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Study of Changes in Habitat Type Distribution and Habitat Structure of Nech Sar National Park, Ethiopia

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ABSTRACT

Habitat loss and habitat fragmentation are major threats of protected areas in developing countries. The primary aim of this study was to analyze the spatial and temporal changes of wildlife habitats of Nech Sar National Park (NSNP) and to determine the most threatened habitat types as input for conservation planning. Authors examined the extent and magnitude of habitat change in NSNP between 1985 and 2013 using remote sensing, GIS and patch analyst tool. The NSNP consists of five major habitat types (forest, shrubland, wooded grassland, woodland and grassland. Six categories of landscape metrics (class area, patch size, edge, shape, diversity and interspersion and core area metrics), were computed for each habitat type and year (1985 and 2013) using spatial and temporal analysis. The study results showed that the landscape in NSNP underwent major changes between 1985 and 2013 with the forest and grassland are the most threatened habitats with the mean patch size of forest has decreased from 46.33 ha in 1985 to 13.88 ha in 2013 and the mean patch size of grassland has decreased from 76.52 to 9.81 ha in the same periods, respectively. These values indicate that the mean patch size of forest and grassland have decreased by 32.45 and 66.71 ha and their number of patches increased by 76 and 22, respectively between 1985 and 2013. Increases in habitat fragmentation negatively affect the home ranges of large mammals in the landscape and led to species loss. Therefore, designing management strategies for integrating mosaic habitats will ensure effective protection of wildlife species.

Key words: Habitat fragmentation, habitat loss, home range, landscape metrics, large mammals

INTRODUCTION

Fragmentation of terrestrial habitats as a result of rapid expansion of anthropogenic activities is a widespread phenomenon in most parts of the world and its of great concern for landscape management and protection of endangered species (Law and Dickman, 1998; Fahrig, 2003; Neel *et al.*, 2004; DeFries *et al.*, 2005; Wang *et al.*, 2009). In Ethiopia, expansion of agricultural practices, settlement and increasing pressure from human and livestock population are major threats to several protected areas (Yihune *et al.*, 2008; Mamo and Bekele, 2011; Belay *et al.*, 2013; Fetene *et al.*, 2012).

Anthropogenic activities affect biodiversity of terrestrial ecosystem (Sala *et al.*, 2000) by reducing the size of natural area, increasing edges of habitat boundaries and increasing isolation of subsequent fragments (Ewers and Didham, 2006). These effects also have been shown to affect the abundance of rare and endangered species (Hansen and Rotella, 2002; Wiersma *et al.*, 2004), affect the levels of biodiversity (Ward, 1998; Fahrig, 2003; DeFries *et al.*, 2007) and increase the potential for invasion by non-native plants (With, 2002).

Nech Sar National Park (NSNP) is one of the most threatened protected areas in Ethiopia (Negussie, 2008; Clark, 2010). The vegetation and its degradation were reported (e.g., Andargie, 2001; Aregu and Demeke, 2006; Fetene *et al.*, 2012) and the anthropogenic activities negatively affect the abundance as well as distribution of some wild animals (Doku *et al.*, 2007; Vymyslicka *et al.*, 2010; Fetene *et al.*, 2011; Datiko and Bekele, 2011; Mamo *et al.*, 2012) and led to expansion of non-native species as well as woody species encroachment in the Nech Sar plains (Svialek, 2008; Yusuf *et al.*, 2011). These negative effects on the habitats are related to poor governance, e.g., the institutional instability in the park management and subsequent pressures from the surrounding communities (Negera, 2009; Debelo, 2011, 2012; Kelboro and Stellmacher, 2012).

Though the above mentioned studies clearly pointed to undesirable changes of the natural habitats, there are gaps in the knowledge of quantifying the direction of changes in habitat structure of NSNP. Thus, a study on spatial structure and composition of the landscape is needed to draw conclusions for an effective conservation planning. Landscape composition is referring to the number and occurrence of different landscape elements (McGarigal and Marks, 1995; Sader, 1995; Forman, 1995).

Study of landscape structure for conservation efforts can be achieved through quantifying landscape pattern and composition with landscape metrics of different habitat patches over time (Zheng *et al.*, 1997; Kitzberger and Veblen, 1999; McGarigal *et al.*, 2012). To that end, a variety of landscape metrics have been developed to measure the landscape change and fragmentations (Forman and Godron, 1986; McGarigal and Marks, 1995). Our study focused on some landscape metrics that can be commonly used to determine habitat change and fragmentation in the landscape. These include: Class area, patch size, edge, shape, diversity, interspersion and core area metrics. For simplicity of the terms, these spatial metrics here follows a brief description following McGarigal and Marks (1995) and Turner *et al.* (2001).

Class area (CA): It is a measure of landscape composition; specifically, how much of the landscape is comprised of a particular patch type.

Patch size: It refers to the number or density of patches, the average size of patches and the variation in patch size at the class and landscape levels.

Edge density: Amount of edge relative to the landscape area.

Shape metrics: Shape index (SHAPE) measures the complexity of patch shape compared to a standard shape. SHAPE equals 1 when the patch is maximally compact and increases without limit as patch shape becomes more irregular.

Diversity and interspersion: The diversity index measures the relative abundance of land use types in the landscape. Nearest-neighbor distance is a measure of interspersion that is defined as the distance from a patch to the nearest neighboring patch of the same type, based on edge-to-edge distance.

Core area metrics: Core area is defined as the area within a patch beyond some specified edge distance or buffer width. The Core Area Index (CAI) is basically an edge-to-interior ratio and is compound measure of three landscape metrics called shape, area and edge depth. Its value equals 0% when there is no core area due to the influence of edge factors. It approaches 100% when all the patch size, shape and edge width of the habitat are contained mostly within the core area (McGarigal *et al*., 2012).

The main goal of this study is to document the habitat disturbance and describe the driving factors of habitat change to allow protected area managers and conservationists to prepare solutions for planning sustainable management interventions. The study is conducted based on the following specific objectives: (i) To provide understanding regarding the relationship between landscape function, land cover change, habitat fragmentation and habitat losses in the NSNP; (ii) To identify the most important and most endangered habitats for target species of conservation in the NSNP as well as to quantify their structural characteristics for conservation planning and (iii) To indicate the importance of landscape metrics for habitat studies and to quantify changes in landscape composition.

MATERIALS AND METHODS

Selection and delineation of the study area: The area selected for this study is the terrestrial part of NSNP, one of the protected areas of Ethiopia, 510 km south of Addis Ababa (Fig. 1). The park is one of the degraded national parks in the country (Clark, 2010) and needs immediate conservation efforts to rehabilitate the biodiversity and physical resources. According to the International Union for Conservation of Nature (IUCN) conservation categories (Dudley, 2008), NSNP is classified to category II, where the main objective is to protect and manage functioning

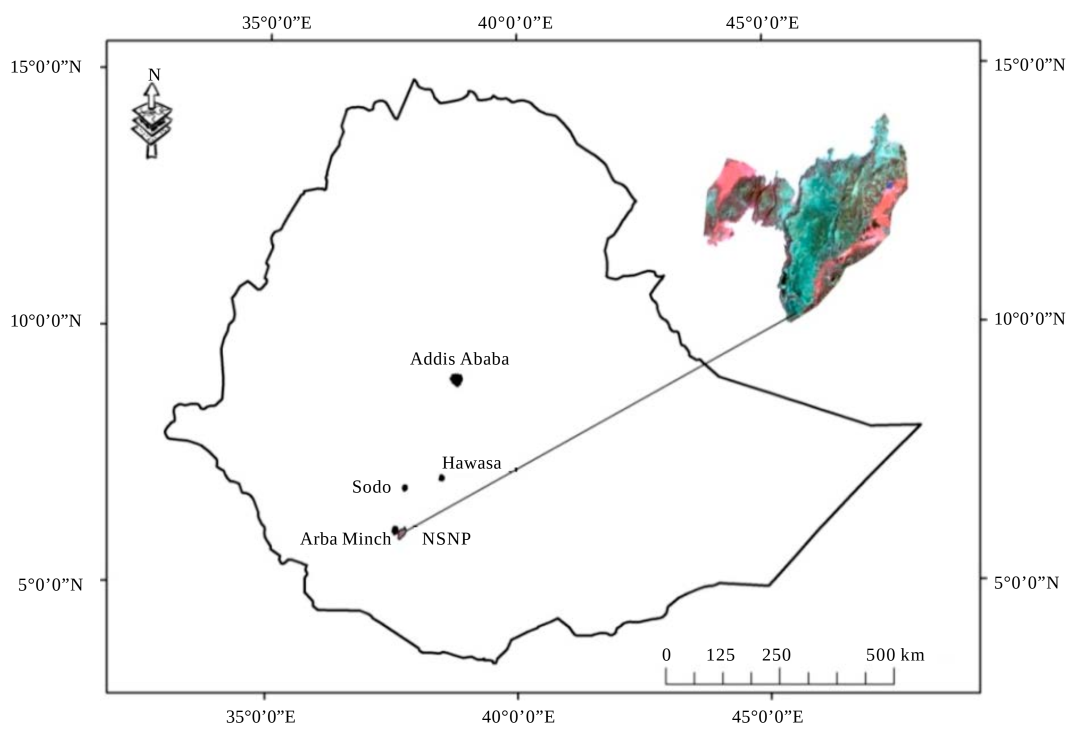

Fig. 1: Map of Ethiopia showing position and terrestrial area of NSNP

ecosystems in a way that may contribute to local economies by promoting educational and recreational tourism on a scale that will not reduce the effectiveness of conservation efforts. NSNP was established in 1974 to conserve the Swayne's hartebeest, which is endemic to Ethiopia (Duckworth *et al.*, 1992; Datiko and Bekele, 2011; Mamo *et al.*, 2012) in the Nech Sar plain and to protect the landscapes between the two Great Rift Valley lakes of Abaya and Chamo.

Vegetation in the park consists of the groundwater forest, grasslands, shrublands and thickets, woodlands and the riparian forest. The terrestrial areas of NSNP are the habitats for a wide range of wildlife species that include but not limited to the endangered Swayne's hartebeest (*Alcelaphus buselaphus swayne*), Grant's zebra (*Equus quagga*), Grant's gazelle (*Gazella granti*), Greater kudu (*Tragelaphus strepsiceros*) (Duckworth *et al.*, 1992; Fetene *et al.*, 2011).

NSNP lies within the Somali-Massai Regional Center of Endemism, one of the major floristic regions in Africa and falls within one of the IUCN's global biodiversity hotspots in the world, named the "Horn of Africa' (Clark, 2010). As a result of an abundant bird fauna in the NSNP, Birdlife International has declared the park as an Important Bird Area of Ethiopia (Edwards, 1996). While the ecological importance of NSNP is well documented, the park is also considered one of the most degraded in the world (Andargie, 2001). Although, NSNP is a protected area under IUCN category II, the eastern part of the park is currently inhabited mainly by local communities who actively engaged in livestock raring and crop farming. These economic activities are the main causes for the loss and fragmentation of wildlife habitats in the NSNP.

Data source and methods of data collection: Remote sensing data were collected from satellite imagery (Landsat TM and ETM+) collected in 1985, 1995, 2005 and 2013 for the park area (Path/Row 169/56). Landsat images were atmospherically corrected using Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) algorithm (Masek *et al.*, 2013) and cloud and cloud shadow were detected and masked from all images using fmask (Zhu and Woodcock, 2012).

Land cover classification was performed using a supervised classification method (maximum likelihood algorithm) with the information generated from ground control points and based on local people knowledge of field observation information about vegetation types. To mitigate misclassification of individual pixels, we used majority analysis to change spurious pixels within a large single class and smoothing the land cover results. A total of seven land cover classes were identified: Forest, shrubland, wooded grassland, woodland, grassland, cultivated land and areas invaded by non-native plants.

Identification of major habitat types: Point data were taken using a regular design for each land cover types. The regular design was first created at office using Hawth's analysis tools for ArcGIS9.3 and the point data from the field used to determine the vegetation type in the study area. Accordingly, five of the seven land cover classes derived from Landsat imagery relate to natural vegetation types and two are direct results of anthropogenic alterations of the landscape. GPS coordinates of field derived mammal sightings using line transects were used to relate land cover types and the most frequently observed mammalian species in the habitat type concerned. Then, the spatial requirement of indicator species' home range data for terrestrial large mammal species were refereed to published sources (Du Toit, 1990; Kingdom, 1997) and compared with the spatial extent available to corresponding species in the NSNP.

Methods of spatial analysis: Spatial metrics (Table 1) were selected in order to assess the habitat structures of NSNP on the basis of the land cover maps that were derived from the supervised classified images.

Table 1: Selected set of spatial metrics for the analysis of habitat structure of NSNP. The selected metrics are based on the definition of McGarigal and Cushman (2002)

Spatial metric	Description	Formula	Description
Percent of Landscape (PLAND)	Measures habitat extent in relative terms of the target landcover class or habitat type	$PLAND = P_i = \frac{\sum_{j=1}^{n} a_{ij}}{A}(100)$	P_i is the proportion of the landscape occupied by the ith patch type (the focal habitat); a_{ij} is the area (m^2) of the jth patch and A is the total landscape area (m^2)
Mean Patch Size (MPS)	Measures the average mean surface of patches and it is used to evaluate landscape fragmentation	$MPS = \frac{\sum_{j=1}^{n} a_{ij}}{n_i}$	MPS is the mean size of patches (ha) a_{ij} is the area (ha) of the jth patch n_i = No. of patches in the landscape of patch type class I
Edge Density (ED)	The amount of edge relative to the landscape area indicating the total length of the patch edge per unit area	$ED = \frac{E}{A}(10{,}000)$	ED = Edge density E = Total length (m) of edge in landscape A = Total landscape area
Mean Shape Index (MSI)	Measures the ratio between the perimeter of a patch and the perimeter of the simplest patch in the same area	$MSI = \frac{\sum_{j=1}^{n} P_{ij} / \min P_{ij}}{n_i}$	pij = Perimeter of patch ij in terms of No. of cell surfaces; min pij = Minimum perimeter of patch ij in terms of No. of cell surfaces, ni = No. of patches in the class
Shannon's Diversity Index (SHDI)	Measures the relative abundance of landcover types in the landscape	$SHDI = \sum_{i=1}^{m} (P_i \ln P_i)$	m = No. of landcover types, Pi = Proportion of the landscape occupied by patch type class I
Mean Near Neighbour distance (MNN)	Measures the degree of isolation and fragmentation of a patch	$MNN = \frac{\sum_{j=1}^{n} h_{ij}}{n_i}$	h_{ij} = Distance (m) from patch ij to nearest neighboring patch of the same type class I ni = No. of patches in the landscape of patch type class I that
Core Area Index (CAI)	An edge-to-interior ratio like many shape indices and represents the percentage of the core area of the patch relative to the total patch area	$CAI = \frac{a_{ij}^{c}}{a_{ij}}(100)$	a_{ij}^{c} = Core area (m^2) of patch ij based on specified depth-of-edge distances (m), a_{ij} = Area (m^2) of patch ij

The spatial metrics were computed using Patch Analyst 5.0 FRAGSTAS interface integrated with ArcGIS 10 (Elkie *et al.*, 1999; McGarigal *et al.*, 2012; Rempel *et al.*, 2012). By selecting the most appropriate landscape metrics for the fragmentation assessment of NSNP, we referred to previous works on similar study elsewhere (e.g., Hargis *et al.*, 1998; Betts *et al.*, 2003; Munroe *et al.*, 2007; Tomaselli *et al.*, 2012) who suggested landscape metrics commonly used in the study of habitat fragmentation and analyzed their sensitivity to the patch size, patch shape and spatial arrangement. Based on these suggestions we performed six categories of spatial statistics in the patch grid analyst tool including: Area metrics, patch density and size metrics, edge metrics, shape metrics, shannon diversity metrics and core area metrics. These metrics have been shown to be effective tools for quantifying the ecological value of existing wildlife habitats (Fahrig, 2003) as they describe composition and configuration of suitable habitat areas in the landscape (Elkie *et al.*, 1999; Antwi *et al.*, 2008; McGarigal *et al.*, 2012).

RESULTS

The result showed that there has been distinct pattern of increase and decrease in different patches of NSNP. Landover transformations in most cases were observed from forest to crop land and from grass land to undesirable invasive species and to shrub encroachments. The magnitude and direction of habitat change within the landscape is indicated in Table 2 with detail landscape metrics indices.

Table 2: Indices of different landscape metrics in the five landcover classes of NSNP

		Selected landscape metrics										
Classes	Year	CA	PLAND	NUMP	MPS	TE	ED	MSI	MNN	MPI	IJI	TCAI
Forest	1985	3196.50	9.62	69	46.33	209040.5	6.29	1.34	371.25	92.00	68.96	60.12
	1995	2531.52	7.62	74	34.21	222406.8	6.70	1.45	186.97	81.11	59.45	48.32
	2005	2380.27	7.19	64	37.19	177268.1	5.35	1.37	189.11	112.82	57.98	55.52
	2013	2012.97	6.09	145	13.88	193263.8	5.85	1.22	310.20	16.39	74.33	51.40
Shrubland	1985	4738.94	14.26	335	14.15	694610.4	20.91	1.36	186.71	89.36	60.62	23.38
	1995	5714.82	17.21	326	17.53	768892.1	23.15	1.40	168.54	123.93	68.85	27.79
	2005	6457.83	19.5	352	18.35	780943.7	23.58	1.34	175.15	145.26	58.05	33.85
	2013	6822.73	20.65	281	24.28	691980.9	20.95	1.36	221.56	151.82	79.62	41.03
Wooded grassland	1985	4243.20	12.77	316	13.43	574751.7	17.30	1.31	192.81	50.98	62.04	29.11
	1995	5623.59	16.93	353	15.93	699431.0	21.06	1.35	175.08	154.85	55.64	34.54
	2005	3563.81	10.76	408	8.73	562700.1	16.99	1.26	204.56	29.61	67.46	24.18
	2013	3086.07	9.34	271	11.39	383460.0	11.61	1.22	274.32	33.54	80.44	34.77
Woodland	1985	12003.39	36.13	320	37.51	1096477.0	33.00	1.36	161.93	1091.38	79.50	44.91
	1995	11045.52	33.26	366	30.18	1153009.0	34.72	1.35	148.38	949.67	73.58	39.63
	2005	12101.82	36.53	333	36.34	1204722.0	36.37	1.38	158.25	875.01	79.28	40.37
	2013	10659.01	32.27	222	48.01	893352.2	27.04	1.36	209.30	904.59	82.68	45.93
Grassland	1985	7652.16	23.03	100	76.52	318819.6	9.60	1.27	253.48	780.35	49.97	73.07
	1995	6922.36	20.85	75	92.3	251988.0	7.59	1.26	384.50	838.49	48.33	76.47
	2005	4249.20	12.83	190	22.36	386746.8	11.68	1.25	253.99	193.58	65.71	47.85
	2013	2178.62	6.59	222	9.81	259219.0	7.85	1.14	351.21	37.49	80.47	38.84

CA: Class area (ha), PLAND: % of landscape, NUMP: No. of patches, MPS: Mean patch size (ha), TE: Total edge (m), ED: Edge density (m ha^{-1}), MSI: Mean shape index, MNN: Mean nearest-neighbor distance (m), MPI: Mean proximity index, IJI: Interspersion Juxtaposition index (%), TCAI: Total core area index (%)

Area metrics: Our analysis showed that notably the areas occupied by forest, wooded grassland and the grassland have decreased, whereas the land, cultivated land and areas under invasive plants have increased between 1985 and 2013 and the woodland showed fluctuating spatial extent during these periods.

We observed that the woodland has covered the largest percentage of the park area as compared to other land cover classes of the NSNP probably due to the reduction in the grassland and wooded grassland.

Patch density and habitat fragmentation: Our results indicate that the grassland and forest area became more fragmented when compared to other land cover types as the mean patch size has decreased (Fig. 2) with an increase in the mean number of patches between 1985 and 2013 (Fig. 3).

Edge metrics: During the study period, all records of edge density are more than 0 and ranged between the lowest 5.35 m ha^{-1} for forest to the highest edge density value 36.37 m ha^{-1} for woodland (Table 2). As a result of increased number of small patches, out of the five habitat types, total edge and edge density is lower for the forest and grassland which in turn affects the home ranges for wildlife movements.

Shape metrics: Mean Shape Index (MSI) of all patch types of NSNP is more than 1 displaying relatively complex habitat shape. MSI becomes 1 when all patches (polygons) are circular with polygons, or square in the case of grids. Decreasing MSI indicates habitat shape has becomes simple. Out of the five habitat types, the forest and wooded grassland habitats have smaller patch size and lower proximity index (Table 2), displaying a more fragmented and isolated patch

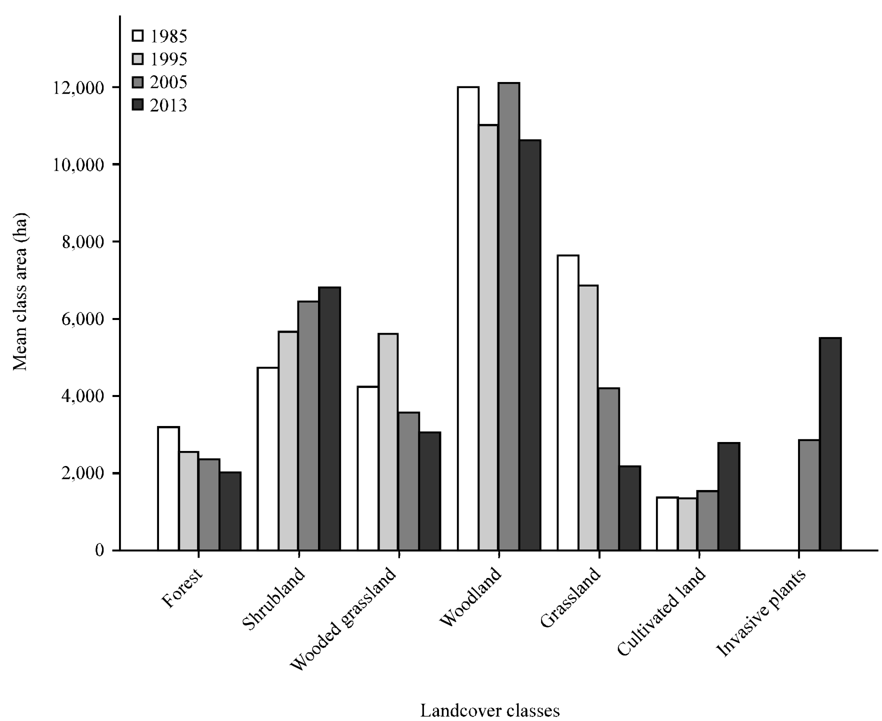

Fig. 2: Mean class area (ha) of different landcover classes at NSNP between 1985-2013

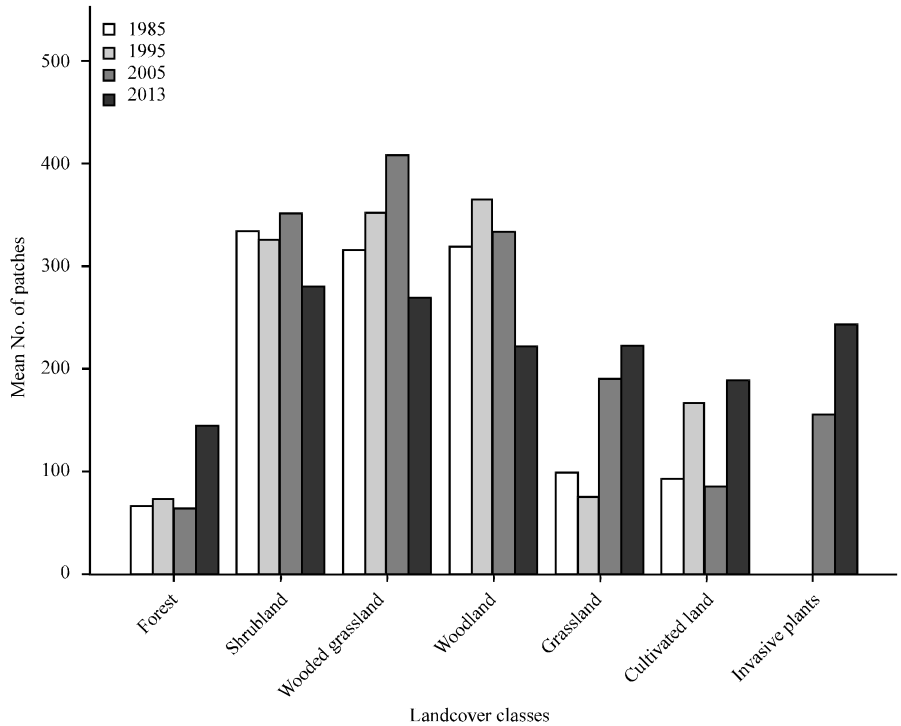

Fig. 3: Mean patch metrics of different landcover classes at NSNP in 1985-2013

distribution. On the other hand, the grassland showed the lowest MSI and lowest mean fractal dimension but higher mean patch size as compared to other land cover classes. The least complex with simplest habitat shapes was observed in 2013 for the forest, wooded grassland and grassland habitats. Grassland habitat shape complexity declined slightly during 1985-2013.

Diversity and interspersion metrics: The landscape level Shannon diversity index values were 1.60, 1.62, 1.73 and 1.77 during the period 1985, 1995, 2005 and 2013, respectively. The Shannon evenness was 0.90, 0.91, 0.89 and 0.91 in the same period, respectively. These results indicated that the land cover classes increased between 1985 and 2013 as the formation of new land cover due to expansion of non-native species and the patches are evenly distributed along the landscape.

The interspersion and juxtaposition index (IJI) of the grasslands showed the lowest value as compared to other habitat types, implying that there are fewer, unevenly distributed patches of around this land overtypes. However, the measure for Mean Nearest Neighbor distance (MNN) showed higher value for the grassland followed by forest as compared to other land cover classes that reflects greater isolation between and among patches. For the woodland, bushland and wooded grassland the MNN (Fig. 4) between 1985 and 2005 is lower as compared to the grassland and forest land cover classes in the NSNP indicating high aggregation of patches in the landscape (Table 2). MNN showed an increasing trend between 2005 and 2013 for all land cover types indicating the formation of isolating patches.

Core area metrics: Our result showed that the average Total Core Area Index (TCAI) between 1985 and 2013 ranges from 31% for scrubland and wooded grassland to 59% for grassland. Lower mean core area index recorded for scrubland and wooded grassland indicating the centers of these patches are relatively close to the edge as compared to the grassland.

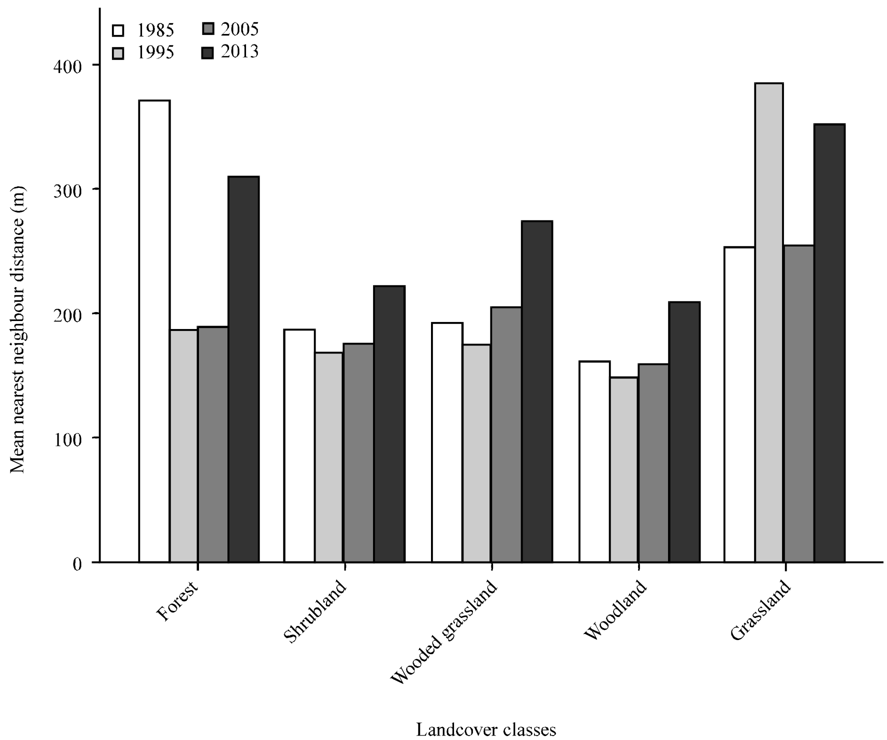

Fig. 4: Measure of mean near neighbour distance along different landcover classes of NSNP

Table 3: Characteristics of different habitat patches in relation to observed frequencies of indicator species

Habitat type	No. of observations Black and white colobus	Water buck	Grant's zebra	Grant's gazelle	Swayne's hartebeest	Greater kudu	Guenther's dikdik
Forest	69	2	0	0	0	0	0
Shrubland	0	0	0	0	0	0	38
Wooded grassland	0	4	61	32	0	39	1
Woodland	0	1	2	3	0	18	26
Grassland	0	0	71	40	2	17	0

Analysis of habitat loss in relation to the distribution of indicator wild animals: Result on the habitat loss reveals that of the five habitat types examined, the forest and grassland habitat types showed the highest loss of patch size by 32.45 and 66.71 ha, respectively between 1985 and 2013 indicating the presence of severe anthropogenic pressure on these important wildlife habitats whereas, the scrubland and woodland increased by about 10 ha in the same periods (Table 2). The disturbance on the habitat type influenced the home range and distribution of indicator wildlife species in the terrestrial habitats of NSNP (Table 3).

According to the field observation on the distribution of indicator species of NSNP, single habitat has been used by several terrestrial mammalian species. For example, the grassland habitat is commonly used by Grant's zebra, Grant's gazelle, Swayne's hartebeest and Greater kudu.

The habitat types are defined based on the frequently observed large mammalian wildlife. For instance, black and white colobus are more frequently observed in the forest as compared to other species and hence the forest is the common habitat for the primates like black and white colobus. Likewise, the grassland is the common habitat for herbivores like Grant's zebra, Grant's gazelle, Greater kudu and Swayne's hartebeest. The scrubland between the two lakes of Abaya and Chamo is used as the habitat by Guenther's dikdik. The wooded grassland supports a large portion of terrestrial mammals particularly the Greater kudu, Waterbuck, Grant's zebra, Grant's gazelle and Guenther's dikdik. The woodland is found the common habitat for Greater kudu and Gunter's dikdik.

DISCUSSION

Our result revealed that the expansion of human activities in the NSNP resulted in the formation of many but small sized patches. An increase in the number of patches in the natural habitat is leading to high degree of fragmentation (Wilcox and Murphy, 1985) and affects the minimum spatial requirement of wildlife species in their respective home range (Turner and Ruscher, 1988; Robbins *et al.*, 1989). Habitat fragmentation occurred in all land cover types of NSNP but is the dominant threat for the forest and grassland.

Fragmentation might not be a problem if the minimum mean near neighborhood distance and minimum patch size criteria of the target species are maintained. Minimum patch size criteria are based on home range and assumed patch size for viable populations of the species (Beaudette, 2000). But the result showed that the fragmented patches of NSNP are too small that could not maintain the spatial requirements of target species. For example, mean home range size of Greater kudu is 90-350 ha during wet summer periods and may expand to 600 ha during droughts and its daily movement is between 1.5 and 3 km (round trip) during wet summer months and up to 8 km in dry winter periods and up to 11 km during disturbance (Du Toit, 1990). But in all Greater kudu habitats of NSNP, the mean patch size range from 12±2 ha for wooded grassland to 50±20 ha for grassland. Therefore, habitat loss and fragmentation in the NSNP has negatively affected the movement and feed requirement of Greater kudu. Similarly the home range for Grant's zebra is 300-500 ha; for Grant's gazelle, 8-1000 ha; for Deface waterbuck, 400 ha; for Guenther's dikdik, 0.3-35 ha and Black and white colobus needs small territories with about 16 ha home range (Kingdom, 1997).

Thus, in NSNP except for Guenther's dikdik and black and white colobus, none of the spatial extent of habitats is sufficient to support the indicator wildlife species that are in habited in the area. Although, the black and white colobus had sufficient home ranges in the ground water forest of Arbaminch; its habitat has been threatened in the Sermele riparian forest as a large portion of this area is converted to cultivated land.

The formation of many smaller patches than mosaic habitats also lead to formation of habitat edges that lead subsequently to a decrease of the core area for each habitat type and create stress from external factors to native plant and animal communities (Collinge, 1996; Ries *et al.*, 2004; Antwi *et al.*, 2008).

The results of mean shape index in this study are not in agreement with other studies (e.g., Moser *et al.*, 2002; Antwi *et al.*, 2008) which is reported that habitat types with larger mean patch sizes were found to have high shape complexity. In our study, the grassland has higher mean patch size but it displayed a lower mean shape index and the scrubland, having lower mean patch size has displayed larger mean shape index. This may be attributed to the natural landscape where, the grassland showed relatively close to regular orientation as compared to the configuration of the scrubland.

Mean Patch Fractal Dimension (MPFD) is another measure of shape complexity which is computed based on perimeter-area relationships of the same patch. In our study, all values of MPFD ranged from 1.03-1.04 indicating lower patch shape complexity. The value of mean fractal dimension approaches one for shapes with simple perimeters and approaches two when shapes are more complex (McGarigal *et al.*, 2012).

The shape of a habitat coupled with the patch size can influence important ecological processes in the landscape such as small mammal migration between and within inter-patches (Buechner, 1989) and woody plant colonization (Hardt and Forman, 1989), as well as influencing animal foraging strategies (Forman and Godron, 1986).

Declining Mean Nearest Neighbor (MNN) values for woodland as compared to other land cover classes of NSNP could be the combined result of the splitting of single large patches into two or more adjacent smaller patches that have low nearest neighbor distances and the emergence of new landcover classes such as invasive plants in close proximity to existing habitat patches of woodlands (Betts *et al.*, 2003). MNN measures the distance that separates patches of the same land use type. An increase in MNN reflects greater isolation between patches of the same classes (McGarigal *et al.*, 2012). Isolation of patches in NSNP is aroused from the expansion of agricultural fields particularly in the forested areas. Settlement in the woodlands, wooded grassland and grazing pressure in the grassland areas are the main causes of habitat fragmentation. Therefore, patch separation in the NSNP is the result of anthropogenic effects.

The lowest mean values for the measure of Interspersion Juxtaposition Index (IJI) were recorded for the grassland (61%) and the higher mean value was recorded for woodland (79%). IJI measures the patch adjacency and when it approaches 100 it indicates that all patch types are equally adjacent to each other and when it approaches to zero it indicates uneven distribution of patch adjacencies (McGarigal and Marks, 1995). In our result of IJI (61-79) indicates that the patches in all habitats of NSNP are fairly adjacent to each other.

For the study period (1985-2013) for the many patches of NSNP the core area index is below 50% implies that many patches in the landscape have been influenced by edge effects. Reduction in the core area could affect the interior parts of the park and is a challenge for the wildlife community as could be liable to external factors. Therefore, preserving and expanding habitat core areas in the protected areas would ensure the survival and security of wild animals in their natural habitat.

CONCLUSION

Our analysis of spatial metrics has sowed that the landscape in NSNP underwent major changes between 1985 and 2013 with the forest and the grassland are the most threatened habitats by anthropogenic activities. The observed direction of changes were from the forest to crop land and from the open grassland to land cover of undesirable non-native species as well as extensive shrub encroachment in the grassland areas. These major changes through habitat loss and fragmentation, negatively affected the mosaic habitat patches and reduced the home range requirements of terrestrial large mammals of NSNP. The habitat loss and disturbance seriously affected particularly the endangered animals like Swayne's hartebeest to the point of local extinction. If the habitat degradation is continuing as observed during the study period, the possibility of NSNP as IUCN category II protected area will be under question. Analyses of landscape and habitat structure through spatial metrics were found to have considerable practical value for the management of NSNP and protected areas elsewhere in the country as such knowledge can be incorporated into conservation planning.

Therefore, it is urgently important to restore the biological and physical resources NSNP to their original condition through planning effective management strategies that could mainstream both the local communities' livelihood and nature conservation with full participation of concerned stakeholders.

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