

Original Research Article

Analysis of Land Use and Land Cover Dynamics in the Highlands of Northern Ethiopia

Abstract

In the highlands of northern Ethiopia, many land use and land cover changes (LULCC) have occurred during different activities of the populations. Despite its coverage and unwise use of natural resources, these land uses and land covers are facing increasing or decreasing their area coverage. Information derived from land use and land cover change detection is important to land conservation, sustainable development, and management of Natural resources. This purpose of this study is therefore concerned with identifying the change in land use and land cover detection of the Wejic watershed. To identify land cover changes detection; remote sensing data, satellite imagery and image processing techniques had done within two dates of 1998 and 2017 using Land sat TM 30 m resolution images using Arc GIS 10.1. Hence, a field survey was carried out in 2017 to identify the major land cover types in the watershed. Detection Analysis of land use and land cover dynamics were calculated from the selected watershed in Southern Tigray, Northern Ethiopia. These land use types were cultivated, forest, bush, shrub, and homestead lands. Furthermore, a normalized difference vegetation index (NDVI) was developed for both years. The land use and land cover change results indicated that forest, cultivated land, and bush land decreased by 4.4%, 2.2%, and 2.4%, respectively. However, shrub land and homestead increased by 5.5% and 3.6%, respectively. Therefore The change detection analysis using GIS and remote sensing could deliver useful information to understand the seasonal patterns of land use dynamics for planners and decision makers; consequently, sustainable land management planning is possible.

Keyword: Satellite image, Change detection, Land use and land cover, Watershed,

1. INTRODUCTION

As Deng (2011) and Bin et al. (2006) reported, “the global environment is facing severe challenges such as changes in land use and land cover (LULC), which is the prominent ecological symbol on the earth’s surface”. Moreover, Turner et al. (2007) reported that “LULC change has been a key research priority with multi-directional impacts on both human and natural systems yet also a challenging research theme in the field of land use change science. Land use affects land cover and land changes in land cover” (Rawat and Kumar, 2015). This articulates social, environmental, institutional, and economic processes (Mas et al., 2014). “Human impacts on the global LULC change are operating at unprecedented magnitudes, rates, and spatial scales” (Turner et al., 1994). Scientists recognize that the magnitude of this change is large (Lambin et al., 2001).

“The LULC pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space. These driving forces, which are also referred to as factors that can be categorized as natural and human-induced, were recognized in the study Watershed” (Yifru A et al., 2011). “The natural factors in the study area include the high intensity of rainfall and steep relief” (Yimer, F. et al., 2007) and soil types. Among the straightforward identified human causative factors are population growth and density, over-intensification of land use, farm size, land tenure status, and lack of policies on land use planning (Yimer, F. et al., 2007).

As rightly noted by Yifru A et al. (2011) “land use and land cover are an endlessly changing process taking place on the surface of the earth”. “Major land cover changes have also occurred at a local level for all land types. For instance, a significant increase in cultivated land at the expense of forestland was found to have occurred between 1957 and 1995 in the Dembecha area, northwest Ethiopia” (Gete, 2001). Kebrom and Hedlund (2000) reported settlements increased at the expense of shrublands and forests between 1958 and 1986 in the Kalu area, north-central Ethiopia. On the other hand, the deforestation trend was reduced through appropriate interventions by promoting the planting of local tree species in the Chemoga Watershed, Blue Nile basin, Ethiopia (Woldeamlak, 2003) between 1957 and 1998. Similarly, Alemayehu (2007) concluded that in the Beressa Watershed (central Ethiopia), there were substantial land use changes in the area during the second half of the 20th century. The most important changes were the destruction of the natural vegetation, increased plantations, and expansion of grazing land.

“To understand the interaction effect of LULCC on earth systems (e.g., hydrosphere, biosphere, and atmosphere), accurate information on what type of change occurs, when and where it occurs, and the rate of changes that occur is needed” (Lambin, 2001). Wejic watershed requires Detection and Analysis of Land Use and Land Cover Dynamics study, which necessarily leads to an improved understanding of the process of land use and land cover change, which researchers and policymakers would pursue to establish effective conservation and management strategies for land resources.

2. MATERIALS AND METHODS

2.1. Area description

The study was undertaken at Wejic Watershed in Raya Azebo district, southern Tigray (Northern Ethiopia) (Figure 1). It is about 5 km west of Moheni town, the district capital. It lies between 39°16'30" to 39°37'30" E and 12°40'30" to 12°49'30" N, with an altitude ranging from 1828 to 3450 m.a.s.l.

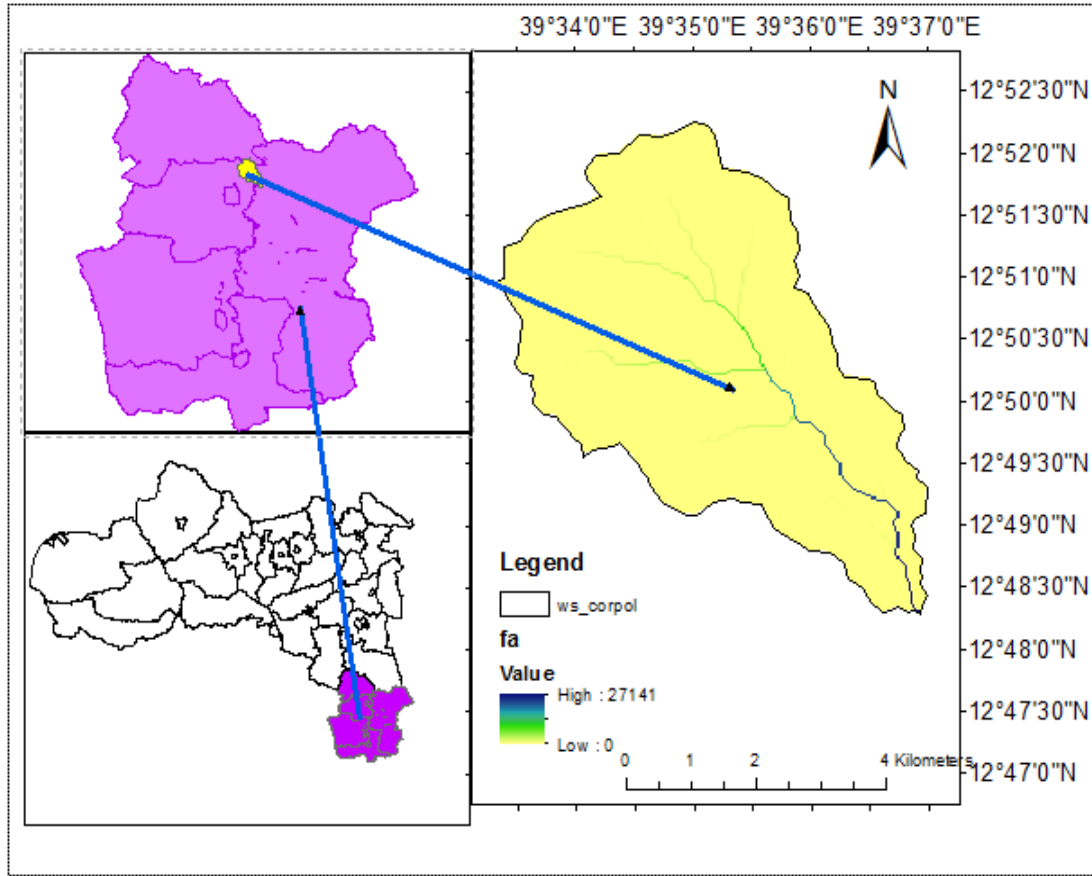


Figure 1 Map of the study watershed

The study watershed is located in three districts, EmbaAlaje (11.5 %), Enda Mohoni (10.9 %), and Raya Azebo (77.6 %). Based on the regional government of Tigray geological map, the study watershed is classified into Alaje formation.

2.2. Climate

A large part of this watershed is in the mid highland zone (80% of area), with the lowland (500-1500 masl) and highland (2300-3200 m.a.s.l.) areas covering 18.6% and 1.4% of the watershed, respectively. Rainfall is bimodal, but potential evaporate-transpiration is high and exceeds rainfall amount in most of the years (Weldeamlak et al. 2015). According to the metrological data of Tigray regional state, the study watershed mean annual rainfall is 690 mm, and the mean monthly temperature varies from 12 to 28.8 oC (Figure 2).

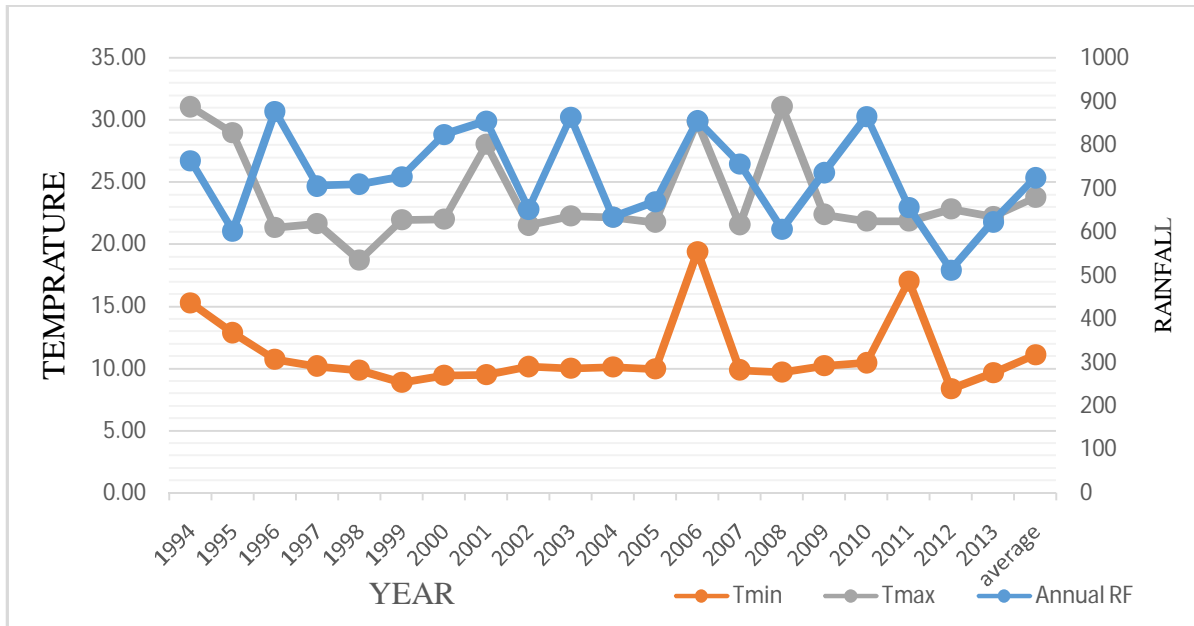


Figure 2 meteorological data of the study watershed

According to FAO (2006) land slope classification, the watershed was classified into seven slope types: flat (<3%), gentle sloping (3–8%), rolling or sloping (8–15%), hilly (15–30%), mountainous (30–40%), steep mountainous (40–60%), and very steep mountainous (>60%). Therefore, the slope in the study watershed varies from flat to very steep mountainous (Figure 3).

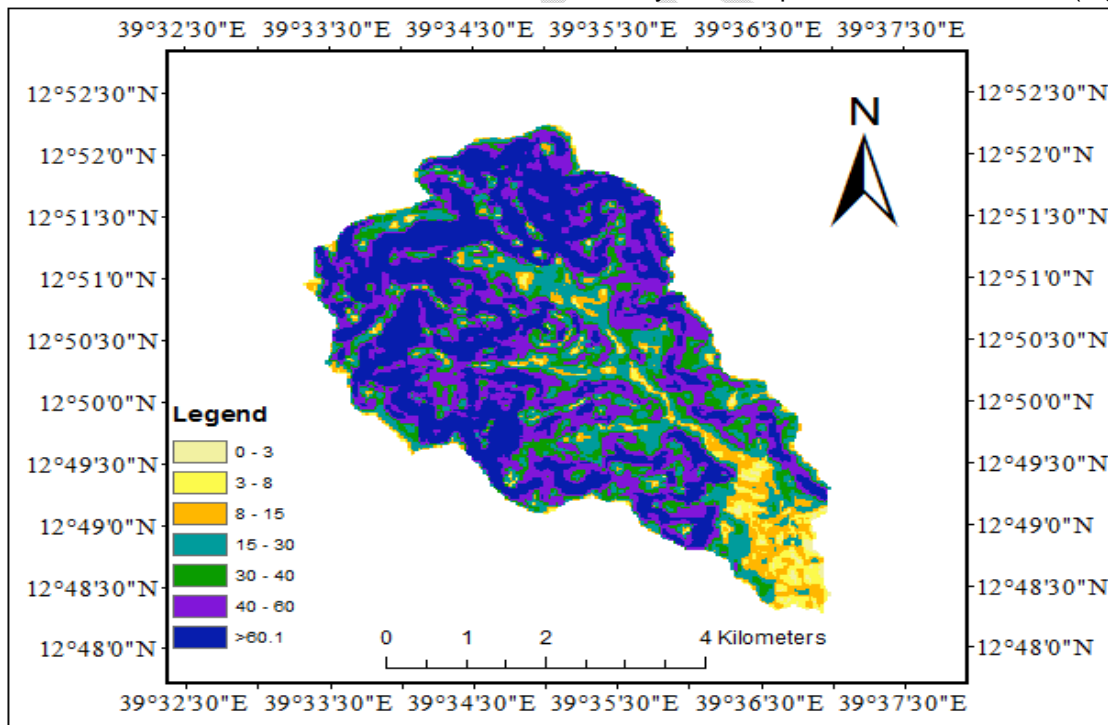


Figure 3 Land Slope classification of the study watershed

2.3. Study methods

2.3.1. Site selection

The study watershed was selected in consultation with the district watershed experts and on field survey following the pre-developed criteria, such as the existence of different land uses, various slope classes/landforms, and the existence of different agro-ecologies and watersheds with an age of two decades or more. As shown in the photo below, the left side and the right side indicate the lower and upper parts of the watershed, respectively (Figure 4).



Figure 4 Photo showing the study Watershed in part (photo: Abadi, 2017)

According to FAO's (2006) landform classification, the Watershed is classified into three parts (landforms) which are the upper part, middle part, and lower part. The entire Watershed contains four land use types.

2.3.2. Data collection and analysis

Land use and land cover data were obtained from Landsat images for the years 1998 TM/Landsat 5 & 8 and 2017 ETM+/Landsat 7 for December. In this month all crops are harvested, and the average monthly rainfall of those years is almost the same. The images were acquired from the United States Geological Survey (USGS) via <http://earthexplorer.usgs.gov/>. The year 1998 was selected because it is the year when an integrated watershed approach was introduced to the Tigray region (Irish Aid, 2006). Land use and land cover types were described based on the land use and land cover description guide proposed by Teka et al. (2014) (Table 1).

Table 1 Land use and land cover description

Land use and land cover classes	Each land use class description
Forest land	Patches with a canopy cover over 50%. These can be remnants of high natural forest, found in small patches around churches, on steep slopes and less populated areas, or recent eucalyptus plantations.
Cultivated land	Annual and perennial crops (>70% of the land), frequently observed on level lands (plains, plateaus, foot slopes, and valley floors)

Bushland	Dominant vegetation lower than 3 m but higher than 1 m with a canopy cover above 15%, or dominant vegetation below 1 m with a canopy cover above 50%
Shrub land	Dominant vegetation lower than 1 m, with a canopy cover below 50% but higher than 5%
Homestead	Residences, administrative buildings, and small industrial, and trade enterprises.

Image pre-processing and post-classification were conducted to correct errors (see Figure 5). A total of 430 ground control points (GCPs) were collected using a global positioning system (GPS). These GCPs were divided into two groups: 50% were used for classification with the Earth Resources Data Analysis System (ERDAS Imagine v 2014), while the remaining points were reserved for validation. Land cover maps for different years were generated using ArcGIS software 10.1, and change detection analyses were performed to assess temporal and spatial variations. The rate of land use and land cover change was calculated for each land use and land cover using the following formula.

$$\text{Rate of change} \left(\frac{\text{ha}}{\text{yr}} \right) = \frac{\text{final study} - \text{initial study}}{\text{time interval}} \text{-----Equation 1}$$

Using this formula, the rate of land use and land cover change from 1998 to 2017 was calculated. This method has been employed by several authors, including Abate S. and K.L. Singh (2011).

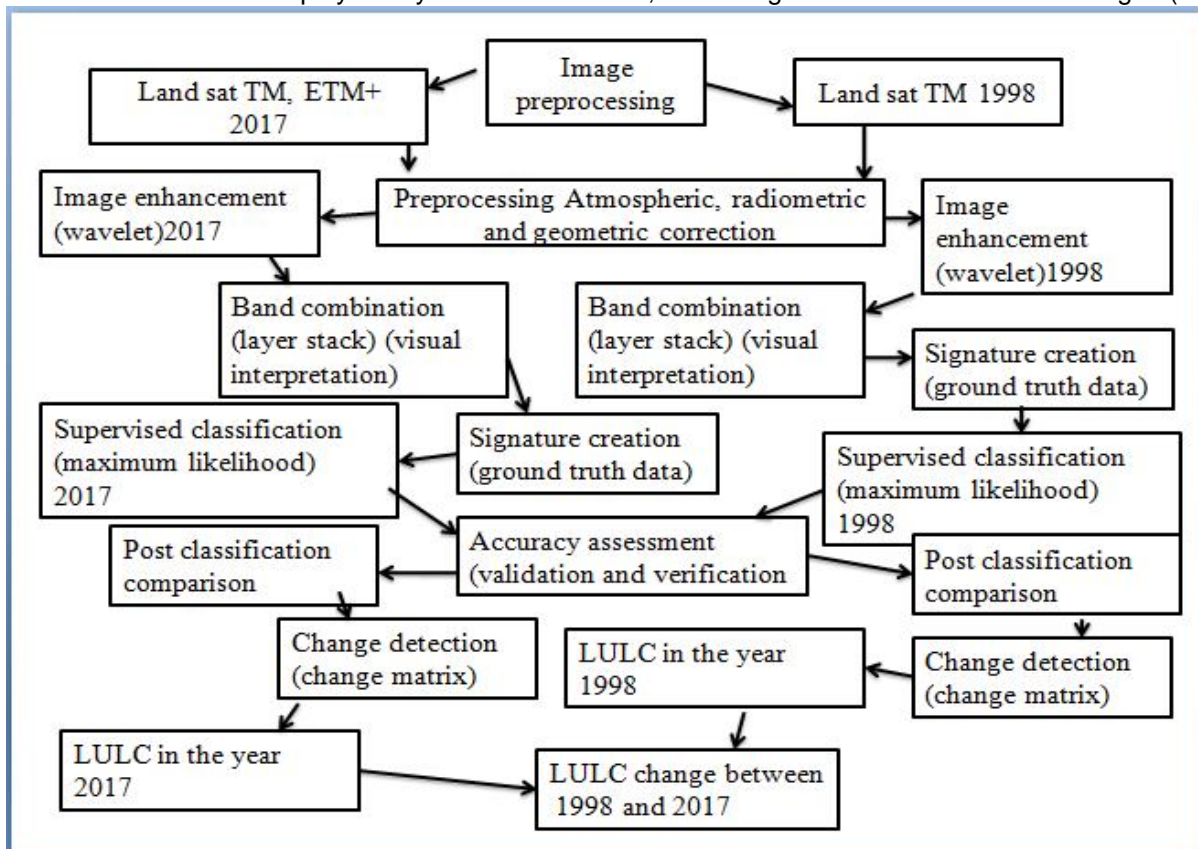


Figure 5 Representation diagrams for analyzing land use and land cover dynamics in the years 1998 and 2017

2.3.3. Accuracy Assessment

In this study, the producer's accuracy, user's accuracy, omission error, commission error, overall accuracy, and kappa coefficient were evaluated to validate the reliability of the land use and land cover classification through pixel-to-pixel comparison for the 2017 LULC categories. The overall accuracy, kappa coefficient, user's accuracy, and producer's accuracy were mathematically estimated using the following formulas:

$$\text{User's accuracy} = \frac{A_{ii}}{(A_{i+})} \dots \dots \dots \text{Equation 2}$$

$$\text{Producer's accuracy} = \frac{A_{ii}}{(A_{+i})} \dots \dots \dots \text{Equation 3}$$

$$\text{Overall accuracy} = \frac{C}{D} \dots \dots \dots \text{Equation 4}$$

Where A_{ii} = total number of observations in row i and column i , A_{i+} and A_{+i} are the marginal totals of row i and column i , respectively. N = total number of observations, C = total number of correct pixels, and D = total number of pixels in the error matrix.

In this study, the land use and land cover change matrix was calculated for the years 1998 to 2017. The overall accuracy value was determined by expressing the sum of the diagonal pixels as a percentage of the total area (Paegelow et al., 2014). Additionally, Fan et al. (2008) discussed various methods proposed to enhance the interpretation of the change matrix. The kappa coefficient is widely recognized as a key metric for accuracy assessment techniques. Consequently, this study calculated overall accuracy, kappa coefficient, omission error, and producer's accuracy results.

Table 2 Level of the kappa coefficient

Kappa coefficient (k_{hat})	Level of agreement/ accuracy
>0.80	Strong
0.40-0.80	Medium
<0.40	Poor

Source (Lillesand and Kiefer, 1994)

3. Results and Discussion

3.1. Spatial and temporal land use and land cover detection

Land use and land cover change detection using remote sensing images has been extensively applied in research related to land use and cover change (LUCC), natural resource management, and environmental monitoring and protection (Tewabe and Fentahun, 2020 and Weldegebriel k.*et al.*, 2021). Spatial analysis was conducted to describe patterns of land cover change and overall land use changes over time. In the study watershed, five major land use and land cover types were identified (see Figure 6): forests, bushland, shrubland, cultivated land, and homesteads. These land use and land cover types are the most dominant in the study area.

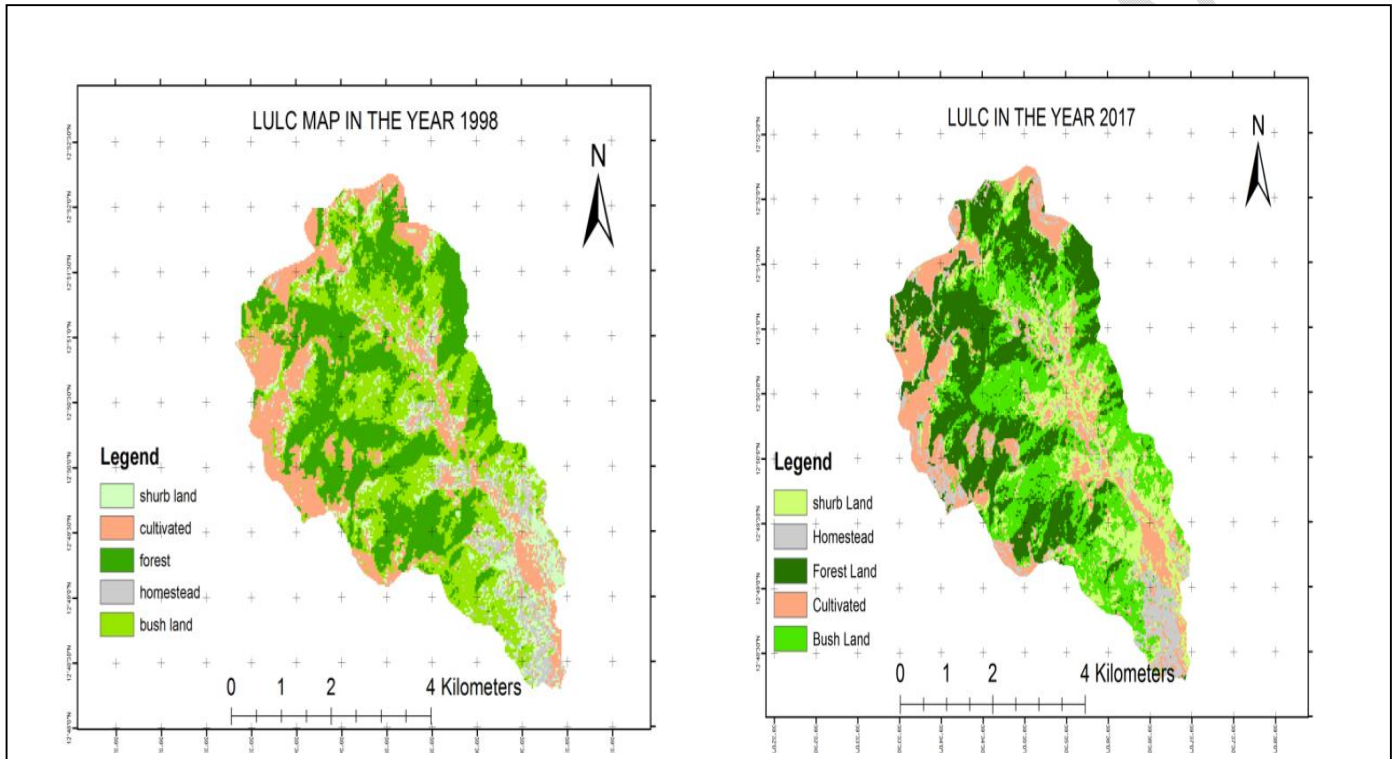


Figure 6 Land cover map of the study periods

Table 3 Land covers classes of coverage in each date of study image

Land cover type	Land cover in each year image of 1998 and 2017			
	1998		2017	
	ha	%	ha	%
Forest	819	32.3	730.3	28.8
Cultivated	509	20.1	464.5	18.3
Bushland	776	30.6	727.7	28.7
Shrub land	272	10.7	381.1	15

Homestead	160	6.3	232.4	9.2
Total	2536		2536	

Analysis of the results revealed that bushland was the dominant land cover class, accounting for 30.6% in 1998 and 28.7% in 2017, while forest land comprised 32.3% in 1998 and 28.8% in 2017. According to the table, only about 20% of the land cover was dedicated to cultivation in 1998, decreasing to 18% in 2017. This decline can be attributed to the implementation of exclosures and land rehabilitation programs, which protected large areas to enhance vegetation coverage during this period. Eskinder et al. (2017) reported a similar trend, noting that cropland coverage decreased by 21.4% between 1984 and 1995. Tewabe and Fentahun (2020) also observed an increasing trend in residential/homestead areas, rising by 9.1%, while forest and bushland experienced declines of 2.3% and 9.8%, respectively. The unsustainable use of forests and illegal construction for resettlement led to reductions in land use coverage for forest, bush, and cultivated areas, dropping by 3.5%, 1.9%, and 1.8%, respectively. Additionally, a dramatic reduction in woodland cover occurred, falling from 8.35% to 0.28%, and grassland cover dropped from 7.75% to 0.91% between 1972 and 2007 (D. Tsegaye et al., 2010).

3.2. The extent and rate of land use and land cover change

As shown in Table 4, shrub and homestead land cover increased from 10.7% to 15% and from 6.3% to 9.2%, respectively. The increase in shrubland primarily resulted from the conversion of bushland and forest land, which are utilized by the population for economic activities, construction, and agricultural purposes. Conversely, the rise in homestead areas was directly linked to the conversion of cultivated land due to new resettlements following single marriages. Most of the resettlement construction in the study area occurred on previously cultivated land. Consequently, the size of cultivated and forest land decreased by 8.7% and 10.8%, respectively, from 1998 to 2017 (Table 4). Additionally, bushland cover declined by 6.2% during the same period. Miheretu et al. (2018) and Terefe et al. (2016) reported similar findings, noting a 14.7% decrease in forest cover between 1973 and 1986, and a further decline of 38.5% between 1986 and 2001. In contrast to the increase in shrubland, shrub areas were reduced by 25.9% from 2001 to 2015, as they were largely converted to cultivation and settlement during this timeframe. The changes in land use and land cover were also mapped (see Figure 6).

Table 4 Changes in land use and land cover from 1998 to 2017

LULC	1998		2017		LULC changes b/n 1998 and 2017		Rate of change Ha/yrs.
	Area (ha)	%	Area (ha)	%	Area (ha)	%	
Forest	819	32.3	730.3	28.8	-88.7	-10.8	-4.4
Cultivated	509	20.1	464.5	18.3	-44.5	-8.7	-2.23
Bushland	776	30.6	727.7	28.7	-48.3	-6.2	-2.42
Shrubland	272	10.7	381.1	15	109.1	40.1	5.46
Homestead	160	6.3	232.4	9.2	72.4	45.3	3.62
Total	2536	100	2536	100	-	-	-

Where he stands for hectares and yrs. is also for years.

The results of the land use and land cover change matrix illustrate both the direction of change and its persistence. The change matrix is presented in Table 5, where the columns represent the categories from the initial study year, while the rows contain the categories from the final study year.

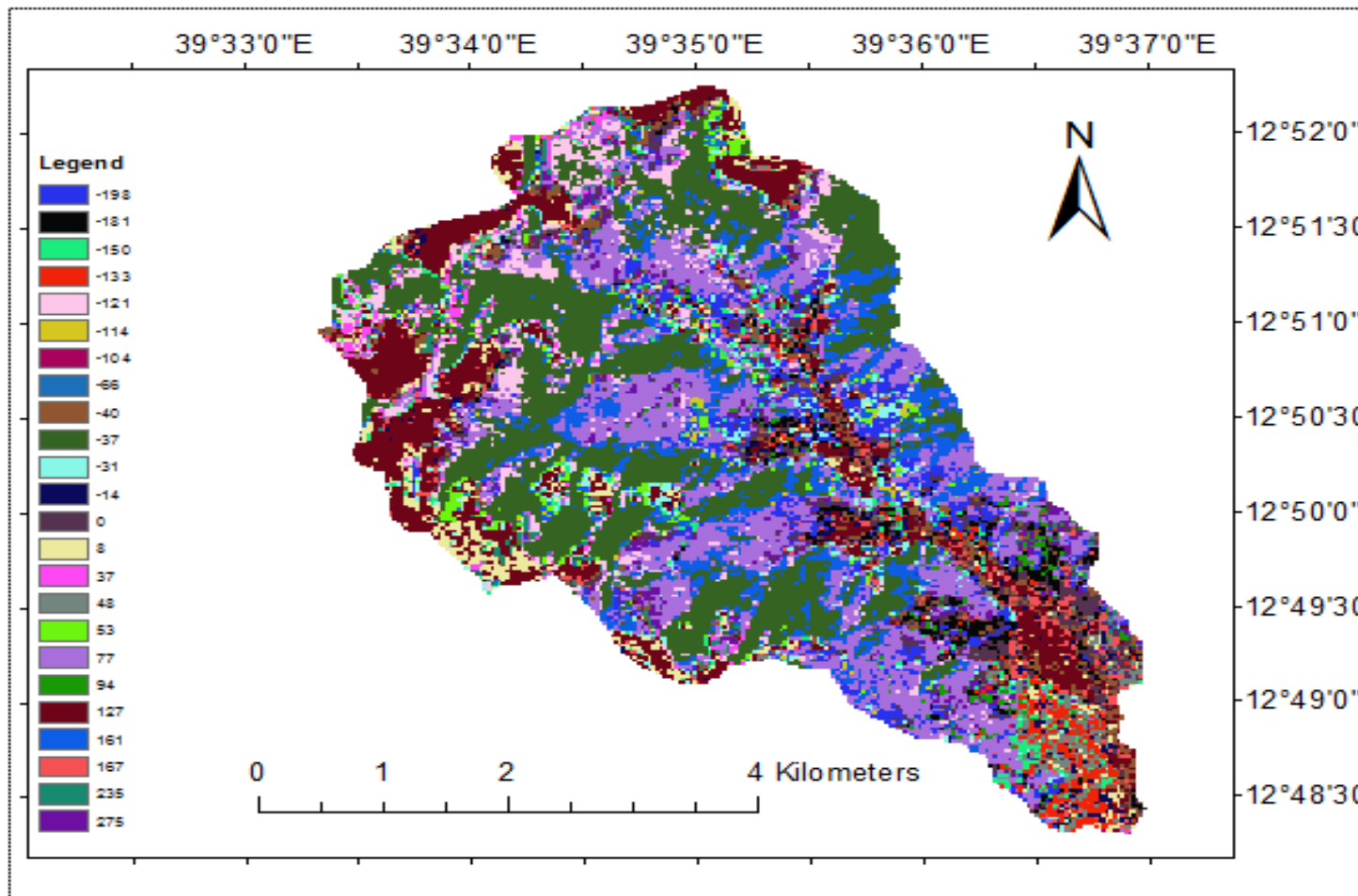


Figure 7 Map of land use and land cover change

Table 5 Summary of LULC change matrix in ha from 1998 to 2017.

From TO	Forest land	Cultivated land	Bushland	Shrub land	Homestead	Total (2017) ^b
Forest land	730	0	0	0	0	730
Cultivated land	0	432.5	20	0	12	464.5
bushland	59.2	61.5	572	15	20	727.7
shrub land	14	15	89	253.1	10	381.1
Homestead total(1998) ^a	15.8 819	0 509	95 776	4 272	118 160.3	232.4 2536

The total sum of the rows represents the amount of land cover for each land use and land cover (LULC) category in the initial study year (1998). Similarly, the total sum of the columns reflects the amount of land cover for each LULC category in the final study year (2017). The changes in land use from one LULC category to another are indicated in each cell of the table. Consistent with these findings, Abate et al. (2011) reported that forest land transitioned into shrubland and bushland, while shrubland shifted into bushland and cultivated land.

3.3. Level of Accuracy assessment

The overall accuracy, kappa coefficient, user accuracy, and producer's accuracy for the year 2017 are summarized in the following table. Overall accuracy reflects the overall results of the confusion matrix and is calculated by dividing the total number of correct pixels (the diagonal values) by the total number of pixels in the matrix. According to Anderson (1976), a minimum accuracy of 85% is required for reliable land cover classification. However, accuracy levels deemed acceptable by some users may not be considered sufficient for others in specific tasks (Geremew, 2013). The kappa statistic is utilized to measure the agreement between two sets of categorizations within a dataset (see Table 6) and to evaluate the accuracy of predictive models by comparing the predictions to a set of field-surveyed sample points (Moriassi et al., 2007).

Table 6 Level of kappa coefficient of agreement

LULC 2017	Reference data					Total	Classification accuracy (%)	
	FL	CL	BL	SL	HS		User's accuracy	Errors of commission
FL	46	0	3	1	0	50	92	8
CL	0	51	0	2	1	54	94.4	5.6
BL	3	4	45	3	0	55	81.8	18.2
SL	1	5	2	33	1	42	78.6	21.4
HS	0	0	0	1	13	14	92.9	7.1
Total	50	60	50	40	15	215	-	60.3
PA	92	85	90	82.5	86.7			
EO (%)	8	15	10	18	13.3			
OA (%)	87.4							
KC	0.84							

Where PA = producers' accuracy, EO = error of omission, OA= overall accuracy and KC = kappa coefficient

4. Conclusions and Recommendations

In this study, LULC detection of Wojic watershed over the last two decades was analyzed. The result of the study showed that significant change detection had been observed during the study period. Shrub land and residential/homestead areas showed an increasing trend of 5.46 and 3.62%, respectively, while forest, bush land, and cultivated areas showed a decreasing trend of 4.4, 2.42, and 2.233%, respectively. This result discovered that the change of forest, bush land, and cultivated land to shrub and residential/homestead areas may cause problems, including changes in stream flow, soil degradation,

and hydrological systems in the watershed. These changes could have implications for sustainable resource management and the livelihood of the local society. Therefore, developed land management practices (soil and water conservation), reinforced agricultural inputs, integrated watershed management (land use planning and management), and active participation of the local community should be advanced to prevent undesirable LULC dynamics in the watershed. In this study, the change detection analysis using GIS and remote sensing could deliver useful information to understand the seasonal patterns of land use dynamics for planners and decision makers; consequently, sustainable land management planning is possible.

Based on the study the following points are recommended:

- Forest land is highly decreased while the correspondent shrub land and homestead is increased in the last two-decade years (1998-2017) and this has to be needed preserve the forest area through protection and afforestation.
- Increasing forest cover through tree plantation and natural regeneration should be encouraged and deforestation must be prohibited in all watersheds of Tigray region.

Disclaimer (Artificial intelligence)

I have hereby declare that generative AI technology have been used during the grammere editing of the manuscript.

Details of the AI usage are given below:

1.poe assistant, it is used online

Reference

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