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Research article

Impacts of Land use Land cover dynamics on Ecosystem services in maze national park and its environs, southwestern Ethiopia

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ABSTRACT

This study investigated the impacts of LULC changes on selected ecosystem services in Maze National Park (MzNP) and its environs in southwestern Ethiopia. Landsat images from 1985, 2005, and 2020 were used to examine land use land cover (LULC) changes. Images were classified using the Random Forest (RF) classifier, and their accuracy was computed in QGIS. Ecosystem service values (ESVs) were then estimated using the benefit transfer method employing Ecosystem Service Valuation Database (ESVD) coefficients. Additionally, socioeconomic survey was conducted to understand the local community's perceptions regarding the dynamics of ecosystem services. The findings revealed a significant increase in croplands (103.7 %) and built-up areas (31.32 %), while riverine forests, water bodies, and wooded grasslands declined. The overall ESVs decreased by 20 %, from 2038.42 million USD in 1985 to 1628.72 million USD in 2020, mainly driven by reductions in riverine forests and wooded grasslands. As for the individual ESVs for the period 1985 to 2020, only food production increased by 0.7 million USD, while water supply, climate regulation, raw materials, and recreation and tourism declined by 180.35, 2.67, 45.72, and 481.62 million USD, respectively. The coefficient of sensitivity ranged from 0.01 to 0.94, <1, revealed that our estimates are relatively robust. Ecosystem services such as grazing, recreation, wild food, and firewood are highly valued by local residents, but they are declining over time due to environmental degradation and restrictions on access to the park. Thus, understanding LULC changes and their impacts on ESVs can help decision-makers design effective protected area management plans and reduce potential conflicts over resource uses. Further investigations are suggested to more accurately quantify ESVs using high resolution satellite imageries and different valuation methods.

1. Introduction

Ecosystems provide a variety of services including food, water, timber, fuel wood, climate regulation, habitat conservation, spiritual and recreational services that are essential for human wellbeing [1]. However, an increasing conversion of forests, grasslands, wetlands and other natural ecosystems to croplands and settlements has exerted a great pressure on biodiversity and ecosystem services [2]. Particularly, land use land cover (LULC) changes which are driven by socio-demographic dynamics and climate change can have profound impacts on ecosystem services provided by water bodies [3], forests [4,5], grasslands [6], and urban areas [7].

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These changes can in turn alter the structure and functionality of ecosystems, affecting their ability to provide goods and services to communities [8]. As a result, LULC change is recognized globally as a major driver of biodiversity loss and the decline of ecosystem services [9]. Understanding the relationship between LULC and ecosystem service values (ESVs) is essential for planning resource management [10].

Africa's ecosystems, which hold significant ecological, social, economic and cultural importance at the national, regional and global levels, have been affected by LULC changes, especially conversion of natural habitats into agricultural lands and urban settlements [11]. Ethiopia exhibits a typical example, where LULC changes are widespread, with agricultural activities and settlements dominating rural landscapes [12]. Maze National Park (MzNP) and its environs are dominantly covered by savanna grasslands and scattered trees, and riverine forests [13]. These landscapes offer a diverse range of provisioning, regulating, and cultural services. The benefits derived from the area include food, water, grazing, thatching grass, firewood, construction materials, wild honey, regulation of the local climate, and recreation and aesthetic values. These benefits play a vital role in sustaining the livelihoods of the local people in the study area, especially during times of drought and famine [14]. However, extensive land use pressures, increased demand for natural resources [15] population growth, expansion of agricultural lands, demand for fuelwood and construction materials, poverty, as well as policy and institutional changes, are among the major causes of LULC dynamics in the country [16–18]. Previous studies in Ethiopia have demonstrated a loss of both individual and overall ecosystem services as a result of LULC changes [12,19–21].

The quantity and quality of services offered by ecosystems depend on the type and status of ecosystems [1]. Each ecosystem provides unique services that cannot be replaced by others [12]. Therefore, assessing the services provided by different ecosystems and quantifying their spatial and temporal changes is crucial for the efficient management of social-ecological systems [22]. In Ethiopia, only few studies have been carried out by quantifying the impacts of LULC dynamics on ecosystem services [4,12,19–21,23–27]. These studies were mainly confined to forest ecosystems of Ethiopian highlands [4,12,21,23], watersheds and basins [24–26], and agroforestry dominated landscapes [27]. Moreover, semi-arid regions, where grasses and shrubs predominate the landscapes, provide crucial ecosystem services such as food production, water supply, climate regulation, fuelwood, grazing, thatching grasses, construction wood, and other benefits have received little attention in previous studies. Furthermore, to the best of our knowledge, the local community's perceptions regarding the benefits obtained from the MzNP and its surroundings have not been studied.

National Parks play a crucial role in biodiversity conservation and in supporting the livelihoods of local residents who rely on natural resources for their survival [28–30] Despite such roles, MzNP is under intense pressure due to human activities such as overgrazing, collection of firewood and construction materials, and frequent bush fires. The core conservation area of the park, in particular, is prone to fires caused by individuals seeking grass for livestock feed in drought affected areas [14]. Consequently, the park and its surrounding area are experiencing changes in LULC, degradation of vegetation resources, and a decline in wild life populations [14,31] These factors have led to environmental deterioration, undermining the ecosystem's many benefits.

The objective of this study is to investigate the impacts of LULC dynamics on key ecosystem services in MzNP and its environs in southwestern Ethiopia. We employed the benefit transfer method to quantify these services and analyzed the local community's

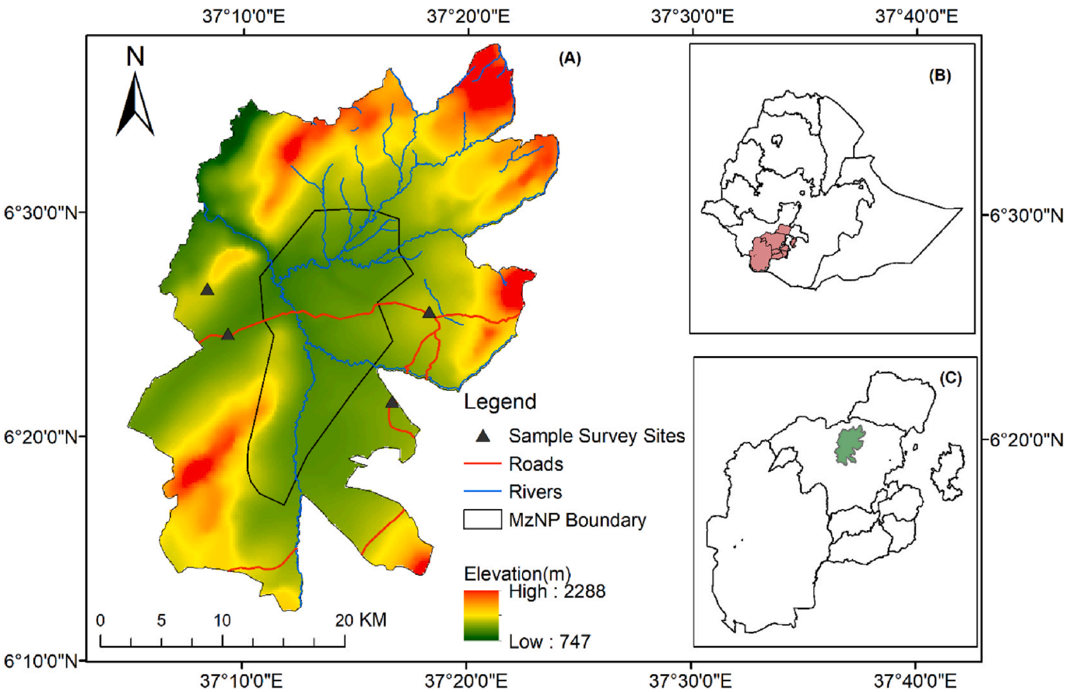

Fig. 1. Location map of the study area.
Note: (A) MzNP and the surrounding districts (B) location of SENRS in Ethiopia, and (C) location of the study area in SENRS.

perception of ecosystem services dynamics to raise awareness and improve decision-making for the effective management and conservation of the park and its environs.

2. Materials and methods

2.1. Description of the study area

The study area, MzNP and its environs (Fig. 1A), is located in Gamo and Gofa zones of Sothern Ethiopian National Regional State (SENRS)(Fig. 1C) of the country (Fig. 1B). The park and the surrounding seventeen (17) *kebeles (the smallest administrative unit in Ethiopia)* constitute the research area. The study area is situated about 468 km southwest of Addis Ababa, Ethiopia's capital. Astronomically, it is positioned between 06°11′35″N – 06°37′49″N Latitudes and 37°03′42″E – 37°24′55″E Longitudes (Fig. 1).

According to the traditional agro-ecological zones of Ethiopia, the study area falls into the *kolla* (lowland with an elevation between 500 and 1500 m above sea level) and *woina Dega* (midland, between 1500 and 2300 m above sea level) agroecological zones [32]. The elevation of the area ranges between 747 and 2288 m above sea level. The landscape includes plains, some slopped areas, small hills, and escarpments surrounded by a rugged mountain range. Data collected from meteorological services agency from 1985 to 2020 shows that the mean annual temperature of the study area is 23.96^{o}C and the annual average rainfall is about 973.38 mm. The mean monthly maximum and minimum temperatures were 31.18 °C and 16.75 °C, respectively. The study area experiences bimodal rainy seasons from March to May and August to October (Fig. 2). The primary means of subsistence for the local communities in the study area is cereal production, followed by livestock rearing. However, tuber crops like sweet potato, taro, and cassava are cultivated as supplements to cereals [31].

2.2. Data sources and methods

2.2.1. Land use land cover data and classification

The data set for LULC change analysis was derived from time series Landsat images of three different periods (1985, 2005, and 2020), obtained from the United State Geological Survey (USGS) website (https://earthexplorer.usgs.gov). Landsat 4–5 Thematic Mapper (TM) was used for 1985, Landsat 7 Enhanced Thematic Mapper Plus (ETM+) for 2005, and Landsat 8 Operational Land Imager (OLI) for 2020, at 30 m spatial resolution (Table 1). The satellite images were sourced for path/row 169/56, fully covering the study area. To avoid cloud cover, all three images were acquired during dry seasons (December to January). Image preprocessing including layer stacking, and the Dark Object Subtraction (DOS) method, image-based atmospheric correction [33], was employed to remove haze, shadow, and dark pixel values caused by atmospheric scattering [34], using the Semi-Automatic Classification Plugin (SCP) in QGIS. The Landsat 7 ETM + image has a scan-line error due to sensor failure on May 31, 2003 [35], which caused gaps in the Landsat 7 images. These gaps were filled using the mask layer provided with the image [36] in QGIS with the 'fill no data' tool.

Training and test data for LULC classification were collected through stratified random sampling techniques from satellite images with high spatial resolution, including Google Earth, SPOT5, and Sentinel. The LULC classifications were carried out using a Random Forest (RF) supervised classification method in R statistical software (R4.1.3) [37]. RF is a powerful classifier known for its ability to predict well even in the presence of missing data. It also helps to avoid over-fitting problems, produces more stable results, and is less sensitive to multi-collinearity compared to other machine learning algorithms [38].The classification identified bare land, built-up area, cropland, riverine forest, and wooded grassland as major LULC classes, with burned area as an additional class in 2020.

To assess the accuracy of LULC classification, 692 verification points were generated from Google Earth, SPOT5, and Sentinel images for the 1985, 2005, and 2020 LULC maps. Reference points were stratified into LULC classes to reduce the standard error of class-specific estimates, based on (Eq. (1)) [39].

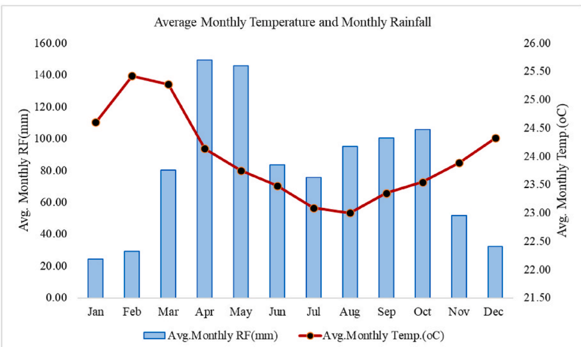

Fig. 2. Characteristics of temperature and rainfall (1985–2020).
Source: National Meteorological Services Agency (NMA), (2022)

Table 1
Description of imagery data used for LULC change analysis.

Imagery Type	Path/Row	Pixel Size(m)	Bands Used	Acquisition Date	Source
Landsat TM	169/56	30*30	1-5 and 7	September 01, 1985	USGS
Landsat ETM$^+$	169/56	30*30	1-5 and 7	01/24/2005	USGS
Landsat OLI	169/56	30*30	2–7	November 12, 2020	USGS

$$N = \sum_{i=1} (wi * si) / so)2 \tag{1}$$

Where, Wi = mapped area proportion of class;
Si = standard deviation of stratum;
So = expected standard deviation of overall accuracy;
C = total number of classes.

The accuracy of the classified image needs to be assessed before it is used as input for any applications [40].Therefore, we assessed the accuracy of images using measures such as Kappa coefficient (Eq. (2)), overall accuracy (Eq. (3)), user's accuracy (Eq. (4)), and producer accuracy (Eq. (5)). The LULC categories used in this study were identified based on Ethiopian LULC classification and coding Standard [41] (Table 2).

$$K = \frac{M\sum_{i=j=1}^{r} nij - \sum_{i=j=1}^{r} ninj}{M^2 - \sum_{i=j=1}^{r} ninj} \tag{2}$$

Where, K = kappa statistics, M = total number of observations in the matrix, r = number of rows in the confusion matrix, nij = number of observations in row i, column j, ni = total number of observations in row I, nj = total number of observations in column j

$$\text{Overall Accuracy} = \frac{\text{Total number of correctly classified pixels(Diagonal)}}{\text{Totan number of reference pixels}} * 100 \tag{3}$$

$$\text{User's Accuracy} = \frac{\text{Number of correctly classified pixels in each category}}{\text{Totan number of reference pixels in that category(the Raw Total}} * 100 \tag{4}$$

$$\text{Producer Accuracy} = \frac{\text{Total number of correctly classified pixels in each category}}{\text{Totan number of reference pixels(the Column Total)}} * 100 \tag{5}$$

Post-classification comparison approach involved calculating percentage changes for each LULC classes over three intervals: 1985–2005, 2005–2020, and 1985–2020, to assess changes in LULC classes. Additionally, changes "from-to" and the areas that remained unchanged for each LULC class from 1985 to 2020 were determined. The percentage change of LULC classes was computed as follows (Eq. (6)):

$$\Delta L = \frac{A2 - A1}{A1} * 100 \tag{6}$$

Where; ΔL is the LULCC proportion, A2 and A1 are final and initial area coverage of the LULC classes respectively.

2.2.2. *Ecosystem services valuation methods*

Based on discussions with local residents, agricultural extension agents, and park staff, six ecosystem services that the local community perceives as major benefits, such as food production, water supply, raw material provision, climate regulation, recreation and tourism, and spiritual experiences, were identified.

To quantify the values of the identified ecosystem services, we employed value coefficients from Ecosystem Service Valuation Database (ESVD) (Table 3), which was updated in 2020 with support from the UK Department for Environment, Food, and Rural Affairs (Defra). The ESVD is a follow-up to the Economics of Ecosystems and Biodiversity (TEEB), containing 4042 values based on 693 studies. These values were obtained from six continents, including Africa [42]. We used the benefit transfer method to quantify

Table 2
Descriptions of LULC types in the study area.

Land use land cover Types	Description
Bare land	Non vegetated area dominated by rock outcrops, eroded and degraded lands
Built-up Area	Land dominated with houses, huts and roads
Cropland	Land used primarily for production of food and fiber. This category includes both cultivated and non-cultivated lands
Riverine Forest	Forest along the water way or the rivers
Water Body	Rivers in the study area
Wooded Grassland	Grasslands with scattered trees, herbs and shrubs
Burned Area	Land surface sufficiently affected by fire and display significant changes in vegetation cover and in the ground surface.

Table 3
LULC classes, corresponding biomes and mean standardized values per ecosystem service biome.

LULC Categories	Equivalent Biome	Mean Standardized Values per Ecosystem Service Biome (Int$/Hectare/Year; 2020 Price Levels)
Bare land	Desert	0
Built-up Area	Built-up Area	0
Cropland	Cultivated Areas	4231
Riverine Forest	Tropical Forest	113657
Water Body	Rivers and Lakes	25538
Wooded Grassland	Grassland	1115
Burned Area	Desert	0

changes in ESVs of the LULC classes for the identified study periods [21,43,44]. Benefit transfer is employed as an alternative method to estimate the economic values of ecosystem services when site-specific valuation information is lacking. It adapts existing valuation information to new policy contexts and is particularly useful when budgets, time, and information accessibility constrain primary data collection [27,45]. The benefit transfer method has been extensively used to value environmental resources in numerous studies [21,26,43,46].

Following the approach proposed by Costanza et al. [43], we calculated the ESVs per unit area for each LULC class based on ESVD value coefficients (Table 3; Table 4). Some land use classes, such as bare land and built-up areas, did not have coefficients in previous studies [4,12,19–21,23–27]. Likewise, in our study, no coefficients were assigned to bare land, built-up, and burned areas. Using the following equations, ESVs of each LULC class (Eq. (7)) and the total values of key ecosystem services (Eq. (8)) of reference years were computed.

$$ESV_{kt} = (A_{kt} \times VC_k) \tag{7}$$

$$ESV_{Tt} = \sum (ESV_{kt}) \tag{8}$$

Where, ESV_{kt} and ESV_{Tt} is ecosystem service value of LULC class “k” at reference year “t” and total value of key ecosystem services for a reference year “t”, respectively. A_k is area in ha of LULC class “k” and VC_k is value coefficient of LULC class “k”

The changes in ESVs were determined by calculating the difference between the estimated values in each reference year (Eq. (9)). Additionally, we calculated individual ESVs obtained from each LULC class and quantified the gains and losses of the identified ecosystem services over the study periods.

$$\text{Percentage ESV Change} = \frac{ESV_{t2} - ESV_{t1}}{ESV_{t1}} * 100 \tag{9}$$

Where, ESV is ecosystem service value, t_1 is initial year and t_2 is final year.

2.2.3. Analysis of coefficient of sensitivity

Given the uncertainties in the value coefficients and the imperfect matches between the biomes used as proxies for LULC types, we conducted a sensitivity analysis to reduce these uncertainties [47]. The coefficient of sensitivity was calculated for each analysis using the standard economics concept of elasticity [47], adjusting the value coefficients of each LULC type by 50 % with (Eq. (10)) for the study periods.

$$CS = \frac{\frac{(ESVj - ESVi)}{ESVi}}{\frac{VCjk - VCik}{VCik}} \tag{10}$$

Where; CS is coefficient of sensitivity, ESV is the estimated ecosystem service value, VC is the value coefficient, i and j represent the initial and adjusted values, respectively, and k represents the land use category. If $CS > 1$, then the estimated ecosystem value is elastic with respect to that coefficient and it is important to accurately define VC, but if $CS < 1$, then the estimated ecosystem value is

Table 4
Detailed presentation of mean standardized values of selected ecosystem services per LULC classes.

Biome	Mean Standardized Values per Ecosystem Service Biome (Int$/Hectare/Year; 2020 Price Levels)						
	Food production	Water supply	Raw Material	Climate regulation	Spiritual experiences	Recreation and Tourism	Total ESV Coefficients
Bare land	–	–	–	–	–	–	–
Built-up Area	–	–	–	–	–	–	–
Cropland	510	604	6	10	–	3101	4231
Riverine Forest	602	47869	11739	658	–	52789	113657
Water Body	2288	9198	92	251	76	13633	25538
Wooded Grassland	–	313	637	73	–	92	1115

considered to be inelastic and robust [44,47].

2.2.3. Socio-economic data collection.

MzNP is surrounded by five *woredas:* such as Kucha, Kucha Alpha, Daramalo, Kamba, and Zala. From these *woredas,* four *kebeles* were purposively selected based on their strong interaction with the park [48] and their long boundary with the park. The selected sample *kebeles* were Morka, Domea, Wagesho, and Mela GayileTossa. According to the *kebele* administration offices, the total number of households in sample *kebeles* were 2203. The total sample size of households for the survey was determined using the sample size determination formula developed by Cochran [49] (Eq. (11); (12)).

$$n_0 = \frac{z^2 pq}{e^2} \tag{11}$$

Where, n_0 *is* the sample size, z is the selected critical value of desired confidence level, p is the estimated proportion of an attribute that is present in the population, $q = 1 - p$ and e is the desired level of precision.

Therefore, with a total number of 2203 households, the calculated sample size was 246. However, since this sample size exceeds 5 % of the total households (110), Cochran's correction formula was used to calculate the final sample size [49].

$$n_0 = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}} \tag{12}$$

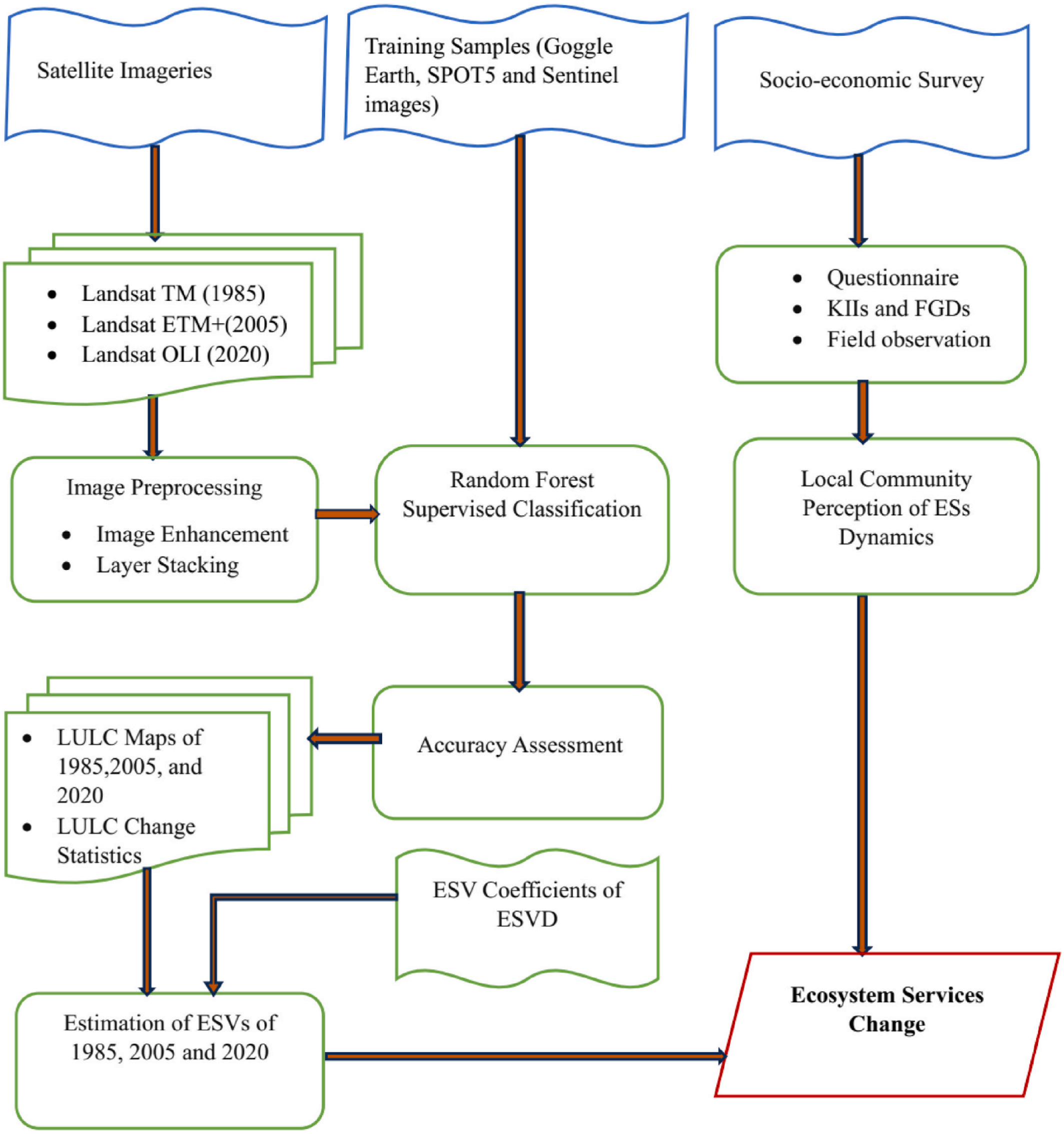

Fig. 3. Methodological framework of the study.

Where, n_0 is the sample size derived above and N is the population size. Hence, the final sample size determined for this study was 221.

Study participants for the questionnaire, focus group discussions (FGDs) and key informants' interviews (KIIs) were selected purposively based on their length of time living in the study area and their knowledge about the park and the benefits they obtain from it. The selection of the respondents was conducted in consultation with *kebele* administrators and agricultural extension agents of each *kebeles*. A total of 221 study participants were selected from the four *kebeles*. Concerning FGDs and KIIs, six FGDs were conducted including two women-only groups and four groups with both women and men, each containing five to seven members in the selected four *kebeles*. In addition, eight KIIs were conducted with *kebele* administrators, residents, and park staff.

For the quantitative data gathered through questionnaires, descriptive statistics such as frequency and percentage were used for analysis. Qualitative information obtained from FGDs and KIIs was thematically classified into two predefined categories: LULC changes and major benefits obtained from the park. And the findings were presented in a narrative manner. Socio-economic data were used to triangulate how the LULC based analysis correspond to local communities' perceptions regarding ecosystem services dynamics. The overall methodological framework of the study is presented in Fig. 3.

3. Results

3.1. Land use land cover change analysis

Image classification processes enabled us to identify six LULC classes for 1985 and 2005, and seven classes for 2020. Table 5 shows the overall accuracy and kappa coefficient values for the years 1985, 2005, and 2020. The overall accuracy was 88.93 %, 93.03 %, and 91.57 %, with kappa coefficient of 0.81, 0.88, and 0.86 respectively. These values indicate very good to excellent agreement with the validation dataset, meeting the required standards (overall accuracy >85 % [50] and kappa coefficient >0.75 [51].

As specified in Table 6, wooded grassland was the most dominant LULC type in the study area covering 62.43 %, 62.26 %, and 60.06 % of the total area in 1985, 2005, and 2020, respectively. Riverine forest was the second most dominant LULC class in 1985 and 2005, making up 18.68 % and 15.4 % of the total area, respectively. However, in 2020, cropland significantly increased and replaced riverine forest as the second most dominant LULC type, accounting for 15.92 % of the total area (Table 6). LULC classes that exhibited positive change progressively over the entire 35 years of the study period were cropland and built-up areas, while riverine forest, water body, and wooded grassland showed a negative change. Due to the park's frequent exposure to illegal fires (Fig. 4B), a new category, burned area (Fig. 4A), was included in the 2020 image, covering 1285 ha or 1.42 % of the total area (Table 6).

The study area experienced a notable expansion of croplands and built-up areas from 1985 to 2020. Croplands experienced the highest increment rate (103.7 %) among the LULC classes, while the built-up area also increased by 31.32 % over the study periods. On the other hand, Water bodies and riverine forests were the two LULC types that showed the largest continuous spatial reduction in the study area, at 37.47 % and 22.35 %, respectively. Despite wooded grassland being the largest LULC type in terms of area coverage in the study area, its rate of change (reduction rate) was the smallest compared to other LULC classes decreasing by 3.78 % from 1985 to 2020. Bare land exhibited an increment of 18.2 %, from 1985 to 2005 but decreased by 45.5 % from 2005 to 2020, with an overall decline of 36 % over the period of 1985–2020 (Table 6; Fig. 5).

The LULC change matrix indicates that the expansion of croplands over the last 35 years period has mainly occurred at the expense of wooded grassland, with 10.89 % (9866 ha) of wooded grassland was converted to farmland. Meanwhile, 46185.6 ha (51 %) of the total area remained unchanged during the study period (Table 7). In general, from 1985 to 2020, cropland and built-up areas displayed a net gain of 7340 and 466 ha respectively, while bare land, riverine forest, water body, and wooded grassland showed net losses (Table 7).

3.2. Ecosystem services valuation

The total values of the identified key ecosystem services of the study area in 1985, 2005, and 2020 were 2038.42, 1704.4, and 1628.72million USD, respectively. The total ESVs of the study area declined by over 20 % between 1985 and 2020 (Table 8). Among

Table 5
Accuracy assessment result of the classified images.

LULC Classes	Accuracy (%)								
	1985			2005			2020		
	PA	UA	Kappa hat	PA	UA	Kappa hat	PA	UA	Kappa hat
Bare Land	88.65	84.82	0.83	92.47	98.23	0.98	94.82	94.69	0.94
Built-up Area	55.50	93.22	0.93	73.67	96.61	0.97	77.59	91.53	0.91
Cropland	70.50	97.33	0.97	98.52	89.33	0.88	86.81	84.00	0.81
Riverine Forest	84.40	88.98	0.86	84.47	80.51	0.77	87.63	98.81	0.99
Water Body	42.49	86.54	0.86	24.09	76.92	0.76	65.63	76.92	0.77
Wooded Grassland	97.16	88.36	0.73	97.96	95.99	0.90	95.57	91.63	0.80
Burned Area	–	–	–	–	–	–	63.58	94.20	0.94
Overall Accuracy	88.93			93.03			91.57		
Kappa Coefficient	0.81			0.88			0.86		

Table 6
Areal coverage of LULC classes and changes in the study periods.

LULC Classes	1985		2005		2020		Area Change (ha)		
	Area (ha)	%	Area (ha)	%	Area (ha)	%	1985–2005	2005–2020	1985–2020
Bare land	7774	8.58	9189	10.15	4945	5.46	1415 (18.2)	−4244 (−46.2)	−2829 (−36.4)
Built-up Area	1360	1.5	1427	1.58	1827	2.02	67 (4.93)	359 (25.16)	426 (31.32)
Cropland	7079	7.82	8881	9.8	14420	15.92	1802 (25.45)	5539 (62.37)	7341 (103.7)
Riverine Forest	16914	18.68	13948	15.4	13133	14.5	−2966 (−17.53)	−815 (−5.84)	−3781 (−22.35)
Water Body	902	0.99	731	0.81	558	0.62	−171 (−18.96)	−173 (−23.66)	−344 (−38.14)
Wooded Grassland	56537	62.43	56390	62.26	54398	60.06	−147 (−0.26)	−1992 (−3.53)	−2139 (−3.78)
Burned Area	–	–	–	–	1285	1.42	–	–	–
Total	90566	100	90566	100	90566	100	–	–	–

Figures in the parenthesis refer to the percentage of change.

Fig. 4. Fire in Maze National Park (A: Land destructed by illegal fire, B: Illegal fire incidence)
Photo Courtesy of Aregahegn, Park officer,2021.

the LULC classes, riverine forest constituted the highest ESV, accounting for 94.31 %, 93.01 %, and 91.65 % of the total values in 1985, 2005, and 2020, respectively (Table 8). Regarding the overall ESV changes across the different intervals, there was a 16.39 %, 4.44 %, and 20.1 % decline from 1985 to 2005, 2005–2020, and 1985–2020, respectively. ESVs from croplands showed considerable positive change across the study years with increment of 25.44 %, 62.39 %, and 103.71 % from 1985 to 2005, 2005–2020, and from 1985 to 2020, respectively. Whereas, ESVs of the remaining LULC classes showed a negative change during the study periods (Table 8).

With regard to the values of individual ecosystem services such as food production, water supply, raw materials, climate regulation, and recreation and tourism, the major contributor was riverine forest constituting the highest ESVs in the study periods. However, despite having the highest ESVs, the values from riverine forests decreased overtime. ESVs only from croplands showed an increment, whereas values from other LULC classes were decreased at varying rates. Only food production service showed a positive change (0.7 million USD increase) from 1985 to 2020. The values of the remaining ecosystem services, e.g., recreation and tourism, water supply, and raw material provision services, experienced declines of 481.62 million USD, 180.35 million USD, and 45.72 million USD, respectively (Table 9). Compared to other LULC classes, the value coefficient and the resulting ESVs of the riverine forest were the largest in all study periods (Table 3, Table 8) making it the prime contributor for the values of all ecosystem services in the study area.

The sensitivity analysis result revealed that the coefficients of sensitivity for ESVs derived from LULC classes in all study periods were less than 1. The coefficient of sensitivity was highest for values from riverine forest (0.94, 0.93, and 0.92 in 1985, 2005, and 2020, respectively) due to their high value coefficient and large area coverage [52]. The estimated coefficient of sensitivity values ranged from a minimum of 0.01 for water bodies to a maximum of 0.94 for riverine forests when the value coefficients for these land cover types were adjusted by 50 % (Table 10). Overall, the sensitivity analysis indicated that the estimates for the study area were robust, despite uncertainties in the value coefficients.

3.3. Local community perception on the dynamics of ecosystem services

Approximately 83.7 % of the study participants had resided in the study area for more than 30 years (Appendix), providing them

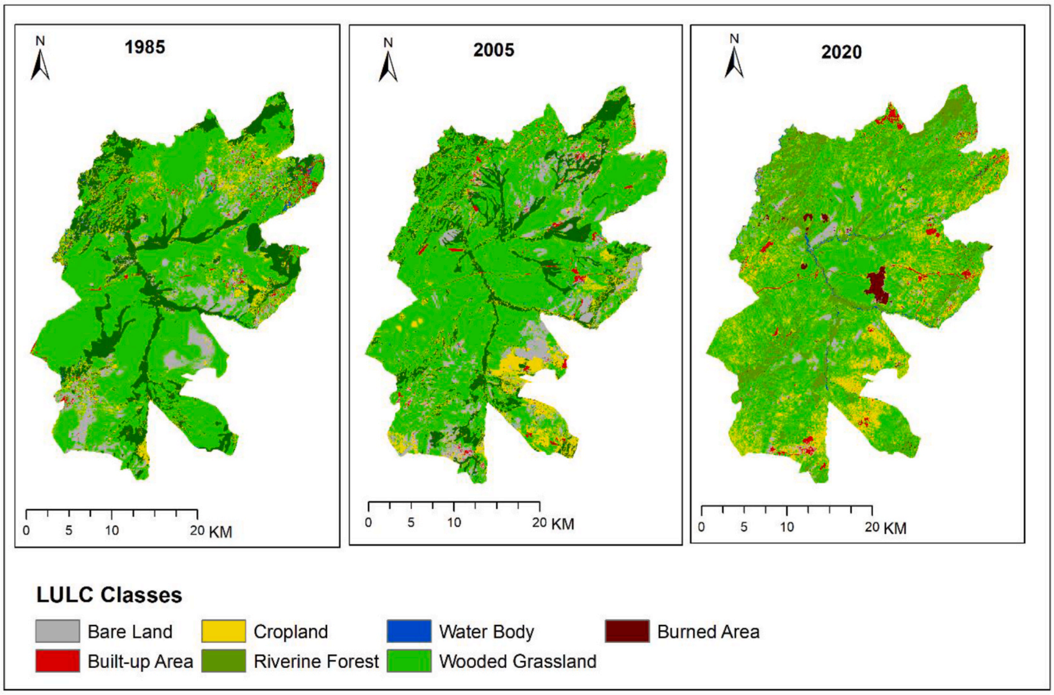

Fig. 5. LULC map of maze national park and its environs in 1985, 2005 and 2020.

Table 7
LULC transition matrix from 1985 to 2020 Change.

From LULC 1985 (%)	Change to LULC 2020 (%) LULC Classes	Bare land	Built-up Area	Cropland	Riverine Forest	Water Body	Wooded Grassland	Burned Area	Total 1985 (ha)	Loss (ha)
	Bare Land	**0.98**	0.18	1.83	0.08	0.01	5.24	0.26	7774	6888
	Built-up Area	0.14	**0.18**	0.35	0.05	0.00	0.76	0.02	1361	1195
	Cropland	0.35	0.05	**0.73**	1.86	0.05	4.75	0.04	7079	6423
	Riverine Forest	0.82	0.51	1.88	**7.51**	0.42	7.17	0.37	16915	10113
	Water Body	0.06	0.03	0.25	0.05	**0.02**	0.58	0.01	903	882
	Wooded Grassland	3.11	1.07	10.89	4.94	0.11	**41.58**	0.72	56537	18883
	Total 2020 (ha)	4946	1827	14420	13134	559	54398	1285	**46185.66**[a]	
	Gain(ha)	4060	1661	13763	6332	538	16744	1285		
	Net change (ha)[b]	−2828	466	7340	−3781	−344	−2139			

Diagonal figures in bold represent percentage of unchanged lands in the study periods.
[a] indicates the total area in hectare remained unchanged from 1985 to 2020.
[b] Net change = gain – loss.

with a deep understanding of the major ecosystem services they receive and how these services have changed over time. The vast majority of survey respondents confirmed that the park and its surrounding environment offer benefits to the local community. Cutting grasses and grazing, collecting firewood and charcoal, recreation, gathering wild food, and harvesting wild honey were among the main benefits mentioned by survey respondents. A significant proportion of respondents (88 %), stated that they have utilized grasses from MzNP for their livestock and for sale to meet household expenses. Additionally, nearly 74 % of the participants indicated that they have enjoyed the natural beauty of an area, including wild animals and forests, for recreation and relaxation. However, water for irrigation, and hunting were reported as the least utilized services, mentioned by less than 16 % of the respondents (Fig. 6).

Table 8
Ecosystem service values and changes from 1985 to 2020.

LULC Classes	ESV (US$ million)						ESV (US$ million) Change		
	1985		2005		2020		1985–2005	2005–2020	1985–2020
	Value	%	Value	%	Value	%			
Bare Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Built-up Area	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cropland	29.95	1.47	37.57	2.2	61.01	3.75	7.62 (25.44)	23.44 (62.39)	31.06 (103.71)
Riverine Forest	1922.39	94.31	1585.29	93.01	1492.66	91.65	−337.1 (−17.53)	−92.63 (−5.84)	−429.73 (−22.35)
Water Body	23.04	1.13	18.67	1.1	14.4	0.88	−4.37 (−18.97)	−4.27 (−22.87)	−8.64 (−37.5)
Wooded Grassland	63.04	3.09	62.87	3.69	60.65	3.72	−0.17 (−0.27)	−2.22 (−3.53)	−2.39 (−3.79)
Burned Area	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00
Total	2038.42	100	1704.4	100	1628.72	100	−334.02 (−16.39)	−75.68 (−4.44)	−409.7 (−20.1)

Figures in the parenthesis refer to the percentage of change.

4. Discussion

4.1. Land use land cover changes

The findings of this study revealed a significant expansion of croplands and built-up areas over the last 35 years (Table 6). Given that agriculture serves as the main means of subsistence for smallholder farmers in the study area [31], population increase and the growing demand for new farmlands and settlements are responsible for the expansion of croplands and built-up areas. Similar findings of increasing expansion of croplands and built-up areas were reported in different regions of the country [12,19,25,53]. On the other hand, riverine forest, water body, and wooded grassland showed a declining trend, albeit in varying proportions. The considerable decline of riverine forest and wooded grassland was primarily attributed to the expansion of croplands and built-up areas (Table 7) in the buffer zone and outside of the park. Several studies in Ethiopia e.g. Refs. [20,24–26] show a decreasing trend in woodland, grassland, and forest land due to the encroachment of croplands and settlements over vegetated areas.

In contrast, the findings of Zewde et al. [14] are partially inconsistent with our findings showing, a rapid increase in scattered trees and grassland cover in MzNP. The discrepancy can be attributed to the difference in the scope of the study area; our study included the park's neighboring *kebeles*, which are more severely impacted by anthropogenic activities than the protected area. This result reveals that naturally vegetated lands outside the park territory are more adversely affected by anthropogenic activities than the core protected area. In addition, the FGDs and KIIs confirmed the encroachment of illegal farming into buffer zones of the protected area, as well as the expansion of built-up areas in some adjacent *kebeles* through deforestation and the subsequent burning of grasses and shrubs. Similarly, Yadeta et al.'s [54]study revealed an increase in agricultural land in Chebera Churchura National Park's buffer zone, while grassland and wooded grassland showed a decline. The quality of services that communities derive from the ecosystems across the country has been altered as a result of the conversion of natural forests and grasslands to agricultural lands, affecting ecosystem structure and function [26]. Therefore, designing and implementing better ecosystem protection and restoration mechanisms inside and outside of protected areas is needed at both the local and national levels.

The establishment of national parks can significantly impact LULC changes by limiting human and domestic animals' access to the park region [54]. Prior to the establishment of MzNP (1985–2005), there was a notable increase in bare lands, primarily at the expense of wooded grassland (Table 6). This trend was driven by unrestricted access to resources, including overgrazing, thatching roofs, and cutting trees for firewood and building material. However, after the establishment of the park in 2005, this trend reversed, and from 2005 to 2020, the percentage of bare lands decreased (Table 6). This change can be attributed to the park's designation as a protected area, which restricted access to resources and allowed degraded fields to regenerate grasses and trees. Similarly [55], revealed that the designation of protected areas increases the naturalization of an area, thus providing beneficial effects on the surrounding environment. However [56,57], reported an expansion of bare lands in Baroiyadhala National Park, Bangladesh, and Awash National Park, Ethiopia, respectively, due to pronounced deforestation and degradation. The KIIs and FGDs noted the rehabilitation of the environment due to restricted access to the park. However, participants expressed concerns that their livelihoods have been negatively affected by these restrictions.

Fire is a natural and important disturbance in grasslands, but it can initiate changes in ecosystems that affect vegetation composition, structure, and patterns, as well as soil and water resources, which are critical to overall ecosystem functions and processes [58]. Fig. 4 and Table 6 show that the burned land in 2020 constituted 1.42 % of the entire study area. This indicates that, in addition to other factors, frequent fire contributed to reduction of wooded grasslands and riverine forests, resulting in the loss of ESVs. In line with this finding, Zewde et al. [14] identified two types of fires practiced in MzNP: controlled fire set by the park staff and illegal fire conducted twice a year by locals to induce the sprouting of new grass for grazing.

4.2. Ecosystem services value changes

In contrast to the improvement of ecosystem services in developed countries where cropland is converted in to forests [59], the majority of developing countries, including Ethiopia, are experiencing significant loss of ecosystem services [5,12,60]. In MzNP and its

Table 9
Individual ecosystem service values of LULC classes from 1985 to 2020.

Ecosystem Services	Land use land cover classes and ESVs of individual Ecosystem service in million USD															
	Cropland			Riverine Forest			Water Body			Wooded Grassland			Total ESV			Overall Change
	1985	2005	2020	1985	2005	2020	1985	2005	2020	1985	2005	2020	1985	2005	2020	1985–2020
FP	3.61	4.53	7.35	10.18	8.4	7.91	2.06	1.67	1.29	–	–	–	15.85	14.6	16.55	0.7
WS	4.28	5.36	8.71	809.66	667.68	628.66	8.3	6.72	5.19	17.7	17.65	17.03	839.94	697.41	659.59	−180.35
RM	0.04	0.05	0.09	198.55	163.74	154.17	0.08	0.07	0.05	36.01	35.92	34.65	234.68	199.78	188.96	−45.72
CR	0.07	0.09	0.14	11.13	9.18	8.64	0.23	0.18	0.14	4.13	4.12	3.97	15.56	13.57	12.89	−2.67
SS	–		–	–	–	–	0.07	0.06	0.04	–	–	–	0.07	0.06	0.04	−0.03
RT	21.95	27.54	44.72	892.87	736.3	693.28	12.3	9.97	7.69	5.2	5.19	5.01	932.32	779	750.7	−481.62
Total	29.95	37.57	61.01	1922.39	1585.3	1492.66	23.04	18.67	9.21	63.04	62.88	60.66	2038.42	1704.42	1628.73	−409.69

Where, FP =Food production, WS = Water supply, RM = Raw material, CR = Climate regulation, SS = Spiritual service, RT Recreation and tourism.

Table 10
Percentage change in the estimated total ecosystem service values and coefficients of sensitivity resulting from a 50 % adjustment in the ecosystem valuation coefficients.

LULC Classes	1985		2005		2020	
	CS	%	CS	%	CS	%
Bare Land VC±50 %	–		–	–	–	–
Built-up Area VC±50 %	–	–	–	–	–	–
Cropland VC±50 %	0.01	0.73	0.02	1.10	0.04	1.87
Riverine Forest VC±50 %	0.94	47.15	0.93	46.51	0.92	45.82
Water Body VC±50 %	0.01	0.57	0.01	0.55	0.01	0.44
Wooded Grassland VC±50 %	0.03	1.55	0.04	1.84	0.04	1.86

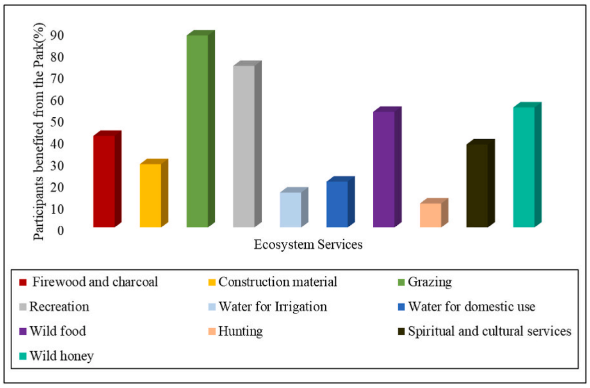

Fig. 6. Ecosystem services from maze national park.

surrounding districts, a considerable loss of ESVs was observed in response to LULC changes over the last 35 years, mostly due to reduction of riverine forests. The overall ESVs of the study area was found to be highly reduced (−409.7 million USD) from 1985 to 2020 (Table 8). This finding is consistent with other studies in Ethiopia, where dynamics of LULC over time have led to the loss of total as well as specific ESVs [12,19,21]. The primary cause for the loss of the overall ESVs was the reduction of ecosystem services obtained from the riverine forest, which constituted the largest share, more than 90 %, in all study periods (337.1 million USD from 1985 to 2005, 92.63 million USD from 2005 to 2020, and 429.73 million USD from 1985 to 2020 (Table 8). Additionally, the ESVs from wooded grassland decreased by 0.17, 2.22, and 2.39 million USD from 1985 to 2005, 2005 to 2020, and 1985 to 2020, respectively. Previous studies [20,21,25,53] have reported similar findings, where the decline of forests, woodlands, and grasslands contributed to the reduction of ESVs.

On the other hand, ESVs from croplands showed an increase of 7.62, 23.44, and 31.06 million USD from 1985 to 2005, 2005 to 2020, and 1985 to 2020, respectively (Table 8). This increase was mostly associated with the expansion of agricultural lands in the study area. The result is supported by previous studies in the central rift valley of Ethiopia [20] and the Bilate Alaba sub-watershed [25], which reported an increase in ESVs from farmlands, likely related to the expansion of agricultural lands.

The analysis of individual ESVs showed that the total value of food production increased between 1985 and 2020 by 0.7 million USD (Table 9), largely due to the expansion of croplands [4,21,23]. The values of the remaining ecosystem services, such as water supply, provision of raw materials, climate regulation, spiritual services, and recreation and tourism, consistently declined from 1985 to 2020, with an overall change of −180.35, −45.72, −2.67, −0.03, and −481.62 million USD, respectively (Table 9). The reduction of these individual ecosystem services was a consequence of LULC changes, particularly reduction of riverine forests and wooded grasslands. This trend is supported by previous studies conducted in different parts of the country [20,23,24]. Although agriculture is the mainstay of Ethiopian economy [61], expanding agricultural lands at the expense of natural vegetation leads to degradation of the ecosystem as a whole and loss of ESVs.

4.3. Sensitivity analysis

Previous studies have identified limitations in using LULC classes as proxies for estimating ESVs due to imperfect matches of LULC classes and the accuracy of the ecosystem value coefficients [43,47]. Despite these limitations, sensitivity analysis in several previous studies indicated that the estimation of ESVs was robust and reliable [4,62–64]. Furthermore, it has been demonstrated that this method is more reliable for the temporal assessment of ESV changes in response to LULC dynamics [64]. In Ethiopia, where ground data collection is expensive and there is a scarcity of historical data on land uses of rural areas, estimating ESVs using LULC classes and established value coefficient is very important. It provides alternatives and robust information for decision making processes at the landscape level, and similar works can be conducted in other parts of the country [12]. Therefore, despite uncertainties, the sensitivity analysis results of this study indicate that the estimated ESVs for the study area using LULC information and value coefficients were robust and reliable.

4.4. Local community perception on ecosystem services dynamics

The local community surrounding the park obtains a variety of ecosystem services, including food, water, grazing, grass cutting, firewood, charcoal, wild food, and wild honey (Fig. 6). Among these services, livestock grazing and grass cutting are the most important benefits for the local community. Therefore, the community in the vicinity refers to the park as "ፓርኩ ካዝናችን ወይም ጎተራችን ነዉ" meaning "The Park is Our Treasury or Granary" in time of drought and famine. The harvesting of grass is mainly permitted by the park administrators to support the poor during hard times. Thus, ecosystem services provided by riverine forests and wooded grasslands are the most important benefits in the study area that sustain the livelihood of the local population. The KIIs and FGDs also revealed that grasses in the park were not only used for the community's livestock but also sold in nearby regions to help people survive during times of drought. Despite the fact that grazing and grass cutting help the local poor in the vicinity, higher grazing intensity reduced vegetation cover [65], contributing to the loss of ecosystem services provided by the park's environment.

Other ecosystem services, such as hunting, access to water, and cutting trees for the building were the least used services (Fig. 6). This is attributed to limited access to the park and legal and cultural sanctions against illegal hunting and tree harvesting. Previous studies also confirmed that delineating a protected area was perceived by the local communities as a reason for losing access to resources [30,66]. Along with access restrictions, vegetation degradation [14] has contributed to the reduction of ecosystem services obtained by people from the park.

According to KIIs and FGDs, the establishment of the park benefitted the vicinity by moderating the local climate, regulating strong winds, and provision of grasses for their livestock. On the other hand, it was a major cause for losing access to resources such as firewood, charcoal, wild food, wild honey, construction material, and hunting of wild animals. Additionally, due to access restrictions to a river that crosses the park, some study *kebeles* are experiencing critical water scarcity for their cattle. In line with this [66,67], stated that rural poor people's livelihoods and well-being are more vulnerable with the establishment of protected areas, especially in developing nations, because their livelihoods are primarily dependent on agriculture and natural resources. As a result, MzNP is perceived by the local community as a reason for losing access to some resources that were previously available to them and as a means of obtaining benefits, either directly or indirectly, from the conservation efforts in the park. These indicate that although the establishment of protected areas has a positive effect on regulation, cultural, and some provisioning services [67], human and livestock activities contribute significantly to LULC changes [54] and the subsequent loss of ESVs.

5. Conclusion

This study assessed the impacts of LULC change on selected ecosystem services in MzNP and its surrounding districts from 1985 to 2020. The results indicate a loss of overall as well as individual ESVs in the study area in response to LULC changes. Among the LULC classes, croplands and built-up areas showed a rapid expansion by 103.7 % and 31.32 %, respectively, largely at the expense of riverine forests and wooded grasslands, while the remaining LULC classes exhibited a negative change. As a result, the overall value of selected ecosystem services declined by 20 % (409.7 million USD) from 1985 to 2020. Among individual ecosystem services, only food production service demonstrated an increase of 0.7 million USD, whereas the remaining ecosystem services, such as water supply (−180.35 million USD), climate regulation (−2.67 million USD), provision of raw materials (−45.72 million USD), and tourism and recreation (−481.62 million USD), decreased throughout the study period. Despite agriculture being the back bone of the country's economy and the wellbeing of its people, illegal encroachment of farmlands onto the natural vegetation and the resulting negative impacts on the ecosystem require proper attention.

Understanding the spatial and temporal patterns of LULC changes and the resulting impacts on ecosystem services can help decision-makers to design effective controlling mechanisms. The findings of this study can be applied to the conservation and sustainable management of natural resources, as well as to the management of protected areas in MzNP and its surrounding districts. The following recommendations are made for decision-makers and stakeholders for application in ecosystem protection and restoration to ensure the long-term sustainability of the region's natural resources.: (1) control illegal farmland and built-up areas expansion in the buffer zone (2) implement measures to control illegal fires, (3) reduce the heavy dependency of the local community on the park for grazing and grass cutting, (4) implement effective protected area management strategies, such as negotiating access route to water points for the community's cattle to minimize conflicts over water use. Finally, further studies are suggested to quantify the values of ecosystem services using satellite imageries with higher spatial resolution and employing different ecosystem services valuation methods (e.g., market price-based methods). This is because the benefit transfer method has limitations, including imperfect matches of LULC classes as proxies and uncertainty in the accuracy of the ESV coefficients.

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Data availability

The data used for this study will be made available from the corresponding author upon a reasonable request.

CRediT authorship contribution statement

Mestewat Simeon: Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Desalegn Wana:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Funding acquisition, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Socio-economic characteristics of survey participants

Socio-economic characteristics		Frequency	Percentage
Gender	Male	145	65.6
	Female	76	34.4
	Total	221	100
Age	20–40	74	33.48
	41–64	95	42.99
	>64	52	23.53
	Total	221	100
Marital status	Single	8	3.62
	Married	176	79.64
	Widowed	25	11.31
	Divorced	12	5.43
	Total	221	100
Family size	<4	38	17.2
	4–8	114	51.58
	9–12	60	27.15
	>12	9	4.07
	Total	221	100
Educational background	Cannot read and write	107	48.41
	Primary	91	41.18
	Highschool and above	23	10.41
	Total	221	100
Source of income	Crop production	17	7.7
	Livestock rearing	4	1.8
	Firewood and charcoal selling	2	0.9
	Other activities	6	2.7
	Crop production and animal rearing	165	74.7
	Crop production, animal rearing, selling firewood and charcoal, and other activities in combination	27	12.3
	Total	221	100
Duration of the residence (year)	<10	4	1.81
	10–20	5	2.26
	21–30	27	12.22
	>30	185	83.71
	Total	221	100

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