

# 1 **Land Use Cover changes in the western escarpment of Rift** 2 **Valley in the Gamo Zone, Southern Ethiopia**

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## 13 ***Abstract***

14 LULC changes are caused by natural and human alterations of the landscape that could  
15 largely affect forest biodiversity and the environment. The aim of the study was to analyzed  
16 LULC change dynamics in the western escarpment of the rift valley of the Gamo Zone,  
17 Southern Ethiopia. Digital satellite images downloaded from USGS were analyzed using  
18 ERDAS Imagine (14) and Arc GIS 10.2 software and supervised image classification was  
19 used to generate LULC classification, accuracy assessment and Normalized Difference  
20 Vegetation Index (NDVI). Drivers of LULC change were identified and analyzed. Four land  
21 classes were identified such as forest, farmland, settlement and water-wetland. Settlement and  
22 farmlands have increased by 7.83% and 5.88%, respectively. On the other hand, both forest  
23 and water bodies and wetland decreased by aerial coverage of 11.03% and 2.68%,  
24 respectively. The overall accuracy of the study area was 92.86%, 94.22% and 94.3% with a  
25 kappa value of 0.902, 0.92 and 0.922, respectively. NDVI values ranged between -0.42 to  
26 0.73. Agricultural expansion (31.4%), expansion of settlement (25.7%) and Fuelwood  
27 collection and Charcoal production (22.9%) were the main driving forces that jeopardize  
28 forest biodiversity of the study area. Integrated land use and policy to protect biodiversity  
29 loss, forest degradation and climate changes are deemed necessary.

30 **Keywords:** Landsat images, Land use/land cover, Change detection, Rift valley

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## 36 **1. INTRODUCTION**

37 Land use land cover change (LULCC) is a major issue of concern with regards to change in a  
38 global environment [1]; changes are so pervasive such that, when aggregated globally, they  
39 significantly affect key aspects of Earth System functioning[2,3]. This directly impacts  
40 biodiversity throughout the world [4]; contribute to local and regional climate change [5] as  
41 well as to global climate warming [6]; are the primary sources of soil degradation [7]; and, by  
42 altering ecosystem services, affect the ability of biological systems supporting human needs  
43 [8]. Such changes also determine, in part, the vulnerability of places and people to climatic,  
44 economic, or socio-political perturbations [9].

45 The land is the major natural resource in which economic, social, infrastructure and other  
46 human activities are undertaken [10]. Thus, changes in land use that has occurred at all times  
47 in the past, currently on-going, and is likely to continue in the future [11, 12]. These changes  
48 have beneficial or detrimental impacts, the latter being the principal causes of global concern  
49 as they impact human well-being and safety [13; 3]. LULC changes are widespread,  
50 accelerating, and the trade-offs offset human livelihood [14]. The rapid growth and expansion  
51 of urban centers, population pressure, scarcity of land, changing technologies are among the  
52 many drivers of LULC in the world today [15].

53 [16] Stated that land cover change occurs through conversion and intensification by human  
54 intervention, altering the balance of an ecosystem, generating a response expressed as system  
55 changes. For centuries, humans have been altering the earth's surface to produce food through  
56 agricultural activities [17]. In the past few decades, the conversion of grasslands, woodlands,  
57 and forests into croplands and pastures has risen dramatically, especially in developing  
58 countries where a large proportion of the human population depends on natural resources for  
59 their livelihoods [17, 18, and 19]. The increasing demand for land and related resources often  
60 results in changes in land use/cover [16] and it has local, national, regional and global causes  
61 and implications [20].

62 In Africa, forests cover about (21.4%) of the land area which corresponds to 674 million  
63 hectares and in Eastern Africa alone approximately 13% of the land area is under forests and

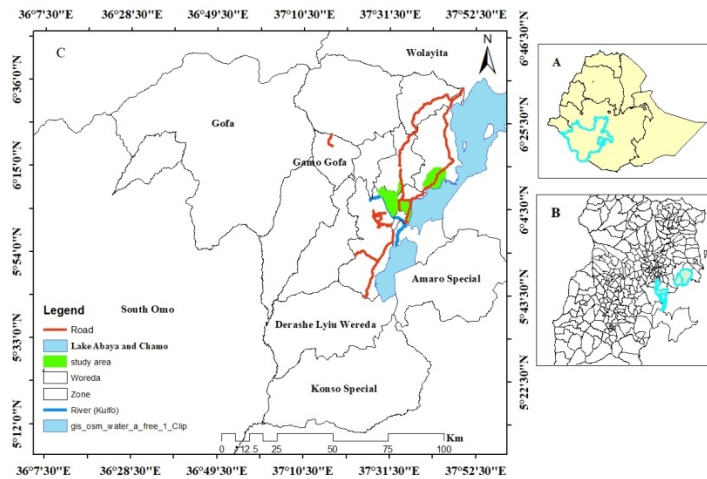
64 woodlands [21]. [22] noted that close to 40% of Ethiopia might have been covered by high  
65 forests and that about 16% of the land area was covered by high forests in the early 1950s  
66 (EFAP 1994). In the early 1980s the high forest cover of Ethiopia declined to 3.6% and  
67 further declined to 2.7 % in 1989 [23]. The recent estimate of the land cover of Ethiopia that  
68 could qualify as 'forests' which includes high forests, woodlands, plantations, and bamboo  
69 forests adds up to 15% [24].

70 Land cover change occurs naturally in a progressive manner but, could sometimes be rapid  
71 and abrupt due to anthropogenic activities [25]. Vegetation cover change is a process in  
72 which the level of diversity and the density of individual species that makes up the natural  
73 vegetation structure are altered as a result of natural and human-induced pressure [26; 27].  
74 Vegetation change mapping and monitoring are useful when changes in the vegetation  
75 attributes of interest result in detectable changes in image radiance, emittance, or microwave  
76 backscatter values [28]. Many research results in Ethiopia indicate some of the critical threats  
77 to forests that need to be seriously addressed. One of these is land use/ cover changes [29, 30  
78 and 31]. There is a dearth of LULC change detection studies in the study area and hence, the  
79 present study aims to evaluate and analyze LULC change detection at the southwest  
80 escarpment of the rift valley of Gamo Zone, Southern Ethiopia.

## 81 **2. MATERIALS and METHODS**

### 82 **2.1 Description of the Study Area**

83 The study was carried out in the western escarpment of the rift valley of the Gamo Zone,  
84 Southern Ethiopia. Gamo Zone is bordered by Dirashe Special Woreda in the South, Gofa  
85 Zone in the NW, Dawro and Wolayita Zones in the north, Lake Abaya and Chamo in the NE,  
86 South Omo in the South and Amaro Special Woreda in the SE (Figure 1). Araba Minch town  
87 is the administrative center of Gamo Zone.



88

89 Figure 1: Location map for the study area (A = Ethio-Region, B = Gamo Zone, C =Study area  
90 (surrounded Zone, Lake Abaya and Chamo, Rivers and Roads all weathered)) (Source: Arc GIS 10.2  
91 and CSA)

92 The study area consists of plains and hillsides of the Gamo mountain ridge between 6°05'N  
93 to 6°12'N and 37°33'E to 37°39'E. The elevation of the area ranging from 1168 m to 2535 m  
94 a.s.l and the slope of the forest ranges between 0 to 32 degrees (Figure 2). The total  
95 population in the study area is estimated to be 195,858 in the 2019 projection population (CSA,  
96 2019) (Table 1). Drainage in the study area is seasonal and many streams from the mountain  
97 chains merge to form the Kulfo and Hara rivers which eventually join the western escarpment  
98 of the Central Rift Valley to Lakes (Chamo and Abaya).

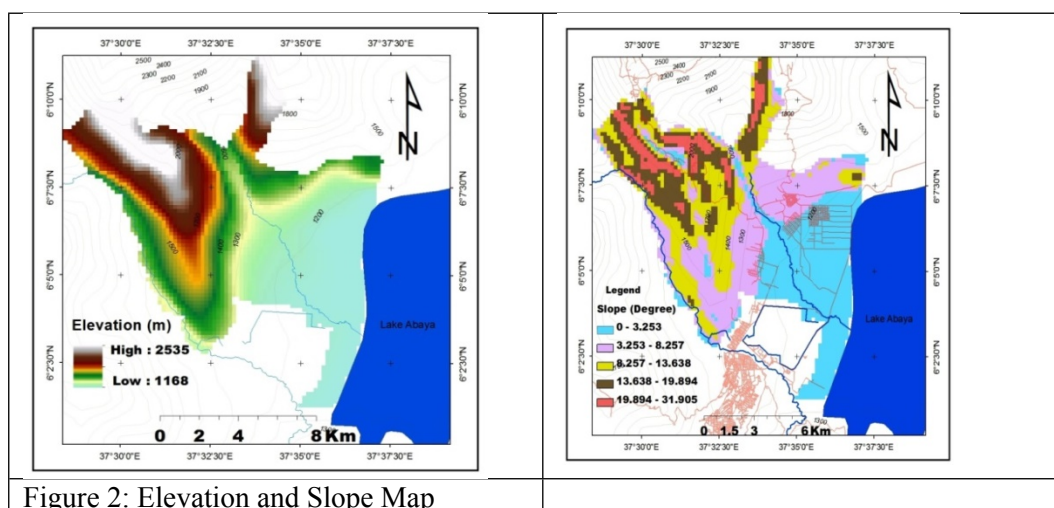


Figure 2: Elevation and Slope Map

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## 100 Population

101 The total population of the study area was increased in the three successive periods (1999,  
102 2009 and 2019) (Table 1) (CSA, 2019).

103 Table 1: Total Population of the study area from 1999-2019 (CSA, 2019)

Year	Arba Minch Zuria			
	M	F	Total	
1999	58,062	55,468	113,530	
2009	82,751	82,929	165,680	
2019	97,905	97,953	195,858	projection population

104

## 105 **Geology and soil**

106 The geology of the Rift-valley escarpment is mainly quaternary volcanic alluvial deposits and  
107 lacustrine clay. Forest and the state farm are composed of three main types: Fluvisols,  
108 Gleysols and Vertisols. Fluvisols consist of soil materials developed in alluvial deposits and  
109 flood plains [32]. The Rift valley floor near Lake Abaya and Chamo is filled with alluvial  
110 sediments. The bedrock in the region consists of basalt, trachyte, rhyolite, and ignimbrite and  
111 the western edges of Lake Abaya are covered by approximately 1 to 2-km wide plain of  
112 lacustrine and swamp deposits [33]. The topsoil textural classes of major soils in its spatial  
113 distribution are mainly dominated by clay loam, light clay, loam sand and sandy clay loam  
114 based on USDA classification.

## 115 **Vegetation Cover**

116 According to [34], the study area is characterized by complex vegetation types such as  
117 *Combretum-Terminalia* woodland vegetation, *Acacia-Commiphora* woodland vegetation and  
118 Dry evergreen Montana forest. The most common tree species in the study area are  
119 *Terminalia brownii*, *Combretum molle*, *Ziziphus mucronata*, *Pappea capensis*, *Cadaba*  
120 *farinosa*, *Vachellia* and *Senegalia Acacia species*, *Balanites aegyptiaca*, *Commiphora*  
121 *abyssinica*, *Rhus natalensis*, *Olea europaea*, *Psydrax schimperiana*, *Acokanthera schimperii*,  
122 *etc.*

## 123 **Climate**

124 The study area has a bimodal rainfall type. Maximum and minimum mean annual rainfall  
125 during 1999-2019 was 1141.1 mm and 491.8 mm, respectively (Figure 3). The maximum and  
126 minimum mean annual temperature was 33.6°C and 15°C, respectively (Figure 3) [35].

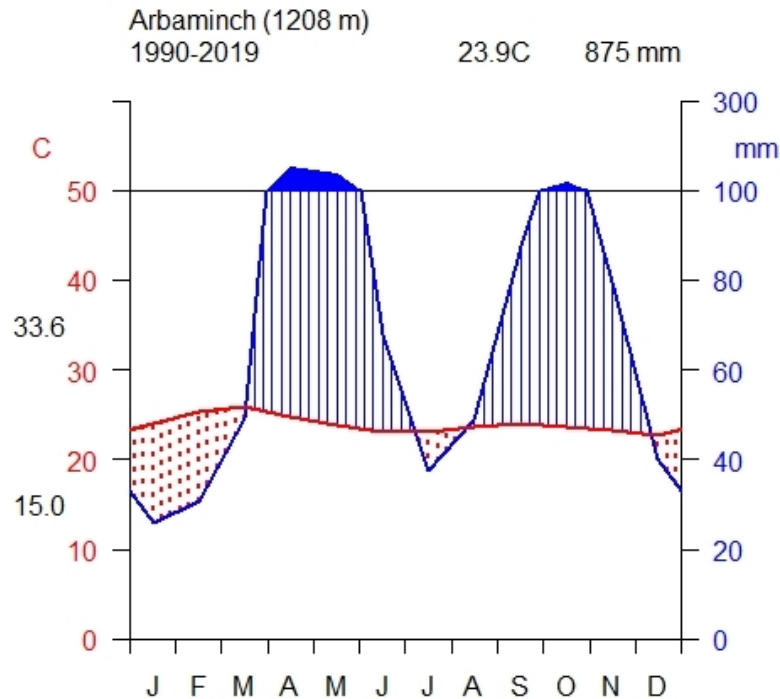


Figure 3: Annual Max. and Min. temp.in  $^{\circ}\text{C}$  and rainfall in mm (1990-2019)

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## 131 2.2 Data types and sources

132 Primary and secondary data were used: Ground control points (GCP) for ground truth were  
 133 collected as primary data using handheld GPS. Secondary data include Landsat Thematic  
 134 Mapper (TM) for the year 1999, ETM+ for the year 2009 and Landsat 8 Operational Land  
 135 Imager (OLI) images for the year 2019 acquired from United States Geological Survey online  
 136 imagery portals ([http:// glovis.usgs.gov](http://glovis.usgs.gov)). Other Geo-spatial data include Shapefiles and  
 137 topographic maps collected from the Central Statistical Agency (CSA) and Ethiopian  
 138 Mapping Agency (EMA) for extraction and delineation of area of interest (Table 2).

139 **Table 2:** Remote sensing data of the study

Acquisition data	Sensors	Path and Row	Spatial Resolution	Number of bands	Format	Source
01/05/1999	TM	169, 56	30m	7	TIFF	USGS
01/05/2009	ETM+	169,56	30m	8	TIFF	USGS
01/05/2019	OLI	169,56	30m	11	TIFF	USGS

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### 141 **2.3 Land-use change assessment (1999–2019)**

142 Digital satellite images were processed classified and analyzed using ERDAS Imagine (14).  
143 Computations of the area and changes in land use categories were made using Arc GIS 10.2  
144 software analytical tools. Pre-processing of satellite images was done to create a more faithful  
145 representation of the original scene. An intensive pre-processing such as geo-referencing,  
146 layer-stacking, resolution merge, and sub sets were carried out to Ortho-rectify the satellite  
147 images into UTM coordinates (WGS, 1984 ) and to remove disturbances such as haze, noise,  
148 steep slope effect, and radiometric variation between acquisition dates. A stacked satellite  
149 image of the study area was extracted by clipping the Area of Interest (AOI) layer of the  
150 Gamo shapefile in ERDAS 14 software.

151 The satellite image was classified using the supervised image classification technique and  
152 employed pixel-based supervised image classifications with the maximum likelihood  
153 classification algorithm [36] to produce LULC maps of the study area. Appropriate band  
154 combinations were obtained and the signatures were used for the supervised classification.  
155 Land cover change detection for the study area was monitored at three intervals: 1999\_2009,  
156 2009\_2019 and 1999\_2019. Supervised classification into four land classes were categories  
157 and distinguished into farmlands, forest lands, settlement, water bodies and wetlands (Table  
158 3).

159 **Table 3:** Characteristics of land cover classes

Class name	Description
Farmlands	Areas used for crop cultivation (Maze, teff, Banana, Mango, etc.).
Dense forest scattered forest and woodland	This habitat is dominated by trees characterized by a multi-storeyed nature with the crown cover of almost 10-50%
Settlement	Different settlements (villages) associated with building
Water_wetland	areas where water cover and may support both aquatic and wetland species

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### 161 **2.4 Accuracy analysis**

162 Since image classification without accuracy assessment is incomplete [37], accuracy  
163 assessment for the images was carried out. The accuracy of the classification was assessed  
164 using producers, users and overall methods of accuracy assessment. The overall accuracy, as  
165 well as Kappa statics, was calculated based on the GCP collected from the identified land-use  
166 types. Kappa statics was calculated by the following equation:-

167 
$$\text{Kappa} = \frac{(\text{observed Agreement} - \text{Expected Agreement})}{1 - \text{Expected Agreement}} \dots\dots\dots(1)$$

168 **2.5 Land use land covers change detection**

169 The LULC maps of three years showing period's with a range of ten years in between (1999,  
170 2009 and 2019) were generated from the satellite imageries using supervised maximum  
171 likelihood classification. To analyze the land cover structural changes in the study area the  
172 table showing the area in hectares and percentage changes between the periods 1999\_2009,  
173 2009\_2019 and 1999-2019 were measured for each LULC type. Change detection was  
174 calculated by:-

175 
$$R = Q_2 - Q_1 / t \dots\dots\dots(2)$$

176 Where, R = Rate of Change, Q<sub>2</sub> = Recent year forest cover in ha

177 Q<sub>1</sub> = Initial Year forest cover in ha and

178 t = Interval year between Initial year and Recent year

179

180 **2.6 Vegetation index**

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182 Normalized Difference Vegetation Index (NDVI) is one of the indicators commonly used to  
183 detect the vegetation cover of the earth's surface i.e. spectral change detection method. NDVI  
184 values were calculated on composite image and used band 3 (Red) and 4 (Near Infrared) for  
185 Landsat 7, and band 4 (Red) come with band 5 (Near Infrared) for Landsat 8. NDVI  
186 approaching calculation of greenness degree of image correlates with vegetation crown  
187 density. NDVI correlates with chlorophyll content and its value is between -1 to 1. NDVI is  
188 calculated as:

189 
$$\text{NDVI} = \frac{\text{NIR} - \text{R}}{\text{NIR} + \text{R}} \dots\dots\dots(3)$$

191 Where: NDVI = Normalized Difference Vegetation Index, NIR=Near Infra-Red Band R=  
192 Red Band

193 **2.7 Drivers of LULC changes**

194 LULC changes are influenced by a number of driving factors. In the study area, human  
195 activity is often mentioned as the major driver of LULC Changes. For a better understanding  
196 of LULC changes data were collected including field observation, focused group discussion



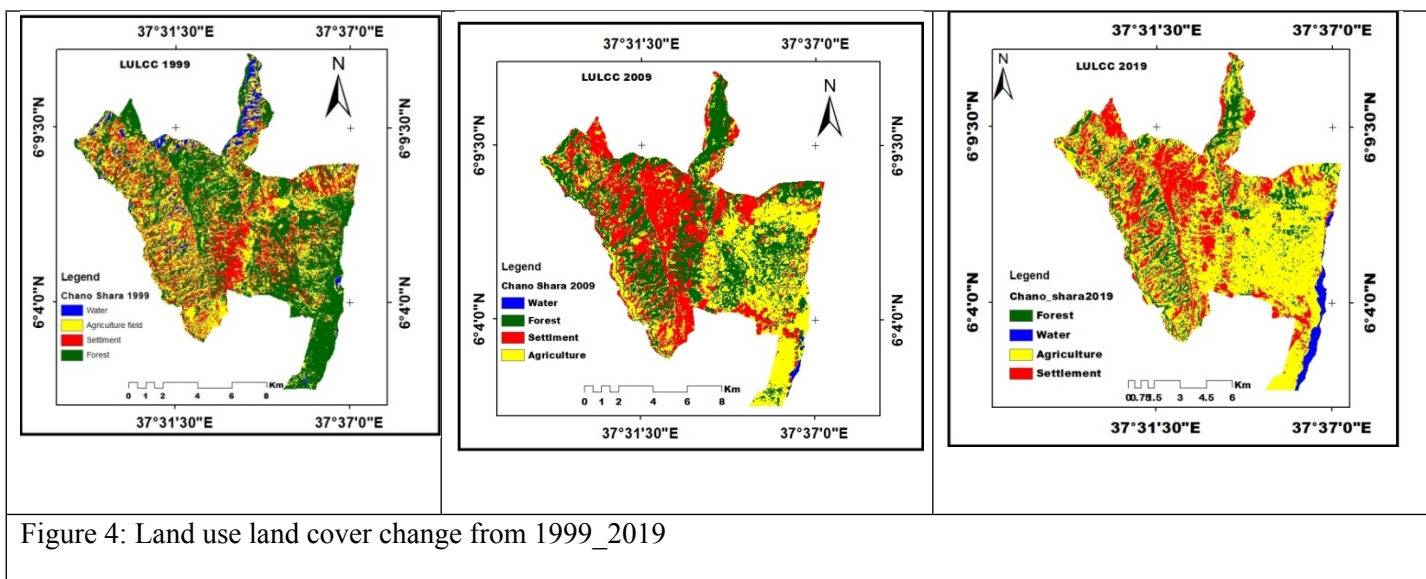
197 (FDG) and key informant interview (KII). KII and FGD were selected based on the  
198 recommendation of local community leaders and agriculture extension workers. The  
199 participants included elders (male and female), agriculture extension workers and youth  
200 jobless. The informants were asked for their consent to participate in the discussion were then  
201 given clear information about LULC changes in the study area. Data were analyzed using  
202 IBM SPSS version 20.

### 203 3. RESULTS AND DISCUSSION

#### 204 3.1 Land use land covers classification

205 The Four land classes identified in the study include forest, farmland, settlement and water  
206 bodies and water-wetlands. The land use land cover categories in Figure 4 show that forest  
207 land class has progressively decreased while farmlands and settlement increased from  
208 1999\_2019.

209



210 Similar results were reported by [38; 39; and 40] showing that farmlands in the Rift Valley of  
211 Ethiopia have expanded as a result of population pressure.[41] has shown that more than 4/5  
212 of the total terrestrial productive land in the Ethiopian Central Rift Valley was lost to  
213 agriculture. Conversions to other land use types have been observed and the image  
214 classification shows a clear conversion of land covers into farmland and settlement (Table 4).

#### 215 3.2 Land use land covers change

216 Results revealed that the extent of land cover changes from forest to farmland in the last three  
217 decades was rapid. The decline of water bodies and wetlands was not as dramatic as the loss  
218 of forests (Table 4). The conversion of farmlands to settlements was equally high. Similar

219 results were reported by [42 and 43] in the Finchaa Catchment, North-western Ethiopia and  
220 Abijata Shalla National Park, respectively. This is due to small-scale irrigation by pumping  
221 water from the lakes and rivers for income generation through the production of fruit and  
222 vegetables. [44] also showed that urban settlements and farmland expansion gained the most  
223 in the area compared to other LULC types, while forest areas exhibited a decreasing trend.  
224 Demand for food and grazing land for the growing population appears to be the driving  
225 factors.

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232 **Table 4:** Land use land covers change (1999\_2019)

Area	Area (ha) ( 1999_2009)	%	Area (ha) ( 2009_2019)	%	Area (ha) (1999- 2019)	%
Forest - Agriculture	1416.156	11.4	2671.36	21.51	1878.42	15.13
Forest - Settlement	500.144	4.03	284.27	2.29	376.529	3.03
Agriculture - Forest	155.922	1.26	105.00	0.85	50.315	0.41
Agriculture-Settlement	142.651	1.15	408.7	3.29	376.529	3.03
Agriculture - Water	235.9683	1.9	166.1	1.34	232.268	1.87
Water - Agriculture	384.342	3.09	401.85	3.24	277.00	2.23

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### 234 **3.3 Land use land covers change detection**

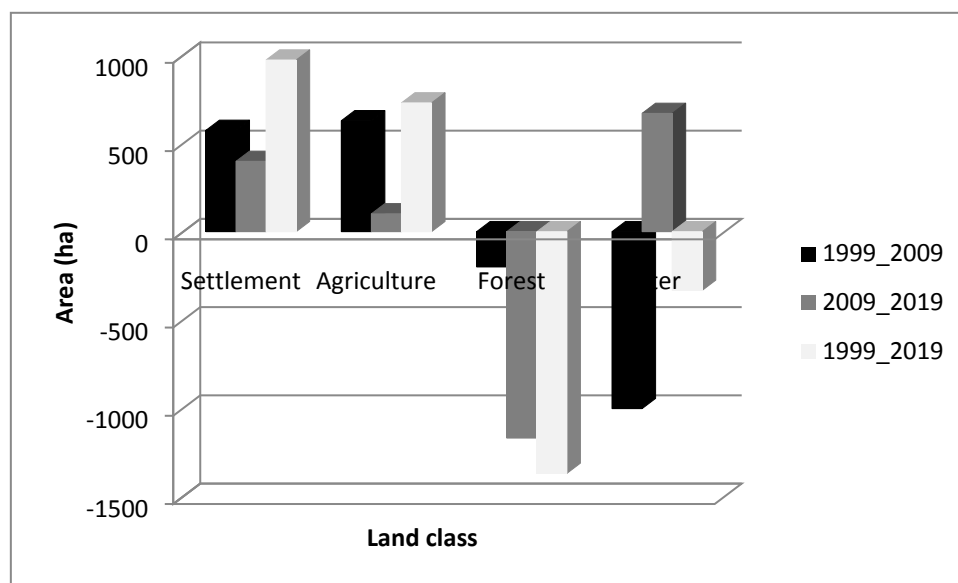
235 LULC change detection was showing that the areal coverage of settlement and farmlands  
236 increased. On the other hand, both forest and water\_wetland were decreased by an aerial  
237 coverage (Table 5). This was due to the conversion of forest and water\_wetland, to settlement  
238 and farmlands increased and also Lake Abaya might be fluctuated increased and or decreased  
239 its volume, but mostly at the expense of forest lands (Table 5). [44] shown that urban  
240 settlements and farmland expansion gained the most in the area compared to other LULC

241 types, while forest areas exhibited a decreasing trend (Figure 5). Demand for food and  
 242 grazing land for the growing population seems the probable driving force, among others.

243 **Table 5:** Land use land covers change detection from 1999 to 2019

Land class	Rate change (r=Q2-Q1/t)					
	1999_2009		2009_2019		1999_2019	
	ha	%	ha	%	ha	%
<b>Settlement</b>	574.17	4.6	398.45	3.2	972.63	7.83
<b>Agriculture</b>	628.62	5.06	101.1	0.81	729.72	5.88
<b>Forest</b>	-199.95	-1.61	-1169.79	-9.42	-1369.74	-11.03
<b>Water</b>	-1002.83	-8.08	670.23	5.4	-332.6	-2.68

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245

246 Figure 5: Change detection of the study area

### 247 3.4 Overall accuracy assessment (1999, 2009 and 2019)

248 The accuracy of image classification was checked with an accuracy matrix using 140, 173  
 249 and 158 randomly selected control points, respectively. The accuracy assessment was  
 250 performed using land-use maps, ground truth points and Google Earth. Three periods (1999,  
 251 2009 and 2019) land use classification have shown, user's accuracy and producer's accuracy  
 252 are greater than 85%, as well the overall accuracy of 92.86%, 94.22% and 94.3% ( Table 7,8  
 253 and 9), respectively (Table 6, 7 and 8). These values indicate the LAND SAT images and the  
 254 methodologies used were so accurate. The Kappa coefficient was also calculated, with a  
 255 value of K= 0.9, which indicates that the classification is almost perfect since it is greater  
 256 than 0.8. [45] argued that overall accuracy values greater than 0.8 indicate in the Landsat and  
 257 the methodologies used to have high accuracy.

258 **Table 6:** Overall accuracy Of the study area (1999)

Land class	Ground truth				Row Total	User's Accuracy
	Settlement	Agriculture	Forest	Water		
Settlement	50	2	1	0	53	94.34 %
Agriculture	0	29	0	1	30	96.67%
Forest	2	2	26	0	30	86.67%
Water	0	1	1	25	27	92.6%
Column Total	52	34	28	26	140	
Producers Accuracy	96.15%	85.3%	82.86%	96.15%		92.86%

259

260 Overall Classification Accuracy = 92.86%

261 KAPPA (K<sup>^</sup>) STATISTICS

262 Overall Kappa Statistics = 0.902

263 **Table 7:** Overall accuracy Of the study area (2009)

Land class	Ground truth				Row Total	User's accuracy
	Settlement	Agriculture	Forest	Water		
Settlement	47	2	1	0	50	94%
Agriculture	1	60	2	0	63	95.25%
Forest	1	1	36	0	38	94.74%
Water	0	1	1	20	22	90.91%
Column Total	49	64	40	20	173	
Producers Accuracy	95.92%	93.75%	90%	100%		94.22%

264 Overall Classification Accuracy = 94.22%

265 KAPPA (K<sup>^</sup>) STATISTICS

266 Overall Kappa Statistics = 0.92

267

268 **Table 8:** Overall accuracy Of the study area (2019)

Land class	Ground truth				Row Total	User's accuracy
	Settlement	Agriculture	Forest	Water		
Settlement	54	2	1	0	57	94.74%
Agriculture	1	40	1	0	42	95.25%

Forest	1	1	30	0	32	93.75%
Water	0	1	1	25	27	92.59%
Column Total	56	44	33	25	158	
Producers Accuracy	96.43%	90.91%	90.91%	100%		94.3%

269 Overall Classification Accuracy = **94.3%**

270 KAPPA (K<sup>^</sup>) STATISTICS

271 Overall Kappa Statistics = **0.922**

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### 274 3.5 Normalized difference vegetation index (NDVI)

275 The statistics and visual observation of the NDVI images over three successive periods  
 276 (1999, 2009 and 2019) showed that major land cover changes have taken in the study area  
 277 (Figure 7). The threshold value of NDVI was approximately 0.73 (Figure 6). The pixels  
 278 having an NDVI value above the threshold were identified as vegetated areas, while low  
 279 NDVI values represented non-vegetated areas. For non-vegetated areas, we found that the  
 280 water bodies were represented by low NDVI values, ranging from -0.28 to -0.42, while the  
 281 pixels having NDVI values in the range of 0.51 to 0.73 were considered as vegetation cover  
 282 areas (Table 9). NDVI analysis has proven that there had been changes in vegetation cover  
 283 between 1999 and 2019 images and higher values were recorded in the period 1999 in the  
 284 study area.

285 **Table 9:** NDVI result of the study area

Statistics	1999	2009	2019
$NDVI = \frac{(NIR - R)}{NIR + R}$			
<b>Low</b>	-0.42	-0.28	-0.37
<b>High</b>	0.73	0.64	0.51
<b>Mean</b>	0.18	0.059	-0.21
<b>SD</b>	0.11	0.095	0.11

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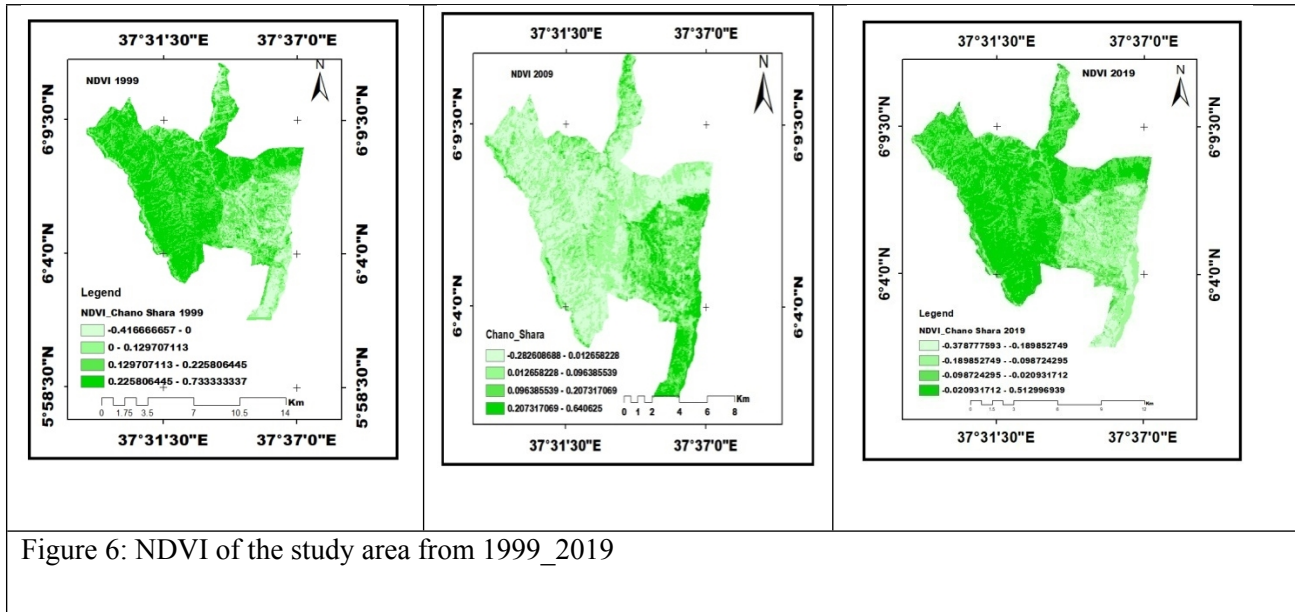


Figure 6: NDVI of the study area from 1999\_2019

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### 288 3.6 Drivers of LULC changes

289 The results of FGD and KII reveal the five major direct driving forces (Table 10). Among  
 290 these, agricultural expansion account, expansion of settlement and Fuelwood collection and  
 291 Charcoal production take large shares.

292 **Table 10:** Proximate causes of LULC changes

No	Driver	Frequency	%	Rank
1	Fuelwood collection, tree cutting and Charcoal production	8	22.9	3
2	Agricultural expansion	11	31.4	1
3	Expansion of settlement	9	25.7	2
4	Fire	2	5.7	5
5	Overgrazing	5	14.3	4
	Total	35	100	

293 The demographic data of the study area over the past three decades has revealed that  
294 population pressure ranked as the top cause of LULC changes (Table 11) [46]. The work of  
295 Lambin *et al* (2003) show that impact human population pressure is causing the accelerated  
296 conversion of natural habitats into agricultural and settlement areas to meet the mounting  
297 demand for food and housing. In Ethiopia, resettlement and villagization programs during the  
298 Military Government had made a significant contribution to the expansion of settlements and  
299 agriculture. Due to the low policy enforcing capacity of the then government landless farmers  
300 cleared forests and occupied as much land as possible to increase the chances of land  
301 ownership.

302 **Table 11:** Underlying causes of LULC changes

No	Driver categories	Frequency	%	Rank
1	Demographic	13	37.1	1
2	Biophysical	8	22.9	3
3	Economic	10	28.6	2
4	Institution and policy	4	11.4	4
	Total	35	100	

303

### 304 **3.7 CONCLUSION and RECOMMENDATIONS**

305 There were four land classes in the study area including forest, farmland, settlement and  
306 water bodies and wetlands. The changes observed in 2009 and 2019 were more rapid than  
307 that in 1999 the expansion of small-scale irrigated farmlands for fruit and vegetable  
308 production. Field observations, KII and focus group discussant confirmed that the main cause  
309 of LULC changes in the study area was the expansion of farmland and settlement. On the  
310 other hand, demographic, economic and biophysical conditions were indirect driving forces  
311 of LULC changes.

312 Linking participatory forest management with an institution and strong monitoring policies,  
313 green legacy and creating awareness to local people is hopped to improve the current status  
314 forest biodiversity and environment of the study area. Furthermore, the land use policy and  
315 environmental rehabilitation policies of the country need to be revised to include biodiversity  
316 hotspots and sequestration of carbon for carbon trading. The environmental trade-offs of fruit  
317 and vegetable productions that fetch good economic income must be mitigated through  
318 payment for ecosystem services that can be channeled for payment to the workforce involved  
319 in green legacy and environmental rehabilitation. Furthermore, promoting none agricultural  
320 economy to the jobless youths and creating forest reserved areas with a buffer zone of the  
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