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ASSESSMENT OF WETLAND DEGRADATION USING GEOSPATIAL TECHNIQUES IN LAKE BOYO, SOUTHERN ETHIOPIA

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Although wetlands occupy less than 6% of the earth's land area, they contribute a lot for ecosystem services than their small area implies. This study aims to model the wetland degradation of Boyo Lake using Geospatial techniques. This study uses Landsat 7 ETM for the year 2000 and 2010 while Landsat 8 OLI used for 2020. The imageries were extracted and geometrically corrected using boundary polygon data using Spatial Analyst Tool in ArcGIS 10.8. Supervised classification was performed using the Maximum Likelihood Classifier. A comparison of land cover statistics assisted in identifying the trend and rate of change at wetland over time. In 2000, water and wetland covered an area of 2743.9 ha (53.3%) and 1680.3 ha (32.7%) of the area, respectively**.** The analysis shows that water and wetland coverage declined to 1922.9 ha (37.4%) and 1309.4 ha (25.4%) while farmland have increased to 1765.23 ha (34.3%) in 2010. Subsequently, area coverage by water and wetland further declined to 1579.1 (30.7%) and 627.94 (12.21 %) respectively, in 2020. The area under wetland is threatened dramatically with increasing encroachment of farmland over the years. Protecting wetlands from degradation needs the multi-stakeholders involvement and policy enforcement.

Keywords: Boyo Lake; GIS; remote sensing; Wetland.

1. INTRODUCTION

About 50% of the global wetland area has been lost as a result of human activities from the estimates of global wetland area range from 5.3 to 12.8 million km^2; about half of the global wetland area has been lost, but an international treaty [1,2] has helped 144 nations protect the most significant remaining wetlands [3,4]. Because most nations lack wetland inventories, changes in the quantity and quality of the world's wetlands cannot be tracked adequately [5]. Despite the likelihood that remaining wetlands occupy less than 6% of the earth's land, they contribute much

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for annually renewable ecosystem services than their small area implies [6, 7].

Throughout sub-Saharan Africa, wetlands provide several ecosystem functions that are crucial to the wellbeing of the people [8]. Nevertheless, there are two main causes for wetland degradation namely natural and man-made causes. The *first* cause of wetland degradation is the natural which includes climate change, the spread of invasive species, over flooding and geologic factors. However natural cause of wetland change is balanced by natural process. The *second* cause of wetland degradation is the human induced which includes agricultural activities, growth in industrial and residential areas, road constructions, malaria eradication, flood prevention and so on [9]. Due to misunderstanding and improper management of the humans, today wetlands are being threatened everywhere in the world. As compared to the above two causes the role of humankind in wetland degradation plays the highest role [10]. Study by Sileshi [11] claims that 65% of wetland disturbances are happened merely by human induced causes, while the remainders have natural causes. Out of these human induced wetland disturbances, 73% are thought to result from direct human actions [12].

Ethiopia is one of the vulnerable countries exposed for wetland degradation [13]. The basic cause for threats of wetland in Ethiopia in general and Lake Boyo wetland in particular include: improper agricultural land expansion, continues land degradation, urbanization and industrialization, absence of appropriate policy, lack of institutional arrangement, capacity shortage, natural and ecological problem are the major threats of wetland [14]. Due to this several environmental and social problem such as: unemployment, biodiversity degradation, ecosystem function and reduce surface area and depth of wetland has been occurring [15].

Ethiopian wetlands can be grouped into four major categories based on ecological zones, hydrological functions, geomorphologic formations and climatic conditions. These categories interlink to form four major biomes, which also describe climatic conditions in Ethiopia [16]. These biomes are the Afro-tropical highlands, the Somali-masai, the Sudan-Guinea and the Sahelian transition zone groups [17]. The Afro-Tropical wetland systems are composed of the central, western, and eastern highlands of Ethiopia that serve as the prime water catchments and sources of its major rivers. The Somali-Masai wetland system exists, in large measure, due to the formation of the Great Rift Valley. Its wetland includes the southern group of the Great Rift Valley lakes and northern group of the Awash Basin together with their associated swamps and marshlands [18]. The Sudano-Guinean wetland system is found in the western low lands of Ethiopia and the Sahelian transitional wetland system is that found in the extreme northeast part of Ethiopia [17].

In order to assess problems related with wetland management it is important to identify wetland dynamics in different life span. In this regard spatial and temporal land use land cover change have greater role to assist and understand change of wetland [19]. However, there are no studies conducted in the Boyo Lake wetland related to wetland mapping and monitoring. Therefore, this study is to quantify the spatial and temporal environmental change using GIS and remote sensing applications in wetland for the period 2000 to 2020.

2. METHODS AND MATERIALS

2.1 Study Area Description

Boyo Lake wetland is located in Shashogo district, which is one of the districts in Hadiya Zone, Ethiopia. Geographically, it lies between 7° 23' and 7° 35' North Latitude and 37° 57' and 38° 06' East Longitude (Fig. 1). The Shashogo district is upper part of Bilate sub-basin, whose tributaries originate from the upper escarpments of Hadiya, Silite, and Guraghe highlands.

The study area experiences the rainfall of bimodal nature in which the months from March to May and June to September are marked by relatively higher rainfall records; while months from November to February are dry. The long rainy season in the area is from June to September. Topographically, in this district, the elevation ranges from 1173.a.s.l to 2200 a.s.l. it has a diversified nature of topography, ranging from very flat to rugged topography. The lowest elevation is at the south eastern part of the area, situated in the main Ethiopian Rift valley at the border of Alaba special district. Altitudinal range of study area falls between 1%and 69% but the dominant slope of the area is between 1% and 2%. Generally, the elevation decrease from west to east. Due to its flat topography at the bottom of the watershed, the study area is prone to flooding during rainy season and affected by erosion deposition at the center. The commonly observed remnant tree species in the study area are Acacia species (*Vachellia tortilis*), Cordia (*Cordia Africana),* Opuntia *(Cactus) and* Eucalyptus species *(Eucalyptus globulus)*. These tree species are observed throughout the study area mostly scattered in the cultivated landscape. Because of long history of agriculture and high population in the area, vegetation cover is very low. (SWARDO, 2020).

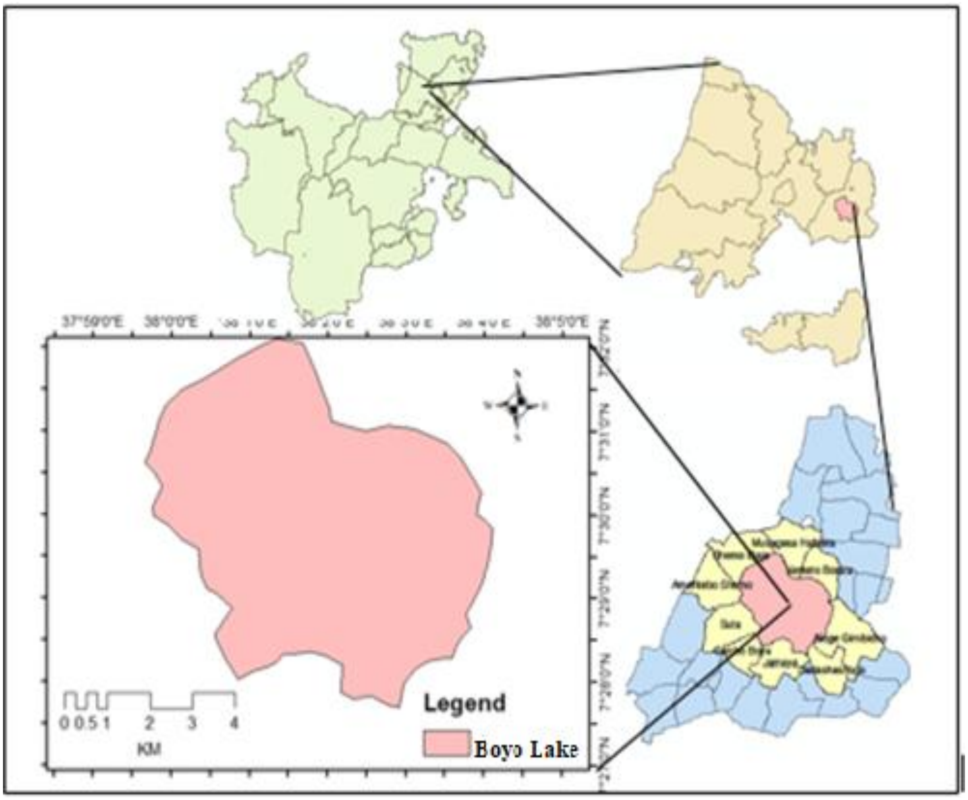


Fig. 1. Map of the study area (Ethio-GIS, 2007)

2.2 Data Sources and Method of Analysis

For this study both spatial and non-spatial data was used from primary and secondary sources. Satellite imagery (LANDSAT) which is the prominent spatial data was obtained from USGS (http://landsatexplorer.esri.com/) and used for land use land cover classification. The ETM Landsat 7 for the year 2000 and Landsat 8 (OLI) for the year 2020 with the resolution of 30m were used for the study. Prior to the data acquisition, processing and analyses, a reconnaissance survey was carried out in the study area. The knowledge acquired from the reconnaissance survey was useful in the selecting the training site for the classification procedure.

ArcGIS 10.8 has been used to analyze, to produce and to map the final output. ERDAS imagine 10.4 was applied to preprocess the imagery, to classify the land use land cover types, for accuracy assessment and for comparison matrix. Google earth pro was used to generate control points for accuracy assessment.

Geo-referencing of the images was not necessary because the imageries were already orthorectified. The imageries were extracted by mask using Spatial Analyst Tool within ArcToolBox of ArcGIS to the boundary data. However, the images were geometrically corrected to WGS84 UTM Zone 37 North coordinate system. In order to analyze the land use and land cover changes during the study years, post classification comparison of the change detection was done. ERDAS Imagine software was used for the pixel-based classification. Supervised classification was performed using the Maximum Likelihood Classifier. The images were classified into four land cover types (water bodies, wetland, farmland, and bareland) based on FAO, (1986) classification land use types. This method of classification involves the procedure of identifying pixels possessing the same spectral features automatically. ERDAS Imagine software was used in digitally processing and identifying the spectral clusters on the Landsat images and ArcGIS was used for the final embellishment of the outputs.

The classified raster output was converted to vector (polygons) to allow for measurements to be done. The area coverage of each of the LULC class was measured using square kilometers (km^2) and hectares (ha) for each of the years under consideration.

A comparison of the land cover statistics was assisted in identifying the change in percentage, trend and rate of wetland change in Boyo Lake wetland over the period. Because the interest of this study is on wetlands, less emphasis was given to the rural built-up and greenery, both of which are aggregated to become one land-use category (as bareland and farmland).

3. RESULTS

3.1 Land use and Land Covers Change Analysis

The overall total area of the land use classes of the study area was 5144 hectares. The major land use and land cover types of the study area was categorized in to four classes; as bareland, farmland, wetland and water derived from the classified of 2000, 2010 and 2020 LANDSAT Images (Figs. 2, 3, 4).

According to the classification in 2000 water and wetland constituted a relatively large area of 2743.9 ha (53.34%) and 1680.3 ha (32.67%) of the area and the lowest proportion was bareland and farmland classes with 196.8 ha (3.83%) and 522.7 ha (10.1%), respectively.

The LULC in the year 2010 shows that water and farmland with 1922.9 ha (37.4%) and 3765.2 ha (34.34%) were the leading classes, whereas wetland and bareland covers an area of 3.3 ha (0.03%) and 285.4 ha (2.44%), respectively (Fig. 3).

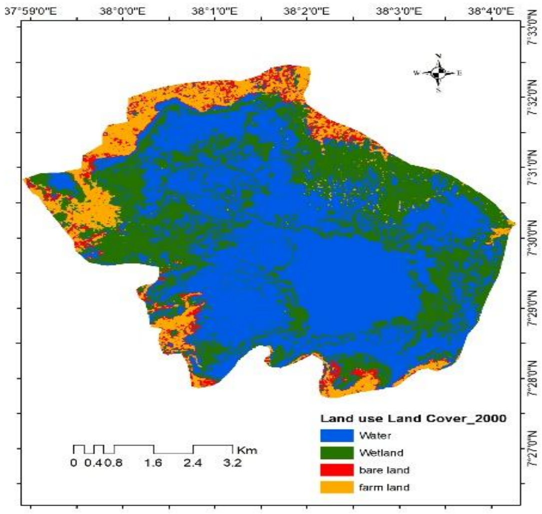


Fig. 2. Land use and land cover types of Boyo Lake wetland in 2000 (authors, 2021)

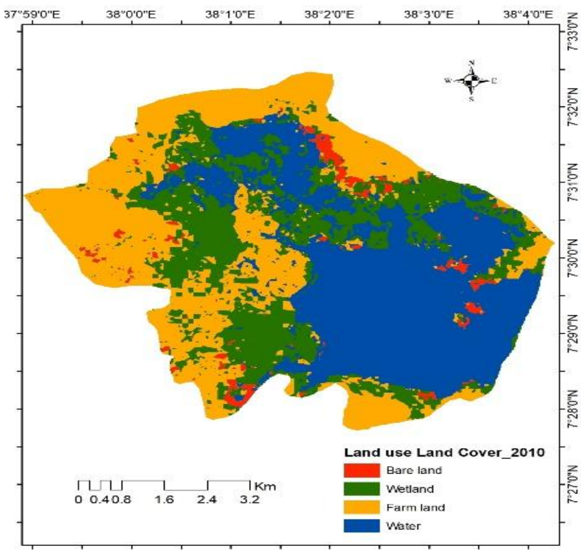


Fig. 3. Land use and land cover types of Boyo Lake wetland in 2010 (authors, 2021)

In 2020, the farmland and water bodies land use types have covered about 2740.1 ha (53.3%) and 1579 ha (30.7%) from the total area, respectively. The wetland has declined to cover an area of 627.9 ha (12.2%) whereas bareland has covered an area of 196.9 ha (3.8%), respectively (Table 1; Fig. 4).

3.2 Land use and Land Cover Change

The land use and land cover change of the dominant land use types in the study area is presented in the Table 1 below. The classified land use and land cover (LULC) maps of the study area witnessed visible dynamics and conversion from one type to another in the study years (Figs 2, 3, 4). In 2000 water bodies and wetland area were the most (53.34% and 32.67%) dominant land cover types in the study area, respectively. However, both land classes showed a decline to 37.4% and 25.4% by 2010 and further shrunk to 30.7% and 12.2% in 2020, respectively. Nevertheless, farmland twisted from 10.16% in 2000 to 34.3% in 2010. Moreover, the farmland has expanded to 53.3% in 2020 whereas the bareland has not been showed significant change, which was 3.83%.

The land use and land cover change in the study area showed that the area under wetland and water bodies were declined, whereas farmland areas has been increased dramatically in the entire study periods. The bareland and forest land have been converted to farmland. The area covered by Boyo Lake has shown shrunk in its coverage due to seasonal sedimentation in the surrounding and by the following expansion of farmland. This situation implies that the expansion of farmland and water abstraction from the Lake and wetland surrounding the Lake caused the deterioration of wetland ecosystem and in turn that resulted on the loss of fauna and flora in the study area, specifically, and in the watershed, in general.

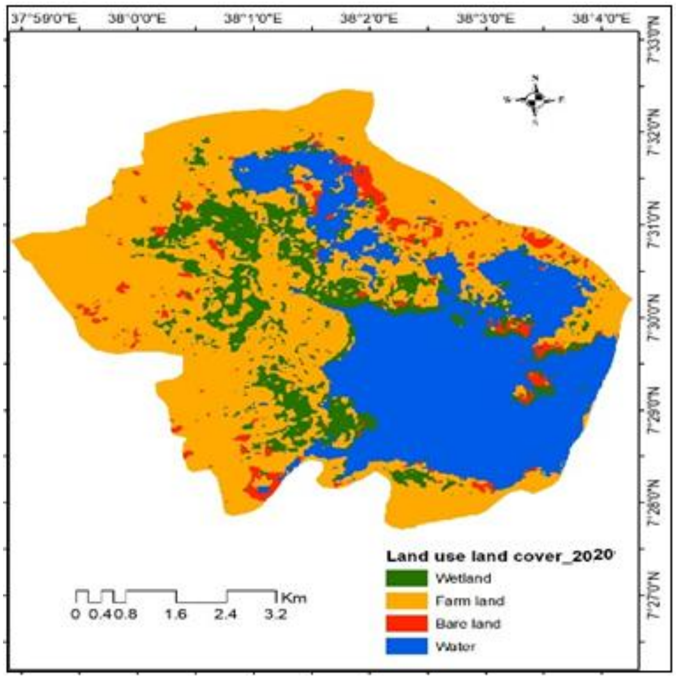


Fig. 4. Land use and land cover types of Boyo Lake wetland in 2020 (author, 2021)

Table 1. Land use and land cover changes of the study area from 2000—2020

ID	Land use types	2000		2010		2020	
		Area (ha)	%	Area (ha)	%	Area (ha)	%
1	Water bodies	2743.9	53.34	1922.99	37.4	1579.1	30.7
2	Wetland	1680.3	32.67	1309.44	25.4	627.94	12.21
3	Bareland	196.8	3.83	146.52	2.85	196.95	3.83
4	Farmland	522.7	10.16	1765.23	34.34	2740.1	53.3
	Total	5144	100	5144	100	5144	100

Source: authors, 2000

3.3 Rate of Land use and Land Cover Changes

The change in land use and land cover was calculated using a weighted average [20]. Between the study periods (2000 to 2010) and (2010 to 2020), farmland was increased with a rate of 8.4 ha/year in the first ten years, and 97.4 ha/year in the later years. It was revealed that the expansion of farmland was on the expense of water bodies, wetland and bareland as it shows in (Table 2). Between 2000 and 2020, 116.4 ha/year and 43 ha/yr of water bodies and wetland had been dropped, respectively. In the study period (2000 – 2020) the bareland area not showed significant change.

3.4 Land use and Land Cover Changes

The extent and rate of land use land cover change of the study area experienced on the three group (2000 – 2010, 2010 – 2020 and 2000-2020) periods was analyzed by comparing each land class. However, this analysis didn't show which class contributed for the actual size of the other. Therefore, conversion tabular matrix has been applied in ArcGIS and compared the records in the comparison table to analyze the source (column) and destination (row) of each land cover type in the study years. The conversion matrix analysis of the land use land cover change of the study area for (2000 and 2010), 2010 and 2020) and 1986 and 2020) is discussed below (Tables 3, 4, 5). The conversion matrix analysis of the land use land cover change of the study area for (2000 and 2010), 2010 and 2020) and 2000 and 2020) is discussed below (Table 3).

3.4.1 Land use and land cover change matrix for 2000 and 2010

The result showed that during this period there was significant land use and land cover changes. The major cover changes observed during this period had been the reduction in the area of wetland, water and bareland by 366.2 ha, 817.1 ha and 56.4 ha respectively. The land use class of farmland increased in this period by 1239.7 ha with a considerable increase in the overall areas. From the total area under study, about 803 ha (70%) of the wetland class has been converted to farmland and water areas, respectively (Table 3). This has caused in overall reduction in the wetland coverage in the first decade of study time.

In a similar manner, an area about 3.4 ha, 5.7 ha, 523.5 ha area have been converted to bareland, farmland and wetland area from water bodies coverage by 2010 in the study area that accounts a sum of 532.5 ha. Likewise, an area of 15.3 ha, 29.4 ha and 758.6 ha of land lost from the wetland to bareland, farmland and water bodies, respectively during the years 2000 to 2010 in the study area. In addition, an area of 181.9 ha, 538.8 ha and 563.1 ha farmland has been changed to bareland, water bodies and wetland, respectively in 2010. To some extent, about 9.0 ha, 52.3 ha and 82.9 ha of bareland area was also changed to farmland, waterbodies and wetland, respectively (Table 3). As a result, farmland has increased by 1239.7 ha while water bodies, wetland and bareland coverage have lost an area of 817.1 ha, 366.2 ha and 56.4 ha coverage, respectively.

Table 2. Land use and land cover changes in all the land use types from 2000 – 2020

ID	Land use types	Area changes in hectare per decade			Area change in hectare per year		
		2000-2010	2010--2020	2000--2020	2000--2010	2010--2020	2000--2020
1	Water	-820.91	-343.89	-1164.8	-82.091	-34.389	-116.48
2	Wetland	1112.64	-681.5	431.14	111.264	-68.15	-43.114
3	Bareland	-376.18	50.43	-325.75	-37.618	5.043	-32.575
4	Farmland	84.93	974.87	1059.8	8.493	97.487	105.98

Source: authors, 2021

Table 3. Land use and land cover change matrix for 2000 and 2010

Land use types (ha)		In 2000				
		Bareland	**Farmland**	**Water bodies**	**Wetland**	**Grand Total**
In 2010	Bareland	2.1	9.0	52.3	82.9	146.3
	Farmland	181.9	476.4	538.8	563.1	1760.2
	Water bodies	3.4	5.7	1393.1	523.5	1925.7
	Wetland	15.3	29.4	758.6	508.8	1312.1
	Grand Total	**202.7**	**520.5**	**2742.8**	**1678.3**	5144.2
	Difference	-56.4	1239.7	-817.1	-366.2	

Source: authors, 2021

3.4.2 Land use and land cover change matrix for 2010 and 2020

In 2010 – 2020 farmland and bareland have shown a net rising of 974.9 and 51.3 ha, respectively, while the water bodies and wetland have been declined by 343.9 ha and 681.5 ha, respectively. Nevertheless, about 978.1 ha (35.7%) area of farmland has been converted to another land use types including wetland, bareland and water bodies. The increment of bareland and farmland in this period was the result of extensive conversion of land under the water bodies and wetland to farmland and leaving the unfertile land idle (Table 4).

On the other hand, the wetland of the study area has shown a dramatic reduction to 627.9 ha from 1309.4 ha during 2010 to 2020. About 968 ha, 1.4 ha, and 3.1 ha of the wetland have been converted to farmland, bareland and water, respectively (Table 4). However, the gain of wetland from other land use types was less than the loss of wetland to other land use types in the specified period.

3.4.3 Land use and land cover change matrix for 2000 and 2020

As it is presented in Table 5, the wetland and water bodies were covered vast area that accounts about 85% of the study area in 2000. The bareland and farmland have been comprised the remaining one third of the area with 3.9% and 10.1%, respectively. The farmland expansion was alarming whereas the wetland and water bodies are shrinking in area (Table 5).

3.5 Wetland Land Cover Changes

Since the study was focused mainly on wetland cover change, the land use and land cover maps were re-classified into two categories as wetland and non-wetland areas (Fig. 5). The results, statistics and the areas derived from the classification of 2000, 2010 and 2020 images are given in (Table 6).

The wetland had covered 1678.3 ha (32.6%) in 2000, however diminished to 1309.7 ha (25.45%) in 2010 and to 631.6 ha (12.27%) in 2020, respectively. But, the other land use types (bareland, farmland and water bodies) which was 67.4% in 2000, has been increased to 74.5% and 87.8% in 2010 and 2020, respectively (Fig. 7).

The statistics explained in (Table 7) that wetland was reduced more than two times during the study period. The wetland area has been reduced 368.9 ha/yr (7.2%), 677.8 ha/yr (13.2%) and 1046.7 ha (20.3%) from 2000 to 2010 and from 2010 to 2020, while the wetland entirely reduced by the same amount, respectively.

Table 4. Land use and land cover change matrix for 2010 and 2020

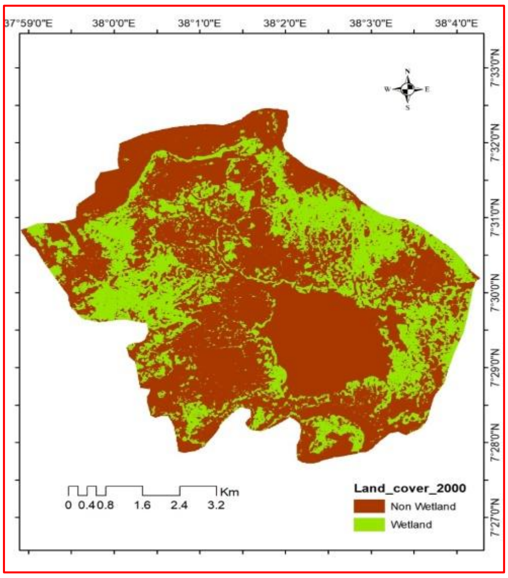
Land use types (ha)		**In 2010**				
		Bareland	**Farmland**	**Water bodies**	**Wetland**	**Grand Total**
In 2020	Bareland	145.7	0.1	49.8	1.4	197.0
	Farmland	0.2	1762.2	9.7	968.1	2740.2
	Water bodies	0.3	0.4	1575.3	3.1	1579.1
	Wetland	0.4	2.5	288.2	336.8	627.9
	Grand Total	146.5	1765.2	1923.0	1309.4	5144.2
	Difference	51.3	974.9	-343.9	-681.5	

Source: authors, 2021

Table 5. Land use and land cover change matrix for 2000 and 2020

Land cover		**In 2000**				
		Bareland	**Farmland**	**Water bodies**	**Wetland**	**Grand Total**
In 2020	Bareland	2.1	9.2	75.4	110.0	196.7
	Farmland	191.4	505.1	1067.8	969.7	2734.0
	Water bodies	3.4	4.7	1195.0	378.8	1581.8
	Wetland	5.3	1.8	404.6	219.8	631.6
	Total	202.6	520.8	2742.8	1678.3	5144.2
	Difference	1.1	2213.2	-1163.9	-1050.4	

Source: authors, 2010



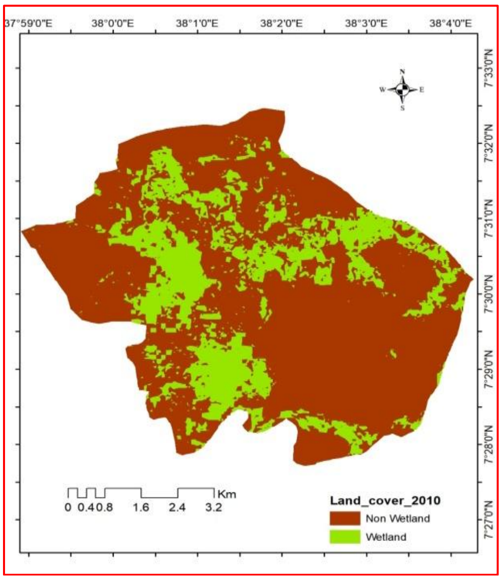


Fig. 5. Wetland and none wetland cover of 2000 Fig. 6. Wetland and non-wetland cover of 2010

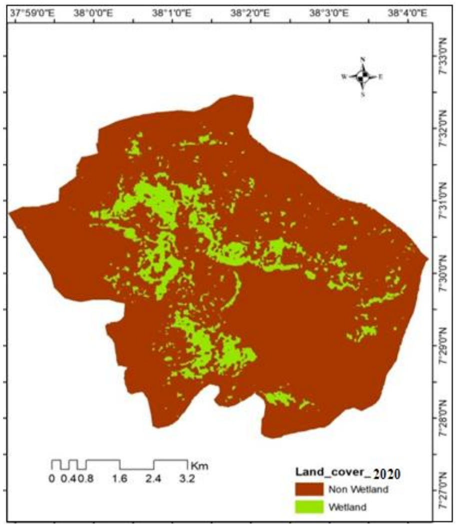


Fig. 7. Wetland and non-wetland cover map of 2020 (authors, 2021)

Table 6. Wetland and non-wetland area coverage from 2000 to 2020

Land use types	**2000**		**2010**		**2020**	
	Area (ha)	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**
Wetland	1678.3	32.63	1309.42	25.45	631.6	12.27
Non-wetland	3465.9	67.37	3834.8	74.55	4512.6	87.73

Source: authors, 2021

Table 7. Wetland cover change per hectare per year (2000-2020)

Land cover	**Change in 2000-2010**		**Change in 2010-2020**		**Change 2000-2020**	
	ha/yr	**(%)**	**ha/yr**	**(%)**	**ha/yr**	**(%)**
Wetland	-368.9	-7.2	-677.8	-13.2	-1046.7	-20.3
Non-wetland	368.9	7.2	677.8	13.2	1046.7	20.3

Source: authors, 2021

4. DISCUSSIONS

The major land use and land cover types of the study area were bareland, farmland, wetland, and water bodies which were derived from the classified of 2000, 2010 and 2020 Landsat images**.** Accordingly, the classified LULC maps of the study area showed visible alterations and transformations in the study years. In 2000 water and wetland were the most (53.34% and 32.67%) dominant land cover classes in the study area, respectively. However, both land use types showed a continuous decrease from 37.4% and 25.4% by 2010 to 30.7% and 12.2% in 2020 whereas farmland climbed to 34.3% and 53.3% in 2010 and in 2020, respectively.

The rate of farmland expansion during the years between 2000 and 2010 was 8.4ha per year while the rate of expansion from the year 2010 to 2020 accounts 97.4 ha per year. This farmland expansion has been occurred in expense of the diminishing water bodies and shrinking wetland**.** In the last two decades (between 2000 and 2020), about 116.4 ha of water bodies and 43 ha of wetland lost to farmland, respectively.

Wetland and water bodies have covered greater than 86% of the study area in the start of study period (2000) with 32.6% and 53.4%, respectively. The bareland and farmland had comprised the remaining 14% of the area, respectively. The farmland expansion was witnessed in the coming two decades, alarmingly that climbed to 53.1%. The water bodies relatively declined from 54% in 2000 to 30.9% until the end of 2020.

From the total area covered by forest (411.8ha or 65%) in the year 2000, about 404.6ha (64%) of forest area converted to farmland while about 5.3ha (8.3%) area declined to bareland and the remaining 1.8ha (2.8%) area and to waterbodies in the following two decades, respectively.

The wetland coverage in the year 2000 was 32.6% of the total area, but it was declined to 25.45% in 2010 and furthermore, shrunk to 12.27% coverage in 2020. Only about 219.8 ha (35%) of wetland of the study area has survived and about 1998.1 ha of it converted to other land use types with the study period.

5. CONCLUSIONS

The land use land cover change in the study area showed that the area under wetland and water were declined, whereas farmland areas has been increased dramatically in the entire study periods. The water body i.e Lake Boyo has also shrunk in its size due to sedimentation on its surrounding and expansion of farmland. This implies that the expansion of farmland and settlement caused high exploitation of bareland and wetland. Because, wetland area that covered 29.4 ha. (2.6%) and water body that covered an area of 758 ha (57.7%) have been converted to farmland that in generally, caused in overall reduction in the wetland coverage. Studies on wetland cover change have an important role for sustainable and healthy environment. This study indicates that the wetland has faced rapid decline by rapid population and cultivation around the lake in the study period.

To overcome the problem soil and water conservation techniques should be applied to reduce the sediment that comes to the Lake. Population pressure was identified as common problem that cause exploitation of land for agriculture. Institutions and stakeholders should be responsible in planning, implementing and monitoring water and wetland. Research on ongoing efforts both local and international level with understanding of past efforts should be given emphasis. Pronouncing policies and measures should be implemented on the improper and inappropriate land use. More researches on mapping and analyzing wetland resource using remote sensing and GIS techniques is crucial.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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