

## Research Article

# Dynamics and Prediction of Land Use and Land Cover Changes Using Geospatial Techniques in Abelti Watershed, Omo Gibe River Basin, Ethiopia

Melkamu Ateka Derebe <sup>1</sup>, Samuel Dagalo Hatiye,<sup>1,2</sup> and Ligalem Agegn Asres <sup>1</sup>

<sup>1</sup>Arba Minch University, Faculty of Water Resources and Irrigation Engineering, Arba Minch, Ethiopia

<sup>2</sup>Arba Minch University Water Resources Research Centre (WRRC), Arba Minch, Ethiopia

Correspondence should be addressed to Melkamu Ateka Derebe; melkamuatoka9@gmail.com

Received 2 March 2022; Revised 24 June 2022; Accepted 11 August 2022; Published 29 August 2022

Academic Editor: Subhan Danish

Copyright © 2022 Melkamu Ateka Derebe et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Ethiopia is a growing country which is in need of scientific ground for land use planning and agricultural-based economy. Evaluation of land use/land cover (LULC) changes helps for proper scheduling and use of natural resources with safe administration in accordance with time and dynamic population growth of the country, specifically in the study area. One of the detailed and useful ways to develop land use evaluation and classification maps is the use of geospatial techniques such as remote sensing and geographic information systems (GIS). The main focus of this study is to evaluate the dynamics of land use and land cover (LULC) changes in the Abelti Watershed, Omo-Gibe River basin, Ethiopia. Maximum likelihood algorithm approach supervised classification method was used for identifying the LULC changes using satellite data to know LULC changes in the watershed. Quantifications of spatial and temporal dynamics of land use/cover changes were accomplished by using three satellite images of 2000, 2010, and 2017 and classifying them via a supervised classification algorithm by using Earth Resources and Development System (ERDAS) software and finally applying the postclassification change detection technique was performed by using ArcGIS 10.3. From the LULC analysis, the increase was observed in the agricultural area and settlement area from 2000 to 2017. On the other hand, shrub land followed a declining trend during the study period. However, forest and bare land followed variable trends during the study period in which forest declined from 2000 to 2010 but increased from 2010 to 2017 and bare land increased from 2000 to 2010 and declined from 2010 to 2017. Generally, the driving force behind this change was population growth, rapid urbanization, and deforestation which resulted in a wide range of environmental impacts, including degraded habitat quality in the watershed.

## 1. Introduction

The connection between human activity and its impact on the environment is represented by LULC changes. Understanding the dynamics that drive LULC changes is critical for effective and long-term land resource management. Deforestation, growth of agriculture, settlements, built-up areas, and mining are all key contributors to land use/land cover (LULC) change, which is one of the major processes leading to the decline of the ecosystem [1, 2]. Due to population growth, deforestation, agricultural expansion, and poor land management, natural land cover can alter

[3, 4]. Land use/land cover change (LULCC) is a term that refers to human modification of the Earth's terrestrial surface, which is usually the result of an interaction between natural and anthropogenic processes. LULCC has a variety of negative socioeconomic and environmental consequences, including a reduction in landscape diversity and complexity [5].

Understanding and measuring LULC changes requires accurate and up-to-date land cover change data. Remote sensing (RS) and geographic information systems (GIS) are critical tools for gathering accurate and timely land use and land cover spatial data, as well as assessing changes in a study

region [6, 7]. The information gathered from remote sensing photographs is usually stored digitally in the form of a grid. In remote sensing, the data box file value is assigned to each cell for the recording of radiation from the Earth's surface at a specific point [8–10].

An increase in the human population generally exerts pressure on natural habitats and leads to a decline in biodiversity resources [11]. Rapid alteration of land use/cover has profound impacts on human and natural environments. One such impact is the increase in the surface temperature due to urbanization. Satellite remote sensing is an important data source to map and monitor LULCC and the spatial distribution of surface temperatures [12].

Ethiopia is a growing country which is in need of scientific ground for land use planning and agricultural-based economy. To obtain reliable and sufficient information for land use planning, new techniques such as satellite images are used. Different types of resolution can be used in remotely sensed data, including spatial, spectral, radiometric, and temporal resolution. Landsat image processing and analysis is a method of studying photographs with the goal of detecting, recognizing, classifying, quantifying, and comparing the value of physical and cultural objects, as well as their pattern and spatial relationship [13–15]. The dynamic nature of land use arising from an increasing population, the expansion of the agricultural sector, and climatic change are happening at an alarming rate in Ethiopia [16].

Understanding the fundamental concepts of LULC can help alleviate issues such as biogeochemical cycles, biodiversity, ecosystem loss, erosion, wetlands degradation, and loss of aquatic creatures such as fish, as well as flora and fauna of various types [17]. Fast population growth, migration from rural to urban regions, the classification of rural areas as urban areas, a lack of ecological service surveys, hunger, ignorance of biophysical limitations, and the use of new technologies are all factors that are pushing LULC changes [18].

Evaluation of land use land cover (LULC) changes helps for proper scheduling and use of natural resources with safe administration in accordance with time and dynamic population growth of the study area. This research focuses on the evaluations of different land use and land cover change detection scenarios of the watershed using three Landsat images which were acquired on 2000/01/27, 2010/01/17, and 2017/01/01 of different land use classes.

In the previous years, different scholars such as [19, 20] tried to identify factors affecting soil erosion, sedimentation problems, and land use/cover class analysis in the Omo Basin, whereas this paper focussed on the upper part of the basin in the subwatershed level and predicted land use and land cover changes in the watershed level. This research also provided important inputs or information about the driving forces which cause land use and land cover dynamics/changes to the concerning stakeholders who would take necessary mitigation measures to have balanced ecological systems in the watershed.

The domain of the study was the Abelti watershed which is a subwatershed of the upper Omo-Gibe River basin located in southern Ethiopia. The focus of this study was to

predict land use and land cover dynamics/changes of the watershed and evaluate of the temporal and special land use and land cover dynamics/changes of the watershed.

## 2. Materials and Methods

*2.1. Description of the Study Area.* Abelti watershed is found in the upper part of Omo-Gibe basin, which is the sub-basin of Omo-Gibe River basin with a total catchment area of 15374 km<sup>2</sup>. The study area, Abelti watershed, is located geographically between 7.350°N and 9.360°N and 36.50°E to 38.130°E latitude and longitude, respectively. The rural communities living across the catchment have a vast expansion of urbanization as rural towns are demanding infrastructures rapidly. It is the main tributary for the Omo-Gibe basin with high and low elevations of 3259 m and 1090 m, respectively. The study area location is represented in Figure 1.

*2.2. Land Use and Land Cover (LULC) Categorization.* This research focuses on a comparative study or analysis of land use and land cover of the Abelti watershed by using RS and GIS tools. The main objective of this study was achieved through the following main objectives: to identify and delineate different LULC classes and patterns of land use change in Abelti from 2000 to 2017 and to integrate supervised classification and visual interpretation using GIS and to examine the potential of integrating GIS with RS in studying the spatial distribution of different LULC changes. Land use/land cover units of the study area were categorized into six classes based on pixel values which have nearly similar pixel value categorization techniques. According to the data obtained from the historical interview and field observation of the study area, these six land use/cover types are dominant classes and are based on the maximum likelihood algorithm classification technique which were the main classification criteria to decide major classes of the watershed.

LULC classifications were carried out using remotely sensed Landsat satellite imageries. ERDAS 2015 image classifications along with Arc GIS10.1 are used for space-based/spatial aspects. In the case of Landsat satellites or images, six different bands were identified. The acquisition dates, sensor, path/row, resolution, and satellite images were used in the present investigation as given in Table 1.

*2.3. Ground Control Points (GCPs).* Ground control points were collected based on normalized difference vegetation index (NDVI) values of each land cover class based on pixel value ranges of each class at which ground control points were taken to produce a signature for supervised classification and accuracy assessment of satellite images of the watershed land use/cover maps. The supervised classification was performed based on 1015 training sample points identified from reference data and then applied to the imagery by using the maximum likelihood classification algorithm and the area covered by each land use and land cover class.

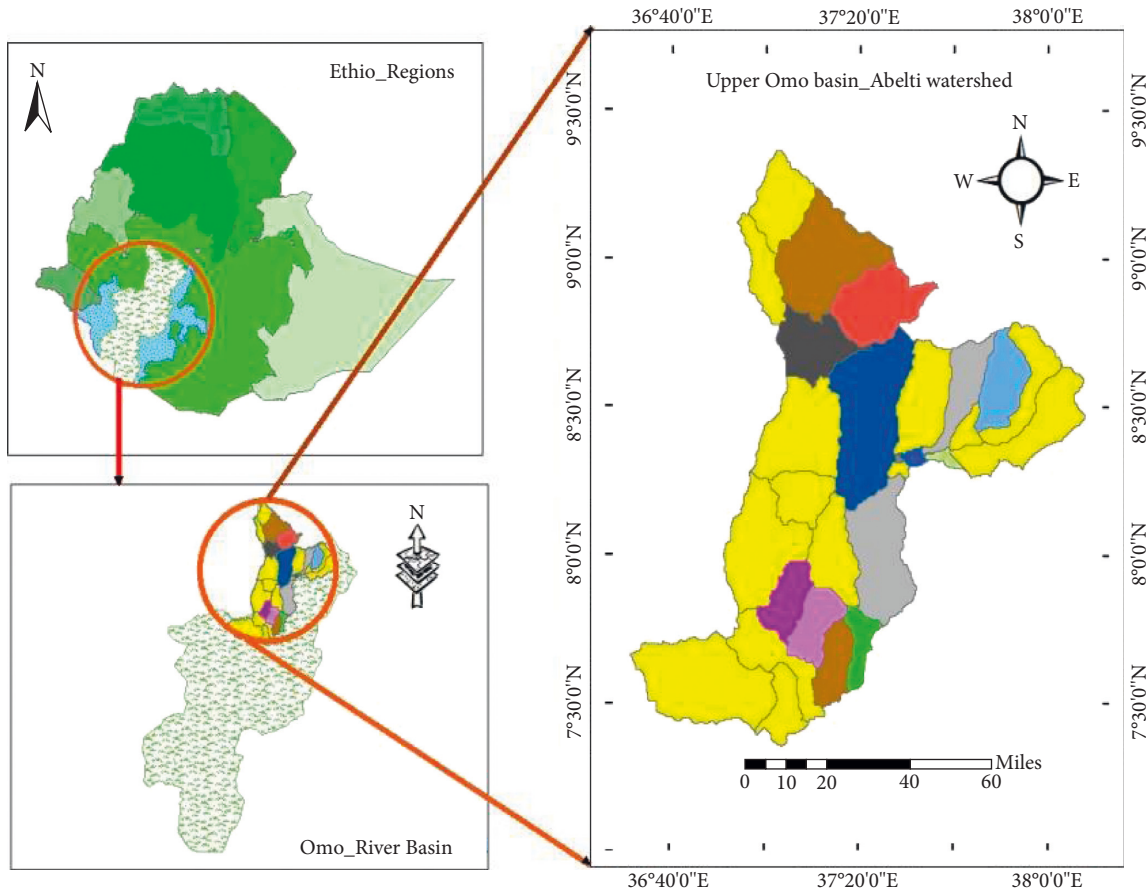


FIGURE 1: Location of the study area.

TABLE 1: Details of satellite data acquisition.

Acquisition date	Path/Row	Producer	Sensor	Resolution (m)
2000/01/27	169/055	USGS	ETM <sup>+</sup>	30
2010/01/17	169/055	USGS	TM	30
2017/01/01	169/055	USGS	OLI	30

**2.4. Image Preprocessing.** Landsat data were used to recognize LULC allocation for selected areas for a period of 18 years from 2000 to 2017, and during this period, three images at 2000, 2010, and 2017 were selected for land cover mapping of the watershed. All satellite images were geometrically connected to the Universal Transfer Mercator coordinate system and geo-referenced to the data in Ethiopia selected by the WGS (World Geodetic System, zone 84). Moreover, preprocessing activities such as radiometric correction and a false colour grid composite image were developed before image classification was performed.

**2.5. Layer Stacking Images.** In order to detect remote sensing images, images signifying different bands must be stacked. And, combining images would increase the final stacked size [3, 21]. This allows different combinations of red, green, and blue colours (RGB) to be shown in the view. Hence, a layer stack is always used for combining multiple images into a single image.

**2.6. False Colour Composite (FCC) of the Image.** To enhance the visualization of the land cover and to prepare the image for future classification, various false colour composites were made. Different band combinations, both true colour composition (TCC) and false colour composite (FCC), were used for classification. From the information obtained or extracted, the spectral responses of various land cover types were analyzed. The best image combination used for land cover identification and LULC mapping were the FCC prepared images using bands 4, 3, and 2 (RGB) for all Landsat TM, ETM+ and OLI satellite imageries.

In general, the LULC assessment was carried out through adopting samples for signatures, accuracy assessment by supervised classification and 175 selected GCPs for validation and analysis of the confusion matrix for all images, and by using the supervised image. Google Earth was used as a reference during supervised classification using the step shown in Figure 2.

**2.7. Accuracy Assessment.** For all land use and land cover classification, accuracy assessment is very important/very crucial, and accuracy assessment allows numerical values for the effectiveness of pixel classification into exact feature classes within the watershed to be determined in this study. It is a method for estimating the fit-in value of a categorized image by comparing it to a reference map [13]. Individual

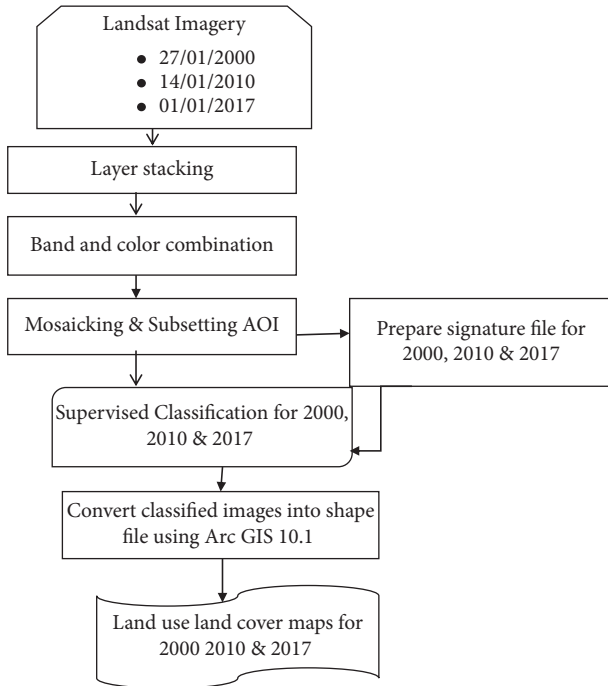


FIGURE 2: Flow chart for land use/cover classification processes.

classification accuracy must be assessed if the classification data are to be effective in change detection. The production of an error matrix, also known as a confusion matrix, is the most popular technique to describe classification accuracy. The cross-tabulation of the categorized land cover and the actual land cover was revealed by the sample site [20].

**2.8. Confusion Matrix.** The main diagonal of the confusion matrix lists is classified pixels. One of the basic accuracy measures is the overall accuracy, which is estimated by dividing the correctly classified pixels by the total number of pixels checked. Accepted accuracy levels by users will not be acceptable to other users for some other functions [21].

**2.9. Producer's Accuracy.** The producer's accuracy can be estimated by dividing the number of correct pixels in one class divided by the total number of pixels as derived from the reference data column total [22].

$$\text{Accuracy of producer [\%]} = 100\% - \text{error of omission [\%]}. \quad (1)$$

**2.10. User's Accuracy.** Correctly classified pixels within the class are divided by the sum of pixels which were classified in that class. One class on the map may have two types of classes on the ground. The latter classes can be referred to as errors of the commission [23].

$$\text{Accuracy of user [\%]} = 100\% - \text{error of commission [\%]}. \quad (2)$$

**2.11. Kappa Coefficient.** It is the determination of all agreements of a matrix, and it is a ratio of the total of diagonal values to the total number of cell counts in the matrix. Kappa values are also classified into three groups. Group A: a value greater than 0.80 (80%) represents a strong agreement; group B: the value between 0.40 and 0.80 (40 to 80%) represents moderate agreement; and group C: the value below 0.40 (40%) represents a poor agreement according to [23].

$$Ka = \frac{N \sum_{i=1}^r X_{ii} - \sum_{i=1}^r (X_{i+} + X_{+i})}{N^2 - \sum_{i=1}^r X_{i+} \cdot X_{+i}}, \quad (3)$$

where  $N$  is the total number of samples in the matrix,  $r$  corresponds to the number of rows in the matrix,  $X_{ij}$  is the number in row  $i$  and column  $j$ ,  $X_{i+}$  is the total for row  $i$ , and  $X_{+i}$  is the total for column  $i$ .

### 3. Results and Discussion

**3.1. Classification Analysis of LULC Changes.** Based on the satellite data obtained from the satellite imagery and according to [24], Abelti watershed has significant changes in land use and land cover changes in recent decades as shown in Figures 3 and 4. The results showed (Figures 3 and 4) that the study area was dominantly covered by agriculture. In the same way, [25] showed that settlement was 5.25% in 2007. According to the satellite imagery data, there was no significant water body which covers the land in the watershed in 2000 until the Gilgel Gibe I reservoir was constructed [25].

Agriculture was still a dominant land use and land cover type of the study area with a slight increase in percentage followed by shrub land, bare lands, settlements, and forest in the year 2010 (Table 2). Likewise, the authors of [25] analyzed that agriculture, forest, settlements, and shrub land were 56.54%, 7.63%, 4.06%, and 31.55%, respectively, during 2010 in the Gilgel Gibe catchment of the Omo basin. At this time, water bodies covered a small percentage of the land use and land cover area which can be evidenced by the construction of reservoirs near Assendabo and Wonchi in the watershed. As can be seen in Figure 4, bare lands, water bodies, settlements, and agriculture increased throughout the watershed, whereas forest and shrub lands decreased in the year 2010.

Agriculture covered around 49.33% of the total catchment coverage, and still, it is the dominant land use pattern followed by shrub land, settlements, forest, and bare lands in the year 2017. Similarly, [14] showed that cultivated lands, forest, and shrub land were 59.57%, 29.14%, and 9.56%, respectively, during 2013 in the Gojeb watershed of the Omo basin. A very slight increase (0.297%) in the area covered by the water body was observed covering a small percentage of area resulted from the constructed reservoir structures nearby the study area. As shown in Figure 4, settlements, water body, agriculture, and forest increased in the watershed, whereas shrub land and bare lands decreased.

The increase in the settlements and agriculture may be attributed to the population increase in the watershed. A

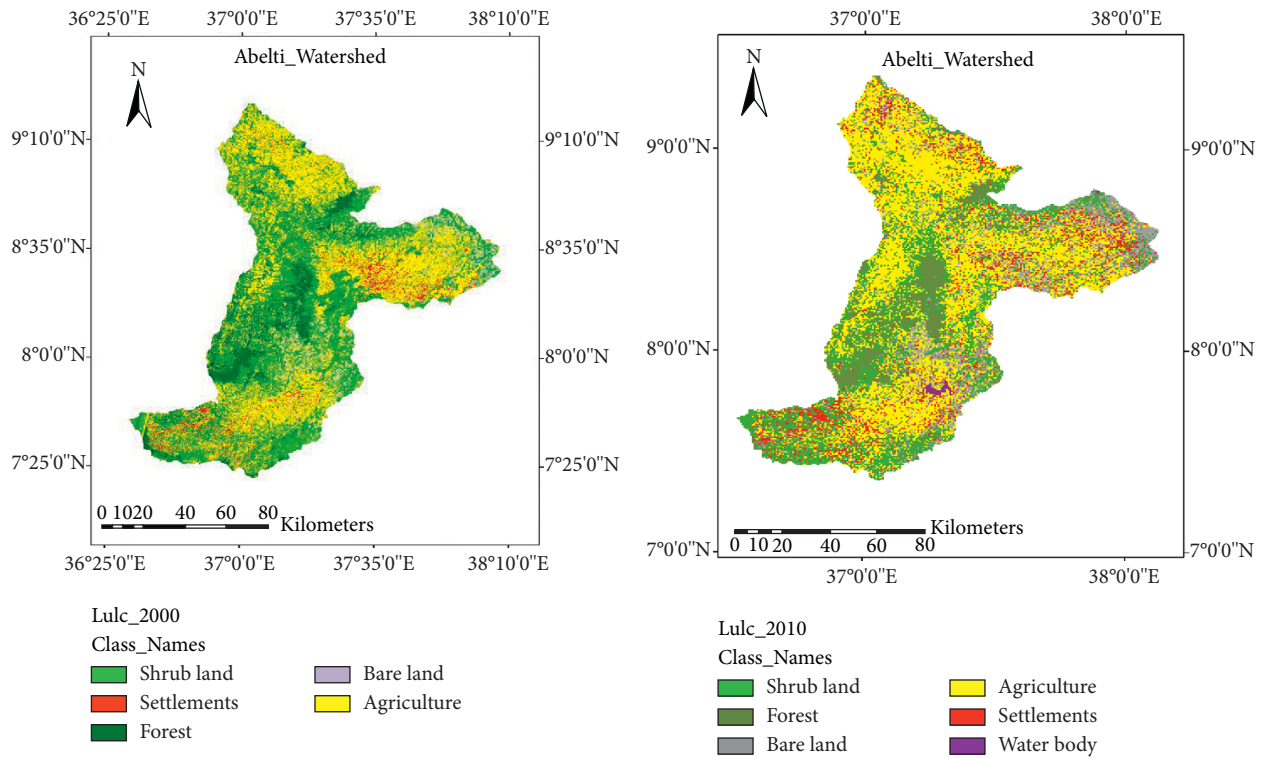


FIGURE 3: Land use and land cover maps of 2000 and 2010.

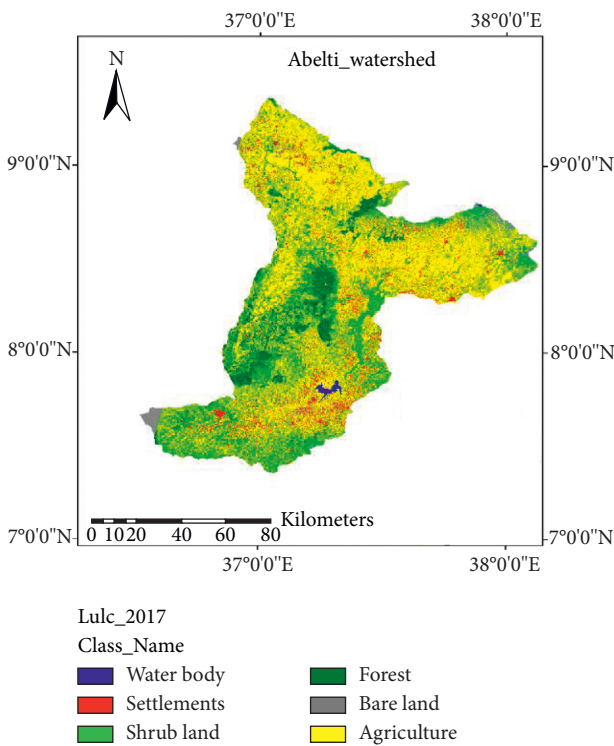


FIGURE 4: Land use and land cover maps of 2017.

slight increase in forest cover between the years 2010 and 2017 can be well described here. This is because of the transform goal of green economy of Ethiopia set by the government intervention and tree plantation programs,

TABLE 2: LULC class distributions and changes of 2000, 2010, and 2017.

Class type	LULC (A) at 2000 (%)	LULC (A) at 2010 (%)	LULC(A) at 2017 (%)
Agriculture	41.231	42.617	49.327
Water bodies	0.000	0.283	0.297
Settlements	5.471	9.439	11.528
Forest	18.938	7.800	10.892
Shrub lands	26.082	24.459	19.305
Bare lands	8.279	15.402	8.652

community awareness, and engagement in tree plantation or protection of the environment from deforestation or any other involvement. A very slight increase in the reservoir area coverage may be attributed to the siltation of silts at the bed of the reservoir which increase or raises the previous reservoir level resulting from silt transport which might have been generated from farm areas [25–27]. LULC class distributions and changes in 2000, 2010, and 2017 (%) are shown in Table 2 and Figure 5.

3.2. Accuracy Assessment of LULC Classification. In remote sensing image or data analysis, accuracy assessment was an important step to determine the degree of ‘correctness’ of the classified satellite images. According to [20, 26, and 28], the minimum accuracy value for reliable land cover classification was 85%. Therefore, as shown in Tables 3–5, the classification carried out in this study produced a Kappa coefficient and an overall accuracy that fulfil the minimum adopted accuracy level of the target reference data.

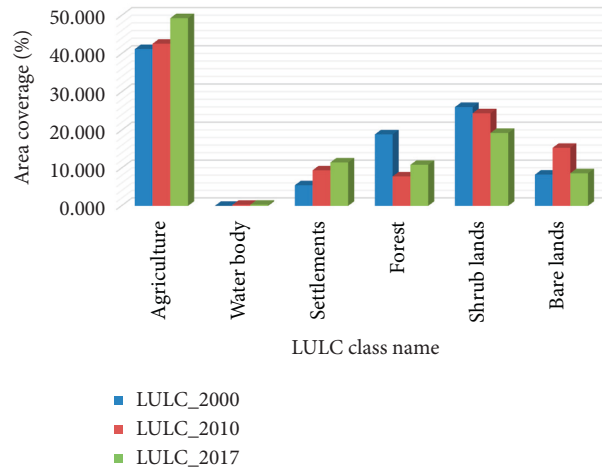


FIGURE 5: Land use/land cover distributions and changes of 2000, 2010, and 2017.

TABLE 3: Confusion matrix accuracy for the classification of 2000.

Classifications data	Reference data						Total	CE (%)	UA (%)
	ST	WR	FR	SH	BL	AG			
ST	25	0	0	0	0	1	26	3.84	96.15
WB	0	0	0	0	0	0	0	0	0
FR	0	0	15	2	0	0	17	11.76	88.24
SH	0	0	7	32	0	0	39	17.95	82.05
BL	1	0	0	0	24	8	33	27.27	72.73
AG	0	0	0	3	2	55	60	8.33	91.67
Total	26	0	22	37	26	64	175		
EO (%)	3.85	0	31.82	13.51	7.69	14.06	0	OA = 86.29	
PA (%)	96.15	0	68.18	86.49	92.31	85.94	100	Kappa coefficient = 0.82	

Source. Own study.

TABLE 4: Confusion matrix accuracy for the classification of 2010.

Classifications	Reference data						Total	CE (%)	UA (%)
	ST	WR	FR	SH	BL	AG			
ST*	28	0	0	0	0	0	28	0	100
WB	0	8	0	0	0	0	8	0	100
FR	0	0	34	2	0	0	36	5.56	94.44
SH	0	0	7	30	0	0	37	18.92	81.08
BL	1	0	0	0	15	5	18	33.33	66.67
AG	0	0	0	0	1	45	46	2.17	97.83
Total	29	8	41	32	13	50	175		
EO (%)	3.45	0	17.07	6.25	7.69	10.00	0	OA = 90.75	
PA (%)	96.55	100	82.93	93.75	92.31	90.00	100	Kappa coefficient = 0.84	

Source. Own study.

According to [27], Kappa values greater than 0.80 (80%) represent strong agreement, and hence, the image classification accuracy of the study was almost in strong agreement.

3.3. Land Use and Land Cover Change Analysis. The land use/cover change was analyzed for the respective years from 2000 to 2010, 2010 to 2017, and 2000 to 2017.

It can be observed from Table 6 and Figure 6 that the watershed has undergone numerous land use and cover changes for the study periods. The result indicated that agricultural land increased from 2000 to 2010 by 3.36% and from 2010 to 2017 by 15.74%. The settlement area increased significantly from 2000 to 2010 by 72.53% and from 2010 to 2017 by 22.13%. The forest declined from 2000 to 2010 by 58.81% but increased from 2010 to 2017 by 39.64%. The

TABLE 5: Confusion matrix accuracy for the classification of 2017.

Classifications	Reference data						Total	CE (%)	UA (%)
	ST	WR	FR	SH	BL	AG			
ST	16	0	0	0	0	0	16	0	100
WB	0	5	0	0	0	0	5	0	100
FR	0	0	40	2	0	0	42	4.76	95.24
SH	0	0	7	28	0	0	35	20.00	80.00
BL	2	0	0	0	12	3	17	29.41	70.59
AG	1	0	0	1	2	56	60	6.67	93.33
Total	19	5	47	31	14	59	175		
EO (%)	15.79	0	14.89	9.68	14.29	5.08	0		OA = 89.71
PA (%)	84.21	100	85.11	90.32	85.71	94.92	100		Kappa = 0.866

Source. Own study. FR = forest; SH = shrub land; ST = settlement; BL = bare land; AG = agriculture; WB = water body; OA = overall accuracy; Kappa = kappa coefficient; EO = error of omission; PA = producer accuracy; UA = user accuracy; and CE = error of commission (CE).

TABLE 6: Percentage distributions and area coverage of the classified LULC types from 2000 to 2017.

LULC class name	Area (%)			Change (%)		2010–2017
	LULC_2000	LULC_2010	LULC_2017	2000–2010	2000–2017	
Agriculture	41.231	42.617	49.327	1.39	8.096	6.710
Water bodies	0.000	0.283	0.297	0.28	0.297	0.014
Settlements	5.471	9.439	11.528	3.97	6.057	2.089
Forest	18.938	7.800	10.892act	-11.14	-8.046	3.092
Shrub lands	26.082	24.459	19.305	-1.62	-6.777	-5.155
Bare lands	8.279	15.402	8.652	7.12	0.374	-6.750

Source. Own study.

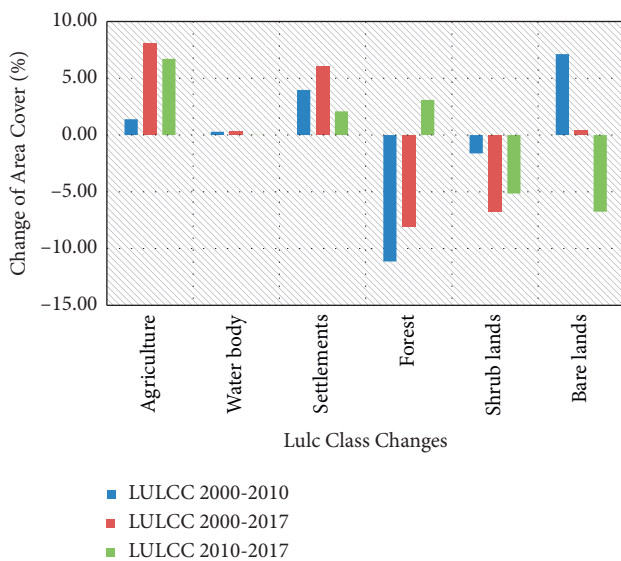


FIGURE 6: Percentage distributions of land cover changes from 2000 to 2017. Source. Own study.

shrub land declined from 2000 to 2010 by 6.22%, from 2010 to 2017 by 21.07%, and also there was a change of bare land during the study period from 2000 to 2010, in which it increased by 86.04%, and from 2010 to 2017, it decreased by 43.83%.

In general, during the eighteen years of this study, numerous land use and land cover changes occurred (Table 6 and Figure 6). Population growth with various demands and

awareness of the population for management practices were considered as the major factors for the occurrence of LULC changes in the study area.

#### 4. Conclusion

The main objective of this study was to evaluate land use and land cover changes in the watershed using Landsat satellite images from USGS for the LULC maps of 2000, 2010, and 2017. Landsat satellite image classifications of LULC maps were performed with ERDAS imagine 2015 integrated with Arc GIS 10.1. From detection analysis, it was observed that the land use changed significantly. Agriculture and settlements continuously expanded whereas shrub lands decreased during the study periods.

For the land use land cover analysis, agricultural land increased from 2000 to 2010 by 3.36% and from 2010 to 2017 by 15.74%. This is due to the adopted irrigation system in the watershed. The settlement area increased significantly from 2000 to 2010 by 72.53% and from 2010 to 2017 by 22.13%. This is due to building upland in the study area. The forest declined from 2000 to 2010 by 58.81% but increased from 2010 to 2017 by 39.64%. This is due to the new drafted millennium goal of Ethiopia set by the government intervention and tree plantation programs, community awareness, and engagement in tree plantation and protection of the environment from deforestation or any other involvement mechanisms. The shrub land declined from 2000 to 2010 by 6.22%, from 2010 to 2017 by 21.07%, and also there was a change of bare land during the study period from 2000

to 2010, in which it increased by 86.04%, and from 2010 to 2017, it decreased by 43.83%.

Therefore, to have balanced ecological systems in the study area, family planning knowledge should be given widely and continuously through formal and informal education in school to manage rapid population growth in the study area, and some other social gathering area and awareness should also be given about natural resources protection and its importance to ecological imbalance.

## Data Availability

The data which are used to support the findings of this manuscript in this study are available from the corresponding author upon request.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

## Acknowledgments

The authors would like to thank Arba Minch University for giving the opportunity to conduct different research studies.

## References

- [1] S. Ahmad, "Land use change detection using remote sensing and artificial neural network: application to Birjand, Iran," *Computational Ecology and Software*, vol. 44, pp. 276–288, 2014.
- [2] A. B. Aneseyee, T. Soromessa, and E. Elias, "The effect of land use/land cover changes on ecosystem services valuation of Winike watershed, Omo Gibe basin, Ethiopia," *Human and Ecological Risk Assessment: An International Journal*, vol. 26, no. 10, pp. 1–20, 2019.
- [3] A. Alemu, E. Garede, Z. Eshetu, and H. Kassa, "Land use and land cover changes and associated driving forces in north western lowlands of Ethiopia," *International Research Journal of Agricultural Science and Soil Science*, vol. 5, no. 1, pp. 28–44, 2015.
- [4] E. Birhane, H. Ashfare, A. A. Fenta, H. Hishe, M. A. Gebremedhin, and N. Solomon, "Land use land cover changes along topographic gradients in Hugumburda national forest priority area, Northern Ethiopia," *Remote Sensing Applications: Society and Environment*, vol. 13, pp. 61–68, 2019.
- [5] M. Olumana, D. Abcdef, D. Dhuga, and C. Abcdef, "Analysis of land use/land cover change in Adei Watershed, central highlands of Ethiopia," *Journal of Water and Land Development*, vol. 41, no. 1, pp. 146–153, 2019.
- [6] Z. Hassan, R. Shabbir, S. S. Ahmad, A. H. Malik, N. Aziz, and A. Butt, "Dynamics of land use and land cover change (LULCC) using geospatial techniques: A case study of Islamabad Pakistan," *Springer Plus*, vol. 5, p. 812, 2016.
- [7] C. Liping, S. Yujun, and S. Saeed, "Monitoring and predicting land use and land cover changes using remote sensing and gis techniques, case study of a hilly area Jiangle, China," *PLoS One*, vol. 13, no. 7, pp. 1–23, Article ID e0200493, 2018.
- [8] T. Belay and D. A. Mengistu, "Land use and land cover dynamics and drivers in the Muga watershed, Upper Blue Nile basin, Ethiopia," *Remote Sensing Applications: Society and Environment*, vol. 15, pp. 1–10, 2019.
- [9] A. Chakravarti and M. K. Jain, "Experimental investigation and modeling of rainfall runoff process," *Indian Journal of Science and Technology*, vol. 7, no. 12, pp. 2096–2106, 2014.
- [10] G. Chakilu and M. Moges, "Assessing the land use/cover dynamics and its impact on the low flow of Gumara watershed, Upper Blue Nile basin, Ethiopia," *Hydrology: Current Research*, vol. 8, no. 1, p. 268, 2017.
- [11] H. Yohannes, T. Soromessa, M. Argaw, and A. Dewan, "Spatio-temporal changes in habitat quality and linkage with landscape characteristics in the Beressa watershed, Blue Nile basin of Ethiopian highlands," *Journal of Environmental Management*, vol. 281, Article ID 111885, 2021.
- [12] A. M. Dewan, R. J. Corner, S. Sciences, and K. Street, "The impact of land use and land cover changes on land surface temperature in a rapidly urbanizing megacity," in *Proceedings of the 2012 IEEE International Geoscience and Remote Sensing Symposium*, pp. 6337–6339, Munich, Germany, July 2012.
- [13] A. Chakravarti, N. Joshi, and H. Panjiar, "Rainfall runoff modelling using artificial neural networks," *Indian Journal of Science and Technology*, vol. 8, no. 14, pp. 1–7, 2015.
- [14] C. Misganaw, "Impact of land use and land cover change on stream flow and sediment yields: a case study of Gojeb watershed, Omo Gibe basin, Ethiopia," *Remote Sensing Application Society and Environment*, vol. 14, no. 1, pp. 84–99, 2017.
- [15] K. Akpoti, E. O. Antwi, and A. T. Kabo-Bah, "Impacts of rainfall variability, land use and land cover change on stream flow of the Black Volta Basin, West Africa," *Hydrology*, vol. 3, no. 3, p. 26, 2016.
- [16] R. Paper, H. E. Getachew, and A. M. Melesse, "The impact of land use change on the hydrology of the angereb," *International Journal of Water Sciences*, vol. 1, pp. 1–7, 2013.
- [17] F. Hua, "Opportunities for biodiversity gains under the world's largest reforestation programme," *Nature Communications*, vol. 7, pp. 1–11, Article ID 12717, 2016.
- [18] T. Belay and D. A. Mengistu, "Impacts of land use/land cover and climate changes on soil erosion in Muga watershed, Upper Blue Nile basin (Abay), Ethiopia," *Ecological Processes*, vol. 10, p. 68, 2021.
- [19] H. Tesfaye, "Modeling-impact of land use/cover change on reservoir (case study on Omo-Gibe basin, Gilgel Gibe III watershed, Ethiopia)," Master Thesis, National Academic Digital Repository of Ethiopia, Addis Ababa, Ethiopia, 2014.
- [20] T. Wakjira, A. Tamene, and T. Dawud, "Land use land cover change analysis using multi temporal landsat data in Gilgel Gibe, Omo Gibe basin, Ethiopia," *International Journal of Science and Technology*, vol. 5, no. 7, pp. 1–15, 2016.
- [21] J. Maina, S. Wandiga, B. Gyampoh, and K. K. G. Charles, "Assessment of land use land cover change using GIS and Remote sensing a case study of kieni central Kenya," *Journal of Remote Sensing & GIS*, vol. 9, no. 1, pp. 1–5, 2020.
- [22] R. G. Congalton, "A review of assessing the accuracy of classifications of remotely sensed data," *Remote Sensing of Environment*, vol. 37, no. 1, pp. 35–46, 1991.
- [23] G. N. Vivekananda, R. Swathi, and A. V. L. N. Sujith, "Multi-temporal image analysis for LULC classification and change detection," *European Journal of Remote Sensing*, vol. 54, no. 2, pp. 189–199, 2021.
- [24] M. Ateka, L. Agegn, and A. Belayneh, "Evaluating the Effects of Land Use and Land Cover Change on Watershed Surface Runoff: Case of Abelti Watershed, Omo Basin, Ethiopia," *International Journal of Earth Sciences Knowledge and Applications*, vol. 4, no. 1, pp. 32–42, 2022.



- [25] S. Martínez and D. Mollicone, "From land cover to land use. A methodology to assess land use from remote sensing data," *Remote Sensing*, vol. 4, no. 4, pp. 1024–1045, 2012.
- [26] A. Geremew, "Assessing the impacts of land use and land cover change on hydrology of watershed: a case study on Gigel-Abbay watershed, Lake Tana basin, Ethiopia," *Msc Dissertation*, 2013.
- [27] C. Gomez, J. C. White, and M. A. Wulder, "Optical remotely sensed time series data for land cover classification: a review," *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 116, pp. 55–72, 2016.
- [28] A. Workaferahu, *Spatio -Temporal Forest Cover Change Detection Using Remote Sensing and Geographic Information system/GIS/Techniques*, pp. 1–100, Addis Ababa University, Addis Ababa, Ethiopia, 2015.