



Land use/land cover change analysis using geospatial techniques: a case of Geba watershed, western Ethiopia

Mitiku Badasa Moisa¹ · Indale Niguse Dejene² · Lachisa Busha Hinkosa¹ · Dessalegn Obsi Gameda³

Received: 4 November 2021 / Accepted: 13 May 2022

Published online: 28 May 2022

© The Author(s) 2022 [OPEN](#)

Abstract

Land use/land cover change is a global environmental problem that significantly affects sustainable development and environmental quality. Anthropogenic activities are one of the main driving forces of land use/land cover change in developing countries like Ethiopia. This study is conducted in the Geba watershed in southwestern parts of Ethiopia. This study aimed to analyze the land use/land cover change over the past thirty years using geospatial technologies. The present study uses Landsat TM 1990, Landsat ETM + 2003, and OLI/TIRS 2020 to examine the land use/land cover change between 1990 and 2020. Land use/land cover classes are classified using a supervised classification method with the maximum likelihood technique. Results show that the agricultural land increased significantly, from 1786.6 km² (37.2%) in 1990 to 3163.2 km² (65.8%) in 2020, representing an increased rate of 45.9 km²/year. On the other hand, dense forest has declined from 2129.2 km² (44.3%) in 1990 to 1127.8 km² (23.5%) in 2020, which declines by the rate of 33.4 km²/year. Our findings suggest that sustainable land use planning and management are critically important in the study area.

Article Highlights

- Land use/land cover change is significantly modified over the past three decades in the study area.
- Geospatial technology is a key tool for Land use/land cover change analysis.
- Forest cover is substantial declined due to agricultural encroachment in the study area.

Keywords Forest cover change · Maximum likelihood · Spatio-temporal · Supervised classification

1 Introduction

Forest deterioration is one of the world's most serious environmental problem [1, 2]. Agriculture is putting more strain on forest resources to feed the world's rapidly growing population [3, 4]. The spread of cultivated land into forest land, timber and charcoal production, and wood harvesting are the main causes of deforestation

in developing countries [5]. Ethiopia, like other developing countries, experienced a rapid decline of forest cover due to agricultural encroachments, overgrazing, and settlements [6, 7]. For instance, forest cover of the country declined from 35% in early twentieth century to 2.4% in 1992 [8]. Recently, the government of Ethiopia is reporting the increasing trend of forest by implementing afforestation and re-afforestation programme. The declining of

✉ Mitiku Badasa Moisa, mitikubadasa10@gmail.com | ¹Department of Agricultural Engineering, Faculty of Technology, Wollega University, Shambu Campus, Shambu, Ethiopia. ²Department of Earth Sciences, College of Natural and Computational Sciences, Wollega University, Nekemte Campus, Nekemte, Ethiopia. ³Department of Natural Resource Management, College of Agriculture and Veterinary Medicine, Jimma University, Jimma, Ethiopia.



forest resources increased the removal of top soil through erosion which may result in agricultural yield reduction and exposed the agrarian communities to food insecurity.

Forests play a critical role in managing climate change by absorbing carbon dioxide and alleviating global climate change [4]. In spite of forest role in climate change mitigation, Ethiopia lost roughly 141,000 hectares of forest (1.1%) per year between 1995 and 2010 [9].

Mapping of land use/land cover (LULC) is helpful to assess the extent and rate of change over a given period of time [4, 5]. Monitoring of LULC change is critical important to understand what has been lost so far to design appropriate land use planning and management. For instance, forest cover change detection provides vital information for effective forest management [10]. Several studies have been conducted on LULC change analysis in different parts of the country [11–14]. The evolution of geospatial technology allows the users to collect spatial data and use it for analysis, modeling, simulation, and geo-visualization. This technology is very crucial to provide a baseline information for decision and policy makers. Geospatial technologies can acquire data, store, analyze and visualize spatial data in maps, graphs or tables. However, little is known about the status of LULC change in the southwestern parts of Ethiopia in general and the Geba watershed in particular. Thus, this research will provide a baseline information for LULC change monitoring in the study area. The high demand for more agricultural land led to forest encouragement and utilization of hilly areas that significantly affects the micro-climate and accelerate soil erosion which in turn to declines of agricultural yield [15]. Thus, it is good to analyze LULC change over the southwestern parts, which will be used as a baseline information for further studies and policy makers. The rest of the paper is organized as follows. Section 2 presents materials and methods; Sect. 3 present results and discussion and Sect. 4 concludes the paper with sort of recommendation.

2 Methods and materials

2.1 Description of the study area

Geba watershed is located in upper Baro river basin, which is located between 7° 53' 30" to 8° 44' 30" N and 35° 19' 30" to 36° 14' 30" E. Administratively, Geba watershed is found in Ilu Aba Bor Zone of Oromia National Regional State, in southwestern part of Ethiopia. The elevation of the study area ranges between 2582.5 m and 798.9 m above the mean sea level (Fig. 1). Geba watershed cover an area of 4805.3 km².

Based on Food and Agriculture Organization (FAO) soil data, there are seven types of soil in the Geba watershed

which includes calcic xerosols, dystric gleysols, dystric nitisols, eutric cambisols, leptosols, orthic acrisols, and orthic solonchaks. Among all soil types dystric nitisols is the most dominant soil types, which covers about 2380.1 km² followed by dystric gleysols (1185.6 km²) and eutric cambisols (1015.7 km²).

Broad leaf montane forest, wood land, cultivated land and water bodies are the major land use types in the study area. Rapid population growth, deforestation driven by agricultural expansion, forest exploitation for firewood, house construction and furniture's are the major problems that affects the LULC change in southwestern parts of Ethiopia [16]. The climate of the study area is largely characterized by tropical highland humid zones and received unimodal rainfall brought by wind from Indian and Atlantic Ocean with maximum rainfall during summer season (June to August) [17, 18].

The rain-fed agriculture is the major form of crop cultivation in the study area. Teff, maize, sorghum, barley, millet, sesame, groundnut, coffee, hose bean, and pea are the major known crops cultivated in the study area. Similarly, fruit and vegetables such as mango, papaya, citrus, onion, potato, garlic, and carrot cabbage are some of the major cash incomes for the rural household in the study area.

2.2 Data sources

2.2.1 Remote sensing data acquisition and processing

Landsat images from 1990, 2003, and 2020 were utilized to analyze the spatiotemporal LULC change in the Geba watershed. ERDAS Imagine 2015 software is used to process the Landsat images. The study area LULC types were classified over three years (1990, 2003, and 2020) using a supervised classification method with a maximum likelihood algorithm [19, 20] to accomplish spatiotemporal LULC changes. For LULC classification, Landsat TM 1990, Landsat ETM+ 2003, and Landsat OLI/TIRS 2020 were utilized (Table 1; Fig. 2). We use the Landsat images in the month of January to avoid the impact of cloud cover on image quality. Moreover, we perform image pre-processing techniques.

The year 1990 is considered the starting point for LULC analysis due to its historical moment in the Ethiopian government structure. It was the last year of the Darge regime in the country. The year 2003 was chosen because of the mass resettlement programme by the Ethiopian government in response to drought. Finally, the year 2020 was chosen to assess changes in forest cover over the last three decades. In the present study, 20 training areas were taken from dense forest, open forest, agricultural land, and water body, while 30 were taken from settlement land cover class.

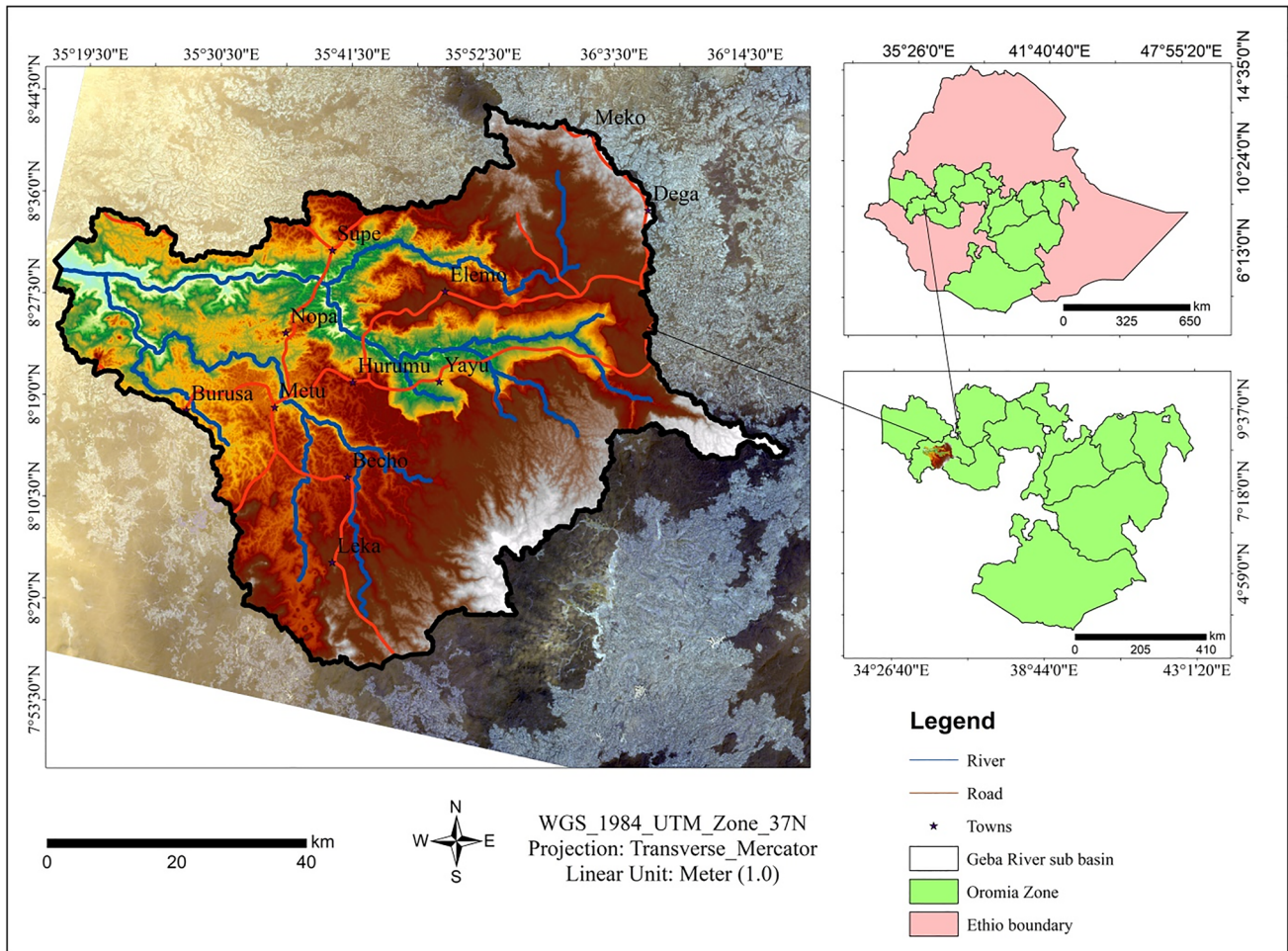


Fig. 1 Location of the study area: Geba watershed-Geba River Sub-basin

Table 1 Remote sensing data used in the study

Date of acquisition	Sensor	Path/row	Multispectral band	Spatial resolution	Source
1/20/1990	TM	170/054	1 to 5 and 7	30*30	USGS
1/15/2003	ETM+	170/054	1 to 5 and 7	30*30	
1/20/2020	OLI/TIRS	170/054	1 to 5 and 9	30*30	

2.2.2 Land use land cover analysis

We classified the LULC of the study area into five major classes such as dense forest, open forest, agricultural land, settlement, and water body based on their dominance (Table 2).

2.3 Classification accuracy assessment

The overall accuracy index [21] is calculated by dividing all properly identified pixels by the total number of pixels in the matrix (Eq. 1). The kappa coefficient measures

the degree of agreement between two maps when all elements of the error matrix are taken into account (Eq. 2).

$$\text{Overall accuracy} = \frac{\text{Sum of the diagonal elements}}{\text{Total number of accuracy sites (pixels)}} \times 100 \tag{1}$$

$$\text{Kappa} = \frac{\text{Obs} - \text{exp}}{1 - \text{exp}} \tag{2}$$

where: Obs is it represents accuracy reported in error matrix (overall accuracy) and Exp is it represents correct classification.

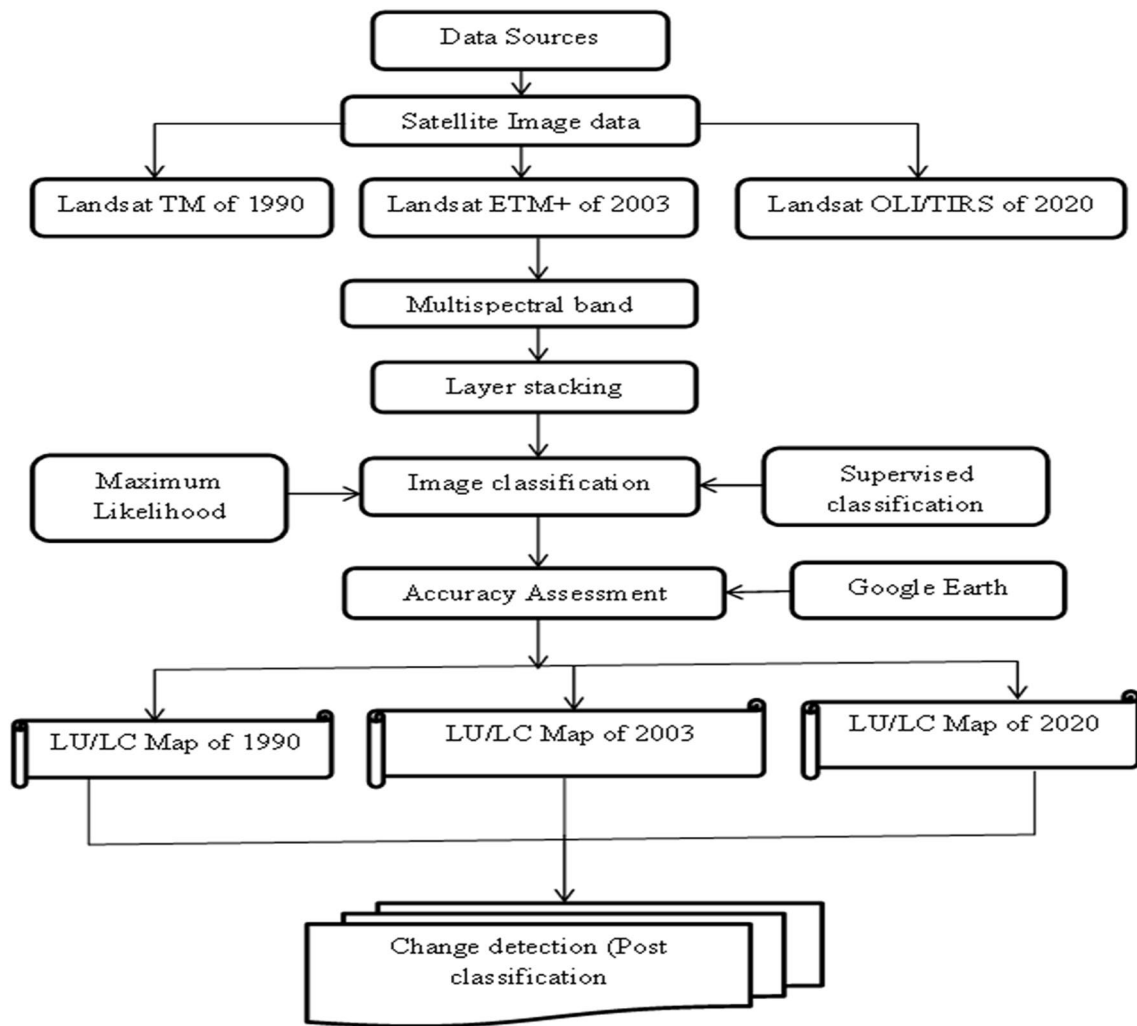


Fig. 2 Methodological flowchart for the determination of LULC change

Table 2 Descriptions of LULC classes used in the study area

LU/LC classes	Description
Agricultural land	Areas used for cultivation, both annuals and perennials and areas used for grazing including partially wet lands
Open forest	Areas covered collected predominantly of redevelopment forest from the previous disruption
Settlement	Areas allotted for permanent residential, commercial areas, institution and infrastructures
Dense forest	The area which are covered by dense forest
Water body	Areas covered with mainly water reservoirs and rivers

2.4 Spatio-temporal land use land cover change detection

The amount of changed area and extent of change should be examined to identify the magnitudes of

change in terms of forest cover change [22]. Furthermore, the percent of change and rate of change were computed (Eq. 3) to show the magnitude of the changes between two periods [4, 23–25].

$$\text{Rate of change} \left(\frac{\text{km}^2}{\text{year}} \right) = \frac{A_2 - A_1}{Z} \quad (3)$$

where A_2 is an area of LULC (km^2) in time 2, A_1 is an area of LULC (km^2) in time 1; Z is Time Interval between A_2 and A_1 in years.

The technique of post-classification was used to detect LULC change [26]. The LULC change matrix was created to show the overall LULC change between 1990 and 2020.

3 Results and discussions

3.1 Analysis of land use land cover change (1990 to 2020)

Landsat imagery of thematic mapper 1990, enhanced thematic mapper plus 2003, and operational land imager 2020 were utilized to analyze the spatiotemporal LULC changes. The study area LULC is classified into five categories: agricultural lands, dense forest, open forest, settlement, and water body. The dense forest cover in the study area is substantial declined during the study period. Due to the increase of agricultural land, the area of dense and sparse forests has reduced. From 1990 to 2020, agricultural land and settlement land cover classes increased, while dense forest, open forest, and water bodies decreased. The LULC conversion, such as dense forest, open forest, and water bodies being converted to agricultural land and settlements, at Geba watershed [15]. Because of rapid population growth, people are forced to convert dense and open forest to agricultural land.

The forest cover has diminished in most parts of Ethiopia due to human activities [27]. Numerous research have confirmed the declining of forest cover in Ethiopia [11–14, 28, 4] claimed that in the Komto forest protected area. Human activities reduced the forest cover of the Geba watershed, owing to agricultural expansion into forest land, the manufacturing of charcoal, the collection of firewood, and the spread of human habitation into the forest, which resulted in the construction of shelter from forest products. Other LULC types, such as agricultural land and settlements, have increased in the study area, while dense and open forest have decreased (Fig. 3).

The dense forest dominated the Geba watershed in 1990, covering 2129.2 km^2 (44.3%), while agricultural land, open forest, water bodies, and settlement covered 1786.6 km^2 (37.2%), 841 km^2 (17.5%), 41.8 km^2 (0.9%) and 6.5 km^2 (0.1%), respectively. This result is similar with [4] findings in the Komto forest protected area, which show a loss in forest cover over the last three decades. The areas of agricultural land and settlement had expanded by 6.6 km^2 (41.8%) and 16.1 km^2 (0.3%) by the year 2003, respectively.

The coverage of dense forest, open forest and water bodies was reduced by 41.9%, 750.5 km^2 (15.6%) and 20.5 km^2 (0.4%), respectively. This result is consistent with [3]. Similarly, in 2020, the area of dense forest and open forest was reduced by 1127.8 km^2 (23.5%) and 457.2 km^2 (9.5%), respectively, while the covering of agricultural land and settlement was increased by 3163.2 km^2 (65.8%) and 37.3 km^2 (0.8%). We discovered that agricultural land is highly increased at the expense of dense forest and open forest, as well as other LULC, over the last three decades in the study area, based LULC change assessment (Table 3).

With kappa values of 0.86, 0.82, and 0.85, the total classification accuracies for the study periods of 1990, 2003, and 2020 were 86.3%, 84.8%, and 87.6%, respectively. A kappa score of larger than ($>$) 0.80 (80%) indicates a significant agreement, while a value of between 0.60 (60%) and 0.80 (80%) indicates a substantial agreement [29].

3.2 Rate of land use land cover change

From 1990 to 2020, the density of dense forest, open forest, and water bodies dropped at rates of 33.4 km^2/year , 12.8 km^2/year , and 0.7 km^2/year , respectively. Since the economy of the study area is depend on agriculture, there is overexploitation of dense and open forests for agricultural production to feed the rapid population growth. Thus, the rapid population growth is one of the main driving forces for the declining of forest resources that negatively affect the forest ecosystems. Over the last 30 years, agricultural land and settlement have grown at rates of 45.9 km^2/year and 1 km^2/year , respectively (Fig. 4). According to our findings, forest cover in the Geba watershed has been quickly declining, which is consistent with earlier research [4, 13, 14, 30]. Similar to forest resources, waterbodies are also experienced a declining trend. In the last 30 years, almost 50% of water bodies has lost due to environmental modification and unwise use of water bodies. The use of irrigation technologies also contributes for the declining of water bodies in developing countries. The declining of rainfall due to loss of vegetation and the increasing of temperature which lead to evapotranspiration may contributes for the loss of water bodies over the study period. The declining of water resources may affect the agricultural yield and set back economic development of a nation [31, 32].

The dense forest and open forest are declined by 1001.4 km^2 and 383.8 km^2 from 1990 to 2020, respectively. The rapid loss of foresee ecosystems requires sound polices to sustain the existence of forest in agriculturally based economy. On the other hand, agricultural land and settlement land cover classes are increased by 1376.7 km^2 and 30.8 km^2 , respectively over study period (Fig. 5). The agricultural and settlement land cover classes are increasing on

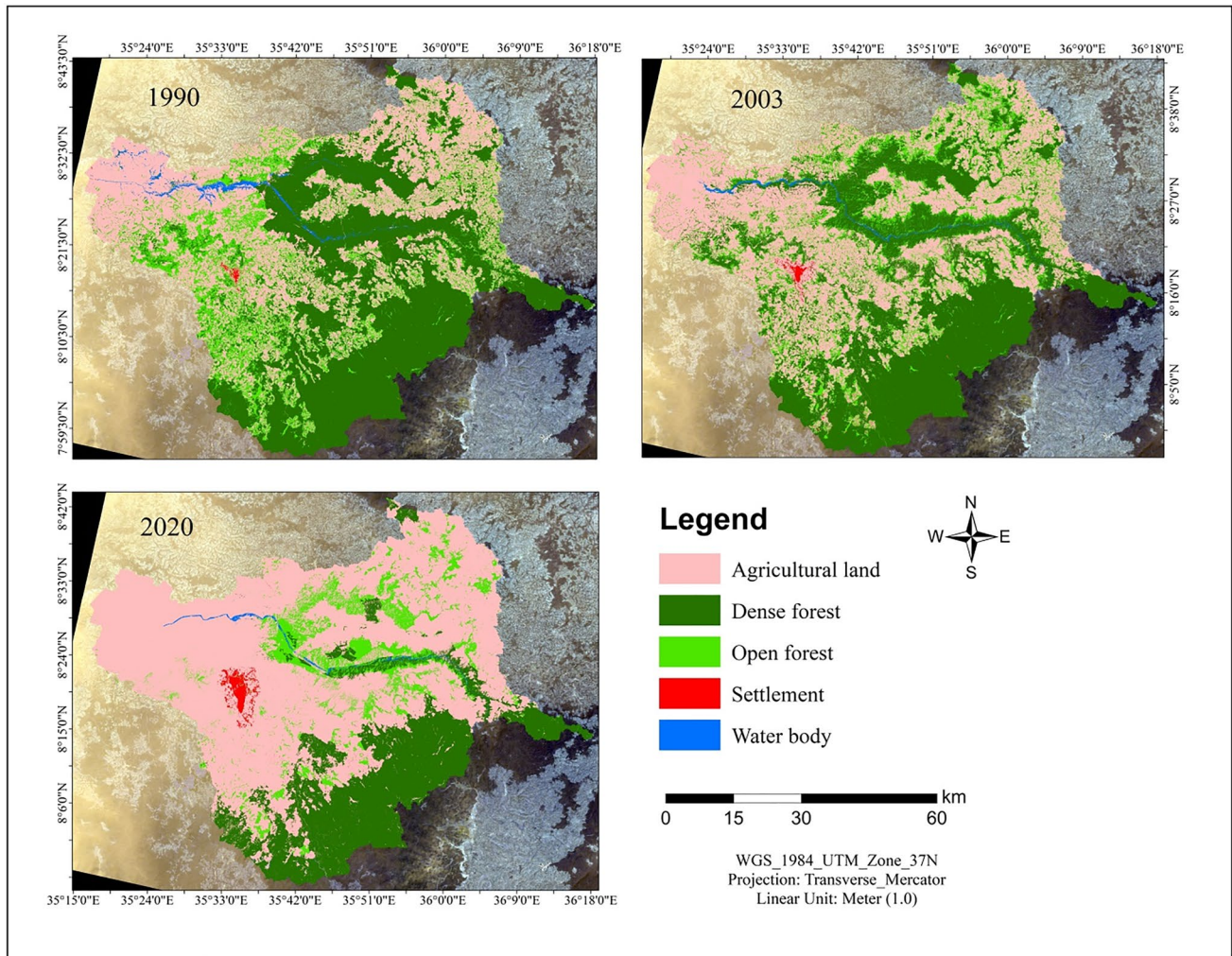


Fig. 3 LULC map of 1990, 2003, and 2020

Table 3 LULC areas in 1990, 2003 and 2020

LULC types	1990		2003		2020	
	Area (km ²)	Area (%)	Area (km ²)	Area (%)	Area (km ²)	Area (%)
Agricultural land	1786.6	37.2	2006.6	41.8	3163.2	65.8
Dense forest	2129.2	44.3	2011.5	41.9	1127.8	23.5
Open forest	841.0	17.5	750.5	15.6	457.2	9.5
Settlement	6.5	0.1	16.1	0.3	37.3	0.8
Water body	41.8	0.9	20.5	0.4	19.7	0.4

the expense of forest resources. This observed change indicates a reduction in forest cover and an increase in agricultural land and settlement land cover classes. Our result is consistent with previous study by [4] who reported that both dense and open forest declined Komto protected forest priority areas in east Wollega zone in Ethiopia. The declining of forest resources may lead to climate change that negatively affect the water quality and availability. The declining of forest resources can raise the surrounding

temperature. The increasing of temperature could result in excess evapotranspiration, which may affect water availability and agricultural production in the region [33]. Water availability are the most significant constraining factors for agricultural production due to water scarcity [34].

In the Geba watershed, the primary LULC is shown (Fig. 6). From 1990 to 2020, 647 km² of dense forest and 750.4 km² of open forest are converted to agricultural land, respectively. The loss of vegetation has a negative

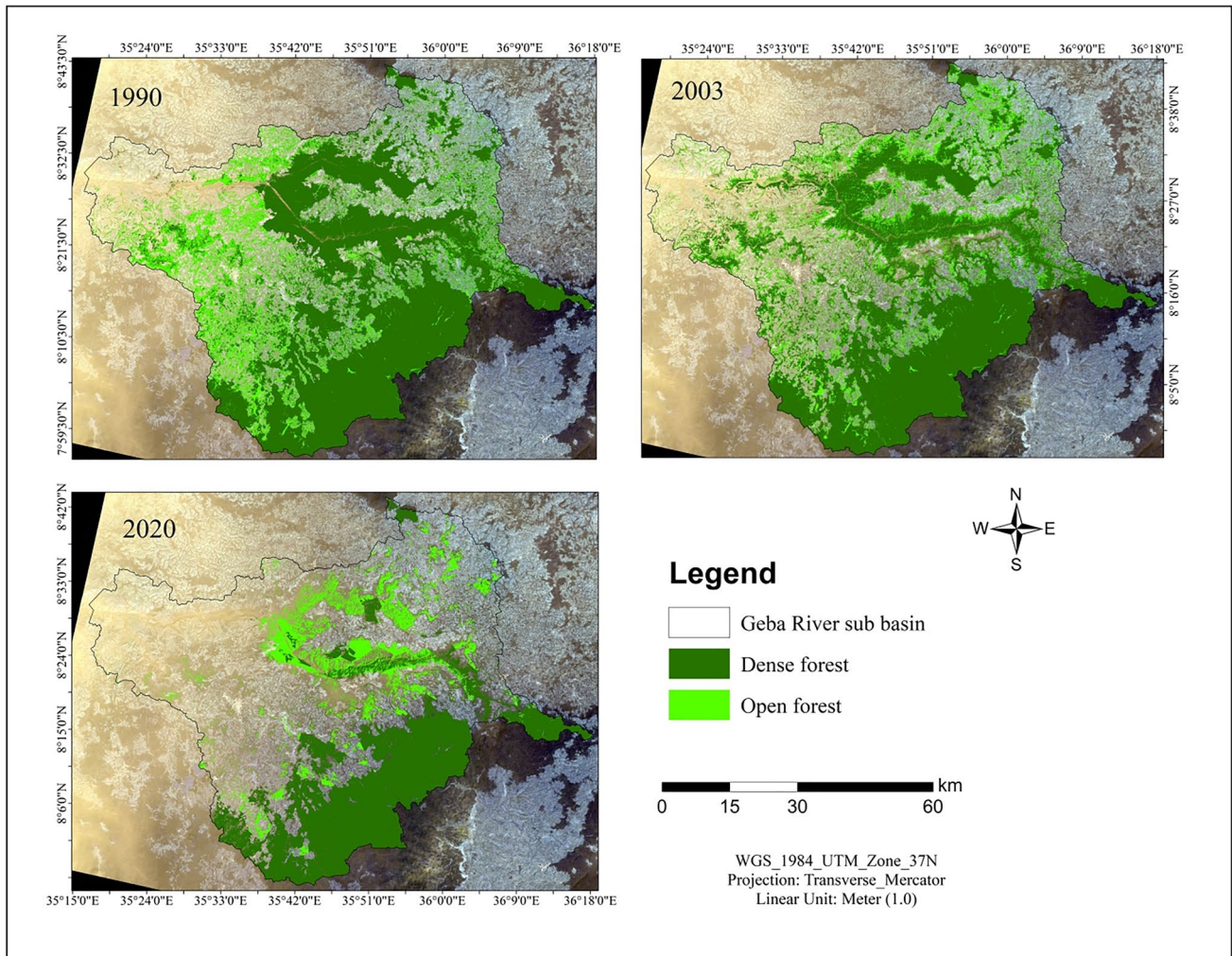


Fig. 4 Forest cover map of 1990, 2003 and 2020

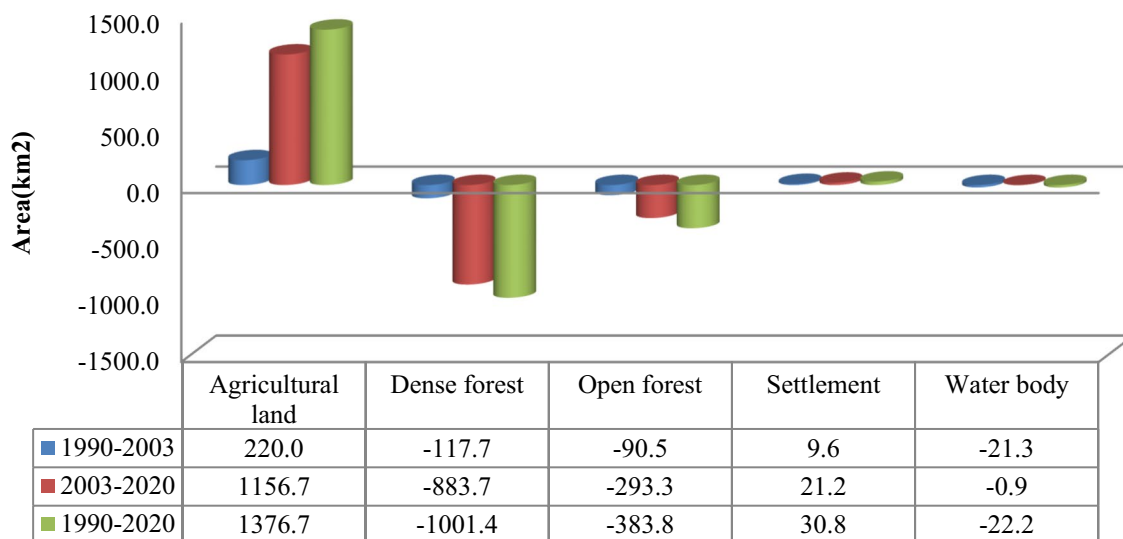


Fig. 5 Trends of LULC in the study area

Table 4 LULC conversion from 1990 to 2020

LULC classes	2020					
	Agricultural land	Dense forest	Open forest	Settlement	Water body	Total
<i>1990</i>						
Agricultural land	1732.1	21.3	20.6	10.5	1.7	1786.2
Dense Forest	647.0	1072.3	393.6	7.0	9.2	2129.0
Open forest	750.4	32.4	39.6	17.6	0.8	840.8
Settlement	0.0	0.0	0.0	3.2	0.0	3.3
Water body	33.1	1.6	3.3	0.0	8.0	46.0
Total	3162.6	1127.6	457.2	38.3	19.7	4805.3

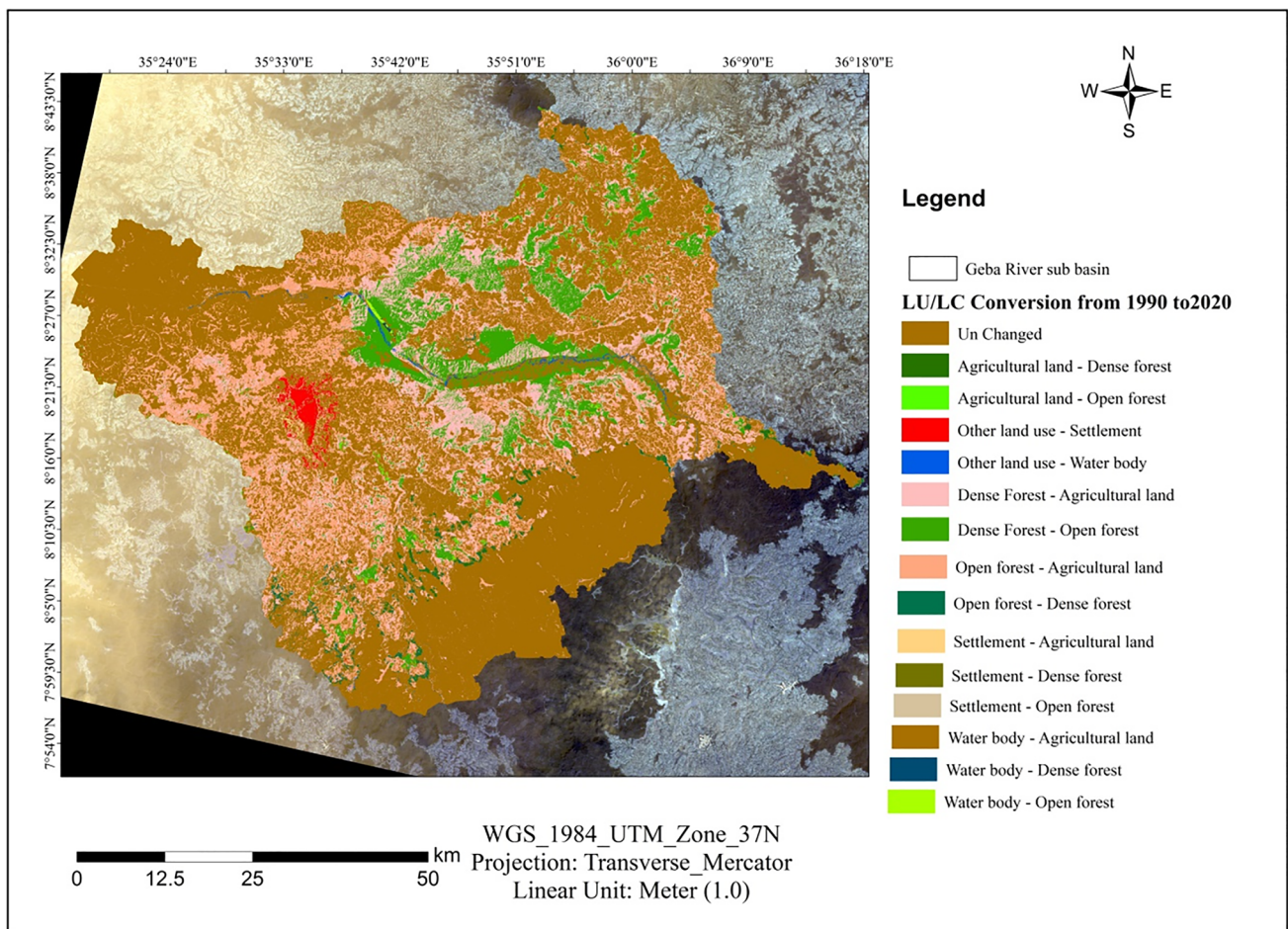


Fig. 6 LULC conversion from 1990 to 2020

impact on environmental conservation. The declining of forest resources by agricultural expansion aggravates the problems of soil erosion in developing countries [35]. The declining of forest cover accelerated soil erosion, which cases food insecurity in developing countries requires policy interventions. From 1990 to 2020, 2855.2 km² remained unchanged in all LULC categories. The results are presented in detail in (Table 4).

4 Conclusions

Geospatial technologies are used to examine LULC change in the present study. The LULC classes of the study area are classified using three years of Landsat imagery. Our results found that there is a rapid conversion of LULC change particularly the forest cover substantial declined over the study period, which might alter the microclimate

and affect community livelihoods. The study's findings suggest that forest cover area has decreased significantly over the last three decades. Results of this study show that a total of 1001.4 km² and 383.8 km² of dense forest and open forest are lost, respectively during the study period. In contrast, agricultural land and settlement land cover increased by 1376.7 km² and 30.8 km², respectively between 1990 and 2020. Agricultural expansions, timber production, charcoal production, firewood collection, and built-up area expansion are the main driving factors of LULC change. The deterioration of forest cover change, increasing of agricultural land and settlement land cover may increase the land surface temperatures and climate change which requires stakeholders' intervention to minimize the potential impacts. Finally, policy intervention specifically, reforestation, afforestation, and community awareness are required to protect and wise use of natural resources (Fig. 6).

Acknowledgements The authors acknowledge Wollega University Faculty of Technology; Wollega University College of Natural and Computational Sciences and Jimma University College of Agriculture and Veterinary Medicine for the existing facilities to carryout desk top analysis.

Author contribution MBM participated in research design, data collection, and manuscript writing; IND and LBH participate in Landsat image processing and analysis. DOG participated in research design, literature review, data analysis and manuscript writing. All authors read and approved the final manuscript.

Funding No funding received for this study.

Availability of data Available in the manuscript.

Declarations

Conflict of interest The Authors declared no conflict of interests.

Consent for publication The authors agreed to publish this manuscript for publication.

Code of availability NA.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

1. Mitchell AL, Rosenqvist A, Mora B (2017) Current remote sensing approaches to monitoring forest degradation in support of countries measurement, reporting and verification (MRV) systems for REDD+. *Carbon Bal Manag* 12:9. <https://doi.org/10.1186/s13021-017-0078-9>
2. Ranagalage M, Gunarathna M, Surasinghe HJP, Dissanayake TD, Simwanda D, Murayama M, Morimoto Y, Phiri T, Nyirenda D, Premakantha VR, Sathurusinghe A (2020) Multi-decadal forest-cover dynamics in the tropical realm: past trends and policy insights for forest conservation in dry zone of Sri Lanka. *Forests* 11:836. <https://doi.org/10.3390/f11080836>
3. Deribew KT, Dalacho DW (2019) Land use and forest cover dynamics in the North eastern Addis Ababa, central highlands of Ethiopia. *Environ Syst Res* 8:8. <https://doi.org/10.1186/s40068-019-0137-1>
4. Negassa MD, Tsega D, Gemedo DO (2020) Forest cover change detection using Geographic Information Systems and Remote sensing techniques: a Spatio-temporal study on Komto Protected forest priority area, East Wollega Zone, Ethiopia *Environ Syst Res*. <https://doi.org/10.1186/s40068-020-0163-z>
5. Muhati GL, Olago D, Olaka L (2018) Land use and land cover changes in a subhumid Montane forest in an arid setting: a case study of the Marsabit forest reserve in northern Kenya. *Glob Ecol Conserv* 16:e00512
6. Tesfahunegn GB (2016) Soil quality indicators response to land use and soil management systems in northern Ethiopia's catchment. *Land Degrad Dev* 27(2):438–448
7. Kindu MT, Teketay SD, Knoke T (2016) Changes of ecosystem service values in response to land use/land cover dynamics in Munessa-Shashemene landscape of the Ethiopian highlands. *Sci Total Environ* 547:137–147
8. Sayer J, Harcourt C, Collins N (1992) The conservation atlas of tropical forests. Macmillan Publishers, Great Britain, Africa
9. FAO (2010) Global Forest resource assessment. Forestry Paper 163, Rome, Italy
10. Shimizu K, Ota T, Mizoue N (2019) Detecting Forest Changes Using Dense Landsat 8 and Sentinel-1 Time Series Data in Tropical Seasonal Forests. *Remote Sens* 11:1899. doi:<https://doi.org/10.3390/rs11161899>
11. Tolessa T, Senbeta F, Kidane M (2017) The impact of land use/land cover change on ecosystem services in the central highlands of Ethiopia. *Ecosyst Serv* 23(C):47–54
12. Feyissa G, Gebremariam E (2018) Mapping of landscape structure and forest cover change detection in the mountain chains around Addis Ababa: the case of Wechecha Mountain, Ethiopia. *RSASE* 11:254–264
13. Minta M, Kibret K, Thorne P, Nigussie T, Nigatu L (2018) Land use and land cover dynamics in Dendi-Jeldu hilly-mountainous areas in the central Ethiopian highlands. *Geoderma* 314:27–36
14. Geeraert L, Hulsmans E, Helsen K, Barecha G, Aerts R, Honnay O (2019) Rapid diversity and structure degradation over time through continued coffee cultivation in remnant Ethiopian Afromontane forests. *Biol Conserv* 236:8–16
15. Mekuriaw T (2019) Evaluating Impact of Land-Use/Land-Cover Change on Surface Runoff using Arc SWAT Model in Sore and Geba Watershed, Ethiopia *Journal of Environment and Earth Science* www.iiste.org ISSN2224–3216(Paper) ISSN 2225 – 0948 (Online) 9, 10.
16. Wubie AM (2015) GIS and remote sensing-based forest change detection for sustainable forest management in Bench Maji Zone, Ethiopia. *Int J Remote Sens Geoscience (IJRSJG)* 4(3):2319–3484

17. Gemedo DO, Korecha D, Garedew W (2021) Evidences of climate change presences in the wettest parts of southwest Ethiopia. *Heliyon* 7:e08009
18. Yang M, Wang G, Ahmed KF, Adugna B, Eggen M, Atsbeha E, You L, Koo J, Anagnostou E (2020) The role of climate in the trend and variability of Ethiopia cereal crop yields. *Sci Total Environ* 724:137893
19. Churches SE, Wampler PJ, Sun W, Smith AJ (2014) Evaluation of forest cover estimates for Haiti using supervised classification of landsat data. *Int J Appl Earth Obs* 30:203–216
20. Wu C, Du B, Cui X, Zhang L (2017) A post—classification change detection method based on iterative slow feature analysis and Bayesian soft fusion. *Remote Sens Environ* 199:241–255
21. Congalton RG (1991) A review of assessing the accuracy of classifications of remotely sensed data. *Remote Sensing of Environment* 37(1): 35–46.
22. Yared M, Sisay T (2019) Assessment of Soil Erosion and Land Use Land Cover Change using RUSLE Model, GIS and Remote Sensing: A case study of Wombeya watershed, Awash Basin, Ethiopia. *International Journal of Current Research* 11(7).
23. Abraham T, Tilashwork Ch, Tesfaye F, Abdlesemmed J (2016) Impact Assessment of Land Use/ Land Cover Change on Soil Erosion and Rural Livelihood in Andit Tid Watershed, North Shewa, Ethiopia. *Archives of Current Research International* 3(1):1–10
24. Eyasu E, Weldemariam S, Bereket T, Wondwosen G (2019) Impact of land use/cover changes on Lake Ecosystem of Ethiopia central rift valley. *Cogent Food & Agriculture* 5:1595876
25. Abebe MS, Deribew KT, Gemedo DO (2019) Exploiting temporal spatial patterns of informal settlements using GIS and remote sensing technique: a case study of Jimma city, South-western Ethiopia. *Environ Syst Res*. <https://doi.org/10.1186/s40068-019-0133-5>
26. Yang X, Zheng X, Lv L (2012) A spatiotemporal model of land use change based on ant colony optimization, Markov chain and cellular automata. *Ecol Model* 233:11–19
27. Abera A, Yirgu T, Uncha A (2020) Impact of resettlement scheme on vegetation cover and its implications on conservation in Chewaka district of Ethiopia. *Environ Syst Res* 9:2
28. Belay T, Mengistu DA (2019) Land use and land cover dynamics and drivers in the Muga watershed, Upper Blue Nile basin, Ethiopia. *RSASE* 15:100249
29. Landis JR, Koch GG (1977) The measurement of observer agreement for categorical data. *Biometrics* 33:159–174
30. Pellikka PKE, Heikineimo V, Hieanen J, Schafer E, Siljander M, Heiskanen J (2018) Impact of land cover change on above-ground carbon stocks in Afromontane landscape in Kenya. *Appl Geogr* 94:178–189
31. Wolteji BN, Bedhadha ST, Gebre SL, Alemayehu E, Gemedo DO (2022) Multiple Indices Based Agricultural Drought Assessment in the Rift Valley Region of Ethiopia. *Environ Challenges* 7:100488. <https://doi.org/10.1016/j.envc.2022.100488>
32. Sultana MS, Gazi Y, Mia B (2021) Multiple indices based agricultural drought assessment in the northwestern parts of Bangladesh using geospatial techniques. *Environ Challenges* 4:100120. <https://doi.org/10.1016/j.envc.2021.100120>
33. Gemedo DO, Korecha D, Garedew W (2022) Monitoring climate extremes using standardized evapotranspiration index and future projections of rainfall and temperature in the wettest parts of southwest Ethiopia. *Environ Challenges* 7:100517. <https://doi.org/10.1016/j.envc.2022.100517>
34. Mancosu N, Snyder RL, Kyriakakis G, Spano D (2015) Water scarcity and future challenges for food production. *Water* 7(3):975–992
35. Moisa MB, Dejene IN, Hirko O, Gemedo DO (2022) Impact of deforestation on soil erosion in the highland areas of western Ethiopia using geospatial techniques: a case study of the upper Anger watershed. *Asia-Pac J Reg Sci*. <https://doi.org/10.1007/s41685-022-00238-7>

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.