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Land use land cover change in and around Chebera Churchura National Park, Southwestern Ethiopia: implications for management effectiveness

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Abstract

Background: Land use-land cover change (LULCC) resulting from anthropogenic activities has been one of the major causes of loss of biodiversity globally. Thus, understanding the dynamics of such LULCC, especially within protected areas, is important to assess their past-present management effectiveness, identify the driving forces and assist future implementation of mitigation measures. The objectives of this study, based on satellite images analysis, were to examine and describe patterns of LULCC within and in the buffer zone area of Chebera Churchura National Park, SW Ethiopia, at five points in time (1985, 1991, 2000, 2010, and 2020); and to examine management effectiveness of the park authority in slowing down the rate of LULCCs after the establishment of the park.

Results: Results showed that different land cover types exhibited varying patterns of change over the last 35 years. However, major differences were detected between the park area boundary and its buffer zone area after establishment of the park. From the year 1991 to 2000 (before the establishment), grassland declined by 52.9% (120.55km^2) and 58.9% (151.9km^2) within the park boundary and its buffer zone, respectively. After the establishment, grassland continued to decline only in the buffer zone. Similarly, agricultural land declined by 13.2% (2.7 km^2) within the park but expanded by 5.4% (3.1 km^2) in the buffer zone prior to park establishment. However, after establishment of the park, agricultural land in the buffer zone increased by 99.4% (99.7 km^2). Grassland and wooded grassland had the opposite trend within the park area before vs after the establishment of the park.

Conclusions: Results of the present study showed that striking differences in the rates of LULCCs within the park area and its buffer zone after establishment of the park, with the implication that the management is effective in slowing down LULCC relative to that in the buffer zone areas. In sum, this study would serve as a showcase on cost-effective means to assess human impacts on biodiversity in protected areas due to policy changes. Findings of the study would serve as a bench mark to evaluate future management effectives of the park authority.

Keywords: Agriculture, Fire, Forest, Grassland, Grazing, Protected area

Introduction

The terms land use and land cover are interrelated and often used separately or interchangeably since they share elements (Arafaine and Asefa 2019). Land use encompasses crop farming, livestock grazing, town establishment, timber production, mineral digging, and other trade-offs in the physicochemical composition of a given

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area associated with the land manipulation type; whereas land cover change encompasses agricultural land, various woody vegetation types, swampy areas, grassland, and other land cover types (Burka 2008). Both land use and land cover change (LULCC) can result from two driving causes: natural and anthropogenic. Natural events such as variability in the climate, floods, unintentional fires, and rainfall shortages may cause land cover change (Guerra et al. 2019). However, the underlying cause of land cover changes is associated with human overuse of natural resources, such as vegetation removal for crop farming, livestock feeding, timber production, and road construction (Guerra et al. 2019). Recently, human-driven changes in land cover are progressing rapidly and mainly impacting the land surface which due to be the rapid population increase and the imbalanced emphasis given by the decision-makers to human development and environmental regulation (Lambin et al. 2003). Reports indicate that, since the mid-1800s, nearly 600,000 km^2 of woodland in the world (Lambin et al. 2003) and approximately half of this in the dryland regions of Africa (Kigomo 2003) have been converted to croplands. Such LULCCs can have long- and short-term effects on the biophysical composition of the area (Detenbeck 1993), as well as reductions in organic matter (De Stefano and Jacobson 2018), changes in biological composition, and biodiversity loss (Arafaine and Asefa 2019). The overall effects are disrupting ecological processes and functions, which, in turn, negatively affect livelihoods of humans who directly or indirectly rely on the ecosystem's vital services (Millennium Ecosystem Assessment 2007). Therefore, understanding the magnitude and direction of land use-land cover change and the drivers and impacts of such changes is a prerequisite for decision-makers in assisting on how to develop policies and strategies for sustainable land manipulation and human development (Geist and Lambin 2002; Arafaine and Asefa 2019). Consequently, studying LULCC has been a growing research area to understand its dynamics and the causes of shift (Nagendra 2008).

Studies of LULCCs are vital to understand and monitor the trends in changes to develop strategies for sustainable conservation and utilization of biodiversity (Willis 2015; Jones et al. 2018; Guerra et al. 2019). Land use-land cover change studies based on established remote sensing data facilitate an essential tool for providing a wide range of information to various decision support systems for natural resource management and sustainable development (Mtui et al. 2017). Interestingly, the availability of remotely sensed data with improved spatial and temporal resolution, coupled with the advancement of computing technologies, has not only made LULCC studies easier and cost-effective but has also enabled researchers to explore inaccessible areas (Wright et al. 2009; Alqurashi and Kumar 2014; Abd El hay et al. 2016; Ayele et al. 2018; Negassa et al. 2020).

Forest and woodland deforestation and degradation in Ethiopia have been increasing, which is driven by high population growth rate of above 2.5% per year (World Bank 2021). This increased population aggravates the conversion of land cover for human settlements, clearing for agriculture, logging, charcoal, and firewood harvesting (Megaze et al. 2013). Such LULCC in the country, in turn, has resulted in the loss of biodiversity and environmental disruption, and socioeconomic crises in the country by causing rainfall disruption and scarcity, floods, and decreasing agricultural productivity (Garedew et al. 2009; Belay et al., 2015). Many studies on LULCC across Ethiopia's protected areas (see Wondie et al. 2011; Fetene et al. 2016; Hailemariam et al. 2016; Nigussie, 2016; Yohannes et al. 2017; Hailu et al. 2018) show a rapid rate of change in most of the protected areas. Given the importance of knowledge gained from such studies for informed-management decisions, LULCC studies of poorly known but critically important protected areas in the country are top priority research area.

Chebera Churchura National Park (CCNP) is one of the most important conservation areas in Ethiopia. The park has been known to be one of the biodiversity-rich, relatively most intact and critically important protected areas in Ethiopia (Acha et al. 2017). The National Park is known to possess nearly one-third of the country's total population of African elephants (*Loxodonta africana*) and the largest population of African buffalo (*Syncerus caffer*) in the country (Megaze et al. 2013; CCNP 2020). The park is located in the upper catchment of the Omo River and has more than 55 annual and perennial rivers and streams that flow to the Omo River. In addition, there are six small and medium sized crater lakes and many hot and cold springs that have cultural and medicinal values (CCNP 2020). Many of the local communities in the catchment are dependent on these aquatic systems for their livelihoods in addition to their significant contribution to the countries mega projects like Koysha Hydro Electric Dam and Kuraz Sugar Factories (Datiko and Bekele 2013; Megaze et al. 2013; CCNP 2020).

Historically, the present park area had been known as Kulo-Konta Controlled Hunting Area where legal elephant hunting had been carried out until the fall of the Derg regime in 1991 (CCNP 2020). Following the downfall of the then dergue regime in 1991, the legal hunting practice was banned, resulting to downgrading from hunting area protection status to a free-access resource use area. This policy change had resulted to encroachment of local communities into the area, impacting biodiversity and natural resources of the area. However, human population in the area has been dramatically increasing (Acha and Temesgen 2015; Acha et al. 2017), posing considerable threats to biodiversity of the park. Specifically, crop farming, livestock herding, human encroachment, and fire are causing LULCCs that affect biodiversity through habitat loss, fragmentation, and loss of connectivity (Megaze et al. 2013). Apart from impacting biodiversity, LULCCs resulting from human-induced threats has contributed to persistent human-wildlife conflicts (Acha and Temesgen, 2015; Acha et al. 2017). Later, recognizing the biodiversity and ecological importance of the area, the government decided to designated the area as a national park in 2005 (Acha et al. 2017). So far, no study has been conducted to examine the extent, rate, and causes of LULCC in and around CCNP.

In this study, we used remote sensed data with the main aim to analyze LULCC within the boundary and buffer zone areas of CCNP in the last 35 years and examine the implications thereof for future conservation measures. Specifically, we attempted to answer the following three research questions: (1) What land use and land cover classes would exist within the park boundary and its buffer zone area at each of the five points in time (1985, 1991, 2000, 2010, and 2020)? (2) What are the patterns and trends of LULCCs within the park boundary and its buffer zone area over the last 35 years? (3) What are the influences of policy changes on the rates of LULCCs? To answer the latter question, we based on background situation of two policy changes have been taken place during the period studied, which could influence human uses of natural resources and thus drive LULCC in the area. Firstly, the area had been protected by the hunting company until hunting was banned in 1991. This policy change and the brief lawless period following the downfall of the then dergue regime in 1991, similar to other protected areas of the country (Jacobs and Schloeder 2001), had led local communities to expand cultivation, grazing and other natural resources use into the present CCNP area. This trend was observed at least for a decade (Jacobs and Schloeder 2001). Later, recognizing the biodiversity and ecological importance of the area and the growing threat facing it, the government decided to designated the area as a national park in 2005 although effective protection was started in 2010 (Acha and Temesgen 2015). Thus, we first assessed the influences of the policy change due to dergue government turnover (hereafter referred to as "the transitional government period") that resulted in downgrading protection status of the area from controlled hunting area to free access area. For this purpose, we compared land use/land cover types during the year of 1985 and 2000. Similarly, we also assessed the influence of the succeeding policy change (establishment of the park) on the rate of LULCCs in the years 2010 and 2020. As is typical of land conversion due to anthropogenic pressures through the increases in grazing, fire, and agricultural expansion in the park (Acha and Temesgen 2015; Acha et al. 2017), we predicted that there would be a reduction in grassland and forest covers due to an increase in cultivation land, while wooded grassland and woodland habitats would either experience little changes or increase in extent since conversion of forest and grassland habitats to cultivation may facilitate transition of forest to these vegetation types. Further, although the area was proclaimed as a national park in 2005, but effective protection was started in 2010. Thus, we hypothesized that (i) LULCC, especially on agricultural land, would be lower within the current park area after its establishment than before, but no difference at the buffer zone, and (ii) there would be a more similar pattern of LULCC between areas within the park and buffer zone before the establishment of the park than after establishment of the park, reflecting management effectiveness of the park.

Materials and methods

Study area

Chebera Churchura National Park is located in a geographical coordinates of 6°56′05″–7°08′02″N and 36°27′00′–36°57′14″E (Fig. 1) and situated 580 km away from the capital in the South Western Regional State of Ethiopia (Datiko 2013). It was established in 2005 to conserve the largest populations of African elephants and Buffalo occurring in the country (Megaze et al. 2013). Other threatened wild mammal species include Hippopotamus (*Hippopotamus amphibious*), African wild dog (*Lycaon pictus*), Lion (*Panthera leo*), and Leopard (*P. pardus*) (Timer 2005), and 137 bird species found in the study area (Woldeyohannes 2006). The park covers an area of 1215 km^2, and the altitude ranges from 550 to 1700 m asl. Average annual rainfall ranges from 1000 to 2290 mm. The temperature varies from 16 to 28 °C (Woldeyohannes 2006).

The natural vegetation of the study area, both within the park and the buffer zone, can be classified into four major types: montane forests, grassland, wooded grassland, and woodland. Montane forests cover the eastern and north western highlands of the area and riparian forests along rivers (Woldeyohannes 2006). Grasslands cover plain areas mainly characterized by having no woody plants or scattered trees (Woldeyohannes 2006). The wooded grassland is the dominant land cover type in the Chebera Churchura area (Ademasu 2006). In addition, water bodies (lakes, swamps, and rivers) and agricultural lands are also found both in the park and the buffer zone (Megaze et al. 2013). Most of the local

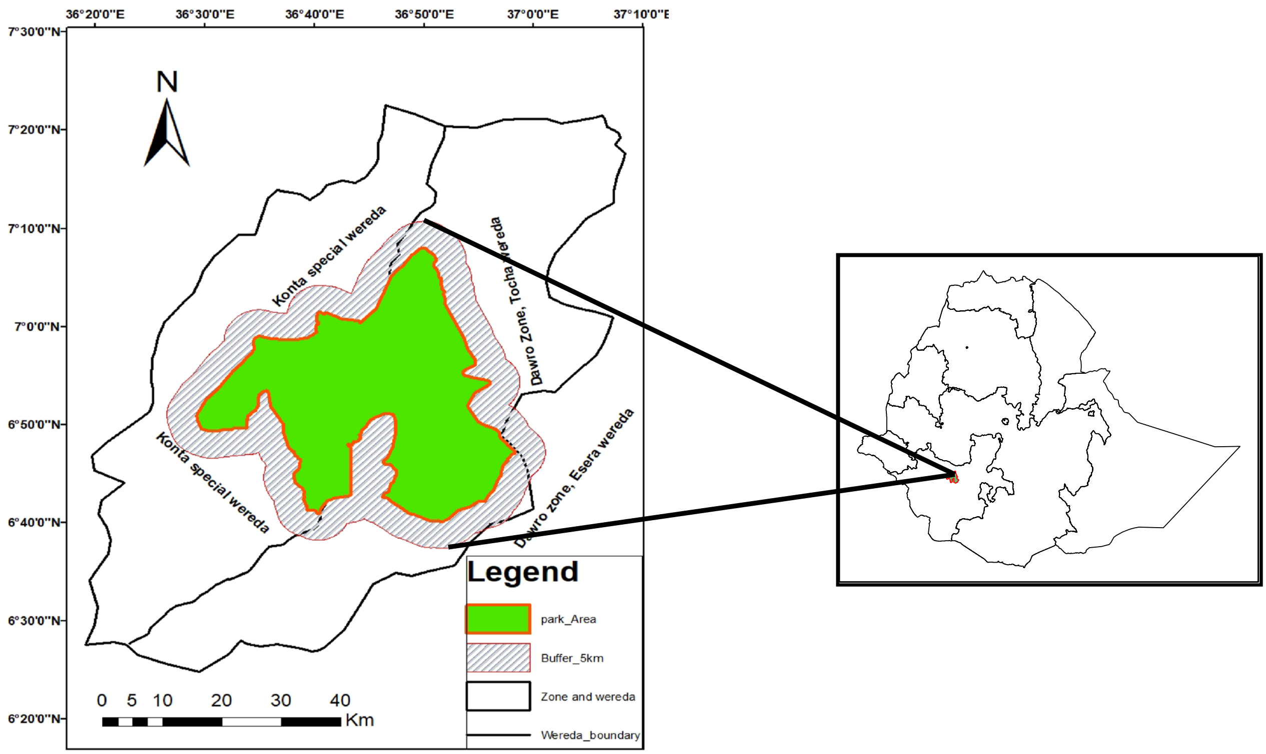

Fig. 1 The location of the study area, showing Chebera Churchura National Park (in green colour fill) and its buffer zone (in grey colour fill) [Coordinate System (GCS WGS 1984)]

communities inhabited in the study area are agro-pastoralists (Acha et al. 2017).

Methods

We used three spatial datasets—Satellite imagery, Google Earth Map, and ground truthing geographical coordinate points collected in 2020—to classify land use and land cover types within and in the buffer zone area CCNP (for detail see Additional file 1: Appendix A). In addition, we also gathered information on land cover change driving forces through informal discussions with experienced park staff.

Satellite image acquisition and preparation

Landsat images (path 169, row 055) of five temporal scales encompassing 35 years (1985, 1991, 2000, 2010, and 2020), all with a spatial resolution of 30 m × 30 m, were downloaded from freely available United States Geological Survey (USGS) (website. htpp://www.usgs.gov) during the month of December for all years and used for land use-land cover change analysis (for detail see Additional file 1: Appendix A). The month of December image was appropriate because of low cloud cover availability and the vegetation still did not lose its greenness while there was no rain, which makes the land cover analysis simple (Hailemariam et al. 2016). The satellite image selection was constrained by the availability of cloud-free images percentage of less than 10% (Roy and Inamdar 2019). ArcGIS 10.8 software was used for image processing and to produce land use-land cover classification maps.

Landsat image processing was performed using atmospheric and geometric corrections tools in ArcGIS 10.8 software (Rahman and Szabó 2021). Firstly, geometric corrections of the satellite images were projected using UTM map projection system and WGS84 Datum. Secondly, the satellite images were geo-rectified using the geometric registration strategy, where images are rectified with ground features to reduce positional inaccuracies which stem from geometric instability of the satellites during the data acquisition (Jensen, 1996). Finally, a composite dataset image was produced for each year; each of these were then clipped to polygon shape files of CCNP and its surrounding 5 km radius buffer zone shape file using ArcGis 10.8 software. The Landsat 5 image band composition 4, 3, and 2 was used for red, green, and blue, respectively, whereas Landsat

8 band composition 5, 4, and 3 was used for red, green, and blue, respectively (Additional file 1: Appendix A).

Image classification

Supervised classification was done using training samples collected from ground truthing points and the use of high-resolution imagery from Google Earth. Ground truthing points were collected prior to image analysis. General Management Plan of CCNP (CCNP 2020), in addition to water bodies, describes four major vegetation types: woodland, wooded grassland, montane forest and riparian forest. Based on this information and consultation with park experts and our experiences, we initially defined seven land use land cover types, by adding agricultural land and grassland to the above four vegetation types and water bodies. Then, ground truthing points taken for each of the seven land use land cover types using hand-held GPS 72H. A total of 208 geographical coordinates were captured at the center of a 100 m × 100 m plot established randomly at areas with at least 40 m radius of uniform land cover type. In addition, name of dominant vegetation type, altitude, slope and aspect were also recorded at each plot. Supervised classification was done using training samples from ground truthing points and the use of high-resolution imagery from Google Earth. Following FAO (2022) land use land cover classes, six land use land cover classes were defined and used for further analysis: agricultural land, grassland, wooded grassland, woodland, water body, and forest.

The Maximum Likelihood Classifier Technique was used in ArcGIS 10.8 software (Rahman and Szabó 2021) for the supervised classification. This technique is the most preferred as it takes into account the most variables by using a covariance matrix. Accuracy assessment was done by comparing the classified map with high resolution imageries from Google earth which are available from the year 1985 through to the year 2020. Accuracy assessment of the classifier was done using a Confusion matrix which compares confusion matrices representing training and validation accuracy (Stehman 1997). For each year, the reference map from the Google earth was used as a ground truth image and the classified Landsat image used as input image, all maps had the same X and Y dimensions, pixel sizes, and spatial reference. The overall accuracy was estimated based on the confusion matrix and kappa coefficient (Arafaine and Asefa 2019).

Extent and changes in land use land cover

As stated in the Introduction, the following LULCCs between two points in time were computed: between 1985 and 2020 for overall change assessment, 1985 and 2000 for the transitional period, 1991 and 2000 to characterize changes before park establishment, and 2010 and 2020 to characterize changes after park establishment.

Accordingly, the area of each land use land cover class for each year was calculated both for the park and its buffer zone. To detect LULCC between any two periods, classified images were compared using the post-classification image comparison technique in ArcGIS 10.8 software (Rahman and Szabó 2021). This technique creates one image based on the difference of the two comparative images from each year, which provides a summary table of the overall changes per class; positive values denote an increase whereas negative values imply a decrease. Rate of conversion for each land cover type over each of the two periods of years was computed by dividing cover change [in km^2] of a particular class by the number of years encompassed in each period (Arafaine and Asefa 2019).

Correlation analyses were conducted using SPSS version 20 (IBM Corp. 2011) to explore the similarities in patterns of LULCC within the boundary and buffer zone areas before and after establishment of the park. The results were used to further evaluate the effectiveness of park management in reducing the rate of LULCC within the park compared to in the buffer zone.

Results

Classification accuracy assessment

The six land cover classes—namely: grassland, wooded grassland, woodland, water bodies, agricultural land and forest areas—and changes detected at each of the five temporal scales studied are shown in Figs. 2 and 3. Overall classification accuracy was 90.5%, 87.3%, 88%, 93.8% and 91.8% and kappa coefficients of 87.4%, 83.1%, 83.3%, 91.9% and 88.9% for the year 1985, 1991, 2000, 2010 and 2020, respectively (Appendix B). Thus, the results of the present analysis suggest that our land cover classification has an acceptable level of accuracy; thus valid conclusions could be made.

Land use and land cover changes within the park area

Our results showed that all land cover classes exhibited some degree of change within the current park boundary over the study period (Table 1). However, the rate of change varied among land cover classes, with grassland being changed the most, showing a reduction from 37% of the total park coverage in 1985 to 12% in 2020, followed by woodland which showed an increase from 12% in 1985 to 35% in 2020 (Table 1).

When changes during the three time periods were considered separately, notable changes detected include 88.54% and 27.73% increases in woodland during the transition period (1985–2000) and after establishment

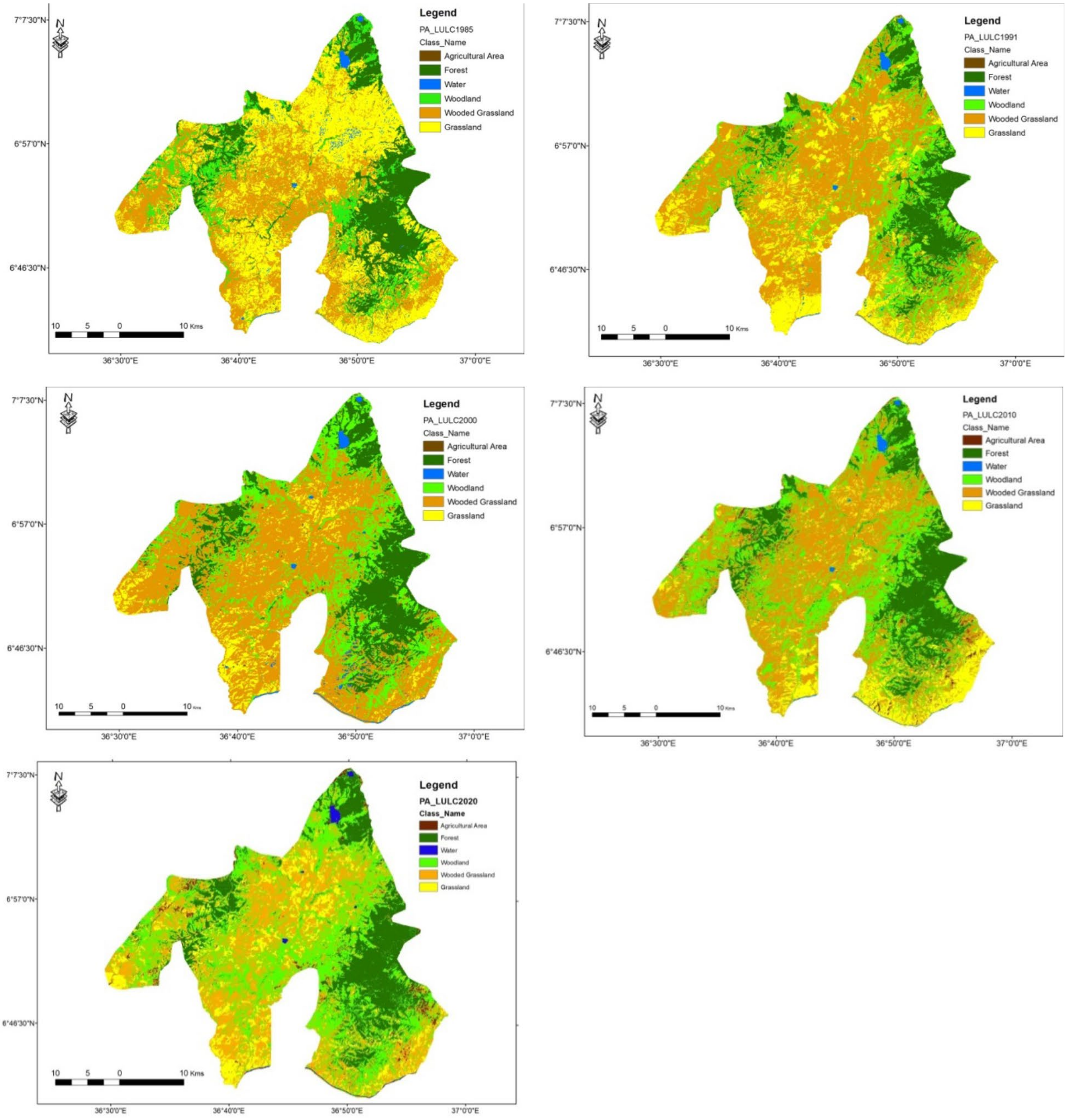

Fig. 2 Land use land cover classes within the park area, from top-left to bottom-right, in 1985, 1991, 2000, 2010 and 2020

of the park (2010–2020), respectively. These increments were at a rate of about 10 km^2 per year during both periods (Table 2). Wooded grassland also showed a 50.41% increase, at a rate of 13.98 km^2 per year, during the transition period; while declined by a quarter after establishment of the park, with annual rate of − 12.63 km^2 per year. Extent of grassland considerably declined both during the transition period and before establishment of the park (1991–2000) by − 77.54% and − 52.79% and annual rate of − 24.71 and − 13.34 km^2, respectively (Table 2).

Land use and land cover change matrices within the park boundary before and after establishment of the park are shown (Table 3a and b). Nearly, 60% of the study area remained unchanged throughout the study period, of which 32% of the stable habitat was woodland. Notable transformations before the establishment of the park

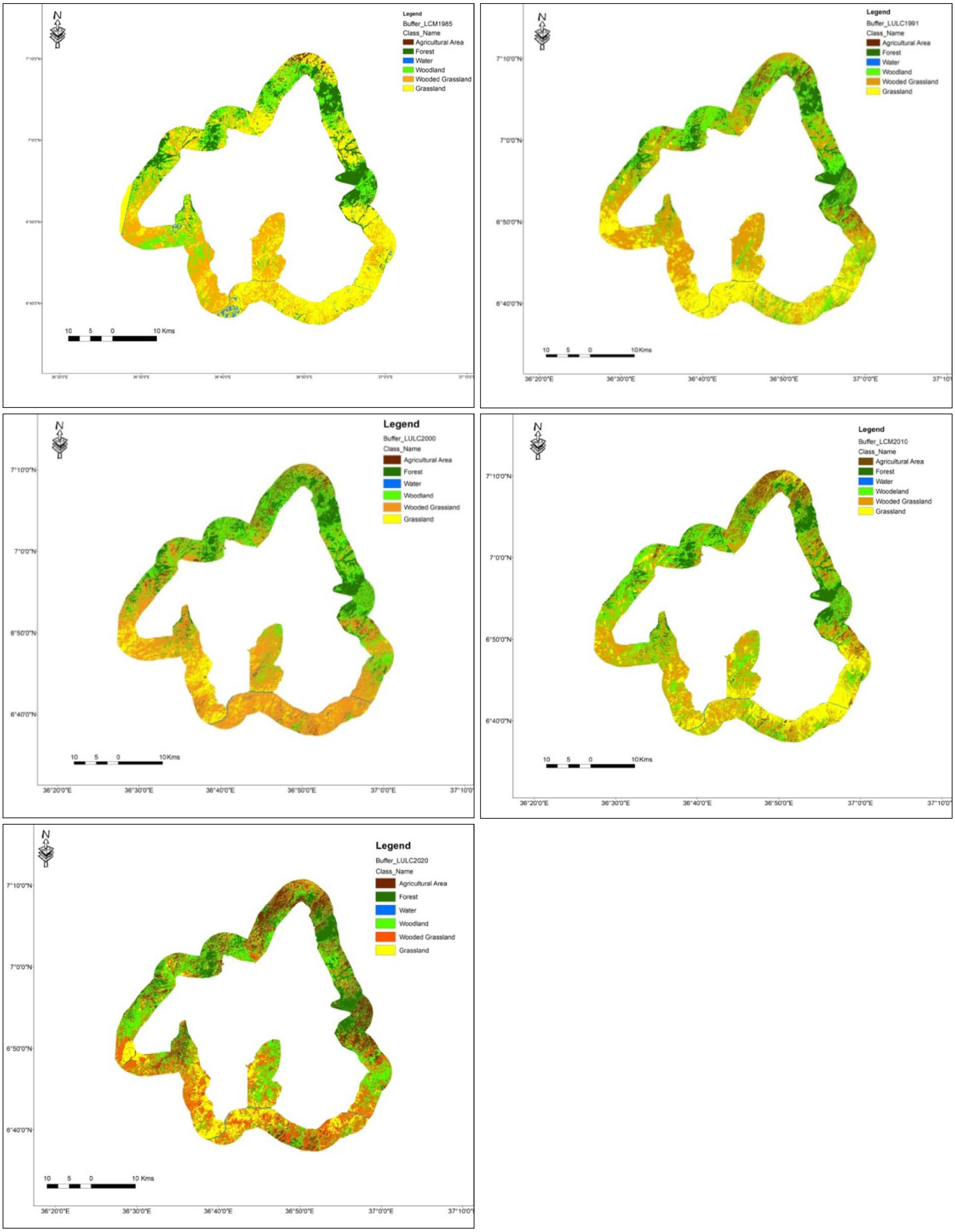

Fig. 3 Land use land cover classes in the park buffer zone areas, from top-left to bottom-right, in 1985, 1991, 2000, 2010 and 2020

Table 1 The land use-land cover types of each year (in km^2 and %) of within the park areas of the CCNP

Land cover type	1985	%	1991	%	2000	%	2010	%	2020	%
Agricultural land	5.99	0.46	20.23	1.55	17.6	1.35	23.52	1.81	33.91	2.60
Forest	227.52	17.47	185.85	14.27	234.19	17.98	243.34	18.69	252.8	19.42
Water	14.68	1.13	9.01	0.69	15.36	1.18	6.8	0.52	8.28	0.64
Woodland	160.35	12.32	265.18	20.37	302.32	23.22	362.41	27.83	462.89	35.55
Wooded Grassland	415.42	31.90	594.29	45.64	625.18	48.01	516.22	39.65	389.9	29.94
Grassland	478.1	36.72	227.49	17.47	107.4	8.26	149.77	11.50	154.29	11.85
Total	1302.06	100.00	1302.05	100.00	1302.05	100.00	1302.06	100.00	1302.07	100.00

Table 2 Changes in land use land cover within Chebera Churchura National Park during transition period (1985 to 2000), before establishment (1991 to 2000) and after establishment (2010 to 2020) of the park

	During transition period (1985–2000)			Before park establishment (1991–2000)			After park establishment (2010–2020)		
LULC type	change (km^2)	Percent change	Change rate (km^2/year)	change (km^2)	Percent change	Change rate (km^2/year)	change (km^2)	Percent change	Change rate (km^2/year)
Agricultural land	11.61	193.82	0.77	-2.63	-13.00	-0.29	10.39	44.18	1.04
Forest	6.67	2.93	0.44	48.34	26.01	5.37	9.46	3.89	0.95
Water	0.68	4.63	0.05	6.35	70.48	0.71	1.48	21.76	0.15
Woodland	141.97	88.54	9.46	37.14	14.01	4.13	100.48	27.73	10.05
Wooded Grassland	209.76	50.49	13.98	30.89	5.20	3.43	−126.32	−24.47	−12.63
Grassland	−370.70	−77.54	−24.71	−120.09	−52.79	−13.34	4.52	3.02	0.45

Table 3 Matrix of land use and land cover change (in km^2) within the current boundary of Chebera Churchura National Park (a) 1991 to 2000 (before establishment) and (b) 2010 to 2020 (after establishment) of the park. Values in bold font indicate stable land cover

		Year 2000 (km^2)					
	LULC type	Agricultural land	Forest	Grassland	Water bodies	Wooded grassland	Woodland
(a) Before park establishment							
Year1991 (km^2)	Agricultural land	**2.47**	0.09	0.68	0.01	10.07	6.91
	Forest	0.06	**167.84**	0.01	0.46	0.24	17.24
	Grassland	4.67	0.15	**56.8**	1.03	147.58	17.26
	Water bodies	0.01	0.39	0.01	**7.25**	1.2	0.15
	Wooded grassland	8.8	1.15	49.18	1.09	**412.23**	121.84
	Woodland	1.55	64.49	0.26	5.52	54.45	**138.91**
		Year 2020 (km^2)					
	LULC type	Agricultural land	Forest	Grassland	Water bodies	Wooded grassland	Woodland
(b) After park establishment							
	Agricultural land	**5.34**	0.12	8.36	0.07	4.08	5.55
Year 2010 (km^2)	Forest	0.63	**211.74**	0.26	0.37	1.63	28.71
	Grassland	5.93	0.29	**50.93**	0.67	70.37	21.58
	Water bodies	0.05	0.21	0.17	**6.01**	0.22	0.14
	Wooded grassland	14.33	1.30	83.63	0.26	**252.79**	163.91
	Woodland	7.63	39.14	10.94	0.90	60.81	**242.99**

(during free access period) observed were from grassland to wooded grassland (148 km^2), wooded grassland to woodland (121.8 km^2), and woodland to a forest (64.5 km^2) (Table 3a). However, after the establishment of the park, larger changes were detected in the transformation from wooded grassland to woodland (163.9 km^2) and from the former to grassland (83.6 km^2) (Table 3b).

Land use land cover changes in the buffer zone of the park

In the last 35 years, agricultural land and woodland increased by 174 km^2 (679%) and 115 km^2 (55%), respectively, in the buffer zone of CCNP. Whereas, grassland, forest, wooded grassland and water bodies had declined by −232 km^2 (−56%), −36 km^2 (−25%), −15 km^2 (−5%) and −6 km^2 (−44%), respectively (Table 4).

Considering the three time periods separately, different patterns of changes had emerged. During the transitional period, for example, grassland showed the most change, declining a total of −308.82 km^2, or −74.41%) at a rate of −20.59 km^2 per year. In contrast, Wooded Grassland had increased by 67.24% (a total of 198.77 km^2 gain at a rate of 13.25 km^2 per year. Woodland also increased by 35.18% or 4.88 km^2 per year (Table 5). Before establishment of the park, only grassland showed a decline from 258 km^2 to 106 km^2 in 2000 (Table 4). Among other land cover types, wooded grassland gained 100 km^2 (25% of its original size in 1991) and forests increased by 35 km^2 (31%), indicating an annual increasing rate of 4 km^2 per year (Table 5). After the establishment of the park, on the other hand, agricultural land doubled (100 km^2 in 2010 vs 200 km^2 in 2020), and woodland increased from 305 km^2 in 2010 to 323 km^2 in 2020, which was a gain of 18 km^2 (6%) or an annual increase of 2 km^2 (Table 5). In contrast, wooded grassland declined by −24% at a rate of −9 km^2 per annum. Similarly, grassland also declined by −10% or at a rate of 2 km^2 per annum (Table 5). The annual rate of change was faster for grassland before the establishment of the park, a decline of 152 km^2 (36.6% of its original extent in 1985) during the period or of 16.9 km^2 per year. However, this land cover type showed a minor change after the establishment of the park (Table 5). Forest and woodland also showed considerable changes during both periods: an increase of 35 km^2 and 10.5 km^2 in extents of forest and woodland before the establishment of the park, and 13 km^2 and 18 km^2 of forest and woodland cover, respectively, after the establishment of the park (Table 5). Wooded grassland was the most changed land cover type after the establishment of the park, showing a decline of −90 km^2 (28% of its original extent), while its annual rate of change was only about 9 km^2 per year (Table 5). Nearly, 46% of the study area remained unchanged throughout the study period, of which 31% of the unchanged habitat was woodland (Table 5).

Examining LULCC matrices at buffer zone of the park during the two periods, significant changes detected before establishment of the park were from grassland to wooded grassland (178 km^2), wooded grassland to woodland (85 km^2), woodland to wooded grassland (55 km^2) and wooded grassland to grassland (43 km^2) (Table 6a). After establishment of the park, however, notable changes detected were from grassland to wooded grassland (91 km^2), and from wooded grassland to woodland (90 km^2), to grassland (82 km^2) and to agricultural land (66 km^2) (Table 6b).

Comparison of LULCC between within park and buffer area

A simple correlation test showed that the similarity in patterns of LUCC between within the park and the buffer zone were significant during both periods, with stronger during the period prior to establishment of the park (Pearson's correlation coefficient [r_s] = 0.91, N = 6, P < 0.001) than after establishment of the park ($r_s = 0.63$, N = 6, P < 0.05). However, no significant patterns in LULCC changes before and after establishment of the park were found both within the park boundary ($r_s = -0.01$) and at the buffer zone ($r_s = -0.23$). Overall, three LULC types characterize the variations in patterns of LULCC before and after establishment of the park within and at buffer zone of the park. Grassland showed declining cover both within boundary and buffer zone of

Table 4 Extents (in km^2 and %) of land use-land cover types in the buffer zone of the CCNP in each year studied

No	Land cover type	1985	%	1991	%	2000	%	2010	%	2020	%
1	Agricultural land	25.62	2.33	57.32	5.20	60.43	5.48	100.33	9.10	200.04	18.14
2	Forest	144.75	13.14	115.7	10.49	151.07	13.70	121.87	11.05	108.78	9.86
3	Water	13.42	1.22	6.5	0.59	9.09	0.82	2.74	0.25	7.52	0.68
4	Woodland	208.27	18.90	271.1	24.58	281.54	25.53	304.67	27.63	322.74	29.27
5	Wooded Grassland	295.62	26.83	394.21	35.74	494.39	44.83	370.05	33.56	280.21	25.41
6	Grassland	415.02	37.58	258.05	23.40	106.2	9.63	203.04	18.41	183.42	16.63
	Total	1102.70	100.00	1102.88	100.00	1102.72	100.00	1102.70	100.00	1102.71	100.00

Table 5 Changes in land use land cover in the buffer zone of Chebera Churchura National Park during transition period (1985to 2000), before establishment of the park (1991 to 2000) and after establishment (2010 to 2020)

LULC type	During transitional period (1985–2000)			Before park establishment (1991–2000)			After park establishment (2010–2020)		
	change (km2)	Percent change	Change rate (km^2/year)	change (km^2)	Percent change	Change rate (km^2/year)	change (km^2)	Percent change	Change rate (km^2/year)
Agricultural land	34.81	135.87	2.32	3.11	5.43	0.35	99.71	99.38	9.97
Forest	6.32	4.37	0.42	35.37	30.57	3.93	−13.09	−10.74	−1.31
Water	−4.33	−32.27	−0.29	2.59	39.85	0.29	4.78	174.45	0.48
Woodland	73.27	35.18	4.88	10.44	3.85	1.16	18.07	5.93	1.81
Wooded Grassland	198.77	67.24	13.25	100.18	25.41	11.13	−89.84	−24.28	−8.98
Grassland	−308.82	−74.41	−20.59	−151.85	−58.85	−16.87	−19.62	−9.66	−1.96

Table 6 Matrix of land use and land cover change (in km^2) in the buffer zone of Chebera Churchura National Park (a) before establishment of the park (1991 to 2000) and (b) after establishment (2010 to 2020). Values in bold font indicate stable land cover

	Year 2000 (km^2)						
	LULC	**Agricultural land**	**Forest**	**Grassland**	**Water bodies**	**Wooded grassland**	**Woodland**
	(a) Before park establishment (1991 to 2000)						
Year 1991 (km^2)	Agricultural land	**17.77**	0.25	1.08	0.01	16.11	22.10
	Forest	0.70	**96.80**	0.02	0.14	0.13	17.85
	Grassland	6.93	0.09	**62.28**	1.61	178.09	9.05
	Water	0.00	0.23	0.00	**3.34**	2.90	0.06
	Wooded grassland	22.17	1.57	42.47	0.57	**242.48**	84.95
	Woodland	12.86	52.13	0.41	3.43	54.69	**147.54**
	Year 2020 (km^2)						
	LULC	**Agricultural land**	**Forest**	**Grassland**	**Water**	**Wooded grassland**	**Woodland**
	(b) After park establishment (2010 to 2020)						
Year 2010 (km^2)	Agricultural land	**63.86**	0.17	14.23	0.44	9.43	12.20
	Forest	3.61	**87.36**	0.52	0.47	1.53	28.38
	Grassland	11.70	0.53	**66.23**	1.25	91.18	32.15
	Water	0.03	0.10	0.21	**1.86**	0.24	0.30
	Wooded grassland	66.32	0.66	82.26	1.00	**129.36**	90.45
	Woodland	54.51	19.96	19.97	2.50	48.47	**159.26**

the park before establishment of the park, but it showed a slight increase within the park boundary but declined by a factor of 10 within the buffer zone after establishment of the national park. Agricultural land declined before establishment of the park but increased by 44% after park establishment, while it was consistently increasing at the buffer zone throughout the study period. Forest cover showed an increase within the park boundary both before and after establishment of the national park, while at the buffer zone it increased before park establishment and declined then after. Wooded grassland showed increases and then decreases both inside and outside the park, while woodland showed increased throughout the period both inside and outside the national park (see Tables 1, 2, 3 and 4).

Discussion

Analysis of 35 years (1985–2020) LULCC showed that rapid changes, especially increases in agricultural land, in land use land cover detected during the transitional period between 1985 and 2000. This result is expected and in line with reports showing that severe loss of biodiversity and protected areas crises in Ethiopia did take place following the downfall of the then Dergue regime in 1991 (Jacobs and Schloeder 2001). Overall, three land use land cover types can characterize the variations in patterns of LULCC before and after the establishment of the park both within and in the buffer zone of CCNP. Grassland showed declining cover within the boundary and buffer zone of the park before the establishment of the park. It displayed a slight increase within the park boundary but declined by a factor of 10 within the buffer zone after the establishment of the national park. The declining grassland cover but increasing wooded grassland coverage observed inside and outside the current park area before establishment of the national park (before 2005) are as expected and attributed to the interactive effects of fire intensity and livestock grazing. Before the establishment of the national park, livestock grazing was evenly practiced across the whole study area (Megaze et al. 2013). In the meantime, the area has been subjected to recurrent fire burning by locals to induce the sprouting of new grass for grazing and to clear the grass from paths crossing the national park and connecting villages (Woldeyohannes 2006). Increased grazing intensity causes reduced grass biomass (see Gomes et al. 2020; Sankaran et al. 2005; Wragg et al. 2018; Zhang et al. 2018) that, in turn, reduces fire intensity, that benefits woody plants to regenerate, thus facilitating the shift from grassland to wooded grassland. This result is in agreement with the previous study reports (Sankaran et al. 2004; Yusuf et al. 2011). On the other hand, the slight increase in grassland inside the park after the establishment of the national park can be related to the reduced livestock grazing within the park boundary that leads to increased grass biomass and may increase fire intensity that destroys wooded grassland. As reported by many authors (Gomes et al. 2020; Wragg et al. 2018), processes similar to those discussed above may also explain the transformation from grassland to woodland observed in the present study within the national park. In contrast, the decreased grassland cover in the buffer zone after the establishment of the national park may partly be attributed to unregulated heavy livestock grazing, resulting in the degradation of grasses but facilitating woody plant encroachments. These findings are consistent with the study report by van Langevelde et al. (2003) and may reflect the negative effects of heavy livestock grazing on grass biomass that reduce fire intensity and cause a shift from grassland to wooded grassland.

Overall, law enforcement activities that restricted grazing inside the national park after its establishment might have resulted in increased grass biomass that increased the fire intensity, which in turn decreases the wooded grassland and maintains grassland compared to the situation in the buffer zone of the national park. For example, a study by Megaze et al. (2013) indicated that more than 50% of householders inhabiting the area surrounding the national park area use the park for livestock grazing. In addition to the growth in human and livestock populations, the conversion of grazing lands to cultivation areas outside the national park 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.

The increase in water bodies in the buffer zone after the establishment of the park might have arisen from a classification error. Such increases in the extent of water bodies due to classification error reported in some studies (e.g. Mtui et al. 2017). A decline in forest cover was observed only in the buffer zone after the establishment of the national park. The substantial decline in the forest cover noted in the buffer zone after park establishment agrees with reports of other studies (Young et al. 2020) confirming the significant reduction of forest resources in the country to be due to poor management systems. As a result, consistent with our hypothesis, the contrasting trends in forest cover found inside (constant) and in the buffer zone of (declining) the national park following its establishment are most likely attributed to effective law enforcement activities the park management that prohibited deforestation for cultivation within national park area. These findings are in agreement with reports of global-level assessments of the effectiveness of protected areas in improving and/or maintaining forest cover inside protected areas, which is one of the good indicators of effectively protected wildlife conservation areas (Rahman et al. 2006; Nagendra 2018; Geldmann et al. 2020). In addition to this, the annual change rate of agricultural land showed a constant trend within the park area (Fig. 4 A), while the buffer area showed a linear trend (Fig. 4B). These findings fit with reports of similar studies (e.g., Acha et al. 2017; Mtui et al. 2017; Kariuki et al. 2021), demonstrating significant land conversions due to human activities and that establishing and effectively managing protected areas can serve as an important approach, at least, to slow down the rate of change of land cover.

Key informants pointed out that the major drivers of LULCC in the CCNP are crop farming, livestock grazing and fire. These threats, and human-wildlife conflicts, have also been highlighted in previous studies from the area (e.g. Megaze et al. 2013) and in the general management plan of the park (CCNP 2020) as the major conservation issues in the management of the park. However, the LULCC detected in the CCNP is relatively lower compared to the rate of changes detected at many other protected areas in Ethiopia (Fetene et al. 2016; Hailemariam et al. 2016; Yohannes et al. 2017; Hailu et al. 2018; Arafaine and Asefa 2019). This may reinforce the notion that CCNP to be relatively the most intact park in the country (CCNP 2020). Despite this, boundaries of the national park have not been marked with beacons yet, which may facilitate expansion of cultivation into the peripheries of the park boundary areas. Unless dealt with by the park management sooner, the increased agricultural activities in the buffer zone have a tendency to spill over to the center of the national park.

Conclusions

Results of the present study showed that different land cover types had varying patterns of change over the last 35-year period. However, striking differences were detected between within the park area and its buffer zone after establishment of the park. Notably, pronounced declines in grassland and forest areas, but increases in agricultural areas, were observed in the buffer zone of the park. On the other hand, the extents of these land use land cover types were either increased or remained unchanged within the park boundary. Similar to the notion that trends in the extent of forest cover and cultivation lands are among the good indicators of effectively protected wildlife conservation areas (Rahman et al. 2006; Nagendra 2018; Geldmann et al. 2019), these findings suggest that CCNP management is effective in slowing down LULCC relative to that in the buffer zone areas. However, further studies on the faunal and flora diversity are needed to better understand the effectiveness of biodiversity management within the park compared to the buffer zone, as well as to other similar protected areas in the country. In sum, the approach used in this

Fig. 4 The trends of annual change rate of LULC within the park and buffer zone

study would serve as a showcase on cost-effective means to assess human impacts on biodiversity in protected areas due to policy changes. It also has provided valuable information needed to implement effective conservation measures to reduce drivers of LULCC observed in the park. Findings of the study would serve as a bench mark to evaluate future management effectives of the park authority.

Supplementary Information

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Additional file 1. Appendix A. Satellite image downloaded for the land cover analysis. **Appendix B.** Error matrix of park area land use land covers classification of the year (a) 1985, (b) 1991, (c) 2000, (d) 2010, (e) 2020.

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Author contributions

TY conducted field data collection, downloaded satellite images, analysed the data, and drafted the manuscript. ZKT and AA initiated the idea, commented and improved the manuscript, FK and GM commented and improved the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

All the data used are included in the manuscript.

Declarations

Ethics approval and consent to participate

Research permission was obtained from the Ethiopian wildlife Conservation Authority. We also obtained verbal informed consent from all key informants.

Consent for publication

Not applicable.

Competing interests

Authors declare no competing interests exist.

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