained by tropical semi-evergreen forest. In DNP, highest value of edge density, being 8 m/ha was recorded by moderately dense sal forest whereas lowest value of just 0.2 m/ha was registered by class of other plantations (Table 2).

The results for mean shape index revealed that values for all the forest classes in KAT were greater than one indicating that the average patch shape in all forest classes in sanctuary area was irregular (Table 2). In DNP, three highest values of mean shape index obtained were 2.42, 2.38, and 2.37 by three sal forest classes i.e. open sal forest, dense sal forest, and moderately dense sal forest, respectively thus pointing out towards their native character to the tract.

Interestingly, all forest classes in KAT recorded MCA < 50% of MPS while in contrast almost all forest classes in DNP recorded values of MCA >50% of MPS. As core area is affected by shape, this clearly indicated that effect of edge is relatively low in different forest classes of DNP.

Mean nearest neighbour, and interspersion and juxtaposition index: In case of KAT**,** the average distance of similar patch for almost all forest classes came out to be short while the overall interpretation

Table 2 Fragmentation measurement metrics computed for KAT and DNP

Forest Type	% area	PD (patches /100ha)	MPS (ha)	ED (m/ha)	MSI	MCA (ha)	MNN (m)	IJI (%)
Katerniaghat Wildlife Sanctuary - KAT								
Dense Sal	3.1	0.05	59.9	2.8	1.8	24.2	365.8	56.8
Moderately Dense Sal	5.0	0.03	168.3	4.1	2.0	81.1	628.1	52.6
Sal Mixed	1.9	0.04	54.5	1.8	1.7	23.9	556.7	61.5
Open Sal	7.9	0.02	359.5	5.4	2.3	196.6	215.4	68.8
Mixed Deciduous	11.4	0.16	80.0	10.0	1.7	40.8	567.7	85.9
Tropical Semi-Evergreen	12.4	0.14	98.5	12.1	1.8	45.5	262.3	69.0
Tropical Seasonal Swamp	1.6	0.12	15.2	2.4	1.3	4.8	743.6	74.4
Khair and Sissoo	0.7	0.01	75.0	0.6	1.7	35.7	3876.9	65.6
Aegle marmelos	0.7	0.05	16.7	1.2	1.4	3.3	239.3	36.0
Terminalia alata	3.3	0.03	120.7	2.9	2.0	59.0	307.9	39.8
Teak Plantation	9.5	0.13	76.9	7.5	1.7	40.6	323.1	79.9
Other Plantations	1.0	0.10	9.5	1.2	1.2	3.4	671.6	72.1
Dudhwa National Park - DNP								
Dense Sal	11.4	0.01	974.2	3.3	2.3	781.0	2181.8	70.5
Moderately Dense Sal	23.5	0.01	1256.8	8.0	2.3	965.3	424.9	80.6
Sal Mixed	3.7	0.01	361.1	1.5	1.8	259.1	1492.9	70.9
Open Sal	17.7	0.02	449.5	5.8	2.4	307.6	978.1	75.8
Mixed Deciduous	8.3	0.14	59.9	7.0	1.5	29.5	596.2	79.8
Tropical Semi-Evergreen	2.1	0.02	95.7	2.0	2.0	38.1	864.8	58.5
Tropical Seasonal Swamp	3.9	0.21	18.5	5.8	1.5	4.5	326.9	64.4
Teak Plantation	5.0	0.04	114.8	3.3	1.7	65.3	1031.6	78.4
Other Plantations	0.1	0.02	6.1	0.2	1.2	0.1	1106.6	64.2

revealed that patches of different forest classes in DNP were located relatively far from each other (Table 2).

In KAT, values for IJT ranged from 36% to 86%, amply indicating that sal forests were moderately interspersed among all different forest classes (Table 2). The values for IJI in DNP ranged from 58% to 81%. All sal forest classes obtained value more than 70% indicating that all sal forest classes in the national park area were highly interspersed.

Comparison of KAT and DNP

A comparison of extent of fragmentation in two constituent protected areas - KAT and DNP allowed several interesting revelations (Figs. 4 and 5).

Lower values of patch density obtained by most of the forest classes in DNP than those in KAT clearly indicated that forest classes in the national park area were relatively less fragmented, except tropical seasonal swamp forest in DNP which was represented by almost double number of patches as compared to KAT.

A comparison of values of MPS between DNP and KAT showed some striking differences (Table 2 and Fig. 4b). Revelation pointed out that patches of forest classes in DNP were larger in sizes, particularly in case of four classes of sal forest. In other forest classes *viz.,* mixed deciduous forest, tropical semi-evergreen forest, teak plantation, and other plantations, the value of MPS were almost comparable

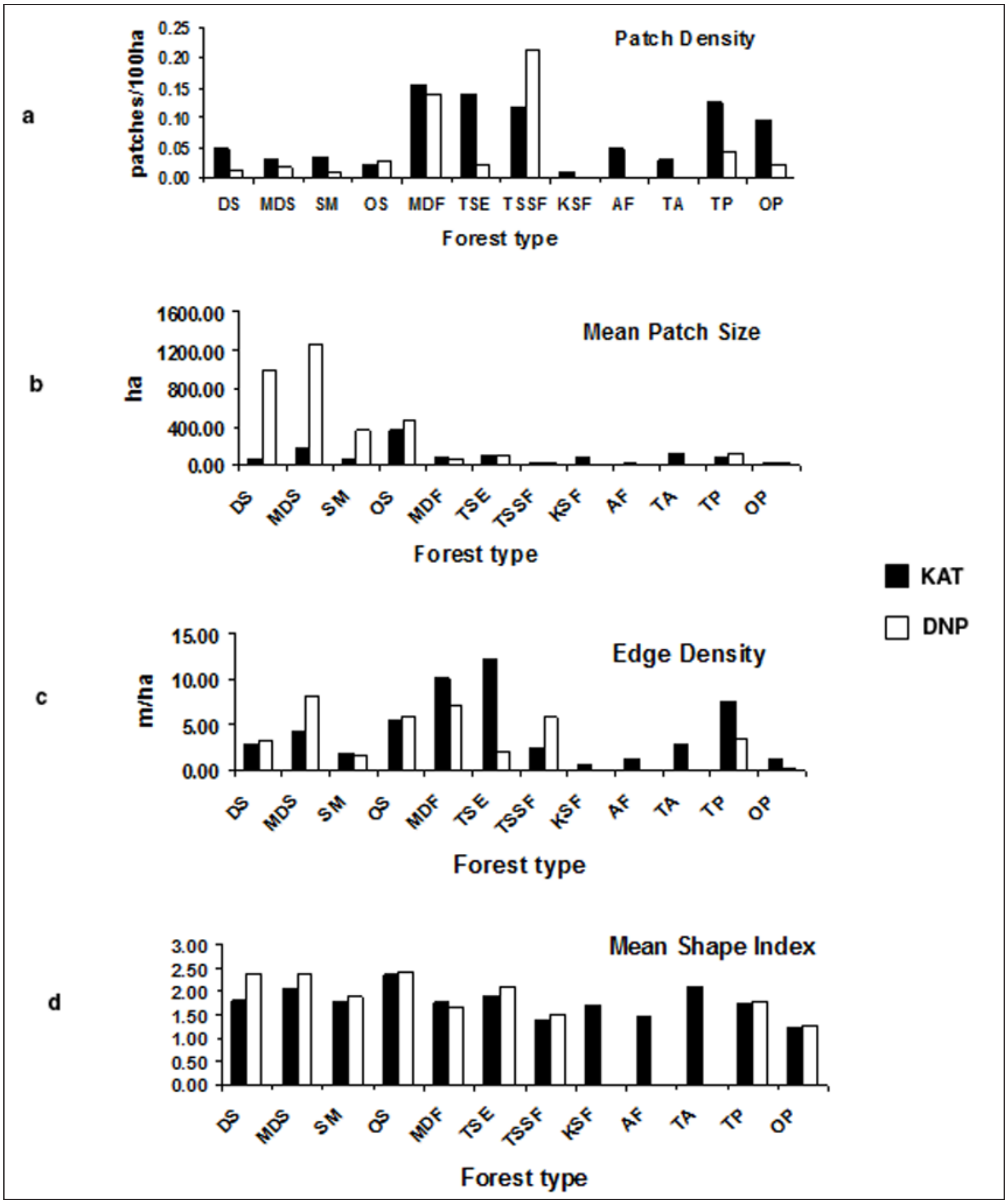

Fig. 4 Comparison of Values of Metrics (Patch Density, Mean Patch Size, Edge Density, and Mean Shape Index) for Different Forest Classes in Dudhwa National Park (DNP) and Katernaighat Wildlife Sanctuary (KAT)
(DS: Dense Sal Forest; MDS: Moderately Dense Sal Forest; SM: Sal Mixed Forest; OS: Open Sal Forest; MDF: Mixed Deciduous Forest; TSE: Tropical Semi-Evergreen Forest; TSSF: Tropical Seasonal Swamp Forest; TA: *Terminalia alata* Forest; KSF: Khair and Sissoo Forest; AF: *Aegle marmelos* Forest; TP: Teak Plantation; OP: Other Plantations)

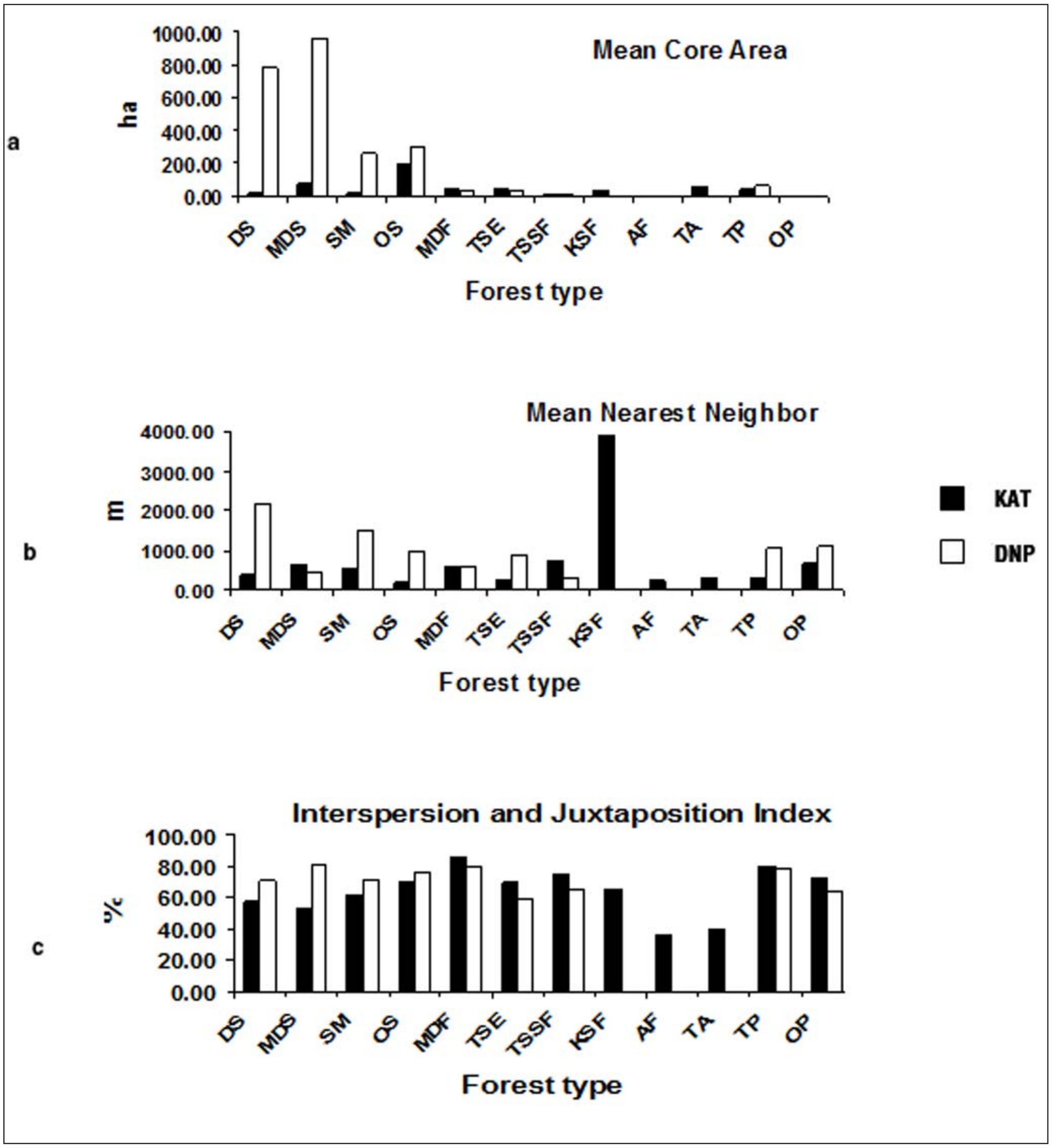

Fig. 5 Comparison of Values of Metrics (Mean Core Area, Mean Nearest Neighbour, Interspersion and Juxtaposition Index) for Different Forest Classes in Dudhwa National Park (DNP) and Katernaighat Wildlife Sanctuary (KAT) (DS: Dense Sal Forest; MDS: Moderately Dense Sal Forest; SM: Sal Mixed Forest; OS: Open Sal Forest; MDF: Mixed Deciduous Forest; TSE: Tropical Semi-Evergreen Forest; TSSF: Tropical Seasonal Swamp Forest; TA: *Terminalia alata* Forest; KSF: Khair and Sissoo Forest; *AF: Aegle marmelos* Forest; TP: Teak Plantation; OP: Other Plantations)

in two PAs (Fig.4b). However, lower values of patch density in such forest classes suggested that these forests were present in less fragmented state in DNP (Fig. 4a).

Figure 4c compares values of edge density and revealed that sal forest classes in KAT and DNP registered almost same edge density except for moderately dense sal forest. However, all other forest classes recorded higher values of edge density in KAT except tropical seasonal swamp forest. The overall comparison indicated that the effect of edge was less prominent in DNP. Comparison of MPS in two PAs could not allow any striking differences (Fig. 4d). Only, dense sal forest and moderately dense sal forest accounted for slightly higher values of MPS indicating their irregularity in shape and pointed towards being present in relatively natural state in DNP.

Notably, the values of MCA in DNP were much higher than those in KAT (Fig. 5a). This could be attributed to less edge effect in DNP as highlighted above. These results indicated towards better habitat quality in DNP as compared to KAT. In addition, this difference in MCA also gave the cue about the process of fragmentation in KAT which encompass significant impact due to changes in configuration rather than due to forest loss.

The values of mean nearest neighbour were found to be low in KAT for most forest classes as compared to DNP (Fig. 5b). This indicates that although forests were less fragmented in DNP but patches were located far apart from each other. Lower values of mean nearest neighbour in case of tropical seasonal swamp forest in DNP and tropical semi-evergreen forest in KAT indicated that these two featured forest classes were highly localized in respective PA.

The interpretation of values for IJI indicated that most of the forest classes in both PAs reported almost same level of interspersion (Fig. 5c). Only two exceptions were dense sal and moderately dense sal forest classes in DNP those obtained significantly higher values indicating their high interspersion.

Discussion and conclusions

We examined magnitude of forest fragmentation in two protected areas within the Dudhwa landscape as well as compared them. This way we compared the result of forest management activities (clear cutting, development of rail and road network, and plantations) among them, ultimately allowing us to determine which one has been most severely impacted.

Reed *et al*. (1996) has pointed that the changes in the shape, edge, density and diversity related measures reflect the impact of forest management in the landscape. Several authors have concluded that the forest fragmentation tends to increase the number of patches, decrease the MPS and interior forest habitat (enhanced edge and reduced MCA), and decrease the amount of old growth forests (Ripple *et al*., 1991; Spies *et al*., 1994; Bennett, 2003; Holt and Debinski, 2003; Miyamoto and Sano, 2008). Present study distinctly supports findings of above authors and also reflected the impact of prolonged phase of active forest management followed by a relatively short phase of passive management of forests in DNP during past three decades or so after its designation as a national park.

Both PAs have the presence of large extent of areas under plantations especially of teak indicating that the area was widely planted. In addition, moderately large patch size, irregular shape, and high interspersion of these plantation patches added that during the present passive phase, teak has managed to establish itself well in KAT as well as DNP despite being an exotic species to the tract. Plantations covered 5% area of DNP while the extent of teak and other plantations in KAT was 10.5%.

In KAT, the impact of clear cutting along with infrastructure development is quite apparent as only 18% of the area remained under different classes of sal forest albeit it being the dominant forest class of this tract. Furthermore, open sal forest registered the largest extent among all classes of sal forest while dense sal forest class which is indeed the matured or old growth forests contributed less. In contrast, different sal forests were found to be least fragmented in DNP and in natural state as indicated by their actual areal extent, patch density, MPS, and high shape index.

In addition, all the forest classes in KAT acquired the irregular shapes but recorded the MCA < 50% of MPS which pointed that the shape of patches of these forests had been affected by edges created during road development and clear cutting. Similarly, in Oregon USA, Spies *et al*. (1994) reported a decrease in mean interior patch area from 160 to 62 ha/patch following clear cutting. In an analogous study, Ripple *et al*. (1991) found that patch area was reduced by 17% as a result of clear cutting. Shinneman (1996) found that shelter wood cutting had essentially depleted core old-growth forest area in the Black Hills National Forest, USA. Roads in this study reduced MPS and patch core sizes by > 70%. Interestingly, almost all the forest classes in DNP recorded MCA >50% of MPS thus indicated the low effect of edge. Patches of different forest classes in DNP were found to be located relatively at far distance from each other.

It is amply clear that biotic pressure has contributed to fragmentation of the Dudhwa landscape. The comparison appears worthwhile between two protected areas which belong to same *Terai* tract and were once connected to each other. The high patch density and concurrent less MPS of forest classes in KAT as compared to forest classes in DNP indicated forests in DNP were relatively less fragmented than different forests in KAT. This was especially applicable in the case of sal forests. The areal extent and MPS of old growth forests i.e. dense sal and moderately dense sal forest classes were quite large in DNP as compared to KAT. Distinctly, DNP recorded significantly higher values of MCA representing greater forest interior habitat as compared to trend followed by forest classes in KAT. This could be attributed to less edge effect on the shape of the patches of forest classes in DNP. The mean shape index could not allow any striking differences except in the case of Dense sal forest and moderately dense sal forest which pointed towards being present in relatively natural state in DNP. This was further endorsed by these two forest classes being better interspersed as compared to KAT. Counter intuitively, the inter patch differences were found to be large in DNP which indicated that although forests are less fragmented in DNP but patches are located far apart from each other. Most of the forest classes reported similar interspersion in both protected areas.

In nutshell, the analysis of chosen metrics definitely revealed that the forests in the national park were less fragmented and of better habitat quality than forests in sanctuary (KAT). The magnitude of fragmentation was related to dominating forest classes, land use, and level of protection. The plausible reason for the difference could be benefit of protection that the national park has enjoyed for such a longer period than the sanctuary and suspension of forestry operations much earlier (ca. 30 years) in the national park.

Implication for management and conservation

The process of landscape change as a result of fragmentation caused primarily by forest management activities (clear cut, development of rail and road network, and plantations) has far-reaching consequences for native plants, vertebrates and invertebrates, particularly survival of threatened species. Several studies have reported that timber harvesting or clear cutting results in disproportionate removal of late succession forests (Ruggiero *et al*., 1994; Tinker *et al*., 1998). For birds and mammals those depend on late-succession stands, this could have resulted in qualitative and quantitative reduction of their suitable habitat in case of KAT. Further, large core areas are important habitat features for some mammals, especially forest carnivores (Tinker *et al*., 1998) and thus might be getting greatly affected in KAT. It has been well established that an elusive carnivore species like tiger requires adequately large 'inviolate' areas for breeding. Tiger being territorial animal advertises its presence in an area and maintains a territory. The tiger land tenure dynamics ensure presence of prime adults in a habitat which acts as 'source' population, periodically replacing old males by young adults from nearby forest areas. Gopal *et al*. (2007) in 'guidelines for preparation of tiger conservation plan' has highlighted the critical requirement of an 'inviolate' space of 800-100 so as to maintain a viable population of 80-100 tigers. Tiger being a 'flagship' species also ensure viable population of co-predators and prey species besides ecological integrity of the entire habitat. DNP and KAT are two large remnant and important habitat blocks not only for tiger but several other endangered species of Terai.

It is worth mentioning that the tenuous interconnectivity among patches of similar forest classes in DNP could effect movement and dispersal of faunal species. In addition, clear cuts and roads block the movement of some species, resulting in population fragmentation and increased competition for resources in remaining forest resources (Lovejoy *et al*., 1986; Noss, 1993). The effect of fragmentation on the species was outside the scope of this study, but a direct analysis of the impact is warranted and should be a significant part of current management planning.

The FRAGSTATS analysis applied in the present study has been used in various regions of the world. However, because of the different data source and classification classes, it was difficult to compare directly the index values from various regions. The set of seven metrics quantified in this study are simple and proved useful for quantifying complex spatial processes and can be used as an effective means of monitoring in Dudhwa landscape. The approach of landscape level assessment and monitoring by select metrics has been recommended and adopted by many authors for different protected areas across the world (Riitters *et al*., 1995; Botequilha. and Ahern, 2002; Schindler *et al*., 2008). As both PAs - DNP and KAT are in recovery phase after prolonged phase of active forest management, changes in composition of forest patches and configuration must be monitored and effects of land use and management interventions on landscape spatial pattern must be analysed. This knowledge can then be used to assess progress in conservation efforts and to improve management decisions not only for Dudhwa landscape, but also in other similar landscapes.

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