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Research Article

Trends of Land Cover Change and Conservation Challenges of Grevy's Zebra (*Equus grevyi*, Oustalet 1882) in Hallaydeghe Asebot Proposed National Park, Southeast Ethiopia

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Large parts of biodiversity in protected areas (PAs) and their ecosystem services have been deteriorated due to land cover change over time. To reverse these effects, analysis of land cover change is essential. One of the protected areas, Hallaydeghe Asebot Proposed National Park (HAPNP), was assumed its land cover change and was undergone from one habitat type to others during the last three decades. As a result, wildlife species particularly Grevy's zebra (*Equus grevyi*) in HAPNP are facing conservation challenges. Here, we aimed to examine the land cover changes of HAPNP for the period of 1990–2021 and assess Grevy's zebra conservation challenges so as to improve the protection of the park and conservation of the species. Landsat images for the years 1990, 2006, and 2021 were generated to analyze land cover change of the study area. In addition, ground control points and information from elder and knowledgeable informants were collected to substantiate the result. Household survey, key informant interviews, and field observation checklist were utilized to collect data on conservation challenges. To generate land cover change maps, the satellite image for each period was classified using supervised classification. Content analysis was used to analyze conservation challenges of the species. The findings of this study revealed that 12.2% of grassland cover lost from 1990 to 2021 (i.e., an estimated annual average loss 0.4%). The remaining grassland cover in the HAPNP was aggregated in a small land area. On the other hand, the size of bushland increased by 26.4% during the same year (i.e., an estimated annual average gain 0.9%). These findings have implications for conservation and management of grazers. Major drivers for conservation challenges of Grevy's zebra were habitat degradation, unintegrated development, and poor law enforcement practices. Grassland restoration program and species conservation challenges' intervention strategy should be designed and implemented to safeguard the natural habitat and the species that occur in the HAPNP.

1. Introduction

Globally, there has been a decline in biodiversity over the last four decades, attributed in large parts to habitat fragmentation and land conversion [1–3]. Protected areas (PAs) are areas of biodiversity conservation and shaped by the land uses, species, and ecological process in the surrounding landscape and should not be viewed in isolation [4, 5]. External influences can decrease the effective size of a PA, limiting their ability to protect biodiversity and ecosystem functions [6–8]. Specifically, there is a link between increases in anthropogenic activities such as land cover changes owing to changes in agricultural land use, urbanization and illegal extraction within and around PAs, and species extinction which may exacerbate impacts on PAs [9–11]. These have affected functionality of the PAs.

Loss of functionality of PAs from surrounding land-use modification is a particularly daunting problem in developing nations. However, the resources in and around PAs are more critical to people living adjacent to PAs in developing nations because their livelihoods are often more directly dependent on the land [12]. Natural disturbances,

ecological processes, and human activity cause the landscapes of protected areas (National Parks and watersheds) to change over time [13]. Therefore, to ensure the effectiveness of PAs in the developing world, it is necessary to understand changes driven by the surrounding landscape.

Protected areas in the majority of Eastern African countries frequently encountered land-use changes as a result of growing human and livestock populations [14]. The relationship between people and the environment where they live in is the main focus of land use and land cover change (LULCC) concerns [15].

In Ethiopia, protected areas have faced a range of conservation challenges. The root causes of biodiversity conservation challenges in Ethiopia are associated with lack of adequate capacity, commitment, organizational set-up, and lack of monitoring of the implementation strategy on the status and trends of conservation challenges [16]. The land cover changes in and around the protected areas of the country are common as a result of anthropogenic impact such as increased heavy grazing, fire, agricultural expansion, and poor application of land-use policy [17].

Hallaydeghe Asebot Proposed National Park (HAPNP) was designated as a Wildlife Reserve with a primary objective to conserve, manage, and propagate wildlife within it. The area was specifically selected to serve as a corridor between Awash National Park and the surrounding plains so that the wildlife population of Awash National Park would be protected through freedom of migration [18]. The area is home to a number of wildlife species including Grevy's zebra, Soemmering's gazelle (*Gazella soemmeringi*), Beisa oryx (*Oryx gazella*), Gerenuk (*Litocranius walleri*), Salt's dikdik (*Madoqua saltiana*), African wolf (*Canis lupaster*), Spotted hyena (*Crocuta crocuta*), Aardwolf (*Proteles cristatus*), and Ostrich (*Struthio camelus*). It is also a remnant grazing land for the Afar and Issa pastoral communities, in which livestock numbers are a social indication of the owner's wealth status [19]. Wildlife resources including Grevy's zebra that live in HAPNP are facing different forms of conservation challenges elsewhere that stem from expansion of invasive species, heavy grazing, and poaching and habitat degradation [20].

Consequently, over the last 30–40 years, Grevy's zebra has experienced dramatic reductions in range and numbers and are now found only in northern Kenya and in small pockets in Ethiopia. A recent study conducted by Tolera et al. [21] indicated as there are no more than 75 individuals of Grevy's zebra in the area. Grevy's zebra in HAPNP is mostly isolated and has unique population [22]. The major challenge facing conservationists is to identify and mitigate the causes of the decline in Grevy's zebra's range and population size. As already mentioned, the anticipated justifications for Grevy's zebra population and range decline are habitat degradation, poaching, competition with livestock for critical resources, expansion of invasive species, and drought [23–27]. The same factors might have affected the range and population size of Gravy's zebra in HAPNP of Ethiopia.

Thus, this study investigated the land cover change and conservation challenges for Grevy's zebra in HAPNP. As information relating to the land cover change and conservation challenges to these species is limited, assessing trends in land cover change in the stated protected area is important. So, assessing of changes in land cover using remote sensing and satellite imagery analysis and predicting is very important and could be useful to document land converted to other land-use types affecting the species. Remote sensing techniques provide an effective means of monitoring and measuring land cover change over spatial and temporal extents and may provide practitioners with insights into future land-use change processes [28]. Satellite and aerial imagery analyses have versatile applications that allow us to measure spatial and temporal changes in and around PAs [29, 30]. It also uses globally available satellite imagery, making it a widely accessible research methodology for scientists in both developed and developing nations.

In a similar manner, we expected that anthropogenic activities would raise conservation challenges in the study area. In order to inform existing conservation efforts and offer a foundation for reducing Grevy's zebra conservation issues in HAPNP, it was anticipated that the information gathered from this study would be able to explain the land cover change in the protected area and the conservation challenges in their natural range.

2. Methods

2.1. The Study Area Description. Hallaydeghe Asebot Proposed National Park is located about 280 km away from Addis Ababa in the Ethiopian Rift Valley between latitude of 8° 92′ and 9° 48′ and longitude 40° 25′ and 40° 63′. Its former name was Alledeghi Wildlife Reserve, and the primary objective was to "conserve, manage, and propagate the wildlife within it." HAPNP has a semiarid climatic condition. The site is dominated by a large alluvial plain with mountains rising along the eastern border of the proposed park [31]. The site was selected to serve as corridors between Awash National Park and the surrounding plains so that through migration, the wildlife population of Awash National Park would be protected [18]. Currently, there are 13 kebeles belonging to three Woredas, namely, Amibara, Meiso, and Haruka in which the protected area occurs (Figure 1). The community surrounding this protected area practice pastoral mode of life. The area is home to a number of wildlife species including Grevy's zebra (*Equus grevyi*), lion (*Panthera leo*), Soemmering's gazelle (*Gazella soemmeringi*), Beisa oryx (*Oryx gazella*), Gerenuk (*Litocranius walleri*), Salt's dikdik (*Madoqua saltiana*), African wolf (*Canis lupaster*), Spotted hyena (*Crocuta crocuta*), Aardwolf (*Proteles cristatus*), and Ostrich (*Struthio camelus*) [32].

The major vegetation types in and around the HAPNP include grassland, bushland, shrubland, wooded grassland, riverine forest, and highland forest [33]. Chrysopogon plumulosus and Sporobolus iocladus contribute a relatively substantial percentage of the herbaceous vegetation on the plains [33]. The southern, northern, and western edges of the protected area are bush-grassland or shrubland, with Senegalia senegal being the dominant species here, as well as in some parts of the grassland. The woody plant species in the plains of this study site include Prosopis juliflora, Senegalia

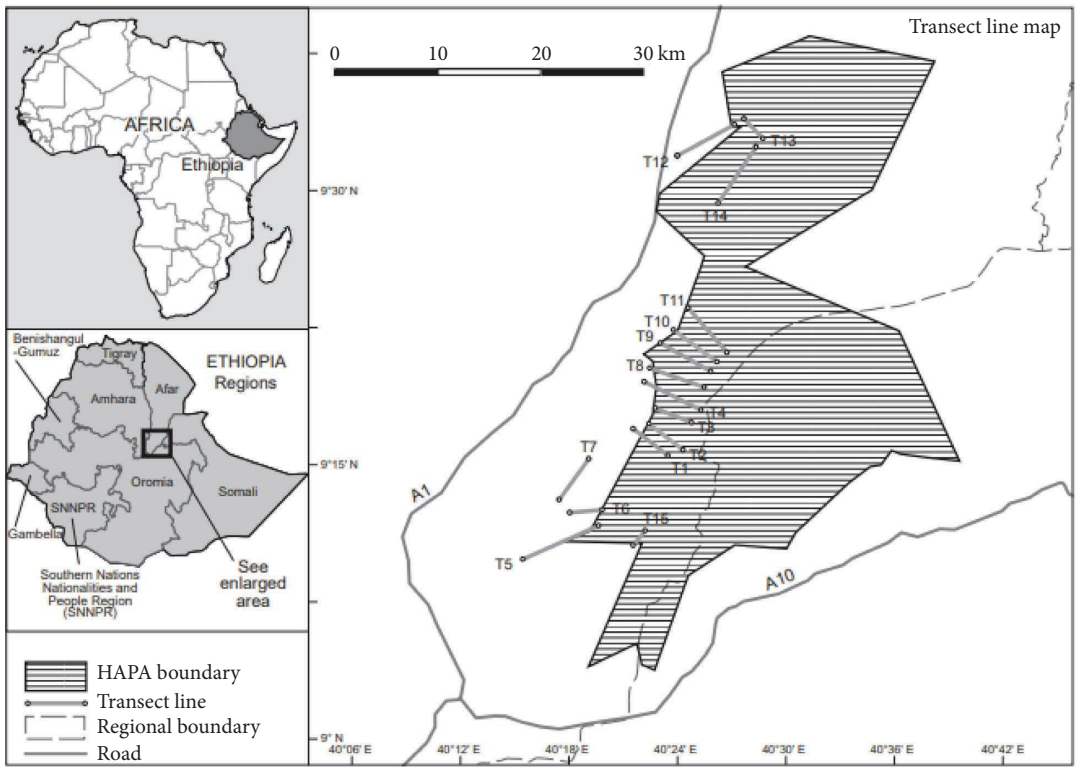

Figure 1: Study area map and transect lines used (adopted from [21]).

senegal, Vachellia tortilis, Balanitis aegyptiaca, Cadaba spp., and Grewia spp. Some of the highland forests of Mount Asebot include Cordia africana, Croton macrostachyus, Erythrina abyssinica, Juniperus procera, Olea europaea, Podocarpus falcatus, and Rhus vulgaris [34].

2.2. Data Collection Method

2.2.1. Spatial Data Collection. Landsat images were retrieved from United States Geological Survey (https://earthexplorer.usgs.gov). Multisensor and multitemporal images were utilized to estimate the size and directions of land cover change (Table 1). Landsat satellite imagery covering the area was collected in 1990, 2006, and 2021. Therefore, this study was interested in finding out the LULC change detection in these periods using Landsat images. The effects of cloud cover were considered during satellite image selection. Satellite images were accessed with minimum cloud cover (<10%) at early and mid of dry season (November to mid-April). Ground training points (GTPs) were also collected. High resolution images available at Google Earth Engine were used as supplementary tool for ground training points.

For 1990 and 2006 LCC map, GTPs were collected from the false color composite of 1990 and 2006 satellite images with the help of elders and knowledgeable people [39]. GTPs were taken by well-trained staffs of the proposed park. A minimum of 50 points for each major land cover category were collected following [40]. The land cover of HAPNP was categorized into five major different classes: grassland, woodland, bushland, forest, and settlement. The vegetation description was based on the classification provided by [41].

2.3. Conservation Challenges in the Data Collection Method

2.3.1. General Approach. The list of species conservation challenges was first prepared in English by researchers and translated into Afarigna language by native language speakers to minimize confusion. Moreover, during data collection, the native language speakers read the developed questions for the respondents and probed them for the response they provided to minimize error made during response provision. The list of Grevy's zebra conservation challenges presented for respondents were habitat degradation, poaching, drought, disease, predation, roadside killing, weak law enforcement, and unintegrated development to research participants. Based on the list provided to them, they asked to rank from top to down. The interview average length time had been 90 minutes.

2.4. Quantitative Data Collection

2.4.1. Sampling Techniques and Sample Size Determination. The preliminary survey was made to estimate the distance of the surrounding kebeles from head quarter of the park. Based on the preliminary survey, kebeles were classified into three domains (less than 5 km, 6–10 km, and >10 km). After

Table 1: Definition of land cover category across its definition.

LU/LC types	Working definition/description
Forest	Landscape dominated by land spanning at least 0.5 ha covered by trees, dense woodlands, and dense bamboo, attaining a height of at least 2 m and a canopy cover of at least 20% or trees with the potential to reach these thresholds which could be natural/manmade [35]
Bushland/shrubland	Areas covered by densely growing woody vegetation of shrubby habit, generally more than 0.5 m and less than 7 m in height at maturity and without a definite crown [35]
Woodland/savannah woodland	An area consists of trees that is branched, Acacia-Commiphora, deciduous and ranges from 8 to 20 m in height, crowns may touch grasses, and herbs are present [36]
Openland/grass	Land covered by grasses and other herbs, either without woody plants [37]
Settlement	Permanent residential areas (mainly urban built-ups), refugee camps, and rural villages which are clearly visible and identified on satellite image and having extent of at least one hectare in the study area [38]

stratifying kebeles into three strata based on their distance and accessibility from headquarter of the park, one kebele was selected using random sampling techniques from each strata and a total of three kebeles were considered. Then, household sample sizes were calculated using the Yamane [42] formula. The formula is expressed as

$$n = \frac{N}{1 - N(e)^2}, \quad (1)$$

where n is the sample size, N is the population size/sampling frame, and e is the error of prediction which was 0.05 (95%).

The selected kebeles had a total of 996 households (N). Then, the total respondents were 285. The distribution of sample respondents to each kebele was made based on the proportion of the population size of the selected kebele. Finally, the study household was selected from each selected kebele by using systematic random sampling. The first household was randomly selected, and thereafter, every K^{th} household were taken until the desired sample size is reached (where $K = N/n$). Those family member individuals who had a better understanding about study issues were purposively selected.

2.5. Qualitative Data Collection

2.5.1. In-Depth Interviews. In-depth interviews were carried out using structured and semistructured questions. In doing so, the participants for the in-depth interviews were selected purposively based on the responsibilities they have, experience, and relevance to issues under study. Accordingly, from nearby Woredas animal science, plant science, and natural resource management experts and police officers had participated. Chief Warden and senior staff members of HAPNP had also participated. The issues discussed were the current conservation challenges of Grevy's zebra and possible solutions for sustainable conservation of species. The protected area field personnel who were interviewed through the method were considered knowledgeable in view of their involvement in protected area management over time.

2.5.2. Observation Checklist. A digital camera was used during filed observation to take the photos of conservation challenges' effects. Moreover, it was undertaken to augment the reliability of information collected through different sources. To undertake field observation checklist, a walk along transect line was conducted. A total of 15 transect lines of varying lengths were established, and they were purposefully placed using GPS (Figure 1). At least 1500 meters separated the adjacent transects. The ends of each transect were not less than 1000 m from the habitat margin. Transects were laid north to south direction in order to reduce impact of the sunlight. While the longest transect was 17 km, the shortest transect has 5 km length. The main road that connects Ethiopia with Djibouti crosses the HAPNP. So, the data on impact of road side killing were collected via a mix of roadside walk and drive [43, 44]. The length of the road in that data collection held was 23.5 km. The data were collected by driving 4WD vehicles at a speed of 20–30 km/h, once a day. Road kill locations were recorded using a GPS (Garmin GPS72H). Once recorded, road kill was removed to avoid recounts. In addition, desk review was held to make stronger the findings of the study.

2.6. Data Analysis

2.6.1. Data Analysis for LCC. To generate land cover change maps, the satellite image for each period was classified using supervised classification. The methodology adopted for land use/cover change analysis is summarized in Figure 2. Overall, it involves radiometric normalization, land cover classification, accuracy assessment, and postclassification analysis using ArcGIS 10.8 and QGIS 3.26.3. Radiometric corrections of satellite images were carried out by converting DN values into radiance values using derived calibration coefficients. Radiometric correction is a technique for improving the brightness magnitude of a satellite picture for better visibility and analysis. By adjusting the bias and gain levels for each band, radiometric correction may be used to translate digital numbers (DNs) into Top of Atmosphere (TOA) radiance measurements [45].

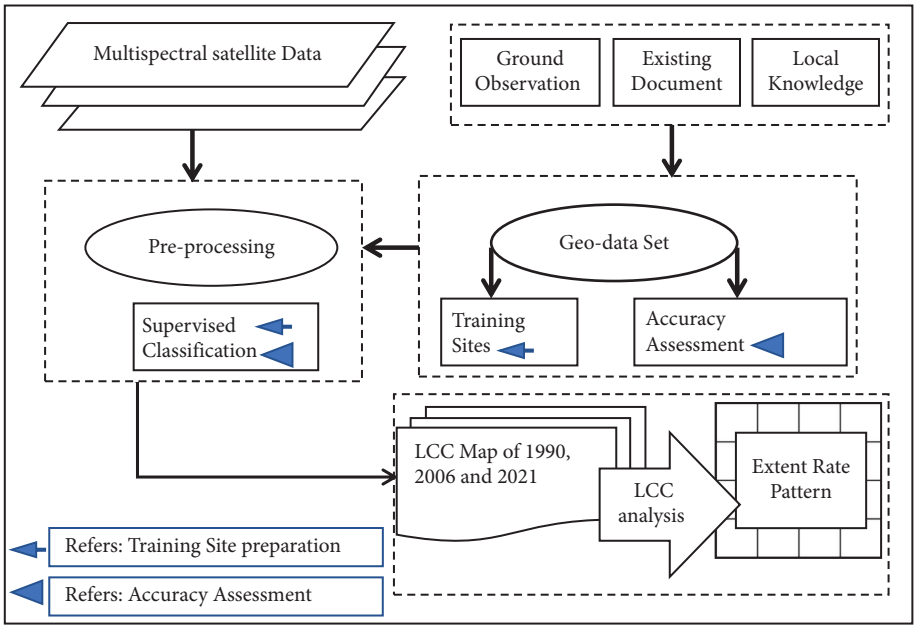

Figure 2: Study approach adopted for the analysis of land use/cover changes of HAPNP.

Following the supervised classification of imagery, the postclassification change detection algorithm was performed to determine changes in land cover [46, 47]. This post-classification approach provides statistical evidence on how land cover has changed and is used to calculate and produce map of land cover changes over time. According to Han et al. [48], the most common methods for the detection of land change are image overlay, principal component analysis, change vector analysis, image rationing, and the normalized difference vegetation index (NDVI). In this study, classification comparisons of land cover statistics had been used. Each land cover type's covered areas over time have been compared. Then, the directions of the changes (positive or negative) in each land cover type had been determined.

$$\text{Percentage of land use land cover change} = \frac{\text{Area final year} - \text{Area initial year}}{\text{Area initial year}} x100. \tag{2}$$

The accuracy of the land cover classification was assessed using a confusion matrix to compare the 1990, 2006, and 2021 classification results to the ground observations. For each land cover class, a contingency matrix was generated and the overall accuracy, the Kappa statistic, and the producer and user accuracy for each class were calculated [49]. The total accuracy was calculated by dividing the number of correctly classified elements (i.e., the sum of the diagonal elements in an error matrix) by the total number of pixels included in the evaluation process. The Kappa statistic is an alternative measure of the classification accuracy that subtracts the effect of random accuracy, and it quantifies how much better a particular classification is compared to a random classification.

$$\begin{aligned}
\text{User's accuracy} &= \frac{\text{Number of Correctly Classified Pixels in each Category}}{\text{Total Number of Reference Pixels in that Category (The Row Total)}} x100,\\
\text{Producer accuracy} &= \frac{\text{Number of Correctly Classified Pixels in each Category}}{\text{Total Number of Reference Pixels in that Category (The Column Total)}} x100,\\
\text{Total (overall) accuracy} &= \frac{\text{Total Number of Correctly Classified Pixels (Diagonal)}}{\text{Total Number of Reference Pixels}} x100,\\
\text{Kappa Coefficient } (T) &= \frac{(\text{TSxTCS}) - \sum(\text{Column Total } x \text{ Row Total})}{\text{TS}^2 - \sum(\text{Column Total} - \text{Row Total})}.
\end{aligned} \tag{3}$$

2.7. Data Analysis for Conservation Challenges. Content analysis was used to analysis the conservation challenges. Furthermore, statistical package software for social science (SPSS) version 25.0 was used to compare and rank the conservation challenges of the species.

3. Results

3.1. Land Cover Change (LCC) of HAPNP. Substantial land-use land cover change was undergone in HAPNP between 1990 and 2006. The grassland coverage was 59,824.42 ha (32.66%) during 1990. The grassland coverage of the area declined to 50,503.69 ha in 2006. Contrarily, from 1990 to 2006, bushland increased by +13,298.73 (7.22%) (Table 2).

In 1990, the large areas were covered by woodland and grassland, respectively, while settlement area coverage was very small (Figure 3). The details of land converted from one type to the other during 1990–2006 is provided in (Table 3) that is found under appendex section.

Between 2006 and 2021, period bushland increased by 35,229.32 ha (19.23%). In contrast, grassland decreased by 8.12% (Table 4). The details of land converted from one type to the other during 2006–2021 is provided in (Table 5) that is found under appendex section.

During 2006, the large area coverage was woodland and bushland, respectively, while settlement area coverage was minimal (Figure 4).

The land cover of HAPNP in 2021 was forest land 7,534.61 ha, shrubland 89,307.96 ha, grassland 37,458.72 ha, woodland 48,149.44 ha, and settlement 749.23 ha (Figure 5). The details of land converted from one type to the other during 1990–2021 is provided in (Table 6) that is found under appendex section.

The conversion of woodland to shrubland 9,213.31 ha was seen to be the largest land cover change that occurred between the years of 1990–2006 in HAPNP. The smallest change was from woodland to settlement 0.5 ha. Between 2006 and 2021, substantial land cover change from grassland to shrubland 14,324.37 ha had occurred. During the same period, woodland to forest 1.34 ha was the smallest land cover change that occurred. In general, from 1990 to 2021, the significant land cover change was undergone from grassland to shrub/bushland 16,790.32 ha.

The accuracy of land cover map of the 1990, 2006, and 2021 was assessed using GTPs collected during field mission and high resolution images available at Google Earth Engine as a supplementary tool. For the 2021 land cover map, aerial photographs taken in 2021 and detailed ground survey conducted in 2021/22 were used as reference. Overall, land use/cover classification accuracy levels for the three dates range from 89 to 94 percent with Kappa statistics ranging from 0.84 to 0.91 (Table 7). These accuracy levels satisfy the minimal accuracy required by [50] for satellite-derived land use/cover maps; hence, they were sufficient for the analysis of the research area.

3.2. Conservation Challenges of Grevy's Zebra/Equus grevyi/

3.2.1. Sociodemographic Information of Respondents. When we look at the respondent's profile, 90% of the respondents from the society who participated in ranking of Grevy's zebra conservation challenges were men and 69% of the respondents lack formal education and are illiterate. Out of the total respondents, 41.3% were within the age bracket of 30–40. Respondents in this area are agropastoralists, with goats and sheep being the most common livestock types.

3.2.2. Grevy's Zebra Conservation Challenges. Based on respondent's survey, field observation checklist, and in-depth interviews with staff members and other relevant stakeholders, the conservation challenges of Grevy's zebra were prioritized. Accordingly, habitat degradation was identified as a top conservation challenge for Grevy's zebra. Unintegrated development and week law enforcement, respectively, were identified as the second and third conservation challenges for Grevy's zebra in HAPNP (Table 8).

3.2.3. Grevy's Zebra Conservation Challenges and Their Drivers in HAPNP

Habitat degradation: the expansion of invasive plant species, Ruthenium *Parthenium hysterophorus*, *Abutilon figarianum*, and Mesquite *Prosopis juliflora*, was in and around the proposed park. Furthermore, exotic plant species include *Eucalyptus Viminal's*, *Eucalyptus citriodora*, *Eucalyptus globules*, *Eucalyptus saligna*, *Euclea racemosa*, *Grevillea robusta*, *Jacaranda mimosifolia*, *Jatropha curcas*, *Leucaena leucocephala*, *Schinus molle*, and *Senna didymobotrya* which are another pressing problem. Moreover, the practice of heavy grazing by pastoralist livestock, human-induced fire, and the local communities' harvesting of park resources for different purposes were considered as the main causes for Grevy's zebra habitat degradation. Moreover, there are diminishing sizes of grassland habitat due to land cover change. Most of the corridors through species crosses from one side to the other side are disconnected.

Poaching: although not confirmed during this study period, the information gained through key informant interviews and other relevant people indicates that Grevy's zebra is illegally hunted by local communities for medicinal purpose. The local communities believe that the foot of Grevy's zebra is used to heal from leprosy diseases.

Drought: HAPNP is found in a harsh environment where there is not enough rainfall and prolonged dry season aggravated by climate change impacts.

Diseases: although the local communities practice the pastoral mode of lifestyle, the culture of vaccinating domestic livestock is very poor. Grevy's zebra and

Table 2: Area and proportion of LCC in HAPNP between 1990 and 2006.

LULC type	1990		2006		Difference (1990–2006)
	Hectare	%	Hectare	%	Hect. (%)
Forest	13,527.34	7.34	18,659.36	10.19	+5,132.02 (2.85%)
Openland/grassland	59,824.42	32.66	50,503.69	28.57	−9,320.73 (4.09%)
Settlement	187.99	0.11	175.38	0.10	−7.25 (0.01%)
Bushland/shrubland	40,779.91	22.30	54,078.64	29.52	+13,298.73 (7.22%)
Woodland/savannah woodland	68,880.79	37.59	59,782.93	32.64	−5,311.09 (4.95%)
Grand total	183,200.00	100.00	183,200.00	100.00	—

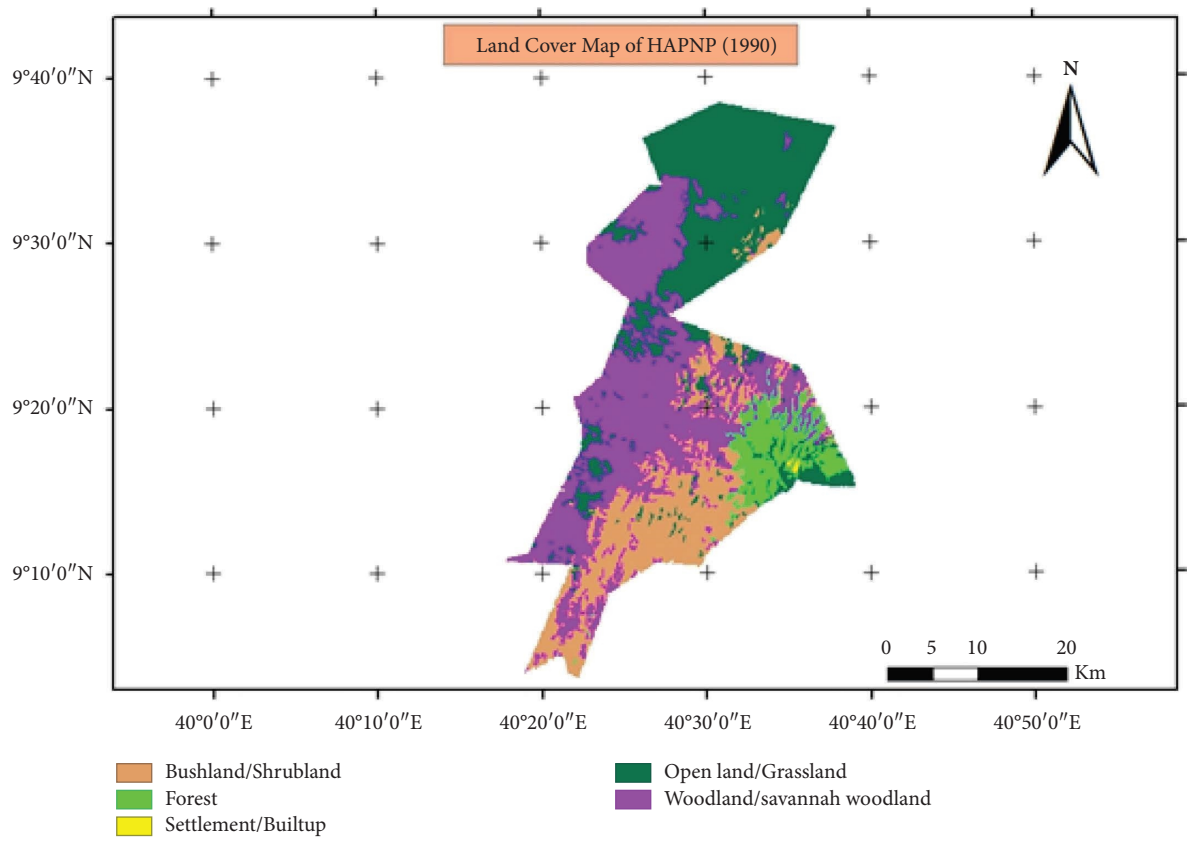

Figure 3: LCC map of HAPNP during 1990.

Table 3: Land-use land cover change of HAPNP (1990–2006).

No	Class change (1990–2006)	Area change (ha)
0	Forest—forest	6637.03
1	Forest—openland	244.23
2	Forest—settlement	16.21
3	Forest—shrubland	1107.16
4	Openland—forest	1735.28
5	Openland—openland	23662.41
6	Openland—settlement	24.59
7	Openland—shrubland	1393.06
8	Openland—woodland	8525.09
9	Settlement—forest	57.98
10	Settlement—openland	0.43
11	Settlement—Settlement	52.80
12	Shrubland—forest	2315.45
13	Shrubland—openland	630.05

Table 3: Continued.

No	Class change (1990–2006)	Area change (ha)
14	Shrubland—settlement	3.17
15	Shrubland—shrubland	20229.88
16	Shrubland—woodland	929.48
17	Woodland—forest	263.46
18	Woodland—openland	5339.70
19	Woodland—settlement	0.50
20	Woodland—shrubland	9213.31
21	Woodland—woodland	25914.55

Table 4: The LCC of HAPNP between the years of 2006–2021.

LULC type	2006		2021		Difference (2006–2021)
	Hectare	%	Hectare	%	Hect. (%)
Forest	18,659.36	10.19	7,534.61	4.11	−11,124.75 (6.08%)
Openland/grassland	50,503.69	28.57	37,458.72	20.45	−13,044.97 (8.12%)
Settlement	175.38	0.10	749.23	0.41	+573.85 (0.31%)
Bushland/shrubland	54,078.64	29.52	89,307.96	48.75	+35,229.32 (19.23%)
Woodland	59,782.93	32.64	48,149.44	26.28	−11,633.49 (6.36%)
Grand total	183,200.00	100.00	183,200.00	100	—

Table 5: Land-use land cover change of HAPNP (2006–2021).

No	Class change (2006–2021)	Area change (ha)
0	Forest—forest	4089.298433
1	Forest—openland	30.776738
2	Forest—settlement	145.344607
3	Forest—shrubland	6744.942997
4	Forest—woodland	21.076864
5	Openland—forest	116.611491
6	Openland—openland	11550.54068
7	Openland—settlement	188.123854
8	Openland—shrubland	14324.37065
9	Openland—woodland	3692.740597
10	Settlement—forest	14.809235
11	Settlement—openland	6.915092
12	Settlement—settlement	48.840648
13	Settlement—shrubland	29.170219
14	Shrubland—forest	237.782829
15	Shrubland—openland	3973.723092
16	Shrubland—settlement	8.919153
17	Shrubland—shrubland	23655.48888
18	Shrubland—woodland	4100.968158
19	Woodland—forest	1.342165
20	Woodland—openland	6600.269824
21	Woodland—settlement	38.370632
22	Woodland—shrubland	8032.104158
23	Woodland—woodland	20659.72636

domestic cattle graze together from Hallaydeghe grassland plain. From the respondent's views and field observations, it was possible to understand that the condition facilitated the zoonotic disease transmission.

Predation: in HAPNP, there are large carnivores like lion and hyena that can prey on Grevy's zebra. In contrast, the species move to water points at night when the site is free from human activities. The condition facilitates the predation process over species.

Road side killing: the main road that connects Ethiopia with Djibouti crosses through HAPNP. Despite the presence of many vehicles that use the road, there is no speed breaker, not enough sign posts, and awareness raising posters for drivers. In views of respondents and the researcher, field observations made roadside killing to be considered as one of the conservation threats for Grevy' zebra.

Weak law enforcement: there was severe shortage of manpower, especially scouts, who can enforce the rule

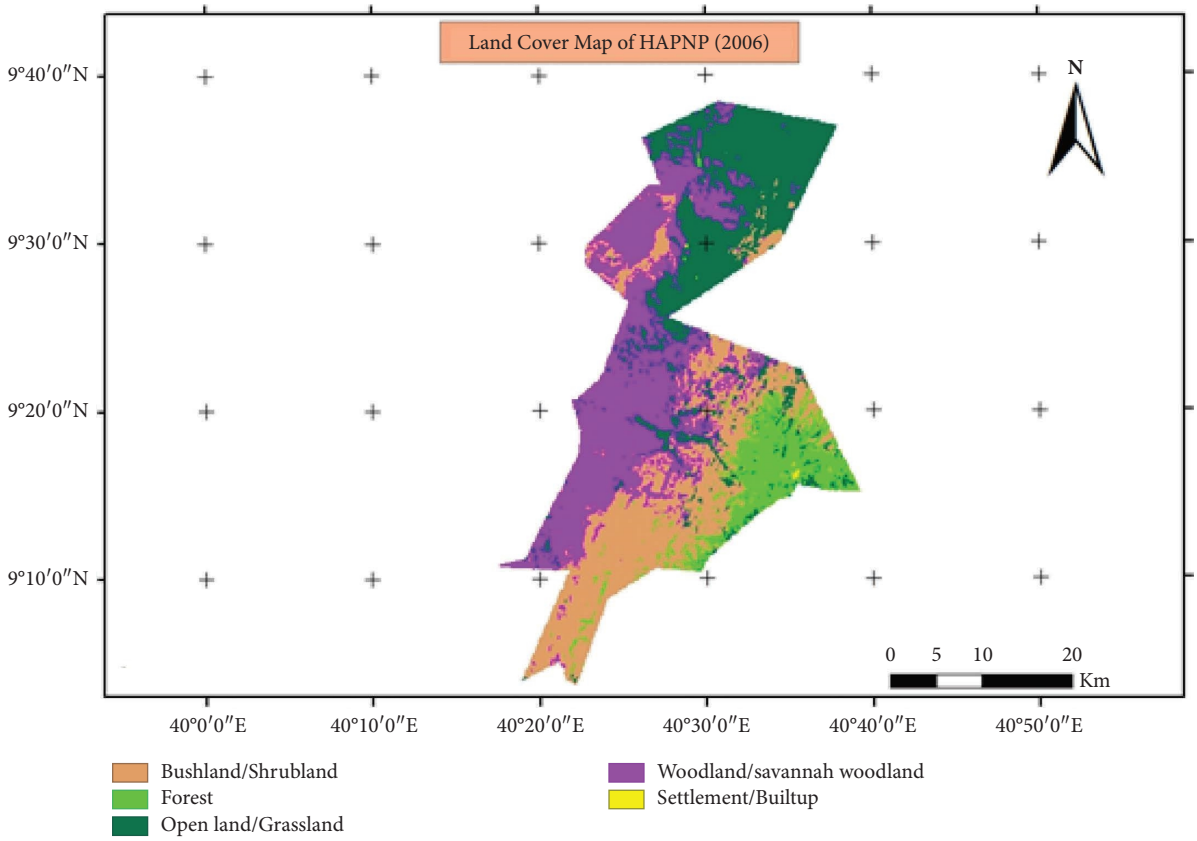

Figure 4: LCC map of HAPNP during 2006.

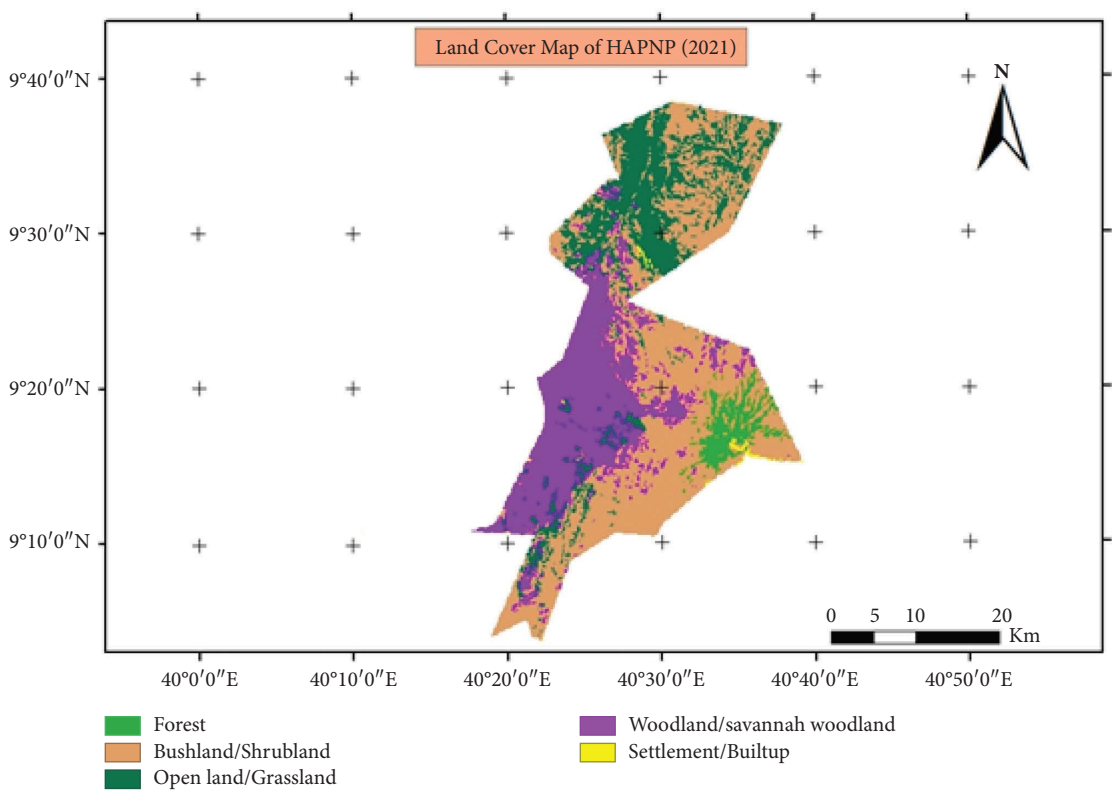

Figure 5: LCC map of HAPNP during 2021.

Table 6: Land-use land cover change of HAPNP (1990–2021).

No	Class change (1990–2021)	Area change (ha)
1	Forest—forest	3927.584988
2	Forest—openland	0.940913
3	Forest—settlement	10.211783
4	Forest—shrubland	3995.423686
5	Forest—woodland	65.190919
6	Openland—forest	335.094405
7	Openland—openland	13408.20823
8	Openland—settlement	336.27016
9	Openland—shrubland	16790.32267
10	Openland—woodland	4398.576207
11	Settlement—settlement	39.738158
12	Settlement—shrubland	16.101354
13	Settlement—woodland	2.109389
14	Shrubland—forest	76.396584
15	Shrubland—openland	2111.271565
16	Shrubland—settlement	12.803262
17	Shrubland—shrubland	19992.55332
18	Shrubland—woodland	1881.70601
19	Woodland—forest	60.135139
20	Woodland—openland	6641.861415
21	Woodland—settlement	38.563456
22	Woodland—shrubland	11852.50907
23	Woodland—woodland	22068.82518

Table 7: Summary of LCC classification accuracies for 1990, 2006, and 2021.

LC types	1990		2006		2021	
	Producer accuracy	User accuracy	Producer accuracy	User accuracy	Producer accuracy	User accuracy
Forest	0.89	0.87	0.95	0.914	0.98	0.91
Woodland	0.92	0.96	0.890	0.958	0.94	0.99
Grassland	0.86	0.90	0.92	0.953	0.88	0.92
Settlement	0.84	0.88	0.84	1.000	0.83	0.89
Shrubland	0.97	0.94	0.94	0.953	0.95	0.95
Overall accuracy	92	—	89	—	94	—
Kappa statistics	88	—	84	—	91	—

Overall classification accuracy = 94.19%; overall Kappa statistics = 0.915686.

Table 8: Grevy's zebra conservation challenges prioritized.

List of conservation threats	Respondents voted		Rank
	Frequency	Percentage	
Habitat degradation	274	96.14	1st
Poaching	80	28.07	8th
Drought	236	82.8	6th
Disease	93	32.63	7th
Predation	251	88.07	4th
Roadside killing	247	86.67	5th
Weak law enforcement	258	90.52	3rd
Unintegrated development	270	94.74	2nd

of law. The other pressing problem observed was lack of integration between wildlife stakeholders and inadequate awareness made for local communities regarding Grevy's zebra conservation.

Unintegrated development: the urbanization is expanded by disconnecting the corridors that wildlife uses. Investment expansion that did not align with wildlife conservation is undergoing. These investments disconnected Grevy's corridors.

4. Discussion

The results of the classification produced were acceptable accuracies (Table 7) and are generally compatible with prior studies involving Landsat image classification [51]. We identified various land cover patterns in HAPNP after analyzing the change in land cover between 1990 and 2021. These patterns are likely to affect how well the protected area functions. In 1990, when the area was a wildlife reserve, the land cover of the area was 13,527.34, 59,824.42, 187.99, 40,779.91, and 68,880.79 ha for forest, grassland, settlement, bushland, and woodland, respectively. In HAPNP, considerable spatial expansion in bushland +13,298.73 (7.22%) and a substantial decline in grassland −9,320.73 (4.09%) were recorded during the first fifteen years of the study period (1990–2006). During the second phase of the study period of

LCC (2006–2021), a significant spatial expansion in bushland +35,229.32 (19.23%) and a rapid decrease in grassland −13,044.97 (8.12%) were observed. The decline of the grassland area in and around protected areas concurs with the findings of [52]. This declining of grassland cover but increasing of bushland coverage observed was attributed to the effects of intensity of livestock grazing. Increased grazing intensity causes reduced grass biomass [53–56] that, in turn, reduces fire intensity, that benefits woody plants to regenerate, thus facilitating the shift from grassland to bushland. This result is in agreement with the previous study reports [57, 58]. In addition to the growth in human and livestock populations, the conversion of grazing lands to cultivation areas outside the HAPNP has caused grazing land scarcity. This, in turn, can force people to enter the park boundaries for livestock grazing and other forms of resource use.

Our result confirms with the previous study of the authors in [51] that LCC from forest to shrub conversion was the main form of land cover transition observed in the Kasungu National Park of Malawi. In contrast to the current findings, the study was conducted by the authors in [59] in Awash National Park and the grassland was expanded by 14.2% between 1972 and 1986 as well as by 10.5% of the study area during the entire study period (1972–2006). The land cover change observed in HAPNP was mostly facilitated by expansion of exotic and invassive plant species and this study confirms with the findings of [9] where nonnative or alien species posed a significant threat to protected areas by their both direct and indirect impacts to native species. The posed impacts had effects on broader scale ecological patterns and then contribute for habitat degradation.

Habitat degradation in HAPNP has become the top conservation challenges for Grevy's zebra. One of the main reasons for habitat degradation in the area is livestock overgrazing by nomads (the number of livestock is more than the capacity and potential of pastures), which has decreased high-density pasture volume and increased low-density pasture in this area. These findings have also been confirmed with previous studies, and overgrazing was reported as the most important reason for habitat degradation [60, 61]. Furthermore, our study goes in line with the findings of the study of Kenya's Grevy's zebra Technical Committee assessed and ranked habitat degradation first rank as conservation challenges [62, 63]. Another conservation challenge for the species is the uncontrolled movements of local community for harvesting of grasses, firewood collection, and keeping livestock in this area. Furthermore, there is continual expansion of temporary and permanent settlements in and around the park for the need of animal fodder and water sources. Insufficient monitoring is one main reason for the uncontrolled entry of nomads and livestock into the area, and they have many negative impacts on habitat degradation. These findings have also been confirmed in literature reviews [64, 65].

The other conservation challenge of the species in HAPNP is the practices of unintegrated development around the proposed park. Accordingly, in the HAPNP, the plain of the study area and surroundings have been extensively destroyed due to multiple factors, particularly the interference of different institutions with the management of the PA through the development of physical and economic activities. Through overwhelming influence, different surrounding parts of this PA have been assigned to various organizations or investors for financial exploitation, and they could quickly destroy the ecosystem and habitats of the area.

Moreover, another important issue increasing the conservation challenges for the species in this area is the growth of human activities, particularly urban development and road.

The inability of the protected area to monitor and manage the area due to (staff shortage, limited skill to utilize modern technology to track Grevy's zebra ecological trait, and severe financial shortage), along with the influence of some governmental stakeholders, has led to extensive human activities in the area. These findings were confirmed by the previous study [66].

In addition, the lack of cooperation among different organizations and the protected area staff in protecting this area has caused extensive conservation challenges. Other studies have confirmed these findings [67, 68].

According to the current study report, there is no significant evidence of predation on Grevy's zebra in Hallaydeghe Asebot Proposed National Park. Possibly, the presence of numerous large and medium sized mammals in the proposed park reduced the rate of predation over Grevy's zebra. The findings of this study differ from the study conducted in Kenya that revealed predation as a potential limiting factor in the growth of the population of Grevy's zebra within the range of Grevy's zebra [69]. Lions and possibly hyenas are a major threat to the growth of Grevy's population on Lewa Wildlife Conservancy [70].

5. Conclusion and Recommendations

The study is important because it has revealed trends in land cover changes in Hallaydeghe Asebot Proposed National Park, one of the habitats of the remaining population of Grevy's zebra in the World. There has been reduction in grassland habitat on which the zebra thrives and produce young but increase in bushland, settlements, and woodland coverage from 1990 to 2006 indicating loss of critical habitat of the species. A similar situation has been shown by the study that is decline in grassland habitat being encroached by bushland and other land-use types that has also been increased from 2006 to 2021 possibly leading to the decline in the abundance of zebra in the protected area. These have been compounded by the fact that habitat degradation is the main cause of change in land cover in the area. Furthermore, it has been revealed that habitat degradation and unintegrated developments have been the major challenges to the survival of Grevy's zebra in and around the HAPNP. Generally, the results demonstrated that there are significant conservation challenges posed on the ecosystem components, including key grazing plain of HAPNP. Therefore, urgent conservation efforts that could reduce land use land cover changes are needed. In addition, restoration and

rehabilitation of the grassland habitat for the survival of the ruminant Grevy's zebra in the protected area are highly required. Monitoring and use of remotely sensed data could allow for better decision-making when developing policies and practices to mitigate the impacts of land use change in HAPNP. Furthermore, the conservation challenges identified need attention from wildlife managers and other stakeholders.

Appendix

Land-use land cover change during different times of the year in HAPNP.

Abbreviations

DN: Digital number
EBI: Ethiopian Biodiversity Institute
EWCA: Ethiopian Wildlife Conservation Authority
GPS: Geographic positioning system
GTPS: Ground training points
HAPNP: Hallaydeghe Asebot protected area
HAPNP: Hallaydeghe Asebot Proposed National Park
LCC: Land cover change
LULCC: Land-use land cover change
NDVI: Normalized difference vegetation index
PAs: Protected areas
TOA: Top of Atmosphere.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Ethical Approval

The data collection followed the research code of practice for ethical research. To this end, all the potential respondents of the study were briefed about the purpose of the study, the type of information required, the way the data would be handled and used, and their rights during and after data collection as a participant. After providing the information, they were given the opportunity to ask questions and participate in the survey or not.

Consent

An informed verbal consent was sought and obtained from all participants prior to the interview such that each study participant understands that participation is voluntary and that they are free to withdraw participation at any time, even after verbal consent is granted.

Conflicts of Interest

The authors declare that they have no any conflicts of interest.

Authors' Contributions

Tolera Abirham Negesa conducted data collection, analysis, and preparation of the draft report. Afework Bekele Simegn (Professor) performed the design of the study, reviewing, and editing of the report. Mesele Yihune Tamene (Associate Professor) carried out the design of the study, reviewing, and editing of the report.

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