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Impact of land cover changes on elephant conservation in babile elephant sanctuary, Ethiopia

Abstract

Land-cover changes are a major driving force of habitat modification, which has important implications for the distribution of wildlife species and ecological systems. However, information on the consequences of land-cover changes in wildlife habitat and conservation at local scales is largely absent. Understanding how changes in land-cover can threats the trends of land-cover and wildlife habitat loss in the future is therefore critical for conservation efforts, particularly in protected areas. We used geographical information system and remote sensing techniques, questionnaires and village meetings to assess spatio-temporal patterns of land-cover changes and its impact on elephant distribution, population and seasonal migration in Babile Elephant Sanctuary. Landsat imagery was used to classify and monitor changes in land-cover during 1977–2017. We found that within the sanctuary, agricultural land, bareland and settlements remarkably increased from the year 1977, when they covered about 3.5, 0.3 and 0.1%, respectively to 2017, when it occupied 17.3, 3.7 and 3.4%, respectively. Whereas there was a consistent decrease in woodland and bushland from 56.5 and 31.1% coverage in the year 1977 to 45.3 and 27.2% in the year 2017, respectively. The share of riparian forest cover during the study period (1977-2017) also showed a downward trend from 8.6 to 3.1% between the years 1977 to 2017. Elephant population and distribution data also show declining trend for the past 40 years. Conclusions: Our results demonstrated that the increasing agricultural land and settlements have become a serious threat for ecological integrity for elephant habitat, leading to habitat fragmentation and human encroachment of elephant habitats, and high pressure and competition over resources. This research offers baseline information for land-use planning to balance elephant conservation with livelihood development in Babile Elephant Sanctuary and highlights that managing the impacts of land-cover changes on a full form to be given for human-elephant conflict and elephant habitat loss is a matter of urgency.

Keywords: conservation, habitat loss, human-elephant conflict, land-cover change

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Dejene W Sintayehu,[1] Merkebu Kassaw[2]

[1]College of Agriculture and Environmental Sciences, Haramaya University, Ethiopia

[2]Haramaya Institute of Technology, Ethiopia

Correspondence: Dejene W Sintayehu, Range Ecology and Biodiversity Program, School of Animal and Range Science, College of Agriculture and Environmental Sciences, Haramaya University, PO Box 282, Dire Dawa, Ethiopia, Tel +251-912-356175, Email sintekal@gmail.com

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Abbreviations: LC, land cover; ESs, ecosystem services; BES, babile elephant sanctuary

Introduction

Loss of natural habitat due to land-cover (LC) changes is a major threat to biodiversity globally. It is estimated that 39% of the Earth's terrestrial habitats have been changed into farmland and settlements, and another 37% have been seriously degraded and fragmented.[1] At present, 20–35% of world's wildlife populations are vulnerable with extinction due to habitat loss,[2–4] and will be worsen in the future. It is expected that the population human will increase from 7 billion in the year 2017 to 9 billion in the year 2050, and an additional 10–20% of natural habitat will be replaced by agriculture land and settlement.[5] Moreover, the 21st century land cover changes due to expansion of agricultural land and settlements are expected to have a great impact on natural ecosystems,[6] potentially reducing wildlife distribution and population further.

Forest clearing due to land-cover change has been in the process on a massive scale, leading to widespread soil erosion, excessive evaporation and reduced biodiversity. For instance, during the 1990s, the global natural forest cover was reduced by approximately 2.4%, which was about 94 million ha.[7] The yearly rate of deforestation in Ethiopia is estimated to be 141,000 hectares.[8] Human population growth, increased energy demand, policy change, infrastructural developments, booming investment ventures and forest fire are the key factors that provoked deforestation on the country's plant genetic resources.[9] In the beginning of 1950s, about 16% of Ethiopia's land mass was covered by natural forests, which was below 3.8% in 1982 and only 2.7% or less since 1989.[10,11] These days the remaining extent has further dropped down due to the ever increasing human population, which depends on forest resources for multiple purposes,[12] causing a serious degradation to wildlife habitats.

Land-cover changes are one of the evil driving forces for wildlife habitat modifications. This has major implications for the distribution of wildlife species and ecological systems.[13–15] For instance, Aryal et al.,[16] found that foraging area of blue sheep (*Pseudois nayaur*) have been shifted towards lower elevations due to LC in the Trans-Himalaya Region of Nepal, which pulled leopard (*Panthera uncia*) to lower sites from their higher altitude habitats, causing in severe human–wildlife conflicts.[16] In the Masai Mara–Serengeti ecosystem, the populations of large mammals have been decline by 25% due to land-cover changes.[17–19] Generally, the conservation and management of African elephants, *Loxodonta africana*, has faced challenges due to its long distance migratory nature, large space corridor requirement, competition over resource with human and large habitat requirements outside conservation areas.[20,21]

Elephant is a keystone species in the ecosystem with important roles in ecological dynamics.[21–23] Hence, its persistence is important for the conservation of all elements of biodiversity in the habitat.[22] In contrast, in migratory corridors where there are agricultural activities and human settlements, human–wildlife conflict is a major problem, especially crop and property damage and related risks to life and livelihood.[24] Elephants have been also killed by human in these migratory routes.[25] Furthermore, the decision wildlife managers are largely depends on information which is crucial towards protection of protected areas, often overlooking the importance of long distance wildlife migratory and dispersal areas such agricultural land.[23,24] Therefore, more studies on land-cover change are required to better understand the effects of LC change on conservation of wildlife and identification of their potentially preferred areas.[21,26,27] With the increasing human population and its impact on environment, there is a need to balance conservation with infrastructure and agricultural developments. Particularly in Africa, the population of human is growing rapidly,[5,28] thus, calling for cross-cutting approach on both wildlife conservation and agricultural production.

In Ethiopia, *L. africana*, is one of a wildlife species being conserved in protected areas, and have experienced a considerable reduction in distributions and numbers.[29,30] At present, the species is the first among the 36 Ethiopia's mammalian species that are threatened by arrays of pressures.[29] Since the 1980s, about 90% of elephant population has been lost in Ethiopia, and thus the species is nationally classified as critically endangered.[20,30] Currently viable population of elephants exists in the eastern part of the country at Babile Elephant Sanctuary (BES), which is part of the Somali-Masai Centre of Endemism. This sanctuary was established in 1970 to conserve the unique elephant population in the corner of Horn of Africa. Around 82% of the natural area available for elephants has been lost since 1970s due to land-cover changes as results of expansion of settlements and agricultural land.[31] Conservation of elephant requires a complete knowledge of the habitat preference of the species,[32] and land cover changes in the protected areas (PAs) have significant impact on its conservation efforts as they requires large home ranges. However, studies dealing with land-cover changes and its impacts on elephant distribution and conservation are lacking. Understanding how changes in land-use can impact elephant habitat and conservation is therefore critical for elephant conservation efforts. Therefore, this study intended to examine the dynamics and drivers of land-cover changes and examined the local-scale consequences of land-cover changes for elephant habitat and conservation in Babile Elephant Sanctuary between the time periods of 1977, 1997 and 2017.

Material and methods

The study area

Babille Elephant Sanctuary (BES) is situated in the Somali-Masaai center of endemism. This sanctuary was established in 1970 to protect the only viable elephant population in the Horn of Africa with an extent of 6892 km^2. It is located 560km east of Addis Ababa (the capital city of Ethiopia), within the geographical location of 08°22'30"–09°00'30"N and 42°01'10"–43°05'50"E (Figure 1) with elevation ranges of 850 -1785m a.s.l. Topographically, the study area mainly characterized as flat to gentle slopes, consisting about 84% of the sanctuary, whereas the rest 16% consists of valleys and deep gorges. Several wildlife species found in the sanctuary including the elephant, black-manned lion, leopard and hamadryas baboon. The sanctuary is also a refuge for the black-haired and a range of large sized antelopes and birds.

Image acquisition, processing and analysis

Landsat images were used to analyze land-cover changes in the sanctuary for the years 1977, 1997 and 2017. Dry season and cloud-free landsat images with spatial resolution of 30m were accessed from the United States Geological Survey (USGS) Earth Explorer (http://earthexplorer.usgs.gov). The dates for acquisition of satellite images were slightly differed within and among years, as image acquisition was done within the months of December, January, and February. The images were geo-referenced and radio-metrically corrected. ENVI 5.0 and ArcGIS 10.2 were used during image processing and classification and for making the concluding land cover maps. The description of the land-cover classes was based on the standard land cover classes defined by the United States Geological Survey. Accordingly, six classes were identified, namely, agricultural land, bushland, riparian forest, woodland, settlement and bare land (Table 1).

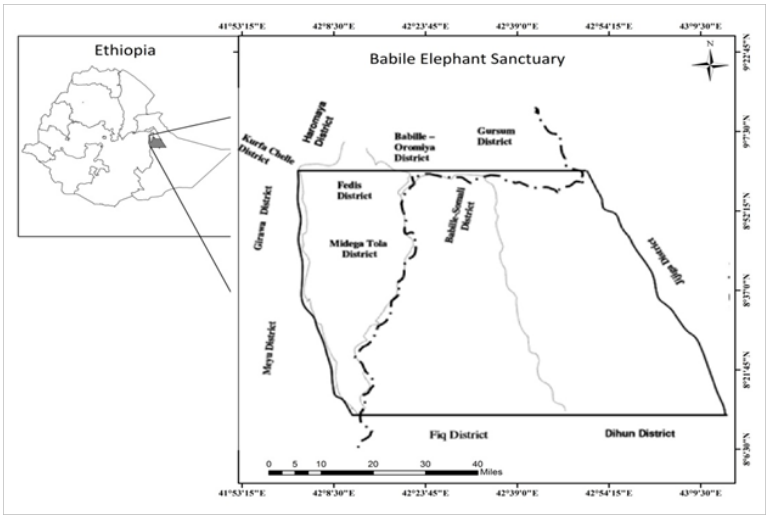

Figure 1 Location of the study area.

Table 1 The description of the land-cover (LC) classes used in Babile Elephant Sanctuary, Ethiopia

LC classes	General description
Agricultural land	Areas of land ploughed or prepared for crop growing (i.e., both areas identifiably under crop agriculture and land under preparation).
Bushland	Areas with shrubs, bush and small trees in which multiple stems and branches are produced from the base of the main stem.
Woodland	Areas dominated by Acacia species with mean height of above 5 m and the canopy cover ranges from 10% to 40% for open woodland and above 40.
Bare land	Areas with essentially no vegetative cover
Riparian forest	A type of forest found along the major perennial rivers. The vegetation is usually evergreen (due to continuous water supply from the rivers).
Settlement	Land, which is mainly covered by rural villages

Satellite images of the years 1977, 1997 and 2017 were imported in ArcGIS (version 10.2) for processing and analysis. World Geographical System (WGS) 1984 geographic coordinate system were used and projected to Universal Transverse Mercator (UTM) Zone for further analysis. Image cleaning, compositing, masking, clipping and mosaicking were done as image processing, classification and analysis. Land-cover changes from landsat images were classified using the maximum likelihood function, which is commonly used among the supervised land cover classification methods.[33] The assumption of most Maximum Likelihood classifiers is that the statistics of the clusters have a 'normal' (Gaussian) distribution. It is also vital to give very precise results,[33,34] as every pixel is given to the class to which it has a maximum likelihood of belonging. Visual interpretation and digital image classification were then combined using GIS functions. Training sites were developed and signature files were created to be used in the supervised land-cover change classification using ArcGIS (version 10.2). The classified mages were verified using ground control points across the study area. ERDAS IMAGINE 10.1 was used for land- use/land-cover classification, analysis, and accuracy assessments. ERDAS change detection statistics tool was used to compare change detection between the years 1977 and 1997, and 1997 and 2017 using a change detection matrix.

Post classification

The purpose of post-classification was to arrive at the LC for the three periods under investigation, i.e., 1977, 1997 and 2017. ERDAS change detection statistics tool (post-classification) was used to compare change detection between pairs of consecutive classified images. Accordingly, the years 1977 and 1997, and 1997 and 2017 were compared using a change detection matrix.

Household interview and focus group discussion

A total of 100 households (located at least 0.5–1km apart) were selected randomly for interview. Extensive field observations and interviews were carried out using a structured questionnaire to the respondents aged 25 years and above, who had been living in the respective location for at least 10 years. Perceptions and awareness of respondents on current land-use types of BES in relation to land-cover changes, elephant conservation, elephant habitat loss and human elephant conflict (HEC), the influence of humans as well as the trend of different land-use pattern changes for the past 40 years and reasons why land-use types have changed were captured. Focus group discussions were additionally done with at least 10 people (who were mainly elders of each division and could remember events in land transformation) in BES. The discussions were distributed across the study site divisions and were guided using the checklist of questions related to land-use changes and its drivers as well as their effect on elephant habitat and conservation and human–elephant interactions in the area. The in-depth information obtained based on people's perceptions and attitudes were analyzed qualitatively and these analyses and graphical presentations were performed using R v3.2.2 (R Core Team, 2015).

Results

Land cover classes and changes in BES

In BES, woodland covered the largest area in the year 1977, 1997 and 2017, followed by bushland and agricultural lands. However, there was a consistent decrease in woodland and bushland from 56.5 and 31.1% coverage in the year 1977 to 45.3 and 27.2% in the year 2017, respectively. The share of riparian forest cover during the study period (1977-2017) also showed a downward trend from 8.6 to 6.3% and 6.3 to 3.1% in the year 1977 to 1997 and 1997 to 2017, respectively. Agricultural land, bareland and settlements remarkably increased from the year 1977, when they covered about 3.5, 0.3 and 0.1%, respectively to 2017, when it occupied 17.3, 3.7 and 3.4%, respectively (Figure 2) & (Table 2).

In general, out of the six LC types identified in the study area, only three, namely agricultural land, settlements and bareland, showed growth over the 40 year study period, while the extents of riparian forest and bushland declined, suggesting that land area that was formerly used by elephants was converted into agricultural land, settlements and bareland (Figure 3) & (Table 3).

Elephant population and distribution decline in BES

Analysis of long-term elephant population census data showed that the population of elephant was declined over the past 40 years (Figure 4). In the study areas, about 85% of the respondents were aware of human elephant conflict issues and 43% of the respondents encountered elephants in their farms at least once in the past 40 years.

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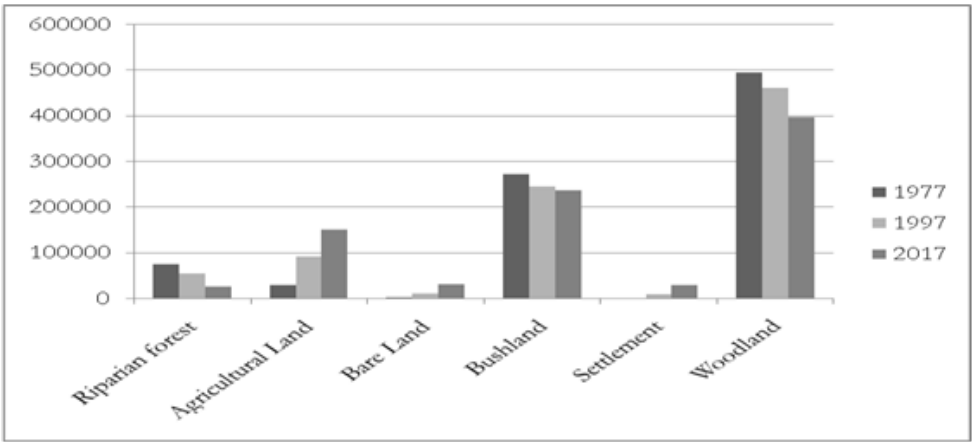

Figure 2 LULC changes in BES during 1977–2017.

Table 2 Area and proportion of land-cover types in BES in 1977, 1997 and 2017

Land Cover Type	1977		1997		2017	
	Area (ha)	Proportion (%)	Area (ha)	Proportion (%)	Area (ha)	Proportion (%)
Riparian forest	74918.97	8.8	54793.17	6.3	27145.17	3.1
Agricultural land	30428.64	3.5	91725.93	10.5	151408.6	17.3
Bare land	2462.94	0.3	11688.39	1.3	32246.91	3.7
Bushland	271496.88	31.1	245813.04	28.1	237617.7	27.2
Settlement	1202.59	0.1	9632.07	1.1	29446.56	3.4
Woodland	493548.57	56.5	460405.44	52.7	396193.9	45.3
Total	874058.6	100	874058.6	100	874058.6	100

Table 3 Area and rate of Land-cover changes in Babile Elephant Sanctuary between 1977 to 1997 and 1997 to 2017

Land Cover Type	1977 to 1997		1997 to 2017	
	Area (ha)	Rate (ha/yr)	Area (ha)	Rate (ha/yr)
Riparian forest	-20125.8	-1006.29	-27648	-1382.4
Agricultural land	61297.29	3064.8645	59682.69	2984.1345
Bare land	9225.45	461.2725	20558.52	1027.926
Bushland	-25683.84	-1284.192	-8195.31	-409.7655
Settlement	8429.48	421.474	19814.49	990.7245
Woodland	-33143.13	-1657.1565	-64211.56	-3210.578

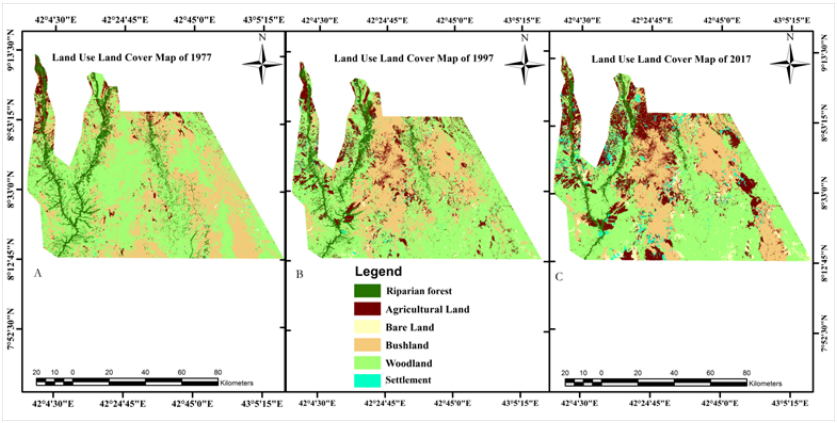

Figure 3 A comparative map showing the actual LULCC in BES in 1977(a), 1997(b) and 2017(c).

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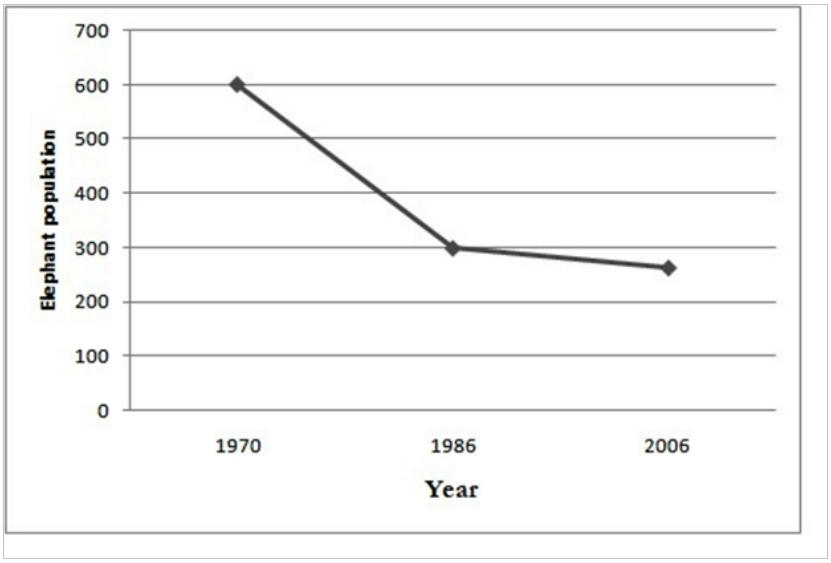

Figure 4 Elephant population trends in Babile Elephant Sanctuary ecosystem from 1975 to 2007. Source: Stephenson 1976; EWCO 1990[20,30]

Factors driving LC change in BES

The analysis of the Land-cover changes, biodiversity and ecosystem services trends have revealed substantial changes in BES Ecosystem over the 40-year study period. Agricultural farms in BES have expanded from about 30,428 ha in 1977 to over 151,408ha in 2017, showing that agricultural expansion was one of the major driving forces of LC changes in the study area. Based on our field observations and questionnaire-based interviews, a number of factors were found to be responsible for the encroachment of agricultural areas into areas formally used solely for livestock and wildlife. Some of the main factors include the government policy that is increasingly discouraging pastoralism in favor of permanent settlement, changing land ownership policies from communal ownership to individual ownership, and the big financial gains derived from mechanized farming as compared to pastoralism. Agricultural expansion therefore is a major threat to elephant conservation and habitat in BES (i.e., conservation of open grazing lands for elephants). At the same time, livestock population trends over the last four decades show that the numbers of cattle and sheep have increased in BES. Demographic factors are also important in understanding LC changes and elephant population and their distribution changes. Over the past four decades, areas are BES has experienced human population growth. As population density increases, the more densely populated areas become less suitable for livestock production and wildlife conservation, and thus people look for alternative sources of income such as expansion of crop land. As population in the area grows, development of permanent settlements is increasing and is associated with the expanding small-holder agriculture. This expansion is taking place in the expansive natural habitats that have served for many years as wildlife dispersal areas.

Discussion

Understanding LC changes and their impacts on wildlife and ecosystem services are critical to guide conservation efforts in protected areas and policy making. Here we show that land-use changes in the semi-arid ecosystem of eastern Africa have important consequences for wildlife conservation and ecosystem services, particularly in and around protected areas. We found, that agricultural land gained the most in the expense of natural forest compared to other LC types during the study period (1977–2017). On the contrary, natural habitat (riparian forest, bushland and woodland) lost substantial areas during the study period with an annual average loss rate of 4475 ha. Similarly, other studies showed the expansion of agricultural land, while natural area showed a declining trend. For instance Yirmed[31] reveled that since in 1970, the natural area available for elephant has shrunk by an estimated 82% as a result of anthropogenic factors. Increases in settlements and agricultural land in the wildlife area might have significant effect on protected area wildlife conservation[26] due to settlements and agricultural land expansion relative to other LC are more permanent and resource intensive.[35] Historically, significant land-use/ land cover changes observed in the late 19th century with the advent of missionaries and early on colonialists in East Africa.[36] Wildlife areas have been known to be productive land for people and animals due to fertile soils and organic matter accumulated for long time.[36,37] The competition for areas allocated for biodiversity conservation and human development such as agriculture and settlements destroyed wildlife habitat and blocked the wildlife migratory routes in many part of the world in general and particularly in east Africa.[38] The population dynamics of large mammals in protected areas is also determined by the relationship they have with the humans in and around their ecosystems.[38]

In and around BES, elephants and other large mammals were widely distributed and migrated up to the Wabi Shebelle Valley and mainly inhabited the eastern and central section of Fafum, Dakata, Erer and Gobele Valleys of the Sanctuary. Yirmed et al.,[20] found that the migratory corridors to the south to Wabe Shebelle Valley were completely interrupted and their movements were restricted only to Dakata Valley in the east and the western escarpment of Gobele River in the west, which were not occupied by agriculture and settlements. Around 82% of the natural range of elephant has been lost since 1970s.[31] Others also showed that the shrinkage of elephant ranges in

Ethiopia has been rapid due to increasing human population and the associated poaching and growing demand for land.[29,39–41] Similarly our study revealed that land-use change due to settlements and agricultural land expansion -were the main drivers of natural habitat loss in BES. This result concurs with the findings of Graham et al.,[21] who showed that in 1925 elephants inhabited about 87% of the African continent, but by 1950 this was dropped to 63%, and by 1975 to 27% due to land-use / land cover changes as results of expansion of settlements and conversion of land for cultivation.[21] Mundia[42] found that agricultural expansion is the most important threat to wildlife conservation.[27,42] Other studies argued that land-use/ land cover change due to habitat encroachment and deforestation have large negative impacts on distribution and population of large mammals[21,26,43–45] Therefore, the increasing agricultural land and settlements has become a serious threat for the survival of elephant and fragmenting elephant habitats.

Habitat fragmentation and encroachment have been the major causes for the decline of elephant population in Kenya from 1200 elephants in the year 1970s to 750 in the year 2003[46] and it was 450 in the year 2010.[47]Similarly, we found that the population of elephant has been declined by 44% for the past 40 years. This might be due to intensification of competition with elephants as a result of expansion of agricultural land and settlements, which are leading to diminishing pastures and suspected to cause more declines in elephant distribution and population. Our questionnaire assessments also indicated that the range of elephants has shrunk considerably because of the increasing demand for agricultural land and progressive development of settlements, coupled with illegal poaching. Currently, the numbers of people who have shifted their lifestyle from pastoralism to mixed agricultural (livestock and crop) cultivation-based economy have been increased. This coupled with encroachments in livestock resulted in disturbances and displacing elephants from most of their previous ranges. Peoples' ever expanding strategy for more land monopolizes essential resources like green areas and water resources for settlements, livestock grazing and crop cultivation have blocked elephants access to water and movement routes. This can increase the encounter rates between human and elephant, and thereby increase human-elephant conflict. Other similar recent finding in Tanzania also showed that urbanization and crop expansion threatened the ecological integrity for elephant habitat, leading to high competition and conflict between elephants and human.[27] Hence, there is an urgent need to critically consider the evolving LC changes and the growing human population that negatively affects the biodiversity in general and elephant population in the area.

Conclusion

Our local scale assessment showed increasing Land-cover changes and the drastic decline in elephant habitats in BES ecosystem over time. These changes are as a result of a number of interconnected factors, but mainly related to habitat loss due to expansion of agriculture, settlements and infrastructure developments, which destroyed elephant habitat, and blocked the main elephant migration corridors and remaining the major concern for the long term survival of elephants. Information about changing patterns of Land-cover changes through time and the factors influencing such changes are important for planning for sustainable utilization of resources. Our results can be used to guide regional conservation efforts such as by the community based conservation at local scale, integrated landscape conservation unions at the federal level, or by state natural resource agencies, to identify regions and species that may deserve priority attention, to inform regional land-use planning, and to enhance understanding of the potential effect of conservation policies in different regions. Generally, in the areas where there is high common interest/resource overlap between wildlife and people, establishment and enforcement of land-use policies that provide wildlife migration corridors, buffer zones and benefit or resource sharing with local community are also essential. This will reduce impacts of human activities and ensure sustainability of wildlife conservation and livelihoods. Therefore, immediate action and restoration mechanisms are needed in order to conserve biodiversity and associated ecosystem services in the area as well as to get benefits provided by the resilience and adaptation potential of semiarid regions, their biodiversity, and their inhabitants.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

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