Environment and Natural Resources Research; Vol. 13, No. 1; 2023
ISSN 1927-0488 E-ISSN 1927-0496
Published by Canadian Center of Science and Education

Spatiotemporal Dynamic of Land Use/Land Cover Changes and Their Drivers in the Fincha’a-Neshe Sub-Basin, Southeastern Blue Nile Basin, Ethiopia

Habtamu Abebe[1,3], Asfaw Kebede[1], Tena Alamirew[2] & Gizaw Desta[2]

[1]Harmaya Institute of Technology, Haramaya University, Ethiopia

[2]Water and Land Resources Center, Addis Ababa University, Ethiopia

[3]Natural Resource and Environmental Engineering, Wollega University, Ethiopia

Correspondence: Habtamu Abebe, Haramaya University Institute of Technology (HiT), Haramaya University, P.O. Box 138, Dire Dawa, Ethiopia. Tel: 251-911-715-676. ORCID: 0000-0002-6071-8132

Received: January 10, 2023 Accepted: March 20, 2023 Online Published: March 30, 2023

doi:10.5539/enrr.v13n1p1 URL: https://doi.org/10.5539/enrr.v13n1p1

Abstract

It is paramount to evaluate the spatiotemporal dynamics of land use and land cover (LULC) changes and their drivers. This is because it helps generate information on biodiversity, land productivity, ecology, and livelihoods for decision-making. Due to land degradation, deforestation, shifting cultivation, high population pressure, and the three national megaprojects (NMPs), the Fincha'a Neshe sub-basin (FNSB) LULC, changes may be unprecedented. This study aimed to investigate the spatiotemporal dynamics of LULC changes and their drivers using remote sensing (RS) data and geographic information systems (GIS). Landsat images 5, 7, and 8 were used for the discrete periods of 1986, 2000, and 2016, respectively. Field observations (Ground control points) and interviews were conducted with key participants to validate the data. Supervised classification with a maximum likelihood algorithm was used to classify the Landsat imagery. The results showed that the FNSB experienced substantial changes in LULC between 1986 and 2016, of which 13.8% (457.3 km^2) were due to NMPs. The cropland cover has expanded by 694.4 km^2 (57.81%) at a rate of 24.60 km^2 year^{-1} at the expense of shrubland, forest, wetland, and grassland. In contrast, shrubland, forest, wetland, and grassland have declined at the rates of 16.8, 3.9, 3.4, and 1.7 km^2 year-^{1} over the entire study period. Population growth and NMPs were the principal drivers of the changes in the LULC of the sub-basin. Thus, the LULC transformation rate observed in the sub-basin requires due attention and mitigation strategies, as it might seriously threaten the sustainability of natural resources and NMPs.

Keywords: land use/land cover change, change drivers, change detection, Fincha’a Sub-basin, Ethiopia

1. Introduction

Ethiopia is Africa’s second-most populated country and has experienced significant LULC changes (Genet, 2020). However, the problem of land cover dynamics is more severe in the Ethiopian highlands. These highlands account for 44% of the country’s landmass and have been cultivated for millennia (Hurni et al., 2005), as in the study sub-basin (Ayana et al., 2014). These highlands have greater potential for cultivation and are preferred for settlements. The greatest potential of highland areas for agricultural production and their suitability for settlement may accelerate the transformation of natural vegetation into agricultural land and human settlements. Population growth, resettlement programs, and climate change are the primary causes of the fast-changing LULC in the Ethiopian highlands (Regasa et al., 2021). Furthermore, other human and natural driving forces may also play a significant role (Yesuph & Dagnew, 2019).

Therefore, changes in LULC affect life support functions and human lives (Othow et al., 2017; Regasa et al., 2021). It has diverse environmental impacts, negatively affecting the water supply, reservoir storage capacity, agricultural productivity, and regional ecology (Chen et al., 2021; Tadesse et al., 2017). Changes resulting from anthropogenic (human activities) and natural (earthquakes, landslides, droughts, and floods) factors may have influenced the LULC dynamics (Solefack et al., 2018) and are principal drivers. Anthropogenic activities are main factors affecting the natural conditions of landscape resources and have detrimental effects on the environment and livelihoods (Regasa et al., 2021), and are the principal drivers of LULC changes (Alemayehu et al., 2019). These include deforestation, wetland drainage, overgrazing, agricultural land expansion, and expansion of industrial and urban areas. They affect human survival and development and raise widespread societal concerns. Complex interactions among socioeconomic, cultural, and policy factors in the biophysical environment have caused LULC changes (Islam et al., 2018; Oo et al., 2019).

Changes in LULC can be caused by the interactions among human activities, natural resources, and terrestrial resources (such as soil, water, and biodiversity). These changes may involve the conversion of grasslands and forests to croplands, pollution, land degradation, vegetation clearance, and transformation to agriculture (Dagnachew et al., 2020; Degife et al., 2019; Islam et al., 2018; Oo et al., 2019). The rate at which these changes occur may threaten ecosystem sustainability and livelihoods (Findell et al., 2017). Thus, changes in LULC are a growing concern of many researchers as they affect the well-being of a nation. For example, it affects biodiversity, hydrological cycles, land productivity, and environmental sustainability (Tariq et al., 2021). Thus, a country must have sufficient information on land resources to determine their use in many interrelated aspects. One such endeavor is LULC change analysis, which discloses the changes between and within the LULC and its associated impacts. Therefore, acquiring reliable and trustworthy information is essential to overcoming haphazard and uncontrolled developmental challenges. This information could help to manage environmental quality, minimize the loss of prime agricultural land, destruction of important wetlands, and loss of fish and wildlife habitats.

Here, scrutinizing trend changes and acquiring up-to-date information is vital; thus, modern technologies such as RS data and GIS tools have emerged. They have been used to estimate and monitor LULC changes in different parts of Ethiopian uplands (Abebe et al., 2022; Halefom et al., 2018). They enable the detection of heterogeneity in the direction, pattern, and magnitude of the LULC changes. Several research projects on LULC changes have been conducted in Ethiopia using these data and tools and have examined LULC dynamics and related determinants, revealing that LULC changes have resulted from rapid population growth (Ganaie et al., 2021; Genet, 2020). Similarly, some studies have been conducted on the FNSB using RS data and GIS tools (Ayana et al., 2014; Tefera & Sterk, 2010). They attempted to assess LULC cover changes and disclosed past changes but did not include the present changes and the significant impact of three NMPs (i.e., Fincha'a hydroelectric power plant (FHEPP) and Neshe hydroelectric power plants (NHEPP) and Fincha'a Valley Sugar Estates (FVSE)) on LULC changes in the sub-basin. These uncomprehended efforts may result in a lack of complete understanding of the cause and effect, magnitude, and spatiotemporal distribution of LULC changes and their analyses, which were far from complete. Thus, these studies may not provide comprehensive and trustworthy information for decision-making for subsequent interventions and developmental endeavors. Therefore, the present study investigated the spatiotemporal dynamics of LULC changes, the impacts of three NMPs on LULC changes, and the implications of these changes. In addition, the study attempted to leverage more computer power and better resolution data to deliver trustworthy information to support decision-making (Ayana et al., 2014).

Furthermore, the sub-basin is worth examining in a broad sense because it 1) is a typical representative of the western highlands of Ethiopia in terms of various environmental attributes such as topography, soil, climate, and socioeconomic conditions; 2) has experienced substantial land deterioration as a result of overgrazing and deforestation; 3) is upstream of the Grand Ethiopian Renaissance Dam (GERD); and 4) has three established NMPs. Therefore, it is essential to thoroughly investigate the spatiotemporal dynamics of LULC changes, including how the established NMPs affect them. Thus, the objectives of this study were to: (1) assess the spatiotemporal dynamics, detect changes and rate of changes in LULC; and (2) analyze the repercussions and determine the factors that cause LULC changes in line with NMPs in the sub-basin between 1986 and 2016.

2. Materials and Methods

2.1 Study Area Description

The FNSB is located in the southeastern Blue Nile, upstream of GERD. The drainage area of the sub-basin is 3,313.7 km^2 and is geographically located between 9°9′53″N and 10°1′00″N latitude and 37°00′25″E and 37°33′17″E longitude (Fig. 1).

The major landforms of the sub-basin are flat to sloping, undulating plains, hills, and mountains. Steep slopes characterize the western half of the sub-basin. A valley floor with flat to gentle slopes was the dominant feature characterizing the lower part of the sub-basin. The elevation ranges from 869 to 3,212 meters above sea level (Fig. 1) and has a tropical monsoon climate with an average annual rainfall of 1,677 millimeters. The rainy season extends from June to September, with peaks occurring from July to September. It is dry from November to March. The sub-basin frequently experiences storms and flash floods during the rainy season. The annual minimum and maximum temperatures for the FNSB are 11.9 °C and 24.2 °C, respectively. The major parts of the sub-basin are cultivated intensively. Teff, maize, barley, and wheat are the principal crops grown in this sub-basin. FNSB has a wide range of soil types dominated by clay-loam, clay, and loam textural classes. Clay soil associated with swamps and temporary wetlands on plains has good-to-moderate fertility. These are characteristics of the most significant parts of the sub-basins. The rest of the catchment is continuously cultivated with low soil fertility (Ayana et al., 2014).

2.2 Data Sources and Method of Acquisition

In this study, two primary data sources were used to assess the LULC changes and their drivers. These data sources included remote sensing and population data. This section describes the data sources, collection methods, and processing procedures.

2.2.1 Population Data

Population data were compiled from census reports of the Central Statistical Agency (CSA) of Ethiopia (CSA, 1991, 1998, 2007). Population data were collected and prepared: a) following the administrative boundary in which the sub-basin was embedded; and b) census data for 1984, 1994, and 2007 were projected to the study periods of 1986, 2000, and 2016 by calculating the growth rate as stated by CSA (2007). The projected population size for each study period was estimated based on the growth rate using equation 2 (Bewket, 2002; Gashaw et al., 2014b).

$$r = \frac{1}{t}\ln\left(\frac{P_2}{P_1}\right) \tag{1}$$

where P_1 is the present population, P_2 is the future population, r is the growth rate in percentage, and t is the number of years between the future and present censuses.

$$P_2 = P_1(1+r)^t \tag{2}$$

Where; P_1 is the present population, P_2 is the future population, r is the growth rate in percentage, and t is the number of years between the future and present censuses.

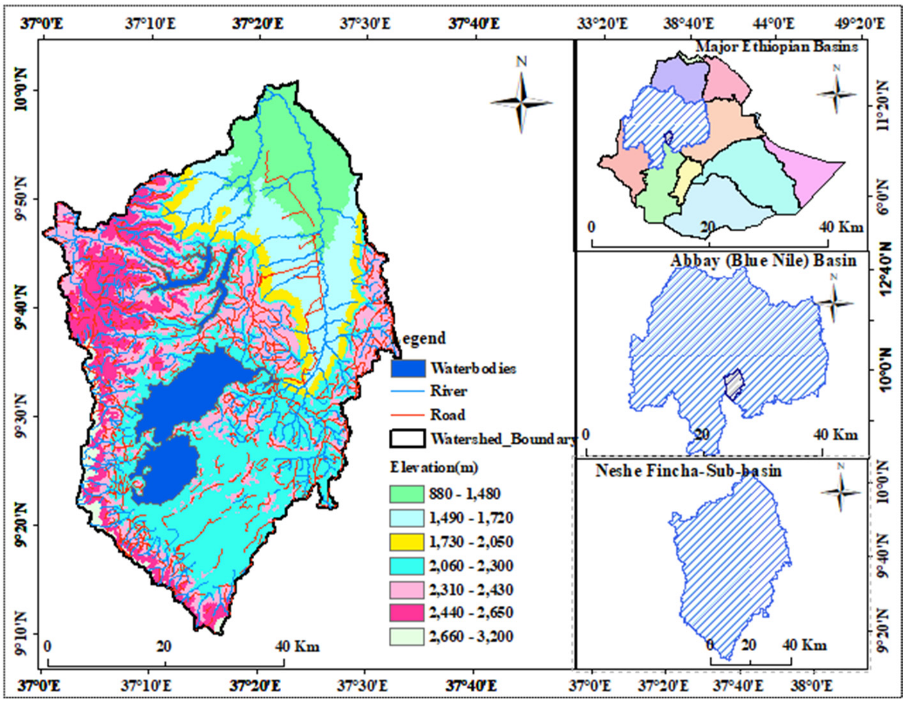

Figure 1. Location Map of the Fincha'a-Neshe sub-basin, Southeastern Blue Nile Basin, Ethiopia

2.2.2 LULC Data

Table 1 provides details of the Landsat data used in this study. In this study, LULC change analysis used ancillary and satellite data. The ancillary data included ground control points, Google Earth data, and topographic maps of the sub-basin at a scale of 1:50000. The satellite data included Landsat 5, Landsat 7, and Landsat 8 for the discrete study periods of 1986, 2000, and 2016, respectively. The study period dates closer to cloud-free imagery accessed from the UGS Earth Explorer used for the study. Field observations, informal interviews, and discussions that helped to generate information in line with the drivers of LULC changes were used.

Table 1. Description of Remote Sensing Data (spatial data) Used for LULC Classification

Image	Acquisition date	Sensor	Path/Row	Resolution	Source
Landsat 5	01/12/1986	TM	169 and 170 /53,54	30 m	Earth Explorer
Landsat 7	02/03/2000	ETM+	169 and 170 /53,54	30 m	Earth Explorer
Landsat 8	01/12/2016	OLI _TIRS	169 and 170 /53,54	30 m	Earth Explorer

2.2.3 Image Pre-processing and Classification

In this study, image pre-processing techniques, such as image enhancement and geometric correction, were performed using the method proposed by Lillesand et al. (2015). This method includes assigning the coordinate system, stacking layers of the separate bands of the datasets, and sub-setting the images. The software packages ERDAS IMAGINE 2014 and ArcGIS10.4.1 were used to complete the pre-processing and post-classification analyses.

Table 2. A Detailed Description of each Land Use/land Cover Type in the Fincha'a-Neshe Sub-basin

No	LULC name	Description
1	Cropland (AGRL)	Cropland may be defined broadly as land used primarily for the production of food and fiber; this category includes both cultivated and non-cultivated lands
2	Bare-land (BARR)	It is a land of limited ability to support life and in which<1/3 has vegetated
3	Forest land (FRST)	This category includes all land with woody vegetation consistent with thresholds used to define Forest Land in the national greenhouse gas inventory.
4	Grassland (RNGB)	Generally, open and continuous flat areas are dominated by grasses, including rangeland and pasture land that is not considered cropland.
5	Settlement (URBN)	Areas of intensive use with much of the land covered by structures.
6	Shrubland (RNGE)	Land with shrubs/bushes canopy covers ≥ 10% or combined cover of bush, shrubs, and trees ≥10%.
7	Water bodies (WATL)	Oceans, lakes, streams
8	Wetland (WETL)	Areas of peat extraction and land covered or saturated by water for all or part of the year (e.g., peat lands) do not fall into the forest land, cropland, grassland, or peat land categories.

Hybrid classification methods involving unsupervised and supervised techniques algorithms were used for image classification. The unsupervised classification was performed before the fieldwork to obtain general insights into the land cover classes in the sub-basin. It is an automated classification system that does not require knowledge of the study site. This enabled us to determine the features that showed the overall LULC clusters of pixels. A supervised classification with a maximum likelihood algorithm was used to classify the images based on the training sets (signatures). The training data set provided by the user directs the software to detect pixels for known land cover types. Thirty to forty training samples were used for each classification. The re-coding work was applied to merge spectrally distinct classes to redevelop the final information classes. Following this classification, eight LULC classes were identified: bare land, cropland, forest, grassland, settlement, shrublands, water bodies, and wetlands. Table 2 presents a detailed description of each LULC type in the sub-basin. Visual interpretation elements and reflectance characteristics of the features in the satellite images from 1986, 2000, and 2016 were used to select the LULC types.

2.3 Accuracy Assessment

The accuracy of thematic maps created using remotely sensed data is vital in most mapping projects. It provides a guide for the quality of a map and its suitability for specific purposes (Congalton & Green, 2019). Therefore, the decision to use a map significantly depends on its accuracy. Collecting reference data (RD) is the first and most important step for any accuracy assessment. Thus, Google Earth and GPS field data from the study site were the data sources for the RD. The RD, independent of the ground truth, was the data source used in the classification scheme. Furthermore, RD should be reliable in making meaningful assessments. Error matrices were used to validate the quality and reliability of the RD. Four tools: Kappa statistics, overall accuracy, user accuracy, and producer accuracy were used.

Kappa statistics and overall accuracy were used to assess the overall classification performance and the user and producer accuracies were used to assess the individual LULC classes (Congalton & Green, 2019). The descriptions and calculations of these terms have been explained by several researchers (Congalton, 2018; Gu & Congalton, 2019). This study determined the accuracy of the three-time steps (1986, 2000, and 2016) of the classified maps. The final maps were produced to achieve the lowest overall accuracy of 85% (Anderson, 1976). A comparison of map features and matrix analysis was performed to define LULC change detection (Lu et al., 2014). In this case, the areas of the LULC categories converted from each class to any other class, and the changes in direction and magnitude were determined.

2.4 Land Use/Land Cover Change Detection Analysis

After the accuracy assessment, maps showing detailed LULC changes in FNSB were produced. The maps produced from the image classification periods of 1986, 2000, and 2016 were used to analyze LULC changes. The various steps developed and used to analyze, quantify, and interpret the map are presented in Fig.2. To validate the data collected on LULC changes in the subbasin, focus group discussions, and informal interviews were conducted. Elderly people believed to have a better historical understanding of the changing LULC trends in the sub-basin were selected. After classifying the images, the spatial distribution of the LULC classes was calculated for each period and the extent of change in land use within and between periods was compared. Changes in the different LULC classes were analyzed using ArcGIS10.4.1, TerrSet-20, and ERDAS IMAGINE2014. The rate of change (km^2/year) and the percentage change in each class during the study period were determined using the formula described by Gashaw et al. (2017).

$$R=\frac{Y_2-Y_1}{N} \tag{3}$$

Where R is the Rate of change; Y_1 is the earlier area of LULC features in km^2, Y_2 is the most current area of LULC features in km^2, and N is the Time interval between Y_2 and Y_1 in Years

$$\Delta A=\frac{(At_2-At_1)*100}{At_1} \tag{4}$$

where ΔA is the percentage change in the area of the LULC class between the initial (t_1) and final (t_2) periods; At_1 is the Area of the LULC class at the initial time; and At_2 is the Area of the LULC class at the final time.

Pixel-based comparisons were conducted to obtain information on changes within each pixel. The most common approaches proposed methodologies were utilized to interpret the changes more, taking “from-to-to” information (Alshari & Gawali, 2021; Olmanson & Bauer, 2017; Singh et al., 2015). By coding the classification results for discrete study periods, the analysis produced a change map showing a complete matrix of changes (e.g., from wetlands to cultivated land and grasslands to forests). In addition, a post-classification approach that reduces the problem of radiometric calibration between dates has been used (Ban & Yousif, 2016; Mishra et al., 2017). A change matrix (Zhang & Weng, 2016) was made with the help of the TerrSet v-20 (Geospatial Monitoring and Modeling System) software. Quantitative data for each LULC were collected in 1986, 2000, and 2016 to determine the gains and losses for each LULC category and this information is an indispensable tool for management decisions.

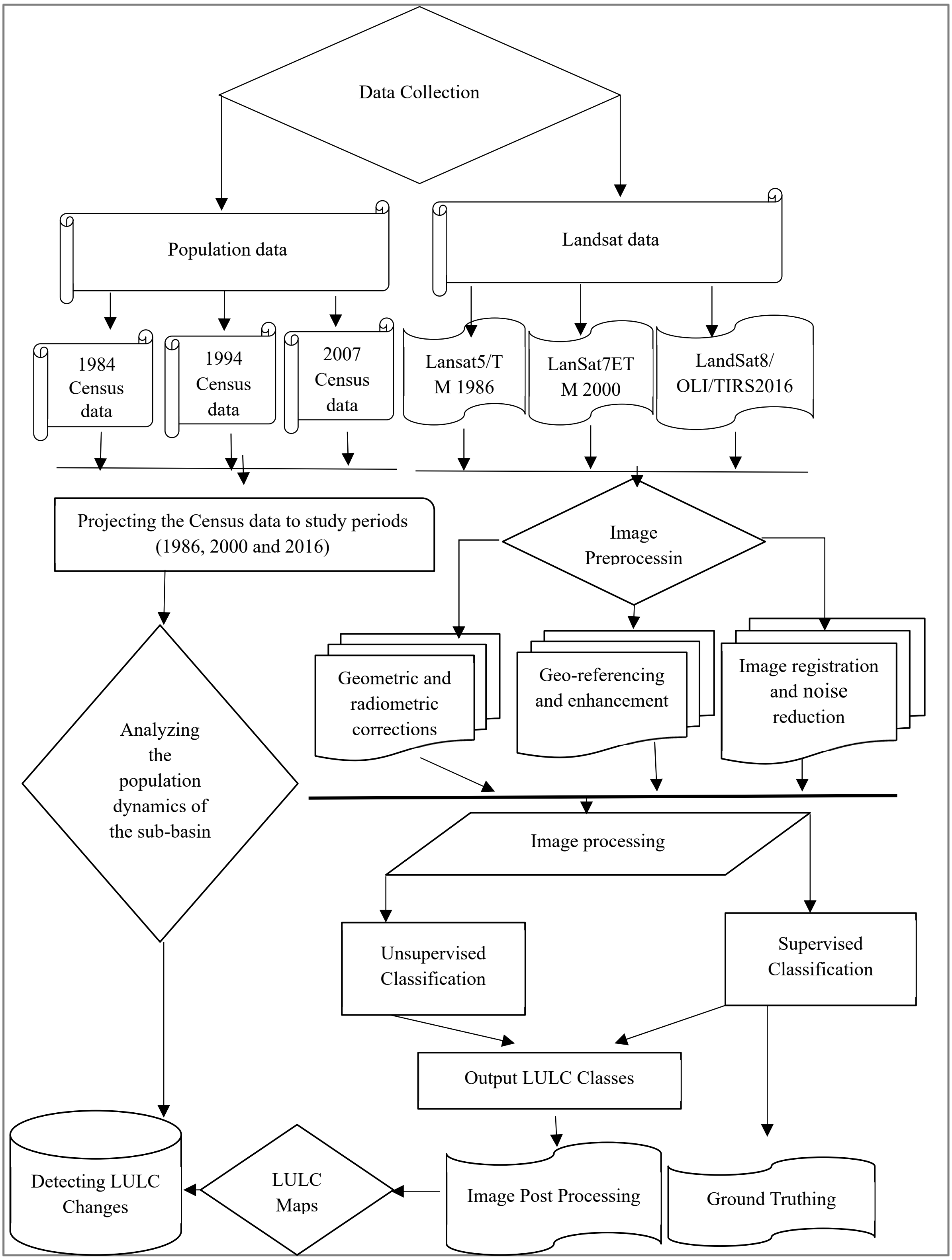

Figure 2. Schematic Flow Chart for the Classification and Analysis of Images

3. Results and Discussions

3.1 Land Use/land Cover Maps Accuracy Assessment

This section evaluates the classification accuracy of the LULC class maps to determine their applicability for land use planning and development. Consequently, for each LULC class over distinct study periods, the assessment estimated the user and producer accuracies. The grassland cover of the sub-basin had the lowest accuracy values for both users and producers. This lower accuracy assessment result might be attributed to the reflectance similarity of grasslands with other land cover classes. For example, Sahalu (2014) reported that other land cover classes appear as agricultural land and vice versa. Václavík and Rogan (2009) reported that agricultural land was the most challenging to classify because it contained a mix of crops at different phenological stages. In contrast, as shown in Supplementary Tables (Table S1, S2, and S3), barren land, settlements, and wetlands had the highest user and producer accuracy. Table 3 presents the overall accuracy assessment values and Kappa statistics of the classified maps for each study period. The overall classification accuracy showed that the categories were well-aligned, and the Kappa Statistics ranged from very good to excellent. As the developed LULC maps satisfied the bare minimum requirement of 85% accuracy for LULC analysis, the findings of the overall accuracy assessment showed that the generated maps could serve well. The resulting maps can then be used for change detection analysis because they show a strong agreement between the categorized LULC classes and geographical data (ground truths).

Table 3. Overall Accuracy Assessment and Kappa Statistic Values of the Classified Images

Year	Overall classification accuracy (%)	Kappa statistics
1986	87.5	0.77
2000	90.1	0.81
2016	93.7	0.88

3.2 Land Use/land Cover Dynamics (1986-2016)

Table 4 and Figs 3 and 4 present the analysis results of the changes in the LULC classes for the distinct study periods of 1986, 2000, and 2016, respectively. Thus, the cropland class increased from 35.1% in 1986 to 43.3% in 2000 and 57.4% in 2016. It has increased at the expense of forests, shrublands, and grasslands. During the first distinct study period, settlement and bare land increased by 184.8% and 203.4%, respectively. The increase in bare land might be attributed to the decline in vegetative cover of the sub-basin. As a result, the bare land expands, making the sub-basin vulnerable to soil erosion, leading to severe land degradation.

Wetlands are one of the principal land cover types of the sub-basin, accounting for 10.10% of the total land cover. It showed a consistent decreasing trend from 10.1% (334.7 km^2) in 1986 to 8.0% (265.1 km^2) in 2000 and further decreased to 7.0% (232 km^2) in 2016 (Fig. 3 and 4 and Table 4). According to the analysis of LULC changes over the past three decades (1986-2016), 102.9 km^2 (30.7%) of wetlands in the sub-basin were impaired. The decline in wetlands is likely attributable to the increased desire for more land for cultivation, its potential use as grazing land during the dry season when cattle feed is limited, and its unique production potential.

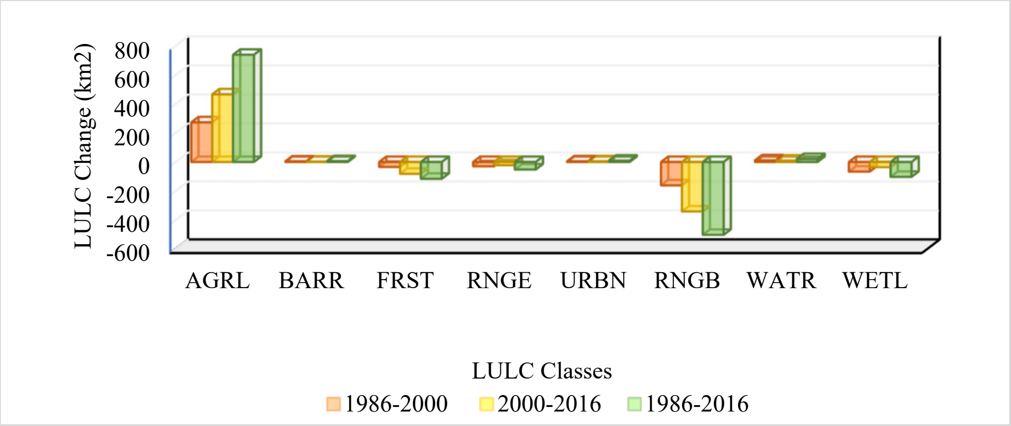

Figure 3. LULC Change of Fincha'a-Neshe sub-basin (1986-2000, 2000-2016, and 1986-2016)

Table 4. The Land Use/Land Cover Dynamic Changes in the Fincha'a-Neshe Sub-basin

	Land use/land cover area (km^2) and% share						Change in land use land cover (km^2) and% share					
LULC-Class	1986		2000		2016		1986-2000		2000-2016		1986-2016	
	Area	%	Area	%	Area)	%	Area	%	Area)	%	Area)	%
AGRL	1163.1	35.1	1436.3	43.3	1902.3	57.4	273.2	23.5	466	32.4	739.2	63.6
BARR	2.9	0.1	6.7	0.2	8.8	0.3	3.8	131.0	2.1	31.3	5.9	203.4
FRST	199.3	6.0	165.0	5.0	83.3	2.5	-34.3	-17.2	-81.7	-49.5	116	-58.2
RNGE	74.6	2.3	44.4	1.3	22.3	0.7	-30.2	-40.5	-22.1	-49.8	-52.3	-70.1
URBN	4.6	0.1	9.0	0.3	13.1	0.4	4.4	95.7	4.1	45.6	8.5	184.8
RNGB	1364.6	41.2	1203.5	36.3	862.0	26.0	-161.1	-11.8	-341.5	-28.4	-502.6	-36.8
WATR	169.4	5.1	180.4	5.4	189.6	5.7	11	6.5	9.2	5.1	20.2	11.9
WETL	335.2	10.1	268.4	8.1	232.3	7.0	-66.8	-19.9	-36.1	-13.5	-102.9	-30.7
Total	3313.7	100	3313.7	100	3313.7	100						

Cropland (AGRL), bare land (BARR), forest (FRST), shrubland (RNGB), grassland (RNGE), settlement (URBN), water bodies (WATR), and wetlands (WETL)

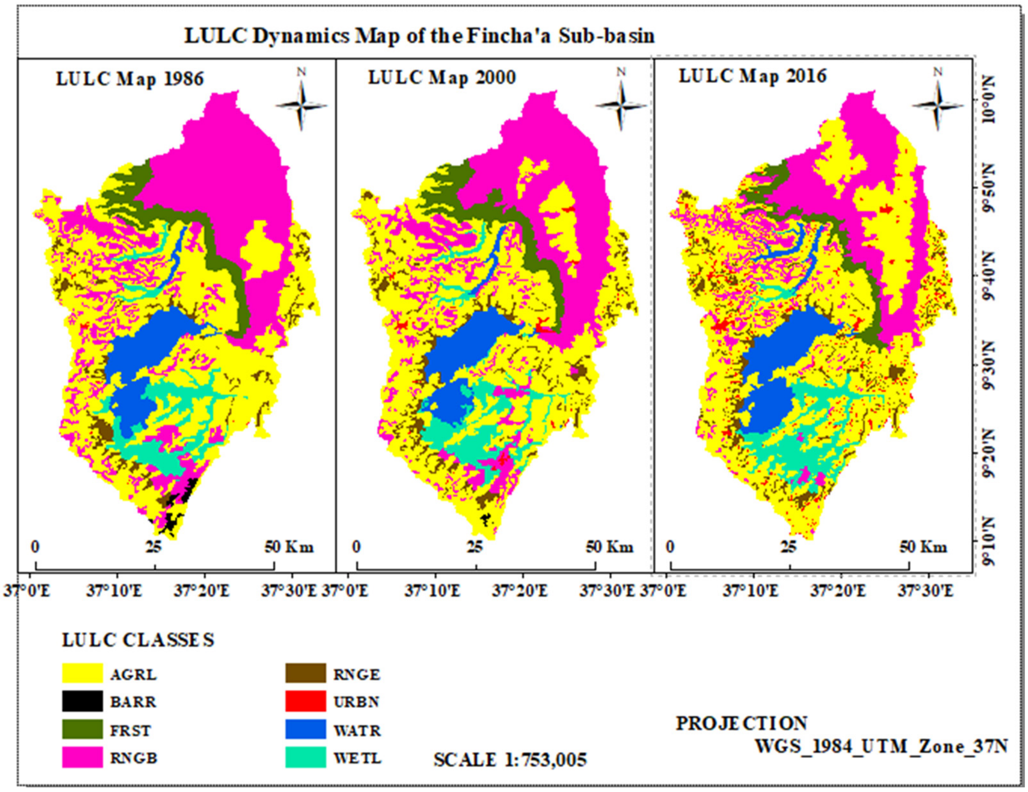

Figure 4. LULC Dynamics Map of the Fincha'a-Neshe sub-basin, 1986, 2000, and 2016

Forest land cover was another dominant LULC class in the sub-basin, covering 6% (199.3 km^2) of the total land cover (Fig 3). However, this land cover declined by 58.2% (116 km^2) over the past three decades (Table 4). This conversion of forest cover to other LULC classes requires immediate intervention that otherwise disrupts ecological balance. Shiferaw and Singh (2011) reported a dramatic expansion of agricultural land and a reduction in forest cover between 1972 and 2003 in the southern Wollo highlands. According to Ayana et al. (2014), the forest cover in the sub-basin decreased by 36,225ha (50.48%) between 1985 and 2005. Shrubland is the first dominant LULC class of the sub-basin and accounted for 41.2% (1364.6 km^2) in 1986 and declined to 36.8% (502.6 km^2) in 2016. Quantitative evidence gathered by interpreting the satellite images showed that the study site experienced significant LULC changes. Shrublands, grasslands, wetlands, and forest land classes showed a significant decline. In contrast, croplands, barren lands, settlements, and water bodies increased during the study period (Table 4; Fig 4, Fig 3). Generally, the conversion in LULC types was vigorous and common across the landscapes. This was because of the wider demands of the growing population, which required more cropland to fulfill the food demand. Meshesha et al. (2016) reported that population growth had transformed the land cover over time.

3.3 Land Use/land Cover Change Detection

Table 5. The Fincha'a-Neshe Sub-basin LULC Transition Matrix (km^2)

	AGRL	BARR	FRST	RNGE	URBN	RNGB	WATR	WETL	TOT (1986)	Loss (km^2)	Loss (%)
	1986 to 2000										
AGRL	**927.6**	8.4	15.4	7.8	3.6	218.7	6.8	12.8	1201.1	273.5	22.8
BARR	4.1	**0.4**	0.6	1.6	0.1	3.4	0	0.9	11.1	10.7	96.4
FRST	15.4	0.2	**115.5**	0.1	0.3	52.8	0.5	7.2	192	76.5	39.8
RNGE	19.7	2	0.2	**32.1**	1.1	11.1	0.3	1.9	68.4	36.3	53.1
URBN	2.5	0	0	0.6	**3.8**	0.7	0	0	7.6	3.8	50.0
RNGB	435.3	2.1	38.4	3.5	3.8	**815.6**	6.3	50.5	1355.5	539.9	39.8
WATR	0.3	0	0.4	0	0	0.8	**168.6**	0.5	170.6	2	1.2
WETL	48.7	0.2	9.8	0.1	0.1	50.4	18.2	**179.7**	307.2	127.5	41.5
Total-2000	1453.6	13.3	180.3	45.8	12.8	1153.5	200.7	253.5	3313.5	1070.2	
Gain (km^2)	526	12.9	64.8	13.7	9	337.9	32.1	73.8	1070.2		
Gain (%)	36.2	97.0	35.9	29.9	70.3	29.3	16.0	29.1			**32.3**
	2000 to 2016										
AGRL	**1284.1**	2	2.5	6	3.8	133.8	1.2	20.2	1453.6	169.4	11.7
BARR	4.9	**6.6**	0.1	0.5	0	1	0	0.2	13.3	6.7	50.4
FRST	42	0	**50.7**	0.1	0	78.1	1.5	8	180.4	129.7	71.9
RNGE	24.7	0	0.1	**13.5**	0	4.6	1.7	1.3	45.9	32.4	70.6
URBN	1.6	0	0.6	0.2	**9.3**	0.9	0	0.2	12.8	3.3	27.3
RNGB	474.5	0.1	29	1	1	**613.1**	7	27.8	1153.5	540.4	46.8
WATR	7.7	0	0.1	0.5	0	3.6	**157.3**	31.6	200.8	43.5	21.7
WETL	55.9	0	0.6	0.1	0	29.7	22.5	**144.8**	253.6	108.7	42.9
Total-2016	1895.6	8.7	83.7	21.9	14.1	864.8	191.2	234.1	**3313.5**	1034.5	
Gain (km2)	611.3	2.1	33	8.4	4.8	251.7	33.9	89.3	**1034.5**	1034.5	
Gain (%)	32.3	24.1	39.4	38.4	34.0	29.1	17.7	38.1			31.2
	1986 to 2016										
AGRL	**1043.4**	7	5.5	5.6	5.7	110.7	5	18.3	1201.2	157.8	13.1
BARR	8.1	**0.4**	0.1	0.4	0	1.2	0.1	0.8	11.1	10.7	96.4
FRST	52.2	0	**44.8**	0	0.1	86	2.7	6.1	191.9	147.1	76.7
RNGE	42	0.2	0.5	**13.4**	0	7.2	2	3.2	68.5	55.1	80.4
URBN	2.7	0	0.2	0	**3.5**	0.7	0	0.3	7.6	3.9	52.7
RNGB	657	0.8	31.4	2.1	4.8	**606.4**	4.8	48.2	1355.5	749.1	55.3
WATR	1.7	0	0.1	0	0	0.3	**143.9**	24.8	170.8	26.9	15.7
WETL	88.5	0.1	1.1	0.2	0.1	52.2	32.7	**132.3**	307.2	174.9	56.9
Total-2016	1895.6	8.5	83.7	21.7	14.2	864.7	191.2	234	**3313.6**	**1325.5**	
Gain (km^2)	852.2	8.1	38.9	8.3	10.7	258.3	47.3	101.7	**1325.5**		
Gain (%)	45	95.3	46.5	38.2	75.4	29.9	24.7	43.5			**40.0**

Land Use/Cover (LULC), Cropland (AGRL), Bare Land (BARR), Forest (FRST), Shrubland (RNGB), Settlement (URBN), Grassland (RNGE), Water bodies (WATR), and Wetlands (WETL).

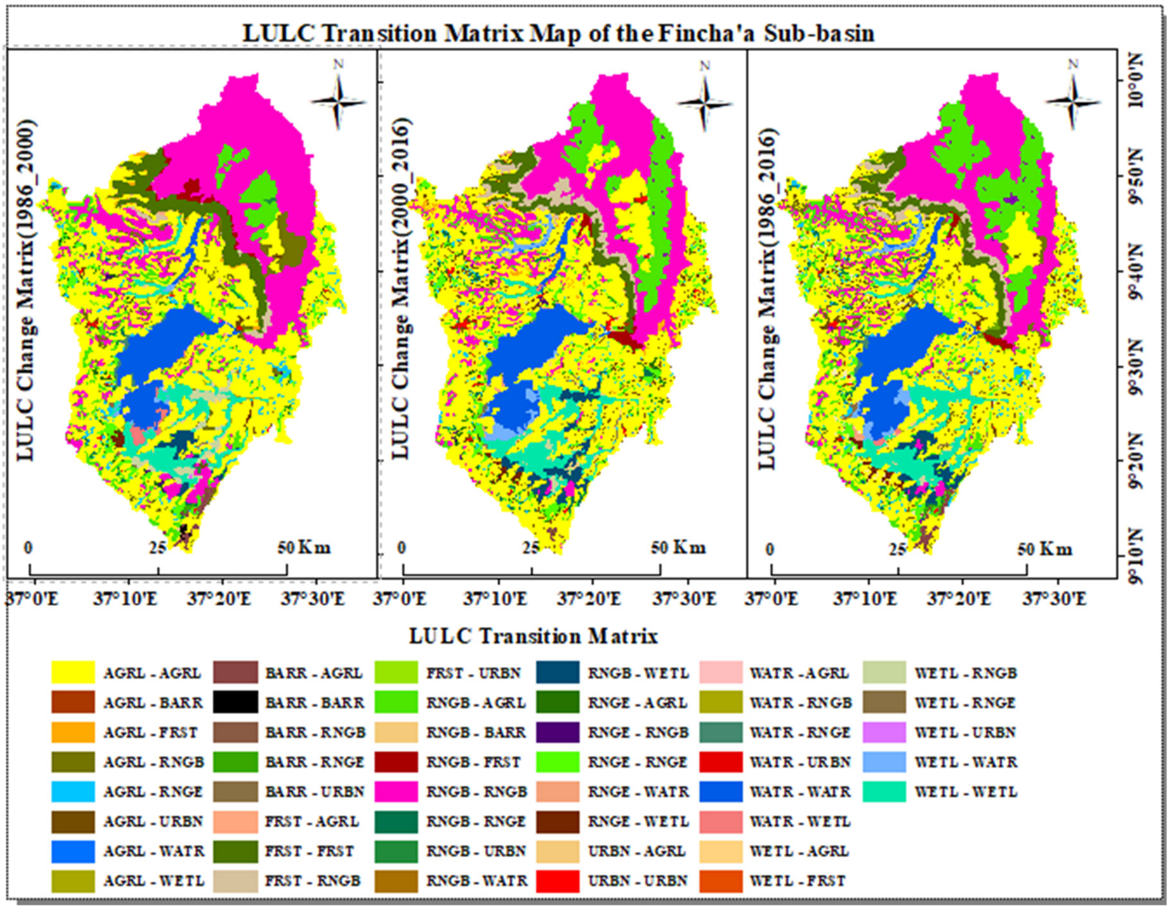

Figure 5. Spatiotemporal Dynamics of LULC Change Matrix Map of the FNSB for the Distinct Study Period

Table 5 shows the matrices of the LULC transformation observed in the sub-basin during the study period. A transformation matrix table was generated for each discrete study period to show the area of each LULC class converted to another. The CROSSTAB module generated using TerrSet-v 20 Geospatial Modelling and Monitoring System software was used for cross-tabulation analysis. During the first study period (1986–2000), shrublands constituted a significant portion of the study area (1355.5 km^2) but later underwent a rapid transformation to other LULC classes, mainly croplands. As a result, cropland cover increased from 36.3% (1201.2 km^2) in 1986 to 43.9% (1453.6 km^2) in 2000. In contrast, the shrubland, grassland, wetland, and forest land cover declined by 14.9%, 33%, 17.5%, and 6.10%, respectively. Croplands gained from shrubland, wetland, forests, bare land, and grassland, respectively, by 435.3, 48.7, 15.4, 4.1, and 19.7 km^2 between 1986 and 2000. In the same period, 8.4, 15.4, 218.7, 3.6, and 12.8 km^2 of cropland cover were transformed into bare lands, forests, shrublands, settlements, wetlands, and grasslands, respectively. In contrast, shrublands has decreased to 202 km^2 (14.9%) from 1986 to 2000, while gaining, 3.4, 11.15, 50.42, 52.80, and 218.7 km^2, respectively, from bare land, grassland, wetland, forest, and cropland in the same period. Thus, the conversion of other LULCs to shrublands did not compensate for the shrinkage during this study period (It lost 539.9 km^2 of its cover to other LULCs and only gained 337.9 km^2 from other LULCs). In general, during this study period, 1070.2 km^2 (32.3%) of the sub-basin experienced an overall LULC change.

The trends in the second and third study periods are presented in Table 5. During the second study period, one exciting event was the decline in bare land from 13.3 km^2 in 2000 to 8.6 km^2 in 2016. The decline in bare land cover may be attributed to the implementation of soil and water conservation practices in the FNSB by the local government. *In general, during the entire study period, 1325.5 km^2 (40%) of the sub-basin LULC experienced a change.* The conversion of natural forests and shrublands to cultivated land may have resulted in considerable losses in natural forests and shrubland cover. Croplands gained most of their cover from the shrublands after conversion. Over the entire study period, cropland has gained a total of 852.2 km^2 from shrubland 657 km^2 (77.1%), wetland 88.5 km^2 (10.40%), and forest 55.2 km^2 (6.1%), and grassland 42 km^2 (4.9%). This finding is consistent with previous studies conducted in the upper Blue Nile basin (Berihun et al., 2019; Betru et al., 2019;

Minta et al., 2018; Wondie & Mekuria, 2018). They reported that the cultivated land expanded at the expense of forests, bushes, and grazing. Relatively, cropland cover increased by 694.4 km^2 (57.81%) over the entire study period, with the greatest increase being registered in the second distinct study period accounting for 30.4% (Fig 5; Table 5).

This study showed that wetlands were converted into croplands and grasslands across the sub-basin. It lost its cover to shrublands, contributing to 47.4% of wetland loss, whereas conversion to water bodies, croplands, and forests accounted for 24.4%, 18%, and 6%, respectively. Studies conducted in other parts of the country and elsewhere have shown that wetlands have declined enormously and have been lost to other LULC classes (Bezabih & Mosissa, 2017; Gebresllassie et al., 2014; Hussien et al., 2018; Moges et al., 2018; Rebelo et al., 2015).

3.4 Rate of Land Use/Land Cover Changes

Table 6 shows the rate of change in LULC in the FNSB over the entire study period. During the first study period, croplands, settlements, and bare lands expanded at rates of 19.5, 0.3, 0.3, and 0.8 km^2 year^{-1}. In contrast, grassland, forest, shrubland, and wetland cover decreased by 2.2, 2.5, 4.8, and 11.5 km^2 year^{-1}. Similarly, the cropland cover increased at a rate of 29.1 km^2 year^{-1} between 2000 and 2016. The analysis showed that shrublands, forests, grasslands, and wetlands had decreased at a rate of 21.3. 5.1, 1.4, and 2.3 km^2 year^{-1}, respectively, in the second study period (Fig 6; Table 6).

When examining forest conversion, shrublands constituted a significant portion, which couldn't be considered an absolute degradation of forest cover. For example, forest, shrubland, and grassland cover losses may have profoundly affected other LULC classes, resulting in erosion-induced land degradation in the sub-basin.

This loss in vegetative cover implies the susceptibility of the NFSB to soil erosion and land degradation and a consequent decrease in the productivity potential of the sub-basin. The continuous decline in the shrubland, forest, and grassland categories may be inversely related to the overall expansion rate in bare land in the sub-basin (Table 6). This expansion rate suggests that the shrinkage of these LULCs directly affected the increase in bare land cover, as observed in this study. Shiferaw and Singh (2011) reported that barren fields increased by 256 ha/year between 1972 and 1985 at the expense of shrubland, forest, and grassland cover. Assefa and Bork (2014); Gashaw et al. (2014a) and Gebrehiwot et al. (2014) reported the same and stated that farmland and settlements expanded at the expense of forests, bare lands, and grazing lands.

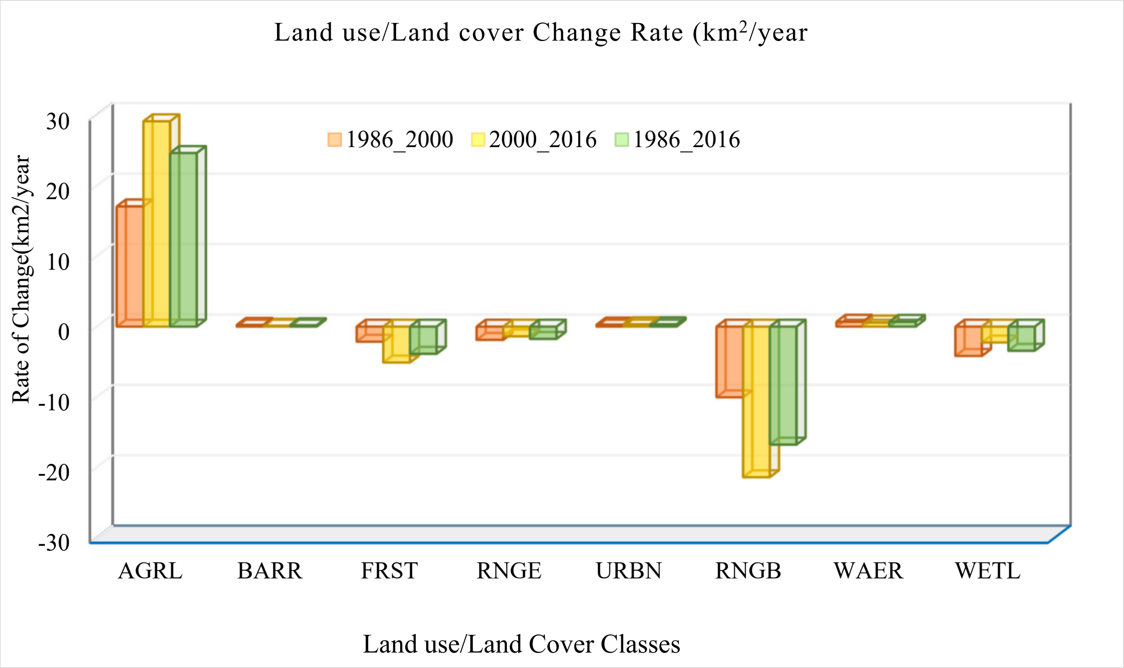

Figure 6. LULC Rate of Change in the Fincha'a-Neshe Sub-basin over the Study Period

Table 6. Rate of Land Use/Land Cover Change of Fincha'a-Neshe Sub-basin

LULC Classes	Rate of change (km^2/year)		
	1986-2000	2000-2016	1986-2016
Cropland	19.5	29.1	24.6
Bare land	0.3	0.1	0.2
Forest land	-2.5	-5.1	-3.9
Grassland	-2.2	-1.4	-1.7
Settlement	0.3	0.3	0.3
Shrubland	-11.5	-21.3	-16.8
Waterbodies	0.8	0.6	0.7
Wetland	-4.8	-2.3	-3.4

3.5 Implications of Land Use/land Cover Changes in Fincha'a-Neshe Sub-basin

Changes in LULC class may not necessarily result in soil erosion or land degradation. However, expanding cultivated land at the expense of other LULC has had undesirable consequences. This study demonstrated that shrublands, wetlands, forests, and grasslands decrease as croplands increase. There might have been a decline in grasslands, which would have left less fodder and resulted in a decline in the number and quality of livestock. This decline in grassland cover may affect livestock productivity by decreasing the food and income from livestock and their products. During the study period, there was a steady decline in grassland cover, limiting the number of animals available for land preparation and transportation. The subsequent decrease in the number of animals resulted in a reduction in the quantity of manure used as a soil fertility amendment, thereby decreasing crop yield. According to studies in the upper Blue Nile basin and elsewhere, the increase in cultivated land at the expense of other LULC categories has detrimental effects on animal productivity and production (Berihun et al., 2019; Hurni et al., 2005; Miheretu & Yimer, 2018; Mulugeta & Legese, 2015).

This study showed that there has been a rapid conversion of LULC classes to croplands. These conversions are associated with the demand for land for crop production to fulfill the food requirements of the growing human population. As land resources are limited, many locals are forced to shift their cultivation to marginal areas. This shift of the cropland towards marginal land might result in intensive erosion, massive degradation, and siltation of water bodies, waterborne diseases, and flood in the sub-basin. In the sub-basin, the LULC class expanded to croplands, grasslands, and barren lands. This shift of LULC class to croplands, grasslands, and barren lands may make fertile soils more prone to erosion and land degradation. Alemu et al. (2015) and Mesene (2017) reported that extensive farming practices coupled with unwise land management practices and limited improved input provision and support for agriculture have brought persistent environmental challenges to watersheds.

The decline in vegetative cover (shrublands, wetlands, grasslands, and forest cover) has caused land degradation and food-insecure subsistence agriculture. During fieldwork, informal discussions with informants confirmed that the productive potential of their land plots had fallen. Reports from agricultural offices have confirmed this finding. Rapid LULC transformations and expansions in croplands and settlements in the FNSB may have caused hydrological, socioeconomic, and environmental problems. Population growth and established NMPs have contributed to the rapid shift in LULC classes in the sub-basin. This shift in LULC might cause a significant loss of natural vegetation and later conversion to croplands and waterbodies in the sub-basin. Tefera and Sterk (2010) reported that 5-8% of the forest cover was devastated because of the resettlement and reallocation of the local population in the sub-basin. Ganaie et al. (2021); Gebrehiwot et al. (2014); Genet (2020) and Kim et al. (2015) reported similar motives for the decrease in forest resources in northwestern Ethiopia due to population growth.

3.6 Drivers of Land Use/land Cover Changes

This study developed two scenarios in line with the drivers of the LULC changes. These scenarios included population growth and NMPs (FHEPP, NHEPP, and FVSE). The first scenario focused on population growth and its direct impact on LULC changes. Here, the sub-basin population growth may be due to the natural growth and establishment of NMPs. Due to the developed NMPs, individuals from every corner of the country and around the globe may migrate to these project areas substantially contributing to the population increase. Consequently, the sub-basin population increased from 257,932 in 1986 to 576,868 in 2016 at an average growth rate of 3.372%, 1.75%, and 2.75% in the distinct study period of 1986, 2000, and 2016 (Table 8).

Subsequently, the population density of the sub-basin was compared to that of its (Ethiopian) counterpart. As a result, in 2016, the population density of the sub-basins was 174.1 persons per square kilometer, compared with 103.6 persons per km^2 in the country (Tables 7 and S4). The increase in population density and the associated land scarcity may have resulted in intense competition over land resources. To fulfill the growing demand of the population, an increase in agricultural production and housing construction is mandatory. Consequently, croplands and settlements have expanded at the expense of forests, shrublands, and grasslands. For example, cropland and settlement increased from 1163.1 km^2 and 4.6 km^2 in 1986 to 1902.3 km^2 and 13.1 km^2 in 2016, respectively (Table 4). The increase in croplands and settlements further pressurized the other LULC classes. Mhawish and Saba (2016) stated that population growth contributed to the expansion of cultivation and degradation. Thus, the growing population may continue to pressure the land cover of the sub-basin. Findell et al. (2017); Gashaw et al. (2014a); Hurni et al. (2005) and Wondie et al. (2016) stated that population growth caused the intensification of land use in rain-fed highlands. This increase in population size has prompted the shortening of fallow periods and the ultimate abandonment of land resources, the conversion of cultivated land into grazing land, and ongoing deforestation. Growing more crops on grazing land reduces the amount of feed available to livestock, which in turn reduces the number of animals and the income from their products.

Furthermore, this study investigated the relationship between population increases, cropland, and settlement expansion. To this end, simple regression and correlation tests were performed. Croplands had a correlation coefficient r^2 of (+) 0.985 and a p-value of less than 0.005 when compared to the population size, indicating a strong association (Table S5). Similarly, the settlement had a correlation coefficient r^2 of (+) 0.96 and a p-value of less than 0.013, indicating a significant association with population size (Table S6). The high positive value of r^2 and small p-value indicate a strong relationship among the competing parameters. These statistical indices demonstrate how population growth affects increases in settlements and agricultural land. As the population increased, more land was required for habituation and agriculture. Therefore, population growth was one of the driving forces behind the LULC changes in the sub-basin. Similar results have been reported by Ouedraogo et al. (2010), Hailemariam et al. (2016), and Fenta et al. (2020), who showed that cropland expansion rates have increased worldwide at the expense of forests, grasslands, and shrublands.

Furthermore, to satisfy the growing population demand, LULC classes (e.g., Forests and forest products) are vital. Population size can, directly or indirectly, influence forest and forest products. This study investigated the relationship between urban and rural housing units and their associated forest and forest product demands. Thus, the growing population demands forests and forest products for infrastructure, housing construction, and cooking. Between 1994 and 2007, 90.4% and 95% of the urban housing units and 94.5% and 95% of the rural housing units used forests and forest products for wall construction (Table S7). Similarly, 96% and 97% of the urban population and 92% and 91% of the rural population, used forests and forest products, respectively, as major sources of cooking fuel in 1994 and 2007. CSA (1998) reported that a higher proportion (98.2%) of housing units in Jimma and East Wollega use firewood/leaves as a major fuel source for cooking. Godfray and Garnett (2014) and Tendaupenyu et al. (2017) reported that a growing population and consumerism are pressurizing agriculture and natural resources.

The second scenario assessed the direct and indirect effects of NMPs on the LULC. Thus, the impact of NMPs was analyzed in line with the LULC dynamics of the sub-basin. Established NMPs can cause LULC changes in two ways: by increasing local population increase and land demand for the NMPs. Because of the established megaprojects, people came to the project site from different corners of the country and subsequently contributed to local population growth. Thus, local population growth and newcomers put excessive pressure on land resources, transforming the land cover into settlements. Additional land was required for the setup and development of these projects. Establishing these NMPs involves tremendous earthmoving and shaping activities that convert the land cover into other classes, thereby triggering soil erosion-induced land degradation. Furthermore, to fulfill their objectives, these projects require extra land. For example, hydropower plants demand more land to accumulate water upstream of the dams for hydroelectric power generation. Two hydropower plants swept 190 km^2 (other LULCs were converted to water bodies) of other land cover classes to spread water upstream of the dam (Table 4). Similarly, the FSVE has swept over 262 km^2 of other LULCs in the sugar cane plantations (SCP) and continues to expand.

Table 7. The Population Number and Population Density of the Study Area

Year	Population size					Pop. Den (Person/km^2)	
	Total	Urban		Rural		Fincha'a [a]	Ethiopia [b]
	Pop.	Pop.	%	Pop.	%		
1984	257,932	16,508	6.4	241,245	93.5	77.8	39.4
1986	275,624	19,724	7.2	255,900	92.8	83.2	42.0
1994	359,372	40,190	11.2	319,182	88.8	108.5	55.2
2000	398,920	47,173	11.8	351,747	88.2	120.4	66.2
2008	462,776	60,724	13.1	402,050	86.9	139.7	83.0
2016	576,868	90,950	15.8	485,918	84.2	174.1	103.6

Source: a= Own work adapted from CSA; b= FAO and World Bank report, 2019

Table 8. The Population Growth Rate of the Study Area

Year	1984-1994 [a]	1994-2007[a]	2007-2016[a]
Annual growth rate (%)	3.372	1.75	2.75
No individual added per annum	8,563	6,253	12,386

Source: a= Own work, calculated

4. Conclusions and Recommendations

The Fincha'a sub-basin is located upstream of the GERD in the southeastern Abbay Basin. The sub-basin underwent significant spatiotemporal changes in LULC, as indicated by a sharp increase or decrease between 1986 and 2016. Croplands were the dominant LULC class over the entire study period and increased by 694.4 km^2 (57.81%) at a rate of 24.6 km^2 per year across the study period. Similarly, the settlement increased from 8 km^2 to 14 km^2 at a rate of 0.3 km^2 per annum. The cropland classes have increased at the expense of grasslands, shrublands, forests, and wetlands. In contrast, shrublands, grasslands, wetlands, and forests declined at rates of 16.8, 1.7, 3.4, and 3.9 km^2 year^{-1} from 1986 to 2016. Compared to other LULC classes, the overall decline in shrub and grassland cover may have affected livestock and crop production. This decline in crop and animal production could have resulted from the reduced livestock feed and the amount of manure required to improve soil fertility. The overall expansion of cropland into shrub and forest lands may have further degraded the vegetative cover of the sub-basin, resulting in new erosion-prone sites. Furthermore, this study assessed the impact of population growth on the natural vegetation in both rural and urban housing units. Of the housing units assessed, both in rural and urban centers, over 90% had used forest and forest products for household energy consumption and construction purposes and hence for natural vegetation (forest and shrubland) degradation.

This study attempted to identify the primary drivers of changes in LULC in the sub-basin during the study period and found that population growth and established NMPs were the main drivers. Due to population growth cropland and settlement expanded significantly to meet the growing demand. The expansion of cropland and settlement caused excessive pressure on the LULC of the sub-basin and triggered changes in the LULC. On the other hand, the three established NMPs (Two hydroelectric power plants (FHEPP and NHEPP) and Sugar Estate (FVSE)) both transformed approximately 452 km^2 (13.8%) of the total land cover of the sub-basin. Established NMPs have displaced and moved the local population to nearby villages, districts, forests, and marginal land. This displacement of the local people may enhance deforestation and the cultivation of marginal lands, thereby increasing soil loss and affecting the hydrology of the sub-basin.

This study suggests the mitigation of the adverse effects of population growth on natural resources by adopting other income-generating off-farm activities (fishing on the two dams) and soil fertility amendments. Furthermore, local governments (GOs) and non-governmental organizations (NGOs) should grant improved land management practices. Land management practices such as soil and water conservation and providing improved agricultural inputs should be implemented to boost agricultural production and productivity. Moreover, local involvement in natural resource management and implementation of land tenure policies are indispensable for sustainable land use. Introducing and adopting alternative energy sources for household energy consumption is vital for reducing the pressure on forests and shrublands. In addition, devising forest development, protection, watershed management, and use strategies is essential to counteract the deteriorating shrubs and bushes and avoid further degradation. Wetlands, the dominant LULC class with unique productivity potential and diverse biodiversity, should have legal ownership to maintain biodiversity and ecosystem balance.

Acknowledgment

The authors acknowledge the financial support provided by the Ministry of Education and the Ministry of Water Irrigation and Energy. Data were acquired, with gratitude from the Eastern Blue Nile Regional Technical Office (ENTRO), the Ministry of Water Irrigation and Energy of Ethiopia, the Ethiopian National Meteorological Agency (ENMA), Ethiopian Mapping Agency (EMA), Ethiopian Electricity, and Ethiopian Sugar Corporation. Local communities' availability for perception study is duly appreciated.

Conflict of interest: The authors declare that there is no conflict of interest regarding the publication of this article.

Funding- The authors did not grant any funds specifically for this work from any funding organization.

References

Abebe, G., Getachew, D., & Ewunetu, A. (2022). Analysing land use/land cover changes and its dynamics using remote sensing and GIS in Gubalafito district, Northeastern Ethiopia. *SN Applied Sciences, 4*(1), 1-15. https://doi.org/10.1007/s42452-021-04915-8

Alemayehu, F., Tolera, M., & Tesfaye, G. (2019). Land use land cover change trend and its drivers in somodo watershed south western, Ethiopia. *African Journal of Agricultural Research, 14*(2), 102-117, https://doi.org/10.5897/AJAR2018.13672

Alemu, B., Garedew, E., Eshetu, Z., & Kassa, H. (2015). Land use and land cover changes and associated driving forces in northwestern lowlands of Ethiopia. *International research journal of agricultural science and soil science, 5*(1), 28-44. https://doi.org/10.14303/irjas.2014.063.

Alshari, E. A., & Gawali, B. W. (2021). Development of classification system for LULC using remote sensing and GIS. *Global transitions proceedings, 2*(1), 8-17. https://doi.org/10.1016/j.gltp.2021.01.002

Anderson, J. R. (1976). *A land use and land cover classification system for use with remote sensor data* (Vol. 964). US Government Printing Office.

Assefa, E., & Bork, H.-R. (2014). Deforestation and forest management in Southern Ethiopia: investigations in the Chencha and Arbaminch areas. *Environmental management, 53*(2), 284-299. https://doi.org/10.1007/s00267-013-0182-x.

Ayana, A., Edossa, D., & Kositsakulchai, E. (2014). Modeling the effects of land use change and management practices on runoff and sediment yields in Fincha watershed, Blue Nile. *OIDA International Journal of Sustainable Development, 7*(11), 75-88.

Ban, Y., & Yousif, O. (2016). Change detection techniques: A review. *Multitemporal Remote Sensing*, 19-43. https://doi.org/10.1007/978-3-319-47037-5

Berihun, M. L., Tsunekawa, A., Haregeweyn, N., Meshesha, D. T., Adgo, E., Tsubo, M., Masunaga, T., Fenta, A. A., Sultan, D., & Yibeltal, M. (2019). Exploring land use/land cover changes, drivers and their implications in contrasting agro-ecological environments of Ethiopia. *Land Use Policy, 87*, 104052. https://doi.org/10.1016/j.landusepol.2019.104052

Betru, T., Tolera, M., Sahle, K., & Kassa, H. (2019). Trends and drivers of land use/land cover change in Western Ethiopia. *Applied Geography, 104*, 83-93. https://doi.org/10.1016/j.apgeog.2019.02.007

Bewket, W. (2002). Land cover dynamics since the 1950s in Chemoga watershed, Blue Nile basin, Ethiopia. *Mountain research and development, 22*(3), 263-269.

Bezabih, B., & Mosissa, T. (2017). Review on distribution, importance, threats and consequences of wetland degradation in Ethiopia. *International Journal of Water Resources and Environmental Engineering, 9*(3), 64-71. https://doi.org/10.5897/IJWREE2016.0697

Chen, J., Li, Z., Xiao, H., Ning, K., & Tang, C. (2021). Effects of land use and land cover on soil erosion control in southern China: Implications from a systematic quantitative review. *Journal of Environmental Management, 282*, 111924. https://doi.org/10.1016/j.jenvman.2020.111924

Congalton, R. G. (2018). Assessing positional and thematic accuracies of maps generated from remotely sensed data. In *Remote Sensing Handbook-Three Volume Set* (pp. 617-636). CRC Press. https://doi.org/10.1016/j.jenvman.2020.111924

Congalton, R. G., & Green, K. (2019). *Assessing the accuracy of remotely sensed data: principles and practices*. CRC press.

CSA. (1991). *The 1984 population and housing census of Ethiopia: analytical report at national level*. Central Statistical Authority, Addis Ababa, Ethiopia.

CSA. (1998). *The 1994 Population and Housing Census of Ethiopia*. Central Statistical Authority Addis Ababa, Ethiopia.

CSA. (2007). *Population and housing census of Ethiopia*. Central Statistics Authority. Addis Ababa, Ethiopia.

Dagnachew, M., Kebede, A., Moges, A., & Abebe, A. (2020). Land use land cover changes and its drivers in Gojeb River catchment, Omo Gibe Basin, Ethiopia. *Journal of Agriculture and Environment for International Development (JAEID), 114*(1), 33-56. https://doi.org/10.12895/jaeid.20201.842

Degife, A., Worku, H., Gizaw, S., & Legesse, A. (2019). Land use land cover dynamics, its drivers and environmental implications in Lake Hawassa Watershed of Ethiopia. *Remote sensing applications: society and environment, 14*, 178-190. https://doi.org/10.1016/j.rsase.2019.03.005

Fenta, A. A., Tsunekawa, A., Haregeweyn, N., Tsubo, M., Yasuda, H., Shimizu, K., Kawai, T., Ebabu, K., Berihun, M. L., & Sultan, D. (2020). Cropland expansion outweighs the monetary effect of declining natural vegetation on ecosystem services in sub-Saharan Africa. *Ecosystem Services, 45*, 101154. https://doi.org/10.1016/j.ecoser.2020.101154

Findell, K. L., Berg, A., Gentine, P., Krasting, J. P., Lintner, B. R., Malyshev, S., Santanello, J. A., & Shevliakova, E. (2017). The impact of anthropogenic land use and land cover change on regional climate extremes. *Nature communications, 8*(1), 1-10. https://doi.org/10.1038/s41467-017-01038-w

Ganaie, T. A., Jamal, S., & Ahmad, W. S. (2021). Changing land use/land cover patterns and growing human population in Wular catchment of Kashmir Valley, India. *GeoJournal, 86*(4), 1589-1606. https://doi.org/10.1007/s10708-020-10146-y

Gashaw, T., Bantider, A., & Mahari, A. (2014a). Evaluations of land use/land cover changes and land degradation in Dera District, Ethiopia: GIS and remote sensing based analysis. *International Journal of Scientific Research in Environmental Sciences, 2*(6), 199. https://doi.org/10.12983/ijsres-2014-p0199-0208

Gashaw, T., Bantider, A., & Mahari, A. (2014b). Population dynamics and land use/land cover changes in Dera District, Ethiopia. *Glob. J. Biol. Agric. Health Sci, 3*, 137-140.

Gashaw, T., Tulu, T., Argaw, M., & Worqlul, A. W. (2017). Evaluation and prediction of land use/land cover changes in the Andassa watershed, Blue Nile Basin, Ethiopia. *Environmental Systems Research, 6*(1), 17.

Gebrehiwot, S. G., Bewket, W., Gärdenäs, A. I., & Bishop, K. (2014). Forest cover change over four decades in the Blue Nile Basin, Ethiopia: comparison of three watersheds. *Regional Environmental Change, 14*(1), 253-266. https://doi.org/10.1007/s10113-013-0483-x

Gebresllassie, H., Gashaw, T., & Mehari, A. (2014). Wetland degradation in Ethiopia: causes consequences and remedies. *Journal of Environment and Earth Science, 4*(11), 40-48.

Genet, A. (2020). Population growth and land use land cover change scenario in Ethiopia. *International Journal of Environmental Protection and Policy, 8*(4), 77-85. https://doi.org/10.11648/j.ijepp.20200804.12

Godfray, H. C. J., & Garnett, T. (2014). Food security and sustainable intensification. *Philosophical transactions of the Royal Society B: biological sciences, 369*(1639), 20120273. https://doi.org/10.1098/rstb.2012.0273

Gu, J., & Congalton, R. G. (2019). The Positional Effect in Soft Classification Accuracy Assessment. *Am. J. Remote Sens, 7*, 50. https://doi.org/10.11648/j.ajrs.20190702.13

Hailemariam, S. N., Soromessa, T., & Teketay, D. (2016). Land use and land cover change in the Bale Mountain Eco-Region of Ethiopia during 1985 to 2015. *Land, 5*(4), 41. https://doi.org/10.3390/land5040041

Halefom, A., Teshome, A., Sisay, E., & Ahmad, I. (2018). Dynamics of land use and land cover change using remote sensing and GIS: a case study of Debre Tabor Town, South Gondar, Ethiopia. *Journal of Geographic Information System, 10*(02), 165. https://doi.org/10.4236/jgis.2018.102008

Hurni, H., Tato, K., & Zeleke, G. (2005). The implications of changes in population, land use, and land management for surface runoff in the upper Nile basin area of Ethiopia. *Mountain research and* *development, 25*(2), 147-154. https://doi.org/10.1659/0276-4741(2005)025[0147:TIOCIP]2.0.CO;2

Hussien, K., Demissie, B., & Meaza, H. (2018). Spatiotemporal wetland changes and their threats in North Central Ethiopian Highlands. *Singapore Journal of Tropical Geography, 39*(3), 332-350. https://doi.org/10.1111/sjtg.12242

Islam, K., Jashimuddin, M., Nath, B., & Nath, T. K. (2018). Land use classification and change detection by using multi-temporal remotely sensed imagery: The case of Chunati wildlife sanctuary, Bangladesh. *The Egyptian Journal of Remote Sensing and Space Science, 21*(1), 37-47. https://doi.org/10.1016/j.ejrs.2016.12.005

Kim, D. H., Sexton, J. O., & Townshend, J. R. (2015). Accelerated deforestation in the humid tropics from the 1990s to the 2000s. *Geophysical Research Letters, 42*(9), 3495-3501. https://doi.org/10.1002/2014GL062777

Lillesand, T., Kiefer, R. W., & Chipman, J. (2015). *Remote sensing and image interpretation*. John Wiley & Sons.

Lu, D., Li, G., & Moran, E. (2014). Current situation and needs of change detection techniques. *International Journal of Image and Data Fusion, 5*(1), 13-38. https://doi.org/10.1080/19479832.2013.868372

Mesene, M. (2017). Extent and impact of land degradation and rehabilitation strategies: Ethiopian Highlands. *Journal of Environment and Earth Science, 7*(11), 22-32.

Meshesha, T. W., Tripathi, S., & Khare, D. (2016). Analyses of land use and land cover change dynamics using GIS and remote sensing during 1984 and 2015 in the Beressa Watershed Northern Central Highland of Ethiopia. *Modeling Earth Systems and Environment, 2*(4), 1-12. https://doi.org/10.1007/s40808-016-0233-4

Mhawish, Y. M., & Saba, M. (2016). Impact of population growth on land use changes in Wadi Ziqlab of Jordan between 1952 and 2008. *International Journal of Applied Sociology, 6*(1), 7-14. https://doi.org/10.5923/j.ijas.20160601.02

Miheretu, B. A., & Yimer, A. A. (2018). Land use/land cover changes and their environmental implications in the Gelana sub-watershed of Northern highlands of Ethiopia. *Environmental Systems Research, 6*(1). 1-12. https://doi.org/10.1186/s40068-017-0084-7

Minta, M., Kibret, K., Thorne, P., Nigussie, T., & Nigatu, L. (2018). Land use and land cover dynamics in Dendi-Jeldu hilly-mountainous areas in the central Ethiopian highlands. *Geoderma, 314*, 27-36. https://doi.org/10.1016/j.geoderma.2017.10.035

Mishra, S., Shrivastava, P., & Dhurvey, P. (2017). Change detection techniques in remote sensing: A review. *International Journal of Wireless and Mobile communication for Industrial systems, 4*(1), 1-8. https://doi.org/10.21742/ijwmcis.2017.4.1.01

Moges, A., Beyene, A., Triest, L., Ambelu, A., & Kelbessa, E. (2018). Imbalance of ecosystem services of wetlands and the perception of the local community towards their restoration and management in Jimma Highlands, Southwestern Ethiopia. *Wetlands, 38*(6), 1081-1095. https://doi.org/10.1007/s13157-016-0743-x

Mulugeta, M., & Legese, T. (2015). Spatiotemporal Environmental Dynamics and its Implications on Rural Livelihoods in Wasarbi-Garba Guracha Watershed, Central Ethiopia. *Clarion University of Pennsylvania, Clarion, Pennsylvania journal of Sustainable Development in Africa, 15*(8), 8.

Olmanson, L. G., & Bauer, M. E. (2017). Land cover classification of the Lake of the Woods/Rainy River Basin by object-based image analysis of Landsat and lidar data. *Lake and Reservoir Management, 33*(4), 335-346. https://doi.org/10.1080/10402381.2017.1373171

Oo, B. N., Aung, K. P. P., & Shwe, K. P. (2019). *Land Use and Land Cover Change Detection Using Remote Sensing and GIS Techniques: A Case Study of Belin Township in Thatone District.* MERAL Portal.

Othow, O. O., Gebre, S. L., & Gemeda, D. O. (2017). Analyzing the rate of land use and land cover change and determining the causes of forest cover change in Gog district, Gambella regional state, Ethiopia. *J. Remote Sens. GIS, 6*(4), 218. https://doi.org/10.4172/2469-4134.1000

Ouedraogo, I., Tigabu, M., Savadogo, P., Compaoré, H., Odén, P., & Ouadba, J. (2010). Land cover change and its relation with population dynamics in Burkina Faso, West Africa. *Land Degradation & Development, 21*(5), 453-462. https://doi.org/10.1002/ldr.981

Rebelo, A. J., Le Maitre, D. C., Esler, K. J., & Cowling, R. M. (2015). Hydrological responses of a valleybottom wetland to land-use/land-cover change in a South African catchment: making a case for wetland restoration. *Restoration ecology, 23*(6), 829-841. https://doi.org/10.1111/rec.12251

Regasa, M. S., Nones, M., & Adeba, D. (2021). A review on land use and land cover change in Ethiopian basins. *Land, 10*(6), 585. https://doi.org/10.3390/land10060585

Sahalu, A. G. (2014). *Analysis of urban land use and land cover changes: a case of study in Bahir Dar, Ethiopia*.

Shiferaw, A., & Singh, K. (2011). Evaluating the land use and land cover dynamics in Borena Woreda South Wollo Highlands, Ethiopia. *Ethiopian Journal of Business and Economics (The), 2*(1).

Singh, S. K., Mustak, S., Srivastava, P. K., Szabó, S., & Islam, T. (2015). Predicting spatial and decadal LULC changes through cellular automata Markov chain models using earth observation datasets and geo-information. *Environmental Processes, 2*(1), 61-78. https://doi.org/10.1007/s40710-015-0062-x

Solefack, M. C. M., Njouonkou, A. L., Temgoua, L. F., Djouda, R., Zangmene, J., & Ntoupka, M. (2018). Land-use/land-cover change and anthropogenic causes around Koupa Matapit Gallery Forest, West-Cameroon. *Journal of Geography and Geology, 10*(2), 201-219. https://doi.org/10.4236/ojf.2022.122012

Tadesse, L., Suryabhagavan, K., Sridhar, G., & Legesse, G. (2017). Land use and land cover changes and Soil erosion in Yezat Watershed, North Western Ethiopia. *International soil and water conservation research, 5*(2), 85-94. https://doi.org/10.1016/j.iswcr.2017.05.004

Tariq, A., Shu, H., Siddiqui, S., Imran, M., & Farhan, M. (2021). Monitoring Land Use And Land Cover Changes Using Geospatial Techniques, A Case Study Of Fateh Jang, Attock, Pakistan. *Geography, Environment, Sustainability, 14*(1), 41-52. https://doi.org/10.24057/2071-9388-2020-117

Tefera, B., & Sterk, G. (2010). Land management, erosion problems and soil and water conservation in Fincha'a watershed, western Ethiopia. *Land use policy, 27*(4), 1027-1037. https://doi.org/10.1016/j.landusepol.2010.01.005

Tendaupenyu, P., Magadza, C. H. D., & Murwira, A. (2017). Changes in landuse/landcover patterns and human population growth in the Lake Chivero catchment, Zimbabwe. *Geocarto International, 32*(7), 797-811. https://doi.org/10.1080/10106049.2016.1178815

Václavík, T., & Rogan, J. (2009). Identifying trends in land use/land cover changes in the context of post-socialist transformation in central Europe: a case study of the greater Olomouc region, Czech Republic. *GIScience & Remote Sensing, 46*(1), 54-76. https://doi.org/10.2747/1548-1603.46.1.54

Wondie, M., & Mekuria, W. (2018). Planting of Acacia decurrens and dynamics of land cover change in Fagita Lekoma District in the Northwestern Highlands of Ethiopia. *Mountain research and development, 38*(3), 230-239. https://doi.org/10.1659/MRD-JOURNAL-D-16-00082.1

Wondie, M., Schneider, W., Katzensteiner, K., Mansberger, R., & Teketay, D. (2016). Modelling the dynamics of landscape transformations and population growth in the highlands of Ethiopia using remote-sensing data. *International Journal of Remote Sensing, 37*(23), 5647-5667. https://doi.org/10.1080/01431161.2016.1246773

Yesuph, A. Y., & Dagnew, A. B. (2019). Soil erosion mapping and severity analysis based on RUSLE model and local perception in the Beshillo Catchment of the Blue Nile Basin, Ethiopia. *Environmental Systems Research, 8*(1), 1-21.

Zhang, L., & Weng, Q. (2016). Annual dynamics of impervious surface in the Pearl River Delta, China, from 1988 to 2013, using time series Landsat imagery. *ISPRS Journal of Photogrammetry and Remote Sensing, 113*, 86-96. https://doi.org/10.1016/j.isprsjprs.2016.01.003

Copyrights