Biodiversity and Conservation (2023) 32:4007–4028
https://doi.org/10.1007/s10531-023-02680-1

ORIGINAL RESEARCH

Observed and projected changes in urbanization and nature conservation in a typical fast growing city of Ethiopia, Jimma

Abebayehu Aticho[1] · Abebe Beyene[2] · Shimelis Aynalem Zelelew[3] · Abebe Nigussie[1] · Tariku Mekonnen Gutema[1] · Vegar Bakkestuen[4] · Desalegn Chala[5,6,7]

Received: 24 June 2022 / Revised: 27 June 2023 / Accepted: 2 July 2023 / Published online: 17 July 2023

Abstract

Urbanization poses a significant threat to biodiversity, particularly in developing nations characterized by high rural–urban migration and inadequate urban planning that fails to consider nature conservation. Insufficient information on how to effectively integrate urban expansion and nature conservation exacerbates environmental problems and hampers mitigation efforts. In this study, we assessed the expansion of Jimma City, a typical rapidly growing city in Ethiopia, over the past 35 years, projected changes for the next 50 years, and identified priority areas for conservation. Landsat satellite images from 1985 and 2020 were utilized to map major land cover types and quantify temporal changes. We employed a Markov chain model to predict changes over the next 50 years and a GIS-based multi-criteria approach to identify conservation priority areas. Our findings underscore the adverse effect of urban expansion on natural habitats. Over the past three decades, built-up areas expanded by sevenfold (721%; 2227 ha) while croplands expanded by 34% (4155 ha). Conversely, natural habitats experienced significant declines: forest cover declined by 39% (5209 ha), grassland by 20% (655 ha) and wetland by 28% (638 ha). Projecting the current trend over the next 50 years showed built-up areas to further increase by about fourfold (436%, 3565 ha). However, open water, wetland, natural forest, and cropland are predicted to decline by 81% (120 ha), 40% (660 ha), 42% (3455 ha), and 55% (8848 ha), respectively. Given the current rate of population growth and rural–urban migrations, urban expansion appears inevitable. Our study emphasizes the importance of designating at least 9040 ha (28%) of the land within the city and its surroundings as high-priority areas for biodiversity conservation. These areas encompass approximately 95% of the remaining forest remnants, 78% of the wetland area, and 22% of the grassland. It is imperative for urban administrations in developing nations to adopt sound policies, strategies, and planning approaches that support the integration of urban development and nature conservation, with special attention given to the preservation of key biodiversity areas. Such efforts are crucial for fostering inclusive, safe, resilient, and sustainable cities.

Keywords Biodiversity conservation · Remote sensing · Urban expansion · Urban planning · Urban biodiversity · Urban ecosystem

Communicated by David Hawksworth.

Extended author information available on the last page of the article

Introduction

Urban expansion poses a significant threat to biodiversity, ecosystem, and has been identified as one of the primary drivers of environmental crises (Seto et al. 2012; Roy and Srivastava 2012; McKinney 2002). The unregulated and unplanned nature of urban expansion is very common in developing countries where it is resulting in substantial socio-economic and ecological challenges (McDonald et al. 2008; Seto et al. 2012; Eigenbrod et al. 2009, 2011; Güneralp et al. 2017) and these impacts are projected to persist in the coming decades (Linard et al. 2013). Historically, urban areas are characterized by high population densities, and relatively slower spatial expansion compared to population growth rates (Seto et al. 2010). However, the current reality is that urban expansion is occurring at an accelerated pace, outstripping population growth rates (Angel et al. 2011). This rapid urbanization, coupled with population growth, intensifies land cover changes and their associated problems (Bilsborrow and Okoth-Ogendo 1992; Lambin and Meyfroidt 2011; Meyer and Turner 1992). According to UN population projection, the global population is expected to reach 9.8 billion by 2050, with the highest growth in urban areas, particularly in developing countries. This implies the problem of urban land cover change is anticipated to continue unless crucial policy and conservation actions are taken (Grimm et al. 2008).

Expansion of urban boundaries into rural areas has profound impacts on hydrological systems, microclimate, natural habitats in general, and biodiversity in particular (Millennium Ecosystem Assessment 2005; Vitousek 1994). Urbanization affects nature (i.e., flora, fauna, landscapes, and other features or products of the earth) directly by transforming the habitat (e.g., habitat fragmentation, degradation, and loss) and indirectly by causing pollution and posing invasion by non-native species (Shanahan et al. 2014; Borges et al. 2020). The direct influence of urbanization on native habitats is expected to intensify in the future (McKinney 2006; Güneralp et al. 2017; Szulkin et al. 2020). Despite the significant impact of urbanization on natural habitats, there is a lack of comprehensive data and research on this topic, particularly in developing countries (McDonald et al. 2019). A few minor changes to urban natural habitat patches can result in high biodiversity loss, impacting genes, species, and entire ecosystems. This loss primarily occurs due to the vulnerability of biodiversity components to environmental changes (McDonald et al. 2019).

Due to the negative impacts of industrial and urban expansions on the environment, many developed nations have prioritized the preservation of critical biodiversity areas within urban settings (Borgström 2009). However, in contrast, most developing nations undergoing rapid urban expansion often neglect the integration of urban planning programs with nature conservation efforts (Lamson-Hall et al. 2019). Consequently, urban expansions in these developing nations occur at the expense of invaluable natural ecosystems that are essential for human and environmental well-being.

The design of cities that promote biodiversity is intricately connected to sustainable urban development and human well-being (Kowarik et al. 2020; Wang et al. 2020; Engemann et al. 2020). The integration of urban planning and nature conservation presents abundant opportunities to allocate land or sea spaces for the benefit of people, plants, and animals, thereby ensuring holistic and sustainable urban development (Kowarik et al. 2020). This integration enhances local biodiversity conservation, addresses climate change, plays a vital role in environmental education, provides ecosystem services, contributes to the well-being of both humans and ecosystems (Dearborn and Kark 2010). A meta-analysis of multiple cities worldwide reveals that the land area, vegetation cover, and age of cities significantly influence biodiversity (Beninde et al. 2015; Aronson et al. 2014), and this influence varies across different areas within cities (Sushinsky et al. 2013). This underscores the significance of identifying, mapping, and conserving biodiversity hotspot in urban settings, as it enables the maximization of ecological, social, and economic benefits (Humphries et al. 2008).

Recent advancements in geospatial technology have significantly enhanced our capacity to accurately identify, map, and monitor changes in natural habitats within urban areas (Skidmore et al. 2011). Applications of geospatial tools enhances our ecological understandings of these changes (Skidmore et al. 2011; Horning et al. 2010) facilitating the identification of priority conservation areas, enables species distribution modeling, and the monitoring of spatiotemporal changes, thereby facilitating the effective allocation of limited conservation resources (Groves et al. 2002). These tools allow for the incorporation of multiple criteria with varying degrees of importance to identify areas of conservation priority and make informed decisions (Sánchez de Dios et al. 2017; Adem Esmail and Geneletti 2018; Mendoza and Martins 2006). Multi-criteria analysis using Analytic Hierarchy Process (AHP) and Geographic Information System (GIS) tools are extensively employed in complex scenarios to streamline decision-making processes, including urban planning, and prioritizing areas for nature conservation.

A couple of studies on urban expansion in east African cities have examined the dynamics of land cover classes, quantified the extent of historical changes, and assessed the spatial patterns (Abrha et al. 2015; Abebe et al. 2019; Fufa et al. 2021; Dessu et al. 2020; Terfa et al. 2019; Lamson-Hall et al. 2019; Agegnehu et al. 2016; Kassa 2014). For example, in Jimma City, the built-up area reported to experience a 41% growth from 1997 to 2017 (Abebe et al. 2019), and 116% from 1984 to 2007 (Abrha et al. 2015). However, despite the land cover change analysis at different periods, limited knowledge exists regarding mitigating impacts on nature as well as on future land cover changes in terms of locations, magnitudes, and rates. In this paper, we present the observed and predicted impact of urban expansion on the natural environment in Jimma, a typical rapidly developing city in Ethiopia, where a number of wildlife species reside in small habitat remnants. We utilize a GIS-based multi-criteria approach to model and map high conservation priority, aiming to mitigate the impact of urban expansion on the natural environment..

Materials and methods

Study area description

Jimma City is situated in southwestern Ethiopia, approximately 350 km away from the capital city of Ethiopia, Addis Ababa (Fig. 1). Throughout its history, Jimma has served as a crucial trading hub in the southwestern region of Ethiopia (Seifu and Záhořík 2017). Over time, the city's boundary has expanded to incorporate surrounding rural areas due to both planned municipal urban growth and the emergence of informal settlements. It is situated at an elevation between 1700 and 1820 m above sea level. The region experiences a mean annual rainfall ranging from 1200 to 2400 mm (CSA 2007), and the average annual temperature ranges from 12 to 28 °C (Gemeda et al. 2020). In 2007, the total population of Jimma City was 120,960, and it is projected to exceed 300,000 by 2022 (CSA 2007).

The city harbours a rich diversity of flora and fauna (Mekonnen and Aticho 2011; Denu 2019). The wetlands in and around the city play a vital role as feeding, breeding, and roosting grounds for different bird species, including the Wattled Crane (*Bugeranus*

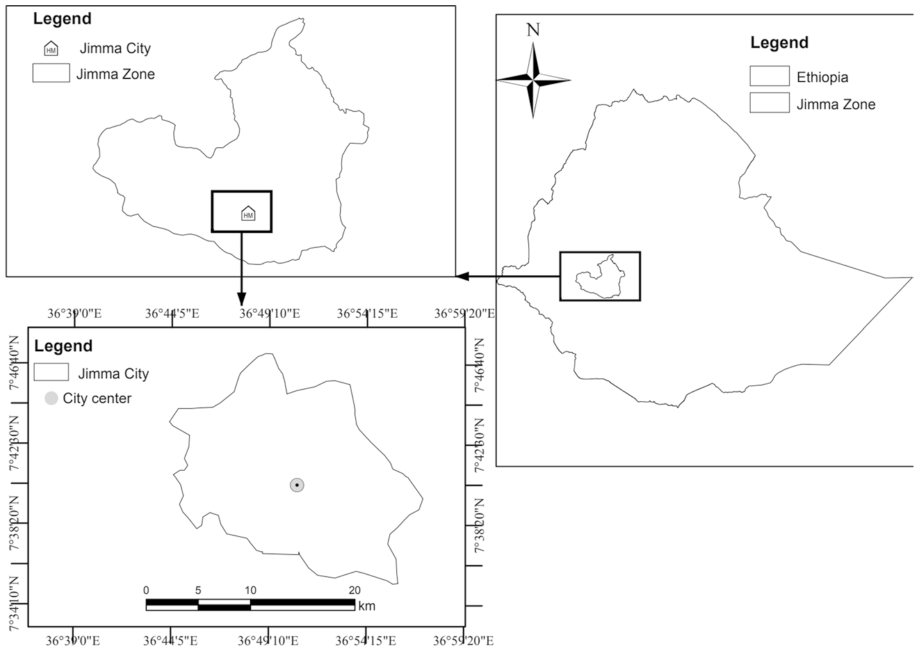

Fig. 1 Study area, Jimma City, located in Jimma Zone of Ethiopia

carunculatus), Black-crowned Crane (*Balearica pavonina*), Saddle-billed Stork (*Ephippiorhynchus senegalensis*), African Black Duck (*Anas sparsa*), and is designated as one of the 69 Important Bird Areas (IBA) in Ethiopia (Demissie et al. 1996). Additionally, the city is home to the common hippopotamus (*Hippopotamus amphibius*). The hilly areas surrounding the city is characterized by grassland, and natural or planted forest, serve as critical habitats for wildlife, contribute to microclimate stability, and help protect against erosion and landslides. These mountain forest patches provide a habitat for different wildlife species, including Duiker (*Sylvicapra grimmia*), Yellow-throated leaflove (*Atimastillas flavicollis*), Long-crested eagle (*Lophaetus occipitalis*), Spotted hyena (*Crocuta crocuta*), Vervet monkey (*Chlorocebus pygerythrus*), Mantled guereza (*Colobus guereza*), and Grivet monkey (*Chlorocebus aethiops*).

Data collection and analysis

Remote-sensing data description and pre-processing

In this study, the classification of the study area's land cover was carried out based on the researchers' experience, visual interpretation of satellite images, and existing literature. Six major land cover classes were identified and visually classified, including built-up areas, cultivated or farmland, water bodies, wetlands, grassland, and forest (Table 1). To validate the classification, field survey was conducted in February 2020 during which a total of 120 ground truth data points were collected, with 20 representing each land cover class. We used 70% of this data for image classification and the rest for validation. Cloud-free Landsat multi-spectral imagery of 1985 and 2020 were obtained from the United States

Table 1 Land cover classes or thematic resolution considered in the study

Cover class	Description
Built-up areas	Developed areas such as settlement or residential places, commercial, industrial, public institutions (e.g., schools, health centres), transportation facilities (e.g., road, airport, and bus stations) and market places
Cultivated lands	Land used for perennial and annual crop production, temporarily uncultivated
Water body	Land surfaces where water is accumulated on permanent basis
Wetlands	Land occupied with marshes, swamps, saturated with water on permanent or temporary basis
Grasslands	Land dominated with grass with/without scattered trees/shrubs
Forest areas	Land covered with natural or planted forest (i.e., tree community) and shrub lands

Geological Survey data server (Table 2). The selection of the acquisition time for the images was based on factors such as image quality and the influence of cloud cover.

After downloading the images, they underwent several preprocessing steps. First, the images were corrected for terrain variation. Then, the images were projected to the Universal Transverse Mercator (UTM) coordinate system. Next, radiometric calibration was performed on the images using TerrSet version 18.31. Radiometric calibration ensures that the pixel values in the images accurately represent the reflected or emitted radiation from the earth's surface. This step helps to improve the accuracy and consistency of the data.

Following the radiometric calibration, a composite raster was created using ArcGIS 10.2.2. The composite band is a combination of six selected bands from the original image, including the blue, green, red, and infrared bands (bands 2–7). This process created a single raster dataset that contained the desired information for the subsequent land cover classification activities. The composite band combines different spectral bands to enhance the visibility and discrimination of different land cover types.

Land cover classification, accuracy assessment and change detection

The maximum likelihood algorithm (MLA) was used to classify the land cover of the study area. This technique is one of the most widely used classification methods for classifying and mapping land cover classes (Mahdianpari et al. 2020).

Table 2 Information on the two multispectral landsat imagery used in the study, Landsat 5 and Landsat 8

Information	Landsat 5	Landsat 8
Sensor ID	TM—thematic mapper	OLI—operational land imager
Pass/Raw	169/055	169/055
Product type	L1T	L1T
Acquisition date	1985/01/09	2020/02/27
Spatial resolution	30 m × 30 m	30 m × 30 m
Quality	Cloud free	Cloud free

We used 70% of the ground truth data to train the algorithm for the entire land cover classification. We carried out the accuracy assessment with the remaining 30% ground truth data on a recent image (2020). A confusion matrix was produced to measure the quality and validity of the classified image. The matrix provides an insightful picture of which cover classes are being classified correctly and incorrectly based on an independent ground truth dataset. The four accuracy measures—overall accuracy, user accuracy, producer accuracy, and Kappa coefficient were computed (Eq. 1) following the standard procedures (Richards and Richards 1999; Congalton and Green 2019). The overall accuracy was calculated by dividing the correctly classified sample units by the total number of sample units in the matrix. Producer accuracy was obtained by dividing the correctly classified samples of a class by the total number of samples in that particular class. User accuracy was obtained by dividing the correctly classified samples of a class by the total number of samples mapped as that class. The Kappa coefficient (K) was used to verify agreement between reference (i.e., actual) and classified data (i.e., chance). Its value ranges from 0 to 1 (i.e., 0 shows no agreement between the classified and reference images; 1 or near 1 shows strong agreement between the classified and reference images).

$$\text{Kappa coefficient (K)} = \frac{\text{Observedaccuray} - \text{agreementbychance}}{1 - \text{agreementbychance}} \tag{1}$$

Land cover change detection analyses were carried out after getting the highest feasible image classification accuracy. The analysis was carried out using a post-classification change detection technique (Eq. 2) (Schulz et al. 2011).

$$\text{Change in land cover class (\%)} = \frac{\text{area in 2020} - \text{area in 1985}}{\text{area 1985}} \times 100$$

Land cover change prediction

In this study, land cover change predictions were carried out for the years 2045 and 2070 (Fig. 2) to explore the magnitude of urban expansion and propose timely counter-measures for sustainable nature conservation and urbanization. The projections were made using Markov Chain Analysis in the Land Cover Modular (LCM) toolset in the TerrSet software. The Markov Chain Analysis is a powerful tool for predicting land cover changes and is wildly applied for land cover predictions (Eastman 2003). It provides land cover transition probabilities between 0 and 1; where zero indicates a high likelihood for the land cover class to remain the same and 1 indicates the highest likelihood of a change.

In our model, we incorporated three variables: slope, elevation, and distances from roads. We are aware that slope and elevation have a significant impact on water flow, land use, economic activities, and various natural phenomena such as flood risk and land sliding. Additionally, variables related to infrastructure development, such as distance from roads, influence social and economic activities. These variables have been widely utilized in previous studies to predict landcover changes (Zhang et al. 2019; Wu et al. 2022; Fahad et al. 2021; Xu et al. 2022; de Noronha Vaz et al. 2012). Nevertheless, we did not make any assumptions regarding the influence of these variables on the prediction process. Instead, our model autonomously learns the direction and magnitude of the variables' contributions by analyzing the spatial distributions of the pixels that have transitioned into urban areas between 1985 and 2020.

Conservation site selection in an urban setting

Before selecting a specific site as a conservation priority, it is crucial to identify the factors that guide the decision-making process. In this study, we identified and analyzed all possible criteria (Table 3) associated with nature conservation using AHP and GIS tools (Fig. 2).

AHP is a multi-criteria decision-making process that helps decision-makers prioritize different criteria and make informed decisions (Saaty and Vargas 2001). This approach is widely used in selecting priority sites for conservation and ecotourism development (Humphries et al. 2008; Bunruamkaew and Murayam 2011). For this study, we conducted a literature review and analyzed local conditions to identify potential criteria for site prioritization. A team of experts from academia, conservation agencies, and urban planners then weighted and scored these criteria for further analysis. Participants ranked the main factors in order of importance using Saaty's fundamental scales (1990) to define priority (Table 4). Sub-factors within each main criterion were also weighted and scored on a scale of 1–5, with 1 indicating low priority and 5 indicating high priority for conservation (Table S1).

Considering the ranges of rare plant and animal species is essential for sustainable conservation planning and site prioritization, as focusing on a single biodiversity component is insufficient to protect the entire ecosystem (Bonn and Gaston 2005). Therefore, we considered both the ranges of threatened plant and animal species when selecting priority conservation areas (Tables S2, S3). The weight and score were used for pairwise comparison and suitability classification. A weighted overlay method was employed to develop a suitability map by overlaying different raster layers and assigning weights based on their importance (Saaty 1990). The pairwise comparison of individual criteria was calculated using Saaty's matrix formula (Eq. 3), where r_{ij} represents the degree of preference between sub-criteria r_i and r_j. If the criteria r_i (in the row) is more significant than criteria r_j (in the column), then r_{ij} sums (1, 2, 3, 4, 5, 6, 7, 8, 9). Conversely, $r_{ij} = 1/r_{ij}$ (Saaty 1996).

$$A = \left[r_{ij}\right] = \begin{bmatrix} 1 & r_{1i} \dots \dots & r_{1j} \\ \frac{1}{r_{1i}} & 1 \dots .. & r_{2j} \\ \vdots & \ddots & \vdots \\ \frac{1}{r_{1j}} & \frac{1}{r_{2j}} \cdots & 1 \end{bmatrix} \tag{2}$$

where A_{ij} are criteria or alternatives; $r_{ij} = 1/r_{ij}$ expresses the degree of preference between criteria r_i and r_j, Saaty's scale is used to express the intensity of the preference between the criteria

The sums of each column in the pairwise comparison matrix were normalized by dividing each cell value in the column by the sum of that column. We then calculated the weights by taking the average value of the entries in each row of the normalized matrix. Additionally, we examined trade-offs that contributed to inconsistency (Saaty and Vargas 2001). To assess the consistency of expert judgment, we computed the consistency index (CI) and consistency ratio (CR) using the following formula (Eq. 4).

$$CI = \frac{\gamma_{\max} - n}{n - 1}; CR = \frac{CI}{RI_n} \tag{3}$$

where n is the matrix size (i.e., the number of criteria or alternatives used), $\gamma_{\max}$ is the largest eigenvalue of Saaty's matrix, RI is the standard random index value obtained from

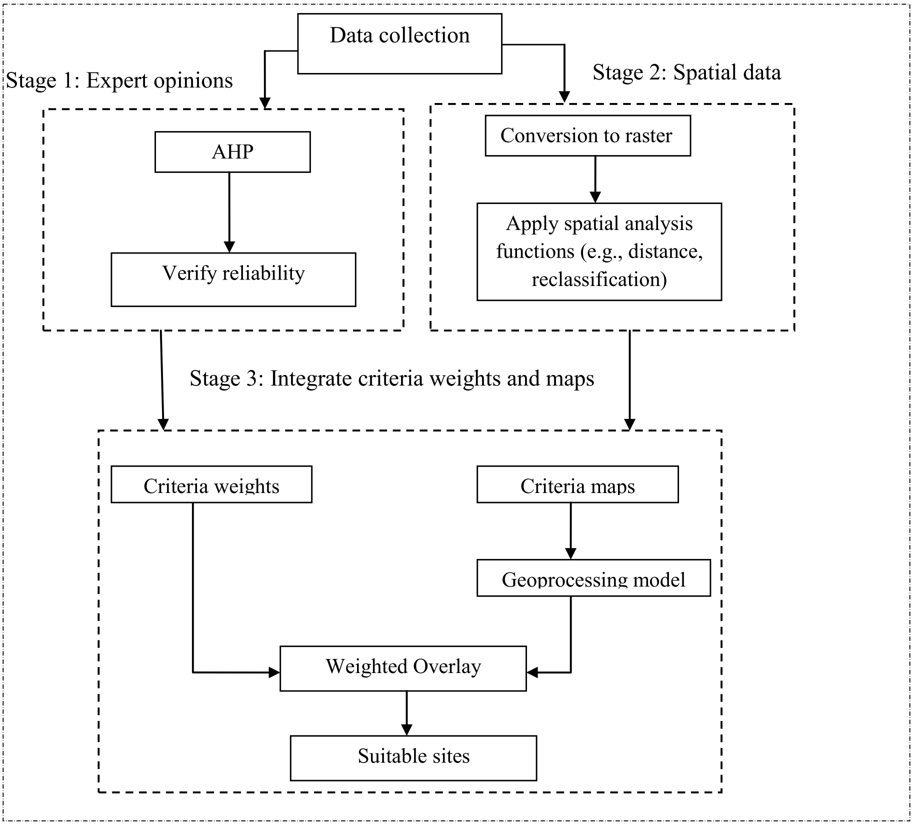

Fig. 2 A framework used for biodiversity conservation priority area mapping. *AHP* analytic hierarchy process

Saaty (1990). CR value ≤ 0.1 is acceptable, CR 0.1 indicates 10% of the expert judgment is inconsistent.

Finally, a conservation priority area map was generated by overlaying the eight input variables (Fig. S1). The weights of the criteria were calculated based on expert judgment following the principles of AHP. The GIS tool was then utilized to convert vector data and conduct spatial analysis. The variables along with their weights were overlaid to create a conservation priority location map for the study area.

Results

Land cover classification accuracy

The land cover classification accuracy of the 2020 image was computed, and all the accuracy measures for each cover class were found to be greater than 85% (Table 5). The overall accuracy was determined to be 87.3%. The Kappa statistic value was 0.92, demonstrating a very good agreement between the classified and true values. For all

Table 3 Spatial explanatory variables for conservation priority mapping and overall expert opinions (also see Fig. S1)

Variables	Descriptions	Expert opinions
Habitat types	Land cover classes of 2020	Intact and natural habitat types with higher priority
Wildlife species	Global conservation status of species based on the IUCN Red List	Landscapes comprising threatened species with higher priority
Land governance	Land ownership (e.g., forest land, wetland, grassland holding) information obtained by interviewing local community members	Government owned lands with higher priority
Slope	Average slope per grid cell in degrees derived from SRTM 90 m	Steeper slopes with higher priority
Distance to stream lines	Euclidian distance from river networks derived from SRTM 90 m	Areas closer to streamlines with higher priority
Distance to main roads	Euclidean distance from highways, and paved roads with one or more lanes derived from study are digital map	Areas closer to roads with less the priority
Distance to historical sites and different institutions	Euclidean distance from historical sites and institutions	Areas closer to historical sites and institutes with higher the need

Table 4 Saaty's scale and their corresponding verbal judgments (*source* Saaty 1990)

Scale	Definition	Explanation
1	Equal preferable	Two factors equally contribute
2	Weak	
3	Moderately preferable	One factor is slightly favours over another
4	Moderate plus	
5	Highly preferable	One factor is highly favours over another
6	Strong plus	
7	Very highly preferable	A factor is favoured very highly over another
8	Very highly plus	
9	Extreme preferable	Evidence favouring over others with highest possible order of proof
Inverse of 1–9	If factor 1, has assigned nonzero value as compared 2, then factor 2 inverse compared to 1	A reasonable assumption

land cover classes, the producer's accuracy exceeded 90%, indicating that the majority of collected validation points belong to the correct cover class. Additionally, the user's accuracy result was higher than 85% for all cover classes, indicating that the majority of the classified cover classes matched the observed classes in the field.

Land cover change in the past 35 years

Results of the maximum likelihood classification (MLA) showed remarkable land cover change over the past 35 years (Fig. 3a). The classified images revealed a transformation where large areas of natural habitats have been converted into built-up areas and croplands (Table 6). Specifically, Jimma City has experienced a remarkable increase of 721% in land area from 309 to 2535 ha over the past 35 years (Fig. 3b). The forest area coverage has decreased by 39%, declining from 13,488 to 8279 ha in overall. Similarly, the grassland and wetland habitat areas have witnessed a decline of 20% (3342 to 2687 ha) and 28% (from 2293 to 1655 ha) respectively.

Table 5 Accuracy assessment (%) different land cover types—carried out on the recent image, image from 2020

Land cover	Producers	Users	Overall	Kappa coefficient
Vegetation	91.3	87.2	87.3	92
Built-up	97.2	93.0		
Grassland	90.7	87.0		
Cultivated	90.5	86.1		
Wetland	92.0	85.1		
Water	96.04	89.30		

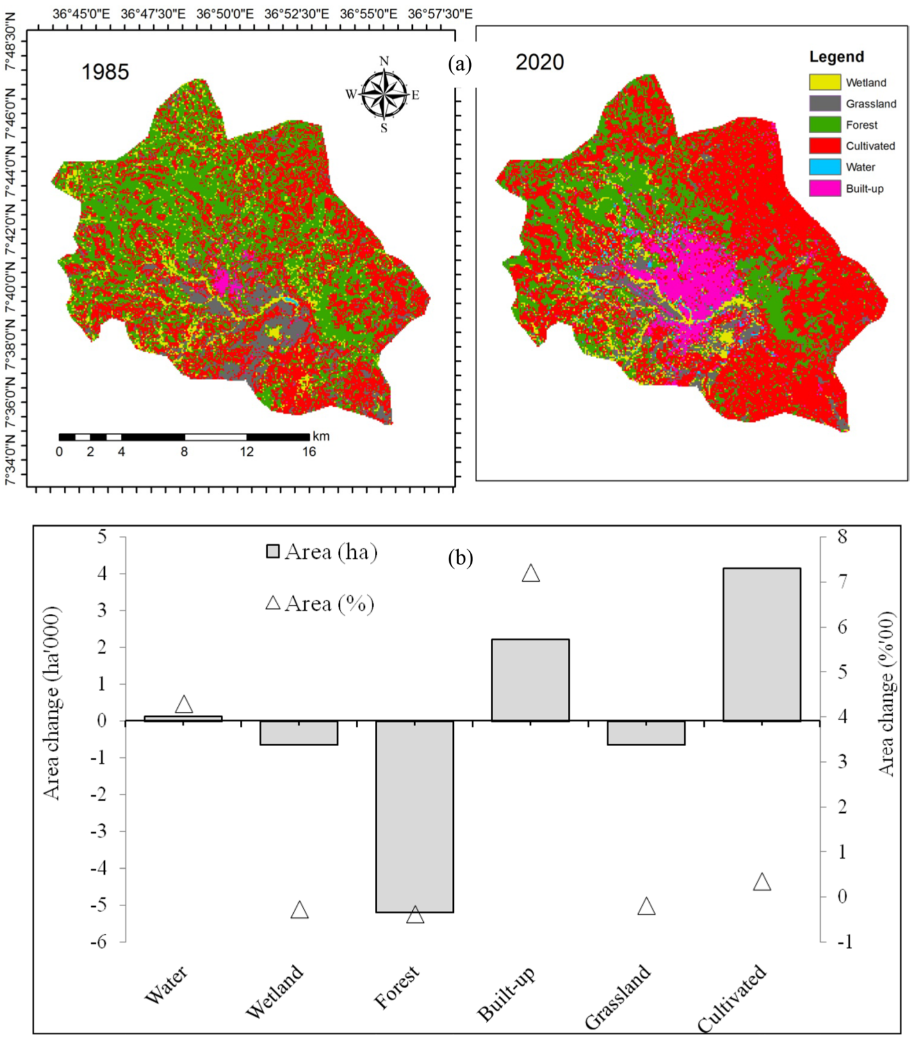

Fig. 3 Land cover maps of Jimma City. **a** Land cover map of 1985; **b** land cover map of 2020; and **c** spatial extent of land cover changes between 1985 and 2020

Land covers change predication

As shown in Fig. 4a, the conversion probability of each land cover class into another class varied in magnitude across the study area. Zero, medium, and high transition potentials were predicted in the urban built-up area, natural habitats, and cultivated land, respectively.

The Markov chain model output shows the land cover prediction of the year 2045 and 2070 by computing the land cover transition probability of each pixel (Fig. 4b, c). The predicted cover change maps indicate extensive urban expansion at the expense of other land cover classes in both projection times. Hence, the current urban built-up area of Jimma City is predicted to increase spatially by 262% (from 2535 to 9182 ha) between 2020 and

Table 6 Land cover change matrix between the two periods (1985 and 2020)

	Cover 2020 (ha)						Total (1985)[a]
	Built-up	Cropland	Forest	Grassland	Water	Wetland	
Cover 1985 (ha)							
Built-up	**214**	71	5	12	2	5	309
Cropland	859	**8608**	1306	793	54	449	12,069
Forest	811	5395	**6105**	594	0	583	13,488
Grassland	544	1381	166	**1024**	44	183	3342
Water	0.0	0.0	0.5	0.0	**0.1**	27	28
Wetland	108	769	696	264	48	**407**	2293
Total (2020)[b]	2535	16,225	8279	2687	148	1655	
Class change (ha)[c]	2321	16,153	8274	2675	146	1649	
Image difference (ha)[d]	2226	4155	4937	– 655	120	– 638	
Change (%)	721%	34%	37%	– 20%	426%	– 28%	

The bold diagonal values represent the area of each class that remains unchanged while the off diagonal values stand for the change in area

[a]Row total sums the amount of land cover for each class of the year 1985

[b]Column total sums the amount of land cover for each class of the year 2020

[c]Total area of a class changed to other class in 2020 for instance built-up—the total area of in 2020 minus area remains unchanged since 1985 (214 ha) equals to 2321 ha

[d]How class changed (i.e., positive value for increase, and negative value for decrease) for example built-up total area in 2020 minus total area in 1985 equals to 2229 ha which is increased

2045 and by 436% (from 2535 to 13,595 ha) between 2020 and 2070. The forecasted spatial urban expansion leads to a decline in open water bodies, wetlands, forestland, and cultivation areas. However, the rate of decrease varies among land cover classes and projection years. The open water area is expected to decline by 35% (from 148 to 96 ha) between 2020 and 2045, and by 62% (from 57 to 148 ha) between 2020 and 2070 (Fig. 4d). Similarly, wetland and forest loss remain significant challenges in the study area for the next 50 years. The expected decline in forestland between 2020 and 2045 is 17% (from 8279 to 6908 ha), and between 2020 and 2070 is projected to be 42% (from 8279 to 4823 ha) (Fig. 4d). The wetland area is also expected to decline, with a decline rate of 41% between 2020 and 2045 (from 1655 to 984 ha), and a decline rate of 40% between 2020 and 2070 (from 1655 to 994 ha).

Conservation priority sites in Jimma City settings

Our AHP-based analysis categorized approximately one-third (28%) of the total area in the city as having a high to very high priority for conservation. Additionally, around 11% of the area was classified as a moderate priority area for conservation (Fig. 5a, b). The high-priority categories consisted of approximately 95% forestland, 78% wetlands, 22% grasslands, and 5% open water bodies (Fig. 6). Furthermore, the moderately favourable group included approximately58% grasslands, 30% forestlands, and 10% croplands.

Among the identified high conservation priority areas, wetlands and water bodies serve as habitat for threatened wildlife species such as the Wattled Crane (*B. carunculatus*),

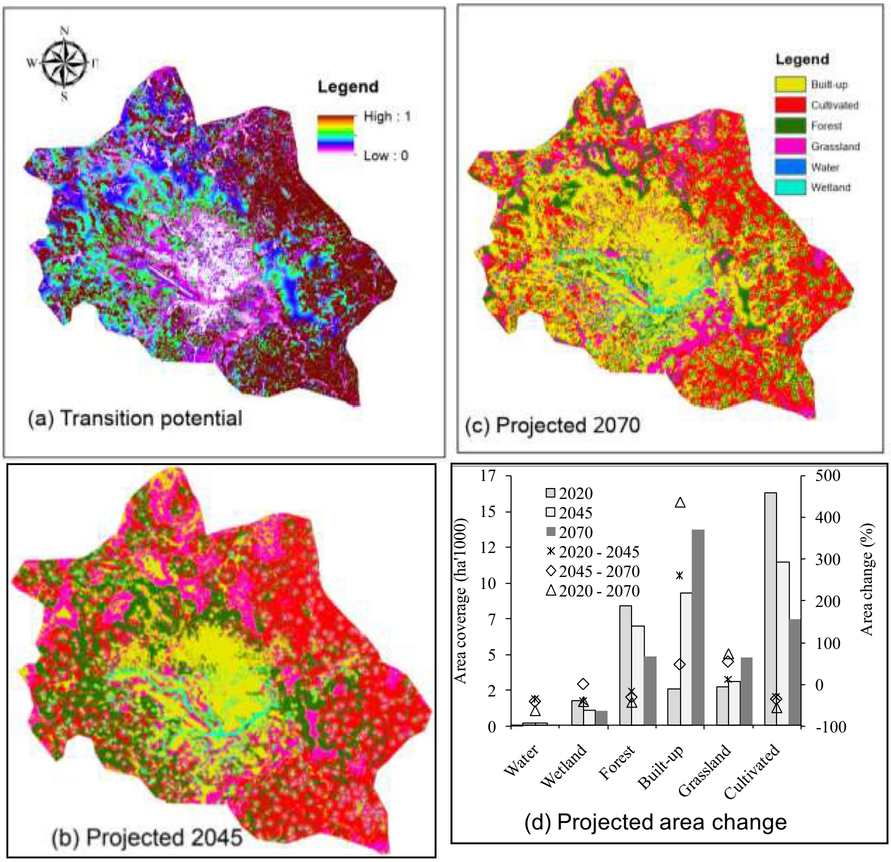

Fig. 4 Projection of current land cover to 2045 and 2070. **a** Transition probability of one land cover class into another class—0 indicates a high likelihood for the land cover class to remain the same and 1 shows a high probability of being converted to other landcover classes, **b** land cover projection to 2045, **c** land cover projection to 2070, **d** the extent of change in each land cover class at these two periods

Black-Crowned Crane (*B. pavonina*), and Hippopotamus (*H. amphibius*). Forest patches, on the other hand, provide shelter for wildlife species including the Common duiker (*S. grimmia*), Yellow-throated leaf love (*A. flavicollis*), Long-crested eagle (*L. occipitalis*), spotted hyenas (*C. crocuta*), Vervet monkey (*C. pygerythrus*), Abyssinian black-and-white colobus (*C. guereza*), and Grivet monkey (*C. aethiops*), as well as plant species such as *Prunes africana*, *Canthium oligocarpum* and *Bergama abyssinica*. The remaining approximately 60% of the categorized areas were considered as low to not priority areas for conservation, predominantly occupied by built-up and cultivated areas.

Discussion

The change detection result reveals significant land cover changes over a 35-years period in the vicinity of Jimma City. Urban sprawl has emerged as the dominant form of land cover change, surpassing other classes such as cropland. This rapid spatial expansion

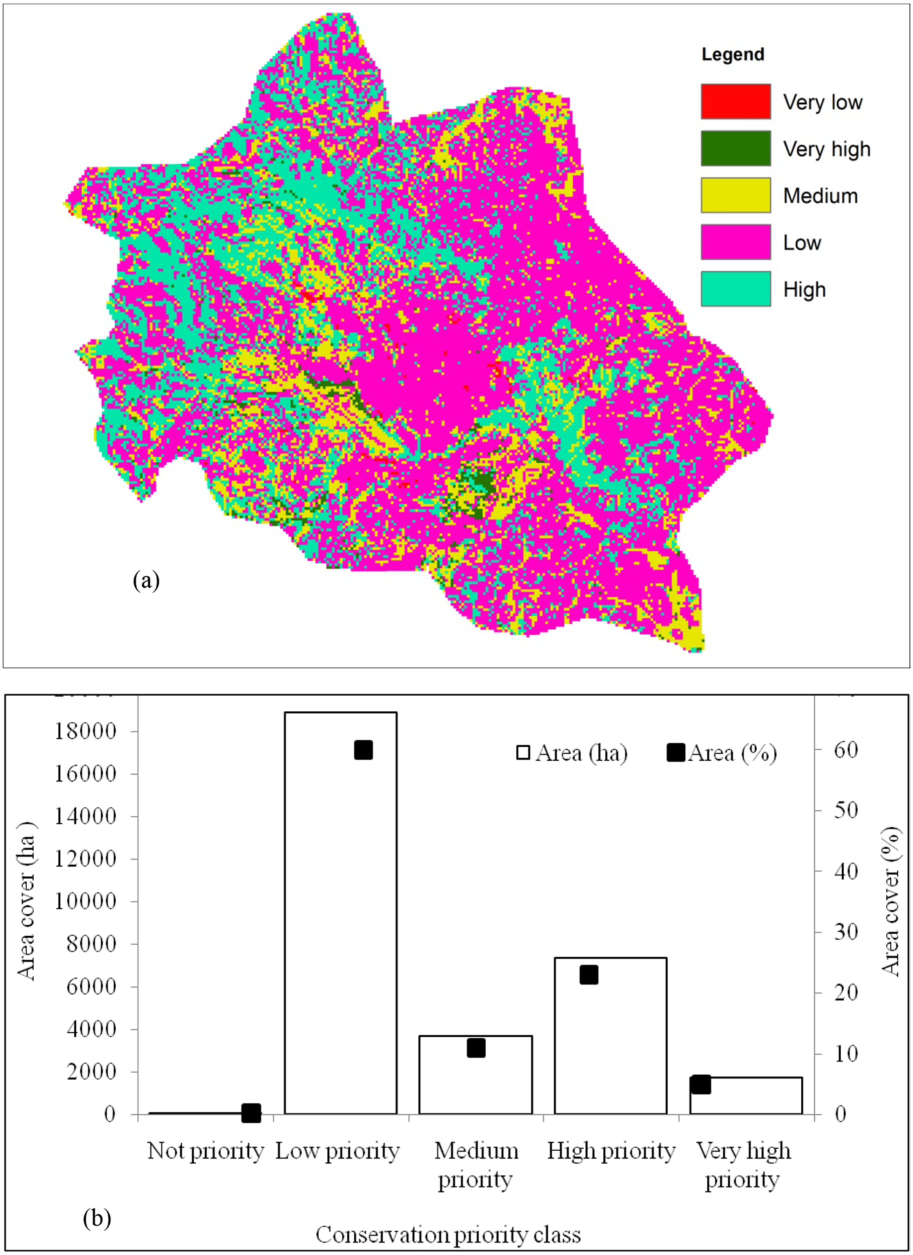

Fig. 5 Biodiversity conservation priority areas of Jimma City. **a** Showing the spatial distribution of each conservation priority classes and **b** showing the area coverage of each conservation priority class

of urban areas, both planned and unplanned, has resulted in the conversion of natural habitats, including forests, grasslands, and wetlands. Similar trends have been observed in other Ethiopian cities such as Addis Ababa, Ariba-Minch, Mekelle, and Bahir-Dar, as reported by previous studies (Abrha et al. 2015; Terfa et al. 2019; Lamson-Hall et al.

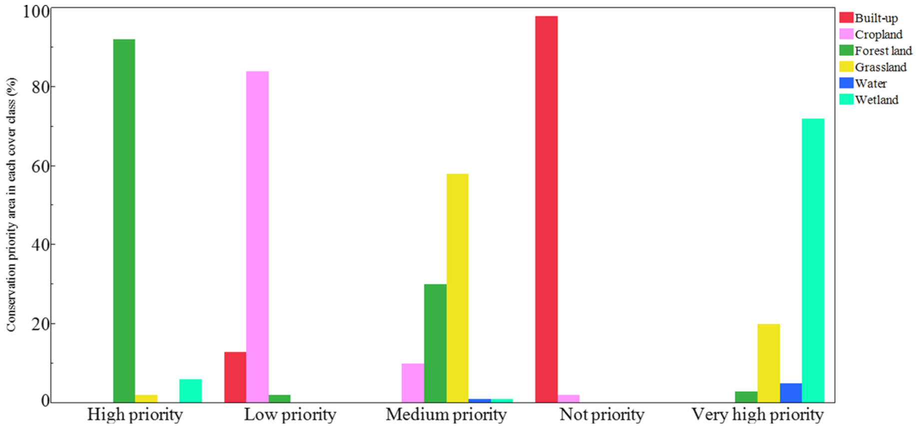

Fig. 6 The percentages of conservation priority areas of each land cover class

2019; Admasu et al. 2019; Fenta et al. 2017; Kassa 2013; Jenberu and Admasu 2020). Comparable findings have also been documented in cities across Burundi, Uganda, Malawi, Burkina Faso and other African countries (Seto et al. 2012; Schneider et al. 2015; Salem et al. 2020; Güneralp et al. 2017; Cohen 2006) and Asia (Xiao et al. 2006; Schneider et al. 2015; Cohen 2006).

Due to economic development and industrialization, rapid urbanization is being witnessed in African and Asian regions, and this trend is expected to continue in the coming decades (Cohen 2006). The driving force behind this urban expansion is the massive rural–urban migration (Gibson and Gurmu 2012; Clech et al. 2020; Atnafu et al. 2014) and the improvements in socioeconomic conditions in urban areas (UN 2015; Seto et al. 2012; Keller and Mukudi-Omwami 2017; Haregeweyn et al. 2012; Fenta et al. 2017). Ethiopia, compared with the sub-Saharan African countries, had the lowest urbanization rate, with approximately 11% of the population residing in urban areas (Schmidt and Kedir 2009). However, this situation has undergone a significant transformation, and currently, around 20% of the Ethiopian population lives in urban areas (AEO 2016; Gebre-Egziabher 2019) indicating a rapid pace of urban expansion.

Unplanned and spontaneous urban expansion into neighboring natural and rural areas can exert pressure on nature, biodiversity, and agricultural land and can result in socio-economic crises such as displacement and a shift from subsistence cultivation to other urban-based economic activities. Similarly, other studies have reported that unregulated urban expansion gives rise to multidimensional socio-ecological impacts (Elmqvist et al. 2013), including unfavorable environmental changes associated with habitat degradation and loss, decline in biodiversity, ecosystem dysfunction, and socio-economic crises such as food insecurity (Güneralp et al. 2017; Ahrends et al. 2010; Abernethy et al. 2016; Jantz et al. 2015).

Between 1985 and 2020, the built-up area of Jimma City expanded sevenfold, and it is projected to increase another fourfold in the next 50 years. A meta-analysis on global urban land expansion indicates that as the size of urban area increases, the annual urban expansion rate decreases (Seto et al. 2011). Similar studies have shown that urban area coverage in several African countries, including Egypt, Guinea, Kenya, Uganda, Rwanda, Burundi, Nigeria, and Ethiopia may rise by 590% in the coming decades (WPP 2011; Seto et al. 2012), which aligns with our current finding. By 2050, approximately 55% of the African population (Güneralp et al. 2017) and 40% of the Ethiopian population (Ritchie and Roser 2018) are expected to reside in urban areas. Furthermore, it is projected that by 2028, 30% of the Ethiopian population is projected to dwell in urban areas (AEO 2016) which is in line with our projection.

The anticipated expansion of Jimma City could exert pressure on limited natural resources, leading to a reduction in ecosystem services such as nutrient cycling, agricultural production, clean water, and air quality, as well as a decline in biodiversity conservation status. Our model projection showed that, approximately 42% of natural forest land, 40% of the wetland, 81% of the open water bodies, and 55% of cultivated lands in Jimma City and its surroundings are expected to further diminish in the next 50 years. This calls for careful urban planning to prevent environmental destruction, urban congestion, pollution, poverty, biodiversity loss, and deterioration of ecosystem services.

A recent study (Mohamed and Worku 2019) highlighted that the spatial expansion of urban areas can have detrimental effects on natural habitats and unique biodiversity and could lead to rural–urban conflicts. Globally, it is projected that approximately 30–44% of forest areas and 2–4% of wetland areas will be converted into urban built-up areas globally, particularly in developing nations (Chen et al. 2020). Furthermore, unregulated and unplanned urban expansion in developing countries has been associated with socio-economic and ecological problems (Linard et al. 2013), including biodiversity loss and the deterioration of ecosystem services (McDonald et al. 2008; Seto et al. 2012; Eigenbrod et al. 2009, 2011). To mitigate the impacts of unplanned urban expansion on the environment, economy, and society, it is crucial for urban planners and policymakers need to consider the preservation of remnant natural habitats, socio-economic improvements, and the promotion of shared prosperity.

Our study has identified conservation priority areas in Jimma City to mitigate the potential environmental, economic, and social challenges induced by projected urban expansion. The study area has been categorized into different conservation suitability classes, revealing that approximately 59.9% consists of non-priority areas such as built-up and agricultural land However, there are significant portions that require conservation attention, including 3668 hectares of priority grasslands, 7334 hectares of high-priority areas encompassing natural forest remnants and coffee forests, and 1706 hectares of very high-priority wetlands and river banks. This indicates that around 28% of the area (approximately 8890 hectares) within Jimma City holds a high priority for nature conservation.

By protecting these priority conservation areas, Jimma City can reap numerous benefits in terms of ecosystem services, recreational opportunities, educational value, socio-cultural significance, microclimate regulation and improved urban life quality. Additionally, conservation efforts can contribute to the preservation of threatened and endemic species, enhancing the overall biodiversity of the region. This approach holds great potential as a leading strategy in realizing an urban greening programs in Africa, mitigating urban environmental degradation, and aligning with Sustainable Development Goal (SDG) 11: building inclusive, safe, resilient, and sustainable cities and settlements. It is crucial to recognize that properly planned and managed areas within urban settings play a pivotal role in biodiversity preservation, the provision of ecosystem services, and socio-ecological well-being. Previous studies have emphasized the significance of integrating spatial urban expansion and conservation efforts with sound policy support. This integration is essential for achieving sustainable economic, social, and environmental development (Hansen et al. 2015). Furthermore, the importance of well-managed urban areas in preserving biodiversity and ecosystem services has been highlighted by researchers such as (Sandifer et al. 2015; Gómez-Baggethun et al. 2013; Aronson et al. 2014, 2017; Beninde et al. 2015; Ives et al. 2016).

Conclusion

Our study highlights the concerning trend of rapid expansion of built-up areas and croplands in Jimma City and its surrounding areas over the past three decades. This expansion has come at the expense of natural habitats and ecosystems. Unfortunately, our predictions indicate that this trend is likely to persist and even accelerate in the next 50 years, posing a significant threat to the remaining natural habitats, biodiversity, and vital ecosystem services. Identifying and delineating conservation priority areas to counterbalance the pressures imposed on nature and biodiversity becomes paramount. Assembling conservation priority areas as an integral part of an urban development program can allow proper allocation of limited conservation resources, address biodiversity conservation, promote sociocultural activities, and enhance urban life quality. Therefore, the fast-growing urban centers in Ethiopia, such as Jimma, should take advantage of protecting sensitive natural habitats around the city through integrating urban planning and nature conservation. By doing so, they can ensure the preservation of valuable ecosystems and their associated benefits, while also promoting sustainable development and a high quality of life for urban residents.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10531-023-02680-1.

Acknowledgements We would like to thank everyone who assisted us in weighing conservation priority area selection criteria. Further, we thank the anonymous reviewers for the insightful remarks, which contributed to the improvement of this paper. We also would like to thank Alemu Gonsamo for reviewing the text and offering valuable feedback.

Author contributions AA conceptualization, methodology, formal analysis; investigation; data creation, original draft preparation; visualization; funding acquisition; AB, SAZ and AN reviewing and editing, and final approval of the manuscript; TMG conceptualization, methodology, validation, reviewing and editing, and final approval of the manuscript; VB validation, reviewing and editing, and final approval of the manuscript; DC supervision, conceptualization, methodology, validation, reviewing and editing, and final approval of the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding The Rufford Foundation Small Grant Program (UK) provided financial support for field data collection.

Data availability Not applicable.

Declarations

Conflict of interest The authors declare no conflict of interest.

Ethical approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

References

Abebe MS, Derebew KT, Gemeda DO (2019) Exploiting temporal-spatial patterns of informal settlements using GIS and remote sensing technique: a case study of Jimma city, Southwestern Ethiopia. Environ Syst Res 8:1–11

Abernethy K, Maisels F, White LJ (2016) Environmental issues in central Africa. Annu Rev Environ Resour 41:1–33

Abrha C, Feyisa GL, Feyssa DH (2015) Analysis of land use/cover dynamics in Jimma city, Southwest Ethiopia. Ethiop J Appl Sci Technol 6:24–34

Adem Esmail B, Geneletti D (2018) Multi-criteria decision analysis for nature conservation: a review of 20 years of applications. Methods Ecol Evol 9:42–53

Admasu WF, Van Passel S, Minale AS, Tsegaye EA, Azadi H, Nyssen J (2019) Take out the farmer: an economic assessment of land expropriation for urban expansion in Bahir Dar, Northwest Ethiopia. Land Use Policy 87:104038

AEO (2016) Africa economic outlook: sustainable cities and structural transformation. African development bank, organization for economic cooperation and development. United Nations Development Programme Tunis.

Agegnehu SK, Fuchs H, Navratil G, Stokowski P, Vuolo F, Mansberger R (2016) Spatial urban expansion and land tenure security in Ethiopia: case studies from Bahir Dar and Debre Markos peri-urban areas. Soc Nat Resour 29:311–328

Ahrends A, Burgess ND, Milledge SA, Bulling MT, Fisher B, Smart JC, Clarke GP, Mhoro BE, Lewis SL (2010) Predictable waves of sequential forest degradation and biodiversity loss spreading from an African city. Proc Natl Acad Sci USA 107:14556–14561

Angel S, Parent J, Civco DL, Blei A, Potere D (2011) The dimensions of global urban expansion: estimates and projections for all countries, 2000–2050. Prog Plan 75:53–107

Aronson MF, La Sorte FA, Nilon CH, Katti M, Goddard MA, Lepczyk CA, Warren PS, Williams NS, Cilliers S, Clarkson B (2014) A global analysis of the impacts of urbanization on bird and plant diversity reveals key anthropogenic drivers. Proc R Soc B Biol Sci 281:20133330

Aronson MF, Lepczyk CA, Evans KL, Goddard MA, Lerman SB, Macivor JS, Nilon CH, Vargo T (2017) Biodiversity in the city: key challenges for urban green space management. Front Ecol Environ 15:189–196

Atnafu A, Oucho L, Zeitlyn B (2014) Poverty, youth and rural–urban migration in Ethiopia. Working Paper, University of Sussex, United Kingdom.

Beninde J, Veith M, Hochkirch A (2015) Biodiversity in cities needs space: a meta-analysis of factors determining intra-urban biodiversity variation. Ecol Lett 18:581–592

Bilsborrow RE, Okoth-Ogendo H (1992) Population-driven changes in land use in developing countries. Ambio Stockholm 21:37–45

Bonn A, Gaston KJ (2005) Capturing biodiversity: selecting priority areas for conservation using different criteria. Biodivers Conserv 14:1083–1100. https://doi.org/10.1007/s10531-004-8410-6

Borges PA, Gabriel R, Fattorini S (2020) Biodiversity erosion: causes and consequences. In: Leal Filho, W., Azul, A., Brandli, L., Özuyar, P., Wall, T. (eds) Life on Land. Encyclopedia of the UN Sustainable Development Goals. Springer, Cham. https://doi.org/10.1007/978-3-319-71065-5_78-1

Borgström ST (2009) Patterns and challenges of urban nature conservation—a study of southern Sweden. Environ Plan A 41:2671–2685

Bunruamkaew K, Murayam Y (2011) Site suitability evaluation for ecotourism using GIS & AHP: a case study of surat thani province, Thailand. Procedia-Soc Behav Sci 21:269–278. https://doi.org/10.1016/j.sbspro.2011.07.024

Chen G, Li X, Liu X, Chen Y, Liang X, Leng J, Xu X, Liao W, Wu Q, Huang K (2020) Global projections of future urban land expansion under shared socioeconomic pathways. Nat Commun 11:1–12

Clech L, Jones JH, Gibson M (2020) Inequality in the household and rural–urban migration in Ethiopian farmers. Evol Hum Sci 2:e9

Cohen B (2006) Urbanization in developing countries: current trends, future projections, and key challenges for sustainability. Technol Soc 28:63–80

Congalton RG, Green K (2019) Assessing the accuracy of remotely sensed data: principles and practices. CRC Press, Boca Raton

CSA (2007) National population and housing census of Ethiopia. Central Statistical Agency (CSA), Federal Democratic Republic of Ethiopia, Addis Ababa

De Noronha Vaz E, Nijkamp P, Painho M, Caetano M (2012) A multi-scenario forecast of urban change: a study on urban growth in the Algarve. Landsc Urban Plan 104:201–211

Dearborn DC, Kark S (2010) Motivations for conserving urban biodiversity. Conserv Biol 24:432–440

Demissie G, Tesfaye Y, Nume S (1996) Important bird areas of ethiopia a first inventory. Ethiopian Wildlife and Natural History Society, Addis Ababa.
Denu D (2019) Plant species richness and diversity in Beda-Buna Coffee Forest, Jimma Zone, Oromia Regional State, Southwest Ethiopia. Ethiop J Educ Sci 15:1–17
Dessu T, Korecha D, Hunde D, Worku A (2020) Long-term land use land cover change in urban centers of southwest Ethiopia from a climate change perspective. Front Clim 2:577169
Eastman JR (2003) IDRISI Kilimanjaro: guide to GIS and image processing. Clark Labs, Clark University, Worcester.
Eigenbrod F, Anderson BJ, Armsworth PR, Heinemeyer A, Jackson SF, Parnell M, Thomas CD, Gaston KJ (2009) Ecosystem service benefits of contrasting conservation strategies in a human-dominated region. Proc R Soc B Biol Sci 276:2903–2911
Eigenbrod F, Bell V, Davies H, Heinemeyer A, Armsworth PR, Gaston KJ (2011) The impact of projected increases in urbanization on ecosystem services. Proc R Soc B Biol Sci 278:3201–3208
Elmqvist T, Fragkias M, Goodness J, Güneralp B, Marcotullio PJ, Mcdonald RI, Parnell S, Schewenius M, Sendstad M, Seto KC (2013) Urbanization, biodiversity and ecosystem services: challenges and opportunities: a global assessment. Springer Nature, Dordrecht
Engemann K, Svenning J-C, Arge L, Brandt J, Erikstrup C, Geels C, Hertel O, Mortensen PB, Plana-Ripoll O, Tsirogiannis C (2020) Associations between growing up in natural environments and subsequent psychiatric disorders in Denmark. Environ Res 188:109788
Fahad S, Li W, Lashari AH, Islam A, Khattak LH, Rasool U (2021) Evaluation of land use and land cover spatio-temporal change during rapid Urban sprawl from Lahore, Pakistan. Urban Clim 39:100931
Fenta AA, Yasuda H, Haregeweyn N, Belay AS, Hadush Z, Gebremedhin MA, Mekonnen G (2017) The dynamics of urban expansion and land use/land cover changes using remote sensing and spatial metrics: the case of Mekelle City of northern Ethiopia. Int J Remote Sens 38:4107–4129
Fufa G, Abajihad M, Amsalu A, Garsem M, Fayisa G (2021) Urban expansion and vegetation cover change in and around Jimma town since 1990. J Environ Earth Sci 11:16
Gebre-Egziabher T (2019) Urbanization and industrial development in Ethiopia. In F. Cheru, C. Cramer, & A. Oqubay (Eds.), The oxford handbook of the Ethiopian Economy. Oxford University Press
Gemeda DO, Feyssa DH, Garedew W (2020) Meteorological data trend analysis and local community perception towards climate change: a case study of Jimma City, Southwestern Ethiopia. Environ Dev Sustain 23:5885–5903. https://doi.org/10.1007/s10668-020-00851-6
Gibson MA, Gurmu E (2012) Rural to urban migration is an unforeseen impact of development intervention in Ethiopia. PLoS ONE 7:e48708
Gómez-Baggethun E, Gren Å, Barton DN, Langemeyer J, Mcphearson T, O'Farrell P, Andersson E, Hamstead Z, Kremer P (2013) Urban ecosystem services. In: Urbanization, biodiversity and ecosystem services: challenges and opportunities. Springer, Dordrecht
Grimm NB, Faeth SH, Golubiewski NE, Redman CL, Wu J, Bai X, Briggs JM (2008) Global change and the ecology of cities. Science 319:756–760
Groves CR, Jensen DB, Valutis LL, Redford KH, Shaffer ML, Scott JM, Baumgartner JV, Higgins JV, Beck MW, Anderson MG (2002) Planning for biodiversity conservation: putting conservation science into practice: a seven-step framework for developing regional plans to conserve biological diversity, based upon principles of conservation biology and ecology, is being used extensively by the nature conservancy to identify priority areas for conservation. BioScience 52:499–512
Güneralp B, Lwasa S, Masundire H, Parnell S, Seto KC (2017) Urbanization in Africa: challenges and opportunities for conservation. Environ Res Lett 13:015002
Hansen R, Frantzeskaki N, McPhearson T, Rall E, Kabisch N, Kaczorowska A, Kain JH, Artmann M, Pauleit S (2015) The uptake of the ecosystem services concept in planning discourses of European and American cities. Ecosyst Services 12:228–246. https://doi.org/10.1016/j.ecoser.2014.11.013
Haregeweyn N, Fikadu G, Tsunekawa A, Tsubo M, Meshesha DT (2012) The dynamics of urban expansion and its impacts on land use/land cover change and small-scale farmers living near the urban fringe: a case study of Bahir Dar, Ethiopia. Landsc Urban Plan 106:149–157
Horning N, Robinson JA, Sterling EJ, Turner W, Spector S (2010) Remote sensing for ecology and conservation: a handbook of techniques. Oxford University Press, Oxford
Humphries HC, Bourgeron PS, Reynolds KM (2008) Suitability for conservation as a criterion in regional conservation network selection. Biodivers Conserv 17:467–492
Ives CD, Lentini PE, Threlfall CG, Ikin K, Shanahan DF, Garrard GE, Bekessy SA, Fuller RA, Mumaw L, Rayner L (2016) Cities are hotspots for threatened species. Glob Ecol Biogeogr 25:117–126
Jantz SM, Barker B, Brooks TM, Chini LP, Huang Q, Moore RM, Noel J, Hurtt GC (2015) Future habitat loss and extinctions driven by land-use change in biodiversity hotspots under four scenarios of climate-change mitigation. Conserv Biol 29:1122–1131

Jenberu AA, Admasu TG (2020) Urbanization and land use pattern in Arba Minch town, Ethiopia: driving forces and challenges. GeoJournal 85:761–778
Kassa F (2013) Conurbation and urban sprawl in Africa: the case of the city of Addis Ababa, Ghana. J Geogr 5:73–89
Kassa F (2014) The rates and effects of urban sprawl in developing countries: the case of Addis Ababa, Ethiopia. Regioninės Studijos 9:135–151
Keller EJ, Mukudi-Omwami E (2017) Rapid urban expansion and the challenge of pro-poor housing in Addis Ababa, Ethiopia. Afr Rev 9:173–185
Kowarik I, Fischer LK, Kendal D (2020) Biodiversity conservation and sustainable urban development. Multidisciplinary Sus 12(12): p 4964. https://doi.org/10.3390/su12124964
Lambin EF, Meyfroidt P (2011) Global land use change, economic globalization, and the looming land scarcity. Proc Natl Acad Sci USA 108:3465–3472
Lamson-Hall P, Angel S, Degroot D, Martin R, Tafesse T (2019) A new plan for African cities: the Ethiopia urban expansion initiative. Urban Stud 56:1234–1249
Linard C, Tatem AJ, Gilbert M (2013) Modelling spatial patterns of urban growth in africa. Appl Geogr 44:23–32
Mahdianpari M, Granger JE, Mohammadimanesh F, Salehi B, Brisco B, Homayouni S, Gill E, Huberty B, Lang M (2020) Meta-analysis of wetland classification using remote sensing: a systematic review of a 40-year trend in North America. Remote Sens 12:1882
McDonald RI, Kareiva P, Forman RT (2008) The implications of current and future urbanization for global protected areas and biodiversity conservation. Biol Conserv 141:1695–1703
McDonald RI, Mansur AV, Ascensão F, Crossman K, Elmqvist T, Gonzalez A, Güneralp B, Haase D, Hamann M, Hillel O (2019) Research gaps in knowledge of the impact of urban growth on biodiversity. Nat Sustain. https://doi.org/10.1038/s41893-019-0436-6
McKinney ML (2002) Urbanization, biodiversity, and conservation: the impacts of urbanization on native species are poorly studied, but educating a highly urbanized human population about these impacts can greatly improve species conservation in all ecosystems. BioScience 52:883–890
McKinney ML (2006) Urbanization as a major cause of biotic homogenization. Biol Conserv 127:247–260
Mekonnen T, Aticho A (2011) The driving forces of Boye wetland degradation and its bird species composition, Jimma, Southwestern Ethiopia. J Ecol Nat Environ 3:365–369
Mendoza GA, Martins H (2006) Multi-criteria decision analysis in natural resource management: a critical review of methods and new modelling paradigms. For Ecol Manag 230:1–22
Meyer WB, Turner BL (1992) Human population growth and global land-use/cover change. Annu Rev Ecol Syst 23:39–61
Millennium Ecosystem Assessment, M (2005) Ecosystems and human well-being. In: Synthesis
Mohamed A, Worku H (2019) Quantification of the land use/land cover dynamics and the degree of urban growth goodness for sustainable urban land use planning in Addis Ababa and the surrounding Oromia special zone. J Urban Manag 8:145–158
Richards JA, Richards J (1999) Remote sensing digital image analysis. Springer, Berlin
Ritchie H, Roser M (2018) Urbanization. In: Our world in data. https://ourworldindata.org/urbanization#note-4
Roy A, Srivastava V (2012) Geospatial approach to identification of potential hotspots of land-use and land-cover change for biodiversity conservation. Curr Sci 102:1174–1180
Saaty TL (1990) How to make a decision: the analytic hierarchy process. Eur J Ope Res 48(1):9–26
Salem M, Tsurusaki N, Divigalpitiya P (2020) Land use/land cover change detection and urban sprawl in the peri-urban area of greater Cairo since the Egyptian revolution of 2011. J Land Use Sci 15:592–606
Sánchez de Dios R, Cabal Ruano C, Domínguez Lozano F, Sainz Ollero H, Moreno Saiz JC (2017) The role of criteria in selecting important areas for conservation in biodiversity-rich territories. Divers Distrib 23:368–380
Sandifer PA, Sutton-Grier AE, Ward BP (2015) Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: opportunities to enhance health and biodiversity conservation. Ecosyst Serv 12:1–15
Saaty TL (1996) Decision making with dependence and feedback: the analytic network process (Vol. 4922, No. 2). RWS publications, Pittsburgh
Saaty TL, Vargas LG (2001) Models, methods, concepts & applications of the analytic hierarchy process. Springer Sci Bus Media 175:350
Schmidt E, Kedir M (2009) Urbanization and spatial connectivity in Ethiopia: urban growth analysis using GIS. Ethiopia Strategy Support Program (ESSP)-II Discussion (Vol. 5, p. 563). Island Press, Washington, DC

Schneider A, Mertes CM, Tatem A, Tan B, Sulla-Menashe D, Graves S, Patel N, Horton JA, Gaughan A, Rollo JT (2015) A new urban landscape in east-southeast Asia, 2000–2010. Environ Res Lett 10:034002
Schulz JJ, Cayuela L, Rey-Benayas JM, Schröder B (2011) Factors influencing vegetation cover change in Mediterranean Central Chile (1975–2008). Appl Veg Sci 14:571–582
Seifu Y, Záhořík J (2017) Jimma town: foundation and early growth from ca. 1830 to 1936. Ethnologia Actualis 17:46–63
Seto KC, Sánchez-Rodríguez R, Fragkias M (2010) The new geography of contemporary urbanization and the environment. Annu Rev Environ Resour 35:167–194
Seto KC, Fragkias M, Güneralp B, Reilly MK (2011) A meta-analysis of global urban land expansion. PLoS ONE 6:e23777
Seto KC, Güneralp B, Hutyra LR (2012) Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. Proc Natl Acad Sci USA 109:16083–16088
Shanahan DF, Strohbach MW, Warren PS, Fuller RA (2014) The challenges of urban living. In: Avian urban ecology. pp 3–20
Skidmore AK, Franklin J, Dawson TP, Pilesjö P (2011) Geospatial tools address emerging issues in spatial ecology: a review and commentary on the special issue. Int J Geogr Inf Sci 25:337–365
Sushinsky JR, Rhodes JR, Possingham HP, Gill TK, Fuller RA (2013) How should we grow cities to minimize their biodiversity impacts? Glob Change Biol 19:401–410
Szulkin M, Garroway CJ, Corsini M, Kotarba AZ, Dominoni D, Szulkin M (2020) How to quantify urbanization when testing for urban evolution. Urban Evol Biol 13–15
Terfa BK, Chen N, Liu D, Zhang X, Niyogi D (2019) Urban expansion in Ethiopia from 1987 to 2017: characteristics, spatial patterns, and driving forces. Sustainability 11:2973
UN (2015) World urbanization prospects: the 2014 revision. Population Division, United Nations Department of Economics and Social Affairs, New York
Vitousek PM (1994) Beyond global warming: ecology and global change. Ecology 75:1861–1876
Wang J, Zheng L, Liu H, Xu B, Zou Z (2020) The effects of habitat network construction and urban block unit structure on biodiversity in semiarid green spaces. Environ Monit Assess 192:1–23
WPP (2011) Department of Economic and Social Affairs. Population Division, 2011. World Population Prospects: The 2010 Revision-special Aggregates. UN
Wu R, Li Y, Wang S (2022) Will the construction of high-speed rail accelerate urban land expansion? Evidences from Chinese cities. Land Use Policy 114:105920
Xiao J, Shen Y, Ge J, Tateishi R, Tang C, Liang Y, Huang Z (2006) Evaluating urban expansion and land use change in Shijiazhuang, China, by using GIS and remote sensing. Landsc Urban Plan 75:69–80
Xu D, Zhang K, Cao L, Guan X, Zhang H (2022) Driving forces and prediction of urban land use change based on the geodetector and CA-Markov model: a case study of Zhengzhou, China. Int J Digit Earth 15:2246–2267
Zhang D, Liu X, Wu X, Yao Y, Wu X, Chen Y (2019) Multiple intra-urban land use simulations and driving factors analysis: a case study in Huicheng, China. Gisci Remote Sens 56:282–308

Authors and Affiliations

Abebayehu Aticho[1] · Abebe Beyene[2] · Shimelis Aynalem Zelelew[3] · Abebe Nigussie[1] · Tariku Mekonnen Gutema[1] · Vegar Bakkestuen[4] · Desalegn Chala[5,6,7]

✉ Abebayehu Aticho
j.aticho@yahoo.com

[1] Department of Natural Resource Management, College of Agriculture and Veterinary Medicine, Jimma University, P.O. Box 307, Jimma, Ethiopia

[2] Department of Environmental Health Science and Technology, Institute of Health Sciences, Jimma University, P.O. Box 378, Jimma, Ethiopia

[3] Department of Wildlife and Ecotourism Management, College of Agriculture and Environmental Sciences, Bahir Dar University, P. O. Box 79, Bahir Dar, Ethiopia

[4] Norwegian Institute for Nature Research, Gaustadalleen 21, 0349 Oslo, Norway

[5] Natural History Museum, University of Oslo, PO Box 1172, Blindern, 0318 Oslo, Norway

[6] Center for Biodiversity Dynamics in a Changing World (BIOCHANGE), Department of Biology, Aarhus University, Aarhus C, Denmark

[7] Section for Ecoinformatics and Biodiversity, Department of Biology, Aarhus University, Aarhus C, Denmark