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Drivers and Implications of Land Use/Land Cover Dynamics in Finchaa Catchment, Northwestern Ethiopia

Wakjira Takala Dibaba[1,2,*], Tamene Adugna Demissie [2] and Konrad Miegel [1]

[1] Hydrology and Applied Meteorology Department, Faculty of Agricultural and Environmental Sciences, University of Rostock, Satower Str. 48, 18059 Rostock, Germany; konrad.miegel@uni-rostock.de

[2] Faculty of Civil and Environmental Engineering, Jimma University, Jimma 378, Ethiopia; tamene.adugna@ju.edu.et

* Correspondence: wakjira.dibaba@uni-rostock.de

Abstract: Understanding the trajectories and extents of land use/land cover change (LULCC) is important to generate and provide helpful information to policymakers and development practitioners about the magnitude and trends of LULCC. This study presents the contributing factors of LULCC, the extent and implications of these changes for sustainable land use in the Finchaa catchment. Data from Landsat images 1987, 2002, and 2017 were used to develop the land use maps and quantify the changes. A supervised classification with the maximum likelihood classifier was used to classify the images. Key informant interviews and focused group discussions with transect walks were used for the socio-economic survey. Over the past three decades, agricultural land, commercial farm, built-up, and water bodies have increased while forestland, rangeland, grazing land, and swampy areas have decreased. Intensive agriculture without proper management practice has been a common problem of the catchment. Increased cultivation of steep slopes has increased the risk of erosion and sedimentation of nearby water bodies. Multiple factors, such as biophysical, socio-economic, institutional, technological, and demographic, contributed to the observed LULCC in the study area. A decline in agricultural yield, loss of biodiversity, extended aridity and drought, land and soil degradation, and decline of water resources are the major consequences of LULCC in the Finchaa catchment. The socio-economic developments and population growth have amplified the prolonged discrepancy between supply and demand for land and water in the catchment. More comprehensive and integrated watershed management policies will be indispensable to manage the risks.

Keywords: drivers; Finchaa; land use/land cover; sustainable; watershed management

1. Introduction

Land use/land cover change (LULCC) is among the major factors that affect biophysical systems at all scales [1]. The major concern in land use/land cover (LULC) results from their direct associations with the planet's fundamental characteristics and processes. The productivity of land, biodiversity, land degradation, hydrological cycle, and environmental conditions are some of the processes [2–5]. LULCC interrupts the ability of natural systems to support human needs and increase the exposure of people and resources to climate change, socio-economic crises, and political worries by reducing ecosystem services [1,6,7]. Additionally, local and global LULCC has increased in recent years [4–6].

In the past, recognition of the importance of the natural environment for human well-being has been less influential in maintaining sustainable development and poverty alleviation strategies [8–

10]. However, the natural environment and poverty are highly correlated with sustainability and development. Depletion and degradation of land and water resources pose a great challenge to the sustainability of the farming system, food, income, and employment [11]. The impacts are severe on the livelihoods of the poor, who are dependent on land and natural resources. The annual global cost of land degradation caused by LULCC and poor land management practice on cropland and grazing land is estimated to be about 300 billion United States Dollar [12]. Sub-Saharan Africa accounts for the largest share, 22% of the total global cost of land degradation. A report by the Food and Agricultural Organization (FAO) [13] showed that land degradation affects the health and livelihood of 1.5 billion people in the world, where women and the poor are most affected.

In recent years, the study of LULCC has become an important topic of research [14–22]. Studies have shown that LULCC has been intense in the highlands of Ethiopia. In particular, the expansion of intensive agriculture, urbanization, and extraction of forest products are accelerating over time to meet the requirements of an increasing population [14,20,23]. However, there are also studies that have reported different trends of LULCC. For example, Alemayehu et al. [21] reported that agricultural land declined while the grassland increased in the Somodo watershed, southwestern Ethiopia. Miheretu and Yimer [16] also reported the expansion of grassland and shrublands in the Gelan sub watershed, northern highlands.

LULCC processes are triggered by the interaction of anthropogenic and biophysical drivers [14,15,18–21,24]. The drivers of LULCC include social, economic, biophysical, and political factors [14,25,26]. The human and livestock population, different agricultural practices, urbanization, drought prevalence, and poor land-use planning have been reported as the main drivers of LULCC in Ethiopia. However, different places have different driving factors and consequences. For example, overgrazing and charcoal productions are the dominant driving factors in Afar and Somali regions of Ethiopia [20], while forest grabbing for investments (coffee and tea plantation and, agriculture), settlements, poor law enforcement, shifting cultivation and land tenure policy has been significant drivers in southwestern Ethiopia. On the other hand, the multifaceted nature of the change drivers and their implications are often poorly understood and scarce in some regions. Furthermore, the national level investigations about the wide ranges of drivers and magnitude of LULCC and its implications are inadequate.

The upper part of the Blue Nile Basin is characterized by a very rich diversity of natural resources, including land, vegetation, genetic diversity, and water in a diverse biophysical and socio-economic environment experiencing multi-faceted pressures [27,28]. Population growth, deforestation, land degradation, a high rate of soil erosion and nutrient depletion, and climate variability are among the major pressures. Consequently, the intended sustainable development in different parts of Ethiopia in general and the study area, in particular, is confronted with the intensive LULCC in recent years.

Relatively abundant water resources in Ethiopia have played a minimal role in the development of the national economy. As a result, the country intends to place a priority on water resource development as an essential strategy for economic and social development [29,30]. The relevance of the water resources for the promotion of sustainable development, however, relies on the management of the ongoing and planned development projects.

The Finchaa catchment has a large share of Ethiopia's hydroelectric power, sugar, and ethanol supply. However, there has been limited multidisciplinary and independent research in the catchment compared to other areas. There are few studies on Finchaa catchment in LULCC [31–33]. Ayana et al. [31] studied how land use and management practices affect surface runoff and sediment yield based on hypothetical scenarios without considering the real spatio-temporal LULCC. Kebebew [32] assessed the state of the LULCC in the Finchaa catchment by considering only downstream of the reservoirs, whereas Tefera and Sterk [33] mainly focused on analyzing the LULCC caused by hydropower dam construction in Finchaa watershed. However, there is no information on the driving factors, spatial-temporal LULCC, and their implication on the entire Finchaa catchment. Thus, up-to-date and spatially accurate time series about land resources are required for the catchment. In LULCC studies, the most important activity involves advancing the understanding of

the causes, processes, and patterns of the changes in different spatial and temporal scales [26,34]. Understanding the spatio-temporal trends of LULCC with a broader socio-ecological system at watershed scale helps to compare different part of the watershed and identify those that are at risk or susceptible to changes. This brings clear insight into the status of the watershed and helps to provide evidence-based interrelationship between the local people and watershed to facilitate more proactive approaches to maintain the water resources and land health.

The goal of this study is to investigate problems of scale and temporal variability of the LULCC in the Finchaa catchment. Specifically, the objectives of this study are (i) analyze the changes in land use/land cover over the last 30 years (1987–2017), (ii) examine the LULC inter-category transitions and the LULCC associations with slope, (iii) identify the major driving factors and explore the implications of the LULCC in Finchaa catchment.

2. Materials and Methods

2.1. Study Area

The study was conducted in the upper Blue Nile Basin, Finchaa sub-basin in Oromia Regional State, Ethiopia. Finchaa sub-basin lies in 9°10' to 10°00' North latitude and 37°00' and 37°40' East longitude, covering a 3781 km² area. The catchment is characterized by high topographic relief, with elevation ranging from 851 to 3213 meters above sea level. The area has large upstream water potential sites, intensive irrigable downstream lands, and high hydropower potential [35]. The sub-basin contains three watersheds; Fincha, Amerti, and Neshe. The detail study area description is shown in Figure 1.
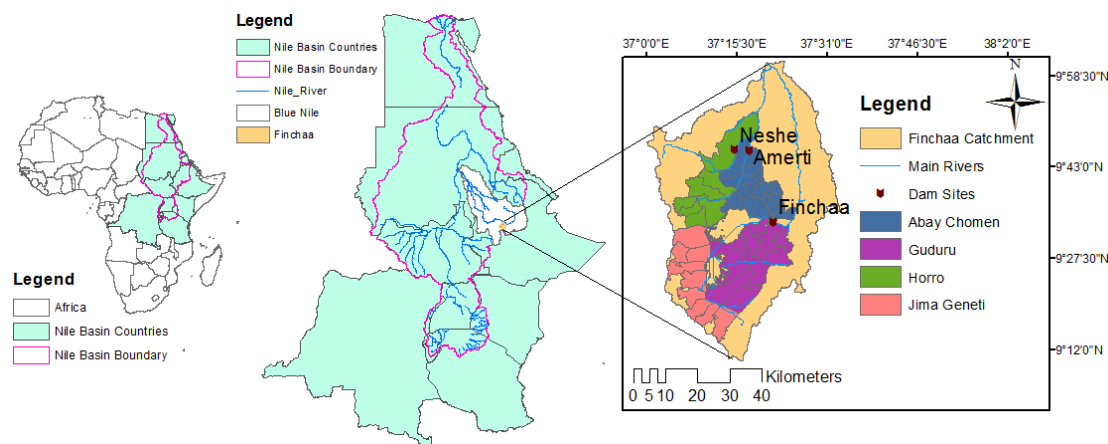

Figure 1. Map of the study areas.

Finchaa sub-basin supports a variety of ecosystems and land use types, such as forest, commercial farm, wetlands, and lakes, which contribute to the national economy. The sub-basin is also an area of interest for international and national hydro-politics due to its downstream connection to the Nile basin.

The annual rainfall of Finchaa catchment ranges from 1367 to 1842 mm, with the lower rainfall occurring in the northern lowlands and the higher rainfall greater than 1500 mm occurring in the southern and western highlands of the sub-basin. June to September is the main rainy season of the catchment, with an average annual rainfall of 1604 mm and a peak occurring between July to August [36]. The mean monthly temperature of the catchment varies between 15.50 to 18.62 °C.

2.2. Data Sources and Methodology

2.2.1. Spatial Data

Landsat images, Digital Elevation Model (DEM), and field data were used in this study. A 30 m DEM obtained from the United States Geological Survey (USGS) at https://earthexplorer.usgs.gov/ was used to delineate the watershed and generate slope maps of the study area. Ground Control Points (GCP) for image classification and accuracy assessment were collected through direct field observations using Global positioning system (GPS), Landsat composites, and Google Earth. Two sets of Landsat Thematic Mapper (TM) imagery and one set of Landsat 8 Operational Land Imager and Thermal Infrared Sensor (OLI-TIRs) image obtained from USGS at https://landsatlook.usgs.gov/ were used for the analysis of LULCC (Table 1). Due to the extent and quality concern, full images for a given year covering the whole catchment on the same day were not available for the catchment. Therefore, different paths and rows were used to get the Landsat images in the same season. To minimize the effects of a seasonal variation in vegetation pattern and distribution throughout a year, the selection of dates of the acquired images was made in the same annual season of the acquired years.

Table 1. Landsat's scenes, sources, and specifications used in this study.

Acquisition date	Satellite image	Sensor	Spatial resolution	Used bands	Sources
January 1987	Landsat TM				USGS
		TM	30	1–5, 7	
January 2002	Landsat TM				USGS
		TM	30	1–5, 7	
January 2017	Landsat8 OLI				USGS
		OLI-TIRs	30,15	1–7, 9, 8*	

Path/row = 169/053, 169/054, 169/055, 170/053, 170/054, 170/055. * In the table above, a spatial resolution of 15 m is used for the panchromatic band 8. TM: Thematic Mapper; OLI-TIRs: Operational Land Imager and Thermal Infrared Sensor.

2.2.2. Socio-Economic Data

We used a socio-economic survey to collect information to improve the understanding of local resources, resources use, interactions with the government decision-making process, and community perceptions of trends and priority issues [37]. Although there are different techniques for the socio-economic surveys based on the purpose of the study, key informant interview (KII) and focus group discussion (FGD) surveying techniques were used in this study. Based on the agro-ecological conditions and proximity of the locations to reservoirs in the catchment, three representative sub-watersheds were selected for FGD and KII. These sub-watersheds cover four districts: Horro, Jima Geneti, Abay Chomen, and Guduru (Figure 1). Fieldwork was carried out by the corresponding author and agricultural experts. A total of seven FGDs, two in each of the upper and lower sub-watersheds, and three FGDs in the middle sub-watersheds were carried out. Each FGDs comprises seven participants drawn from the members of the community. Twenty-two KIIs were held with District and Zonal level experts of Natural Resources management, land use administration, and Environment and climate change. Relevant Geographic Information System (GIS) data were collected for each district.

During both KIIs and FGDs, open-ended questions were used concerning the major shifts in LULC, the relationship among the biophysical environment, institution, socio-economic activities and demography. Discussions on practices and regulations that influence land management in their locality were held to get information on the management perspectives, evaluate the efforts made towards resource management and their challenges. The issue related to land degradation and the most priority issues that require interventions were also discussed. During the discussion and interviews, the main focuses were to get sufficient information about the past and present trend of LULCC, identify the root driving factors of the changes and implications of LULCC on the socio-economic activity of the community and the environment. To better understand the major observed

problems of the catchment and resource management practice, transect walks, field walks, and informal talks with people in their farms/fields were used. Farmers were asked to explain what parts of the landscape were changed and explained why the change had occurred. The farmers were also asked to describe the consequences of the changes in their livelihood, surroundings, and environment. Furthermore, farmers were asked to explain how their socio-economic activity contributes to the land-use change.

Field observation was carried out based on checklists designed in advance to observe the situation in the watershed, and photographs of important sites were taken to enrich the study. With the aid of field observation, information from experts, and review of documents from national and regional offices, eight classes of land use/land cover types were identified as depicted in Table 2. The LULCC analysis in this study is based on these classes.

Table 2. Description of land use/land cover (LULC) classes identified in Finchaa catchment.

LULC Classes	Description
Agricultural land	Areas used for crop cultivation (both annual and perennial), fallow plots, scattered rural settlements, some pastures and plantations around settlements. Sparsely located settlements and roads constructed from earthwork were included here as it was difficult to separate them from agricultural lands.
Rangeland (Shrubland)	Sparsely located trees with brush and shrub form types, bushes, woodlands, grasses, mixed rangelands, and transitional forests (less dense forests) were included.
Forest land	Areas covered with a dense growth of trees that include: evergreen forests, mixed forest land, deciduous forest lands. Plantations of indigenous specious of trees were also considered here.
Urban and built-up	Residential, commercial and services, recreational sites, public installation, infrastructures. Due to their similar reflectance, bare lands and rock query sites were considered here. Roads made from pavement are also included in this category.
Water bodies	Areas that are completely inundated by water like lakes and major rivers.
Grazing land	Area covered with small grasses, scattered bushes and trees, and wetland (intermittent) used for grazing.
Swampy land	Areas that are swampy during both wet and dry seasons
Commercial farm	Areas used for sugarcane plantations and sesame cultivations.

2.2.3. Data Analysis

The analysis and quantification of the spatio-temporal dynamics of the LULC from 1987 to 2017 were achieved through Landsat image processing, classification, and post-processing. Image pre-processing involved geometric and radiometric correction before the image analysis. In this study, only six spectral bands of TM (band 1–5 and 7) and eight spectral bands of Landsat 8 OLI (bands 1–7 and 9) were used during the image processing for LULC classification. A 15-m spatial resolution layer (band 8) found in OLI was fused with 30 m multispectral bands using the Principal Component Analysis (PCA) method found in ERDAS. The pan-sharpened OLI image was used only to get a better visualization and interpretation of the images.

The maximum likelihood parametric rule was used to classify each pixel based on the known ground truth. A minimum of 50 samples is recommended for image classification with maps having less than 12 classes [38]. Based on the recommendation, 50 reference samples for each class were used for image classifications. The reference points were collected from Google Earth for 1987 and 2002. The overall procedures used for image classification were given as follows. The first step was selecting training sites [38,39]. Polygon sampling method was used to sample the training sites from the processed images as it allowed the drawing of polygons for a particular spectral class. Different combinations of bands, image enhancement, and color compositions were used to discriminate and interpret the surface features of the images during the process. The choices of band combinations were selected depending on the applicability of each band as each band is a set of a data file for a

specific portion of the electromagnetic spectrum in identifying the features of the study. The extracted signatures from the sample were evaluated using the histogram technique, and different trials were taken until unimodal distribution was achieved. Then, signatures of the same class were merged by selecting all the signatures of each class. The supervised classification used the cumulated (merged signature) for the land cover map production. The training data sets were used for generating class signatures and for classification of the whole image into meaningful information classes.

2.2.4. Accuracy Assessment

The process of doing an accuracy assessment involved generating a set of points from the classified image and comparing the positions of points whose location was determined by the ground truth data and corresponding coordinates from the original maps [39]. In this study, these sets of points were selected with random sampling. Random sampling was used to select a set of points. Points that were used in training the classification were not used for accuracy assessment. As a result, 460 random points were created and used to develop an error matrix for accuracy assessment. The reference points for 1987 and 2002 were collected from the corresponding Google Earth, original Landsat images, previous reports and maps, and field observation for 2017. Information from interviews and group discussions supported us in getting the historical LULC, for example, forest areas, grazing land, and water resources. Since the resolution of the historical maps for 1987 obtained from the Ethiopian Mapping Agency was poor, a high resolution of Google Earth was used to better identify the land-use classes. A similar approach was used by different studies where the historical maps were poor in Ethiopia [21,22,40–43] and Italy [44].

From the error matrix, overall accuracy, user's accuracy, producer's accuracy, and kappa statistics were derived. Kappa coefficients typically lie between 0 and 1. According to Viera and Garrett [45], kappa value characteristics of value greater than 0.8 denote a strong agreement, a value between 0.4 and 0.8 denotes a moderate agreement, and a value below 0.4 represents the poor agreement.

2.2.5. Land Use/Land Cover Change Analysis

Once the land cover classifications were derived, Arc Geographic and Information System (ArcGIS 10.1) was used to prepare the LULC maps of 1987, 2002, and 2017. Then, the areas of the LULC classes were calculated from the maps, and analysis of LULCC and rates of changes were computed. Total LULCC between the two periods is calculated as follows:

$$\text{Total LULC Gain/loss} = \text{Area of the final year} - \text{Area of the initial year} \tag{1}$$

$$\text{Percentage of LULC Gain/loss} = \frac{(\text{Area of the final year} - \text{Area of the initial year})}{\text{Total area of the catchment}} \tag{2}$$

A LULC matrix was developed by ArcGIS to analyze the LULC inter-category transitions and examined the catchment experience in LULC transitions. The matrix was developed for the 1987–2002 and 2002–2017 transitions. Through the matrix, the area of gains, losses, persistence, and swapping between the LULC types are calculated.

The terrain slope–LULC relationship was developed by overlaying the slope generated from the DEM of the study area and the classified maps. Then, the distribution of LULCC with slope was quantified. The result was helpful to see how continuous demand for agricultural land had brought changes in LULC of higher slope areas.

The socio-economic data from the KIIs and FGDs were analyzed thematically with the focus on the past and current conditions of LULC, drivers, and implications of the LULCC. The ranking was used to identify the most common drivers and consequences of the changes.

3. Result and Discussion

3.1. Accuracy Assessment

The confusion error matrix and Kappa statistics used for the classification accuracy of 1987, 2002, and 2017 LULC maps are presented in Table 3. The overall accuracy for the 1987, 2002, and 2017 maps was 81.7%, 85.4%, and 89.7%, respectively. The Kappa statistics were 0.78, 0.83, and 0.88 for the 1987, 2002, and 2017 maps, respectively. The Kappa statistics showed a strong agreement for the years 2002 and 2017, and good agreement for 1987 [45].

Table 3. Accuracy of land use/land cover maps for 2017, 2002, and 1987

	LULC	WB	GL	AL	SA	CF	FL	RL	UL	UA (%)	K
	WB	41	1	0	3	0	0	0	0	91.11	
	GL	0	55	2	0	1	0	2	0	91.67	
	AL	0	2	91	0	2	1	3	1	91.00	
	SA	2	2	0	34	0	2	0	0	85.00	
	CF	0	0	2	0	45	1	1	1	90.00	
	FL	0	0	1	0	2	55	2	0	91.67	
2017	RL	0	2	1	1	2	3	45	1	81.82	
	UL	0	1	2	0	0	0	0	47	94.00	
	PA (%)	95.35	87.30	91.92	89.47	86.54	88.71	84.91	94.00	89.78	0.88
	LULC	WB	GL	AL	SA	CF	FL	RL	UL	UA (%)	K
	WB	37	0	1	2	0	0	0	0	92.50	
	GL	0	48	3	1	0	0	3	0	87.27	
	AL	1	3	85	0	1	2	2	3	87.63	
	SA	4	1	0	40	0	2	1	0	83.33	
	CF	0	0	3	0	41	3	2	1	82.00	
2002	FL	0	1	2	1	2	51	3	0	85.00	
	RL	0	3	2	2	2	4	46	1	76.67	
	UL	0	1	1	0	3	0	0	45	90.00	
	PA (%)	88.10	84.21	87.63	86.96	83.67	82.26	80.70	90.00	85.4	0.83
	LULC	WB	GL	AL	SA	FL	RL	UL	UA (%)	K	
	WB	37	0	0	3	0	0	0	92.50		
	GL	1	45	1	2	0	4	2	81.82		
	AL	0	2	80	0	1	4	3	88.89		
	SA	1	2	0	39	2	1	0	86.67		
1987	FL	1	4	3	1	41	6	1	71.93		
	RL	0	2	4	3	4	37	0	74.00		
	UL	0	2	5	1	2	2	33	73.33		
	PA (%)	92.50	78.95	86.02	79.59	82.00	68.52	84.62	81.68	0.77	

WB—water bodies, GL—grazing land, AL—agricultural land, CF—commercial farm, SA—swampy area, FL—forest land, RL—rangeland, UL—urban and built-up, UA—user's accuracy, PA—producer's accuracy, K—Kappa statistics.

3.2. Spatio-Temporal Distributions of Land Use/Land Cover Changes in Finchaa Catchment

Agricultural lands, the dominant land use type of the catchment, covered 36.27% of the study area in 1987, 42.64% in 2002, and 51.86% in 2017 (Table 4). Similarly, urban and built-up areas and commercial farms increased from 1987 to 2017. The proportion of urban and built-up in 1987, 2002 and 2017 was 0.12%, 0.27%, and 1.91% of the total area, respectively. The swampy area and water bodies covered 3.57% and 4.31% area of the catchment in 1987, 3.12% and 5.94% in 2002, and 2.49% and 6.05% in 2017, respectively. With the construction of a sugar factory in the lowland areas of the catchment, sugar cane plantation began to appear around 1994. In 2002, the area of the commercial farm was around 4577.5 hectares (1.38%). Since the factory planned to double the production of sugar, the area coverage of sugarcane plantation expanded. Further, the new plantation site was established downstream of Neshe hydropower around 2012. Consequently, the farm was expanded to 18372.7 hectares (5.55%) in 2017.

In 1987, forestland, rangeland, and grazing land were the major LULC accounting for 21.55%, 20.63%, and 13.55% of the catchment, respectively. Similarly, forestland, rangeland, and grazing land

were the major LULC in 2002 and 2017. For the periods of 1987 to 2002 and 2002 to 2017, forestland and rangeland showed the highest decline, whereas agricultural land showed the highest increase. Comparatively, the LULCC was higher for the changes from 2002 to 2017 than the changes from 1987 to 2002.

Table 4. LULC area coverage, status, and changes between 1987, 2002, and 2017.

LULC types	Area						Change (Gain/Loss)					
	1987		2002		2017		1987–2002		2002–2017		1987–2017	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
AGL	119963.4	36.27	141039.3	42.64	171527.8	51.86	21075.9	6.37	30488.5	9.22	51564.4	15.59
CFL	0.0	0.00	4577.5	1.38	18372.7	5.55	4577.5	1.38	13795.1	4.17	18372.7	5.55
FL	71299.5	21.55	58255.6	17.61	30363.1	9.18	−13043.9	−3.94	−27892.5	−8.43	−40936.4	−12.38
GL	44812.6	13.55	40038.8	12.10	33590.5	10.15	−4773.8	−1.44	−6448.3	−1.95	−11222.1	−3.39
RL	68239.0	20.63	55989.7	16.93	42345.6	12.80	−12249.3	−3.70	−13644.1	−4.12	−25893.3	−7.83
SW	11811.8	3.57	10334.7	3.12	8234.1	2.49	−1477.0	−0.45	−2100.6	−0.64	−3577.7	−1.08
UBL	392.2	0.12	885.3	0.27	6320.8	1.91	493.1	0.15	5435.5	1.64	5928.6	1.79
WB	14262.8	4.31	19660.5	5.94	20026.7	6.05	5397.7	1.63	366.2	0.11	5763.9	1.74
Total, ha	330781.3	100	330781.4	100	330781.3	100						

AG—agricultural land, CFL—commercial farm, FL—forest land, GL—grazing land, RL—range land, SW—swampy, UBL—urban and built up, WB—water bodies, negative(-) indicates loss.

The distribution of LULCC over 30 years is given by Figure 2. Expansion in agriculture, commercial farm, and urban and built-up showed continuous increase whereas forestland, grazing land, range lands, and swampy area showed a continuous decline.
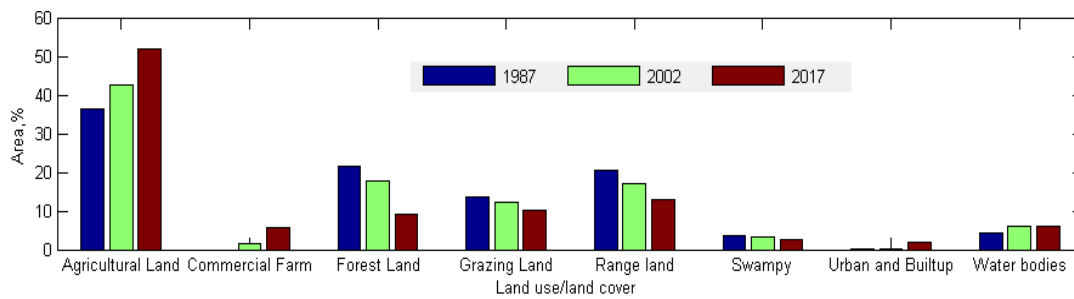

Figure 2. Land use/land cover distribution.

The spatio-temporal distribution of the LULC in the Finchaa catchment is presented in Figure 3. The expansion of the commercial farm was in the lowland areas of the catchment, whereas the major changes in water bodies were upstream of the catchment. The area of grazing land, mainly short grasses with intermittent wetlands, were found in the upper part of the catchment in the Guduru District.
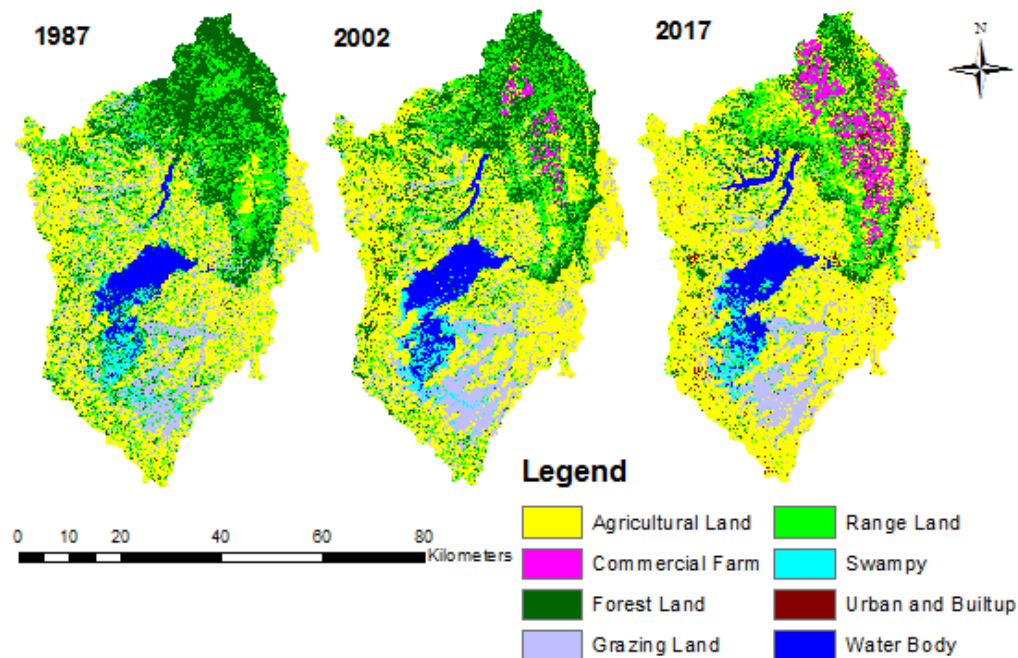

Figure 3. LULC map of Finchaa catchment in 1987, 2002, and 2017.

3.3. LULC Inter-Category Transitions and Changes Trajectories in Finchaa Watershed

The LULCC analysis of Finchaa showed that the catchment experienced intricate LULC transitions. LULC matrix was developed for the 1987–2002 and 2002–2017 transitions. Through the matrix, the areas gained, lost, persisted, and swapped among the LULC types were calculated (Table 5).

During 1987–2002, the highest losses occurred in rangeland class, followed by forest land and grazing land. Urban and built-up areas followed by water bodies and swampy areas showed the lowest loss. Similar patterns of changes were observed during the 2002–2017 period with the highest losses shown by rangeland, followed by forest land and agricultural land, whereas the lowest loss

was shown by urban and built-up followed by swampy area and water bodies. The highest gain for the period of 1987–2002 was shown by agricultural land followed by rangeland and forest land, whereas the lowest gain was shown by urban and built up followed by water bodies. For period's 2002–2017, agricultural land followed by rangeland and grazing land has shown the highest gain while water bodies followed by swampy and urban and built-up area shows the lowest gain.

Concerning net persistence, the ratio of the net change (gain–loss) to diagonals of each class, urban and built-up area has shown the highest net change to persistence ratio during 1987–2002 and 2002–2017. The highest net change to persistence ratio implies the lowest persisting class of the LULC. The lowest persisting LULC class in the Finchaa catchment was urban and built-up followed by rangeland during 1987–2002, whereas agricultural land followed by grazing land has shown the highest persisting LULC class. During 2002–2017, urban and built-up, and commercial farm were the lowest persisting LULC, and water bodies followed by agricultural lands were the highest persisting LULC classes.

Table 5. LULC change transition matrices (ha) for 1987–2002, 2002–2017.

To	2002	AGL	CF	FL	GL	RL	SA	UB	WB	Total	Loss
	AGL	**97894.5**	533.0	2733.4	9600.2	8122.5	528.3	504.1	47.4	119963.4	22068.9
	FL	6571.1	1943.9	**34577.2**	2591.9	21497.2	2227.6	97.5	1792.9	71299.5	36722.3
	GL	14690.2	41.0	2529.3	**19957.2**	5122.8	2085.7	64.3	322.0	44812.6	24855.4
From 1987	RL	20925.0	2015.0	16550.8	6217.4	**20054.8**	1673.3	149.6	653.0	68239.0	48184.2
	SA	694.1	25.7	1769.5	1599.4	1041.7	**2955.7**	5.3	3720.3	11811.8	8856.1
	UB	274.9	0.9	9.1	15.7	22.1	1.3	**68.3**	0.1	392.2	323.9
	WB	1.2	19.1	81.1	52.6	119.5	861.4	1.3	**13126.5**	14262.8	1136.3
	Total	141051.0	4578.5	58250.4	40034.5	55980.6	10333.4	890.6	19662.3	330781.3	
	Gains	43156.5	4578.5	23673.2	20077.3	35925.9	7377.7	822.3	6535.7		
To	2017	AGL	CF	FL	GL	RL	SA	UB	WB	Total	Loss
	AGL	**120348.5**	2979.2	1193.5	4412.3	7507.7	61.4	3798.5	738.1	141039.3	20690.7
	CF	437.4	**3524.9**	200.0	52.2	248.0	19.4	76.2	19.3	4577.5	1052.6
	FL	13623.8	5815.6	**19728.8**	2393.3	15067.3	507.3	819.1	300.4	58255.6	38526.7
From 2002	GL	13186.6	290.1	1034.1	**20534.2**	2349.7	1229.1	275.7	1139.3	40038.7	19504.5
	RL	22532.5	5708.8	7268.3	2934.5	**15494.1**	472.8	1057.9	520.9	55989.7	40495.6
	SA	836.1	21.9	722.2	2740.2	1033.4	**3057.6**	43.7	1879.8	10334.8	7277.2
	UB	525.2	17.5	19.7	21.4	63.2	0.6	**234.4**	3.2	885.3	650.9
	WB	36.9	13.7	199.5	502.4	585.7	2886.9	11.6	**15423.9**	19660.5	4236.6
	Total	171526.9	18371.7	30366.0	33590.5	42349.0	8235.0	6317.2	20024.9	330781.3	159254.4
	Gains	51178.4	14846.8	10637.2	13056.3	26854.9	5177.5	6082.7	4601.1		

The diagonals (written in bold) indicates area of land that remained unchanged for each class during the transition. The net persistence of the LULC during 1987–2002 and 2002–2017 is presented in Figure 4.
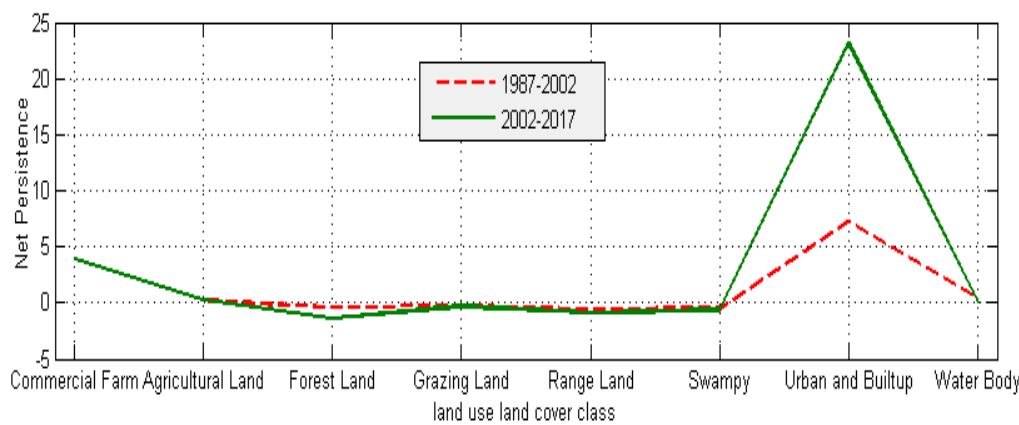
Figure 4. Persistence of the LULC classes.

3.4. Land Use/Land Cover Change with Slope Gradients in Finchaa Catchment

The continuous demand for agricultural land brought changes in LULC, especially in higher slope areas. A large part of the land (22.7%) was found in moderately rolling (8% to 15%), followed by the strongly rolling slope (15% to 30%) with the dominant agricultural land. In 1987, forest lands were higher in undulating slope (2% to 5%), followed by the gently rolling slope (5% to 8%). However, in 2017 forest land was higher in the hilly slope (30% to 60%), followed by a strongly rolling slope. The shift by forest land dominance from the undulating and gently rolling to the hilly and strongly rolling was owing to the agricultural land expansion, urban and built up, and increased water body on the lower slopes. Over the three decades (1987 to 2017), agricultural land expanded with the maximum rate of expansion shown on slope classes of strongly rolling to very hilly. The forestland was decreased in all slope ranges with the maximum rate of loss in gently undulating to moderately rolling slopes. Likewise, the swamp area was decreased in all slope ranges.

From 1987 to 2017, the urban and built-up area expanded in all slope ranges with the highest expansion on the moderately rolling to gently rolling slopes. Grazing land was increased only on the slope ranges of 2%–5% and 0%–2% (gently undulating). The water bodies increased on all slope ranges except with higher slope areas. The highest increase by water bodies was shown on slope ranges from 0% to 2%. In contrast to water bodies, rangeland decreased on all slope ranges except in very hilly slope areas. The highest decline was shown in the slope ranges from 8% to 15%.

The spatial distribution of LULCC with terrain slope in 1987 and 2017 is given in Table 6. Water bodies are dominant in 0% to 2% slope. However, in 2017, water bodies have increased in the slope range of 2%–5% due to the construction of the Neshe reservoir.

Table 6. Terrain slope percent and land use/land cover distribution for the 1987 and 2017 maps.

1987	Percent of slope class and area coverage, hectares						
LU_TYPES	**0%–2%**	**2%–5%**	**5%–8%**	**8%–15%**	**15%–30%**	**30%–60%**	**>60%**	**Total**
AGL	4157.8	16,852.1	19,945.1	40,144.8	33,259.0	5276.6	327.9	119,963.4
FL	5646.2	15,047.5	13,274.8	12,121.4	12,266.6	10,073.2	2869.8	71,299.5
RL	4218.0	12,719.2	11,146.9	14,454.1	16,792.9	7796.2	1111.7	68,239.0
UBL	16.2	68.4	79.9	134.7	64.5	19.1	9.4	392.2
WB	13,054.2	657.0	299.9	204.9	37.5	6.6	2.7	14,262.8
SA	4783.2	2934.0	919.4	730.9	1224.1	955.3	264.9	11,811.8
GL	6699.6	13,299.8	5349.5	7194.6	8671.7	3055.5	541.8	44,812.6
Total, ha	38,575.2	61,578.2	51,015.6	74,985.4	72,316.3	27,182.4	5128.2	330,781.3
2017	**Percent of slope class and area coverage, hectares**							
LU_TYPES	**0%–2%**	**2%–5%**	**5%–8%**	**8%–15%**	**15%–30%**	**30%–60%**	**>60%**	**Total**
AGL	5228.8	22,749.5	27,632.9	54,060.4	50,470.8	10,596.3	789.2	171,527.9
FL	1267.2	4017.0	3892.4	4426.4	6436.3	7600.6	2723.2	30363.1
RL	2271.9	6591.8	6262.9	8208.6	10,876.9	6753.0	1380.6	42,345.7
UBL	332.7	1369.9	1339.9	1774.9	1196.5	269.2	37.8	6320.8
CFL	1768.6	7551.6	6038.0	2773.2	186.7	48.3	6.2	18,372.6
WB	15,716.7	2485.3	1000.9	651.8	156.9	12.3	2.7	20,026.6
SA	4107.6	2648.5	784.9	336.0	177.0	127.3	52.8	82,34.1
GL	7879.7	14,158.5	4039.1	2743.6	2802.8	1767.5	199.4	33,590.5
Total, ha	38,573.1	61,571.9	50,991.2	74,974.8	72,303.8	27,174.4	5192.0	330,781.3

3.5. Drivers and Impacts of Land Use/Land Cover change

The results of FGDs, KIIs, and field observation revealed that both anthropogenic and natural processes derived LULCC. However, anthropogenic activities were found to be predominant and immediate as compared to the natural process as a driver of LULCC. Further, some drivers are not only limited to local specific issues; rather, they are regional, national, and global issues. From a range of different drivers, respondents perceived six human-related activities as major drivers of LULCC in the study area (Table 7). The ranks are derived based on how the variables were selected frequently by the respondents.

Table 7. Drivers of LULCC ranking.

Drivers	Percent %	Rank
Agricultural land expansion	29.67	1
Urbanization and infrastructure development	19.78	2
Timber, fuelwood and wood products	16.48	3
Resettlement	13.18	4
Grazing mismanagement	12.08	5
weak environmental considerations	8.79	6

Based on the information from KIIs and FGDs, the underlying causes of these drivers are the interrelated demographic, socio-economic, institutional, and technological factors. High population growth was perceived as the major driver of the demographic factor causing LULCC. According to the 2007 Population and Housing Census of Ethiopia, the total population of the Horro Guduru Wollega zone was 570,040 [46]. The population was estimated to be 691,871 in 2014 and 747,158 in 2017 [47]. According to KIIs and FGDs, resettlement, immigration, and natural population increases are the causes of population increase.

KIIs and FGDs showed that the focus of the government to build hydropower projects and irrigation projects were among the major socio-economic and institutional causes of LULCC. The expansion of irrigation projects increased commercial farms, and the construction of reservoirs increased water bodies in the catchment. Infrastructure and built-up are also increasing in the catchment. For example, the construction of institutes like the Teacher Training College, Technical and Vocational Education and Training, private colleges, the Wollega University Shambu campus, a sugar factory, the Horro Cattle breed production center, and the Shambu referral hospital contributed to urban and built-up area expansion.

The expansion of hydropower projects has displaced the community from their farmland and forced them to resettle in other places without adequate compensation. The increased resettlement on unproductive lands coupled with the relative depreciation of agricultural land made it difficult for inhabitants to remain, forcing them to move. Further, the lack of jobs for youths and urban developments in the catchment amplified the socio-economic activities for LULCC. Group discussions with the community and interviews with agricultural experts on how the construction of projects and weak environmental consideration caused LULCC were added as follows:

"The construction of Fincha Dam 1973, Amerti Reservoir in 1987, and Neshe Dam in 2012 displaced many households from their farmland and made the community landless. Then, those who have good wealth moved to the town and settled. The poor were forced to work for others who have owned land in other places. Others are also moved to the town to work daily labor activities." (Community Members, Abay Chomen District and Horro District, Focus Group Discussion, March 2018).

"The displacements of the community from reservoir areas have made land scarcity, especially in highland parts of the catchment. Consequently, there were efforts to drain wetlands mainly for agricultural land expansion, which was described in the local language as 'Duula Caffee Qoorsuu' to mean campaign of wetland draining. On the other hand, wetlands are not equally valued as natural resources. For example, there is no one accused of wetland degradation. The use of wetlands for agriculture limited the area of communal grazing where many livestock populations were allowed for grazing." (Agricultural Officer, Guduru District, Key Informant Interview, April 2018).

The expansion of agriculture on communal and private grazing lands reduced the area of grazing lands. Consequently, a small area of land is used frequently for grazing a livestock population beyond its capacity. The experience of the community in using controlled grazing is low.

According to KIIs and FGDs, the community perceived six major consequences of LULCC in Finchaa catchment. These include the decline of agricultural yield, biodiversity, and habitat loss, low and decreasing profitability of farmers, land and soil degradation, water resource decline, and extended aridity and drought.

Losses of soil fertility have caused the decline of agricultural yields. The following quotes show how crop yield and soil fertility is related to the profitability of the farmers:

"Agricultural yields are declined from time to time. Farmer's profitability from agriculture is decreasing. In some areas, the application of fertilizer is not adequate to recover crop yields due to the high decline in soil fertility. Soil acidity is increasing in the region and lack of adequate resources to treat soil acidity have worsened the situation." (Agricultural Officer and Development Agent, Jima Geneti District, Key Informant Interview, May 2018).

"In the past, we used to produce adequate yields. But now, we are losing some parts of our farms as the land is becoming less fertile, and we are not getting adequate yields. Even, the benefits from the crop yields are not enough to cover the cost of the fertilizer. We are struggling just to get a hand to mouth production, and we are unable to support our children for a better life."(Farmer group, Jima Geneti District, Focus group Discussion, May 2018).

The beginning and expansion of the commercial farms initiated the community to start new cultivation in the lowland areas. A 67-year-old man described the past and present situation in the catchment as follows:

"I was born and grew up in Gudane village. When I was young, forestland, woodlands, and grasslands covered a significant portion of the area, and there were a variety of animals. I used to hunt animals like buffalo and bushbuck with my friends. But now, the forests are cleared, and it is difficult to find animals like buffalo in the area." (Abay Chomen District, March 2018).

The interview with the natural resource management expert on forest degradation was

"The community used to destroy forests to have new farmland, to build settlements, for charcoal and domestic fuel, timber and woodworks. Further, farmers expand agricultural lands to natural forests. After cutting the natural forests, the farmers plant exotic trees such as eucalyptus (Eucalyptus globulus), which were mechanisms to own the land. Consequently, forest covers are reduced to remnants and are remained around high pick mountain areas, inaccessible areas, and along streams and valleys areas."(Natural Resource Management officers, Abay Chomen District and Horro District, Key Informant Interview, March 2018).

Currently, landslides have become the common form of land degradation in Jima Geneti (upstream of Fincha Reservoir). They are the main sources of sediment/siltation for the reservoir. An expert interview regarding landslides and their challenge was quoted as follows:

"Landslide was found to be the major problems that destroyed the farmlands, roads, and sometimes houses. The community sometimes perceives landslide as a natural process. However, the areas affected by landslides are areas that have been covered with forest once, but the forest is cleared now and areas that receive high erosion from the hillside. Erosion from the roadside, where there is no proper outlet, also caused gully and landslides. The efforts to manage landslide was limited by resources and skill required as landslide is becoming frequent." (Natural Resources Management Officer and Environment and Climate Change Officer, Jima Geneti District, Key Informant Interviews, May 2018).

The other implication of LULCC revealed in the catchment was the decline of water resources. The discharges from the agricultural field and pollution from urban and domestic wastes are specified as the causes of water resource pollution in the catchment. The interview with the natural resource management expert regarding the status of the reservoir areas and streams described the issue as

"There is no established buffer zone for the reservoir areas, and there are no stream protections. The farmers cultivate until the edge of the stream and the streams are exposed to siltation and scouring by soil erosion. Braided rivers are formed when erosion deposits soil and the river depth gets decreased and begin to form new

channels and even change the flow course." (Natural Resources Management officer, Horro District and Abay Chomen District, Key Informant Interview, March 2018).

"In several areas within the catchment, groundwater is an important source of water supply. In areas where wetlands are drained, the springs are dried out, the levels of hand-dug wells are declined." (Zonal Water Resources Officer, Horro Guduru Wollega Zone, Key Informant Interview, March 2018)

The field observation result was consistent with the interview. When the level of water in the reservoir area declines, free land will be formed. Then, farmers will use the free land for winter cultivation (locally named "Bone") and when the reservoir fills, it will submerge the farm areas and take all the minerals and soil into the reservoir. Figure 5 shows a free area used for winter cultivation around the Fincha reservoir.

Figure 5. A free area used for winter cultivation around the Fincha reservoir. (**a**) Activity around the reservoir; (**b**)Activity around the reservoir surfaces covered with grasses.

4. Discussion

4.1. Land Use/Land Cover Changes

The LULCC analysis of Finchaa catchment over 30 years (1987–2017) revealed a dramatic LULCC (Table 4 and Figure 3). The construction of hydropower projects such as Finchaa and Neshe and Amerti Reservoirs, along with the irrigation projects, were the main contributing factors to the LULCC. A similar study conducted in the northwestern part of Finchaa catchment also revealed that agricultural lands were expanding at the expense of forest and grassland [40]. This finding was also consistent with other research reports elsewhere in Ethiopia [15,19,22,37,48].

Although deforestation occurred throughout the catchment, the high decline of forest cover was because of the expansion of the commercial farms, land expansion, and continuous wood extraction. Before 1987, lowland areas of the catchment (also called Finchaa valley) were covered with forests, woodlands, and rangeland. In the Finchaa catchment, not only the coverage but also the qualities of the forest compositions (especially indigenous plants) were diminished. Studies conducted in different parts of the upper Blue Nile of Ethiopia also reported similar findings. For example, Wubie et al. [15] in the Gumera watershed, Miheretu and Yimer [16] in the Gelan sub-watershed, and Betru et al. [18] in western Ethiopia.

Urban and built-up areas are continuously increasing, with the highest rate in recent years. The increments are due to the expansion and construction of infrastructures like roads, institutions, and settlements. The same trend was witnessed in the Blue Nile basin, the Gelda catchment [49], and the Andassa watershed [50]. The finding was also in accordance with Terfa et al. [51], who showed rapid urban growth in major cities of Ethiopia between 1987 and 2017. Advancement of unplanned urban expansion among zonal, regional, and the capital city of Ethiopia were the main drivers for the conversion of rural landscapes to urban landscapes [20]. Migration from rural to urban also contributed to urban expansion in the Finchaa catchment. For example, the total population of urban inhabitants in the Horro Guduru Wollega zone was 64,736 [46]. In 2017, the population of urban

inhabitants increased to 104,473 [47]. Migrations were caused by three main reasons. They include the lack of farmland, the absence of infrastructures, and the need to engage in trades and urban works. This further supported the view that infrastructure can attract people for job opportunities [33]. Most of the existing farmlands are owned by elders, and the youth have no farmlands, which forced them to migrate to urban areas in search of job opportunies. Likewise, the lack of infrastructure, such as electricity and potable water in rural areas, has led the community to be attracted to urban areas. Relatively wealthy farmers are interested in engaging in trade and other business activities in urban areas.

The findings of forest decline and urban growth were also reported with different studies over Africa. For example, manmade impervious surfaces and built-up have increased at the expense of biomass over the whole of Africa between 2000 and 2015 [52]. A significant decline of shrubland and increased built-up were also witnessed in Botswana between 1984 and 2015 [53]. Mucova et al. [54] in northern Mozambique also reported an increase in the human settlement at the expense of forestland decline. The study on land-use changes and the climate of East Africa reported that agriculture was increased and more intensified, while forest land was decreased between 1986 and 2000 [55].

4.2. Drivers of LULC Dynamics and Their Consequences

Although both natural and anthropogenic drivers of LULCC were stated in the catchment, anthropogenic drivers were marked as the most immediate drivers. The community also enhances the natural process by deforestation and unsustainable agricultural practices, which worsen the effects of the LULCC. Restoring such land degradation and the effect of these processes could take time and require a huge amount of resources. A study conducted in southeastern Ethiopia reported that anthropogenic factors were the major responsible drivers of LULCC [56]. A similar study showed that the effects of anthropogenic drivers are more pronounced than a natural process over a small area within a short period [49].

The construction of the reservoir had displaced farmers and caused land scarcity. The scarcity of land, coupled with the need to farm more land, has led the community to cultivate steep slopes. As presented under the analysis of LULCC with slope (Table 6), agricultural lands and settlements are expanding upward in a steep slope. Discussion and field observation have also confirmed that agricultural lands are still expanding in higher slope areas. It is also reported that the construction of dams in Finchaa catchment has taken over many farms; many farmers have lost their land and are left with nothing [57]. The resettled community cultivates small parcels of land situated either on the steep slope or in flood-prone areas.

Urban development, scarcity of grazing mismanagement, and lack of adequate technology to improve agricultural practices and livestock also contributed to LULCC. A similar study conducted in Munessa-Shashemene reported similar findings that the social, economic, and environmental policies and technology highly contributed to LULCC [24]. Furthermore, LULCC was driven by various intermingling factors like urban expansion, demographic factors, biophysical factors, agricultural expansions, and land tenure policy [22].

The adverse impacts of LULCC were associated with the underlying factors related to human activities. The scarcity of land and the need to farm more coupled with resettlement have reduced grazing lands. The reduction of the grazing land forced the community to reduce their livestock, which has negative effects on household income and their consumption of livestock products. Likewise, population growth and agricultural expansion were associated with biophysical degradations like soil, water, and environment. Equally important to the environmental problem, socio-economic and institutional problems were also posed a significant impact on the sustainability of the sub-basin. For example, increased agricultural land on a steep slope without proper management practices potentially have increased the vulnerability of the land to erosion and sedimentation in water bodies of the catchment. A similar study also reported that LULCC has a significant potential for reducing the production of subsistence agriculture production [16].

The process of the hydro-development process affected local communities and their livelihoods, mostly by changing access to land and also less water [57]. For example, the seasonal fluctuations of water levels often inundate the croplands of the farmers settled near the water bodies. Furthermore, most of the present land-use practices in the catchment are focused on short-term supply satisfaction, which could bring a long-term loss of ecosystem services and the environment.

According to KIIs and FGDs, extended aridity and drought (longer dry season) are increasing in the catchment. The increase in the longer dry season has amplified the effects of water security in the catchment. A climate projection study reported that the upper Blue Nile basin will face regional water scarcity regardless of the increase or decrease in precipitation [58]. It is also reported that significant changes in LULC will further disturb the water balance components of the catchment by reducing infiltration and increasing surface runoff [59].

5. Conclusions

The quantitative spatio-temporal evidence obtained through interpretations of satellite images shows that Finchaa has undergone significant LULCC since 1987. Between 1987 and 2017, agricultural land, commercial farm, urban and built-up areas increased while rangeland, grazing lands, and swampy area decreased. The transition matrix developed to assess inter-category transitions and the change trajectories highlight the dominant dynamic events and internal conversions between LULC classes. The urban and built-up areas show the highest ratio of the net change to persistence, whereas agricultural land has shown the lowest net change to persistence ratio in the 1987–2002 transition. In general, the highest net change to persistence ratio is associated with the lowest persisting LULC classes. The spatial distribution of LULCC with slope shows a continuous expansion of agriculture and settlement and a reduction of forestland and swampy along all slopes. The rangeland has been decreased in all slope ranges except hilly slope areas.

Agricultural expansion, urbanization and infrastructure developments, timber and woodworks, resettlement, uncontrolled grazing, and weak environmental considerations were identified as the major driving factors of LULCC. The adverse impacts of LULCC are associated with the underlying causes of human activities related to the environment, socio-economic, biophysical, and institutional problems. The decline of agricultural yield, biodiversity and habitat loss, low and decreasing profitability of farmers, land and soil degradation, water resource decline, and extended aridity and drought are the major impacts of LULCC perceived by the community. Notably, increased cultivation of lands situated either on steep slopes or in flood-prone areas requires urgent action to avert the challenges of land and soil degradation as it is threatening the survival of forest remnants and other important natural resources. Further, the lifespan of the three reservoirs in the catchment depends on the sustainability of natural resources management.

The qualitative and quantitative study of the LULCC, its driving forces, and the impacts presented in this study could help a decision-maker by providing information that supports integrated watershed management and future developments. Special attention should be given to rehabilitate the degraded lands and to protect the natural resource in the catchment. With this, the undesirable effects of complex environmental dynamics in the catchment can be reduced.

References

1. Foley, J.A.; DeFries, R.; Asner, G.P.; Barford, C.; Bonan, G.; Carpenter, S.R.; Chapin, F.S.; Coe, M.T.; Daily, G.C.; Gibbs, H.K.; et al. Global Consequences of Land Use. *Science*, **2005**, *309*, 570–574,doi:10.1126/science.1111772.

2. Land-Use and Land-Cover Change, Available online: http://sedac.ciesin.columbia.edu/tg/guide_main.jsp. (accessed on 18 September 2019).

3. Githui, F.; Mutua, F.; Bauwens, W. Estimating the Impacts of Land-Cover Change on Runoff Using the Soil and Water Assessment Tool (SWAT): Case Study of Nzoia Catchment, Kenya/Estimation Des Impacts Du Changement d'occupation Du Sol Sur l'écoulement à l'aide de SWAT: Étude Du Cas Du Bassin . *Hydrol. Sci. J.*, **2009**, *54*, 899–908,doi:10.1623/hysj.54.5.899.

4. Oliver, T.H.; Morecroft, M.D. Interactions between Climate Change and Land Use Change on Biodiversity: Attribution Problems, Risks, and Opportunities. *Wiley Interdiscip. Rev. Clim. Chang.*, **2014**, *5*, 317–335,doi:10.1002/wcc.271.

5. Msofe, N.K.; Sheng, L.; Lyimo, J. Land Use Change Trends and Their Driving Forces in the Kilombero Valley Floodplain, Southeastern Tanzania. *Sustainability*, **2019**, *11*, 1–27,doi:10.3390/su11020505.

6. Lambin, E.F.; Turner, B.L.; Geist, H.J.; Agbola, S.B.; Angelsen, A.; Bruce, J.W.; Coomes, O.T.; Dirzo, R.; Fischer, G.; Folke, C.; et al. The Causes of Land-Use and Land-Cover Change: Moving beyond the Myths. *Glob. Environ. Chang.*, **2001**, 11, 261–269,doi:10.1016/S0959-3780(01)00007-3.

7. Lin, X.; Xu, M.; Cao, C.; Singh, R.P.; Chen, W. Land-Use/Land-Cover Changes and Their Influence on the Ecosystem in Chengdu City, China during the Period of 1992–2018. *Sustainability*, **2018**, *10*, 1–20,doi:10.3390/su10103580.

8. Milner-Gulland, E.J.; Mcgregor, J.A.; Agarwala, M.; Atkinson, G.; Bevan, P.; Clements, T.; Daw, T.; Homewood, K.; Kumpel, N.; Lewis, J.; et al. Accounting for the Impact of Conservation on Human Well-Being. *Conserv. Biol.*, **2014**, *28*, 1160–1166,doi:10.1111/cobi.12277.

9. Vira, B. Taking Natural Limits Seriously : Implications. *Dev. Change*, **2015**, *46*, 762–776,doi:10.1111/dech.12175.

10. Schleicher, J.; Schaafsma, M.; Vira, B. Will the Sustainable Development Goals Address the Links between Poverty and the Natural Environment ? *Curr. Opin. Environ. Sustain.*, **2018**, *34*, 43–47,doi:10.1016/j.cosust.2018.09.004.

11. CGIAR, R.P. on W. and E. *Healthy Soils for Productive and Resilient Agricultural Landscapes*; CGIAR Research Program on Water, Land and Ecosystems (WLE). 12p. (WLE Towards Sustainable Intensification: Insights and Solutions Brief 2): Colombo, Sri Lanka, 2017,doi:10.5337/2017.211.

12. Nkonya, E.; Mirzabaev, A.; Braun, J. von. *Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development*; Springer: Bonn, Germany, **2016**, 1–14, doi:10.1007/978-3-319-19168-3.

13. FAO. The State of the World's Land and Water Resources for Food and Agriculture (SOLAW)-Managing Systems at Risk.; 2011, Available online: http://www.fao.org/3/i1688e/i1688e.pdf (accessed on 22 October 2019)

14. Gessesse, B.; Bewket, W. Drivers and Implications of Land Use and Land Cover Change in the Central Highlands of Ethiopia : Evidence from Remote Sensing and Socio-Demographic Data Integration. *EJOSSAH*, **2014**,*2*, 1–23.

15. Wubie, M.A.; Assen, M.; Nicolau, M.D.; Patterns, Causes and Consequences of Land Use/Cover Dynamics in the Gumara Watershed of Lake Tana Basin, Northwestern Ethiopia. *Environ. Syst. Res.*, **2016**, *5*,1–12,doi:10.1186/s40068-016-0058-1.

16. Miheretu, B.A.; Yimer, A.A. Land Use / Land Cover Changes and Their Environmental Implications in the Gelana Sub - Watershed of Northern Highlands of Ethiopia. *Environ. Syst. Res.*, **2017**, *6*, 7,doi:10.1186/s40068-017-0084-7.

17. Ayele, G.T.; Tebeje, A.K.; Demissie, S.S.; Belete, M.A.; Jemberrie, M.A.; Teshome, W.M.; Mengistu, D.T.; Teshale, E.Z. Time Series Land Cover Mapping and Change Detection Analysis Using Geographic Information System and Remote Sensing , Northern Ethiopia. *Air, Soil Water Res.*, **2018**, *11*,1–18,doi:10.1177/1178622117751603.

18. Betru, T.; Tolera, M.; Sahle, K.; Kassa, H. Trends and Drivers of Land Use / Land Cover Change in Western Ethiopia. *Appl. Geogr.*, **2019**, *104*, 83–93,doi:10.1016/j.apgeog.2019.02.007.

19. Degife, A.; Worku, H.; Gizaw, S.; Legesse, A. Land Use Land Cover Dynamics, Its Drivers and Environmental Implications in Lake Hawassa Watershed of Ethiopia. *Remote Sens. Appl. Soc. Environ.*, **2019**, *14*, 178–190,doi:10.1016/j.rsase.2019.03.005.

20. Muke, M. Reported Driving Factors of Land-Use/Cover Changes and Its Mounting Consequences in Ethiopia : A Review. *African J. Environ. Sci. Technol.*, **2019**, 13 ,7, 273–280,doi:10.5897/AJEST2019.2680.

21. Alemayehu, F.; Tolera, M.; Tesfaye, G. Land Use Land Cover Change Trend and Its Drivers in Somodo Watershed South Western, Ethiopia. *African J. Agric. Res.*, **2019**, *14*, 102–117,doi:10.5897/AJAR2018.13672.

22. Yesuph, A.Y.; Dagnew, A.B. Land Use / Cover Spatiotemporal Dynamics , Driving Forces and Implications at the Beshillo Catchment of the Blue Nile Basin , North Eastern Highlands of Ethiopia. *Environ. Syst. Res.*, **2019**, *8*, 21,doi:10.1186/s40068-019-0148-y.

23. Getachew, H.E.; Melesse, A.M. The Impact of Land Use Change on the Hydrology of the Angereb Watershed, Ethiopia. *Int. J. Water Sci.*, **2012**, *1*, 4,doi:10.5772/56266.

24. Kindu, M.; Schneider, T.; Teketay, D.; Knoke, T. Drivers of Land Use/Land Cover Changes in Munessa-Shashemene Landscape of the South-Central Highlands of Ethiopia. *Environ. Monit. Assess.*, **2015**, *187*, 1–17,doi:10.1007/s10661-015-4671-7.

25. Lambin, E.F.; Geist, H.J.; Lepers, E. Dynamics of Land-Use and Land-Cover Change in Tropical Regions. *Annu. Rev. Environ. Resour.*, **2003**, *28*, 205–241.

26. Geist, H.; McConnell, W.; Lambin, E.F.; Moran, E.; Alves, D.; Rudel, T. Causes and Trajectories of Land-Use/Cover Change. In *Lambin E.F., Geist, H. (eds) Land-Use and Land-Cover Change.Global Change - The IGBP Series.*; Springer: Berlin, Heidelberg, 2006.

27. Hurni, H.; Tato, K.; Zeleke, G. The Implications of Changes in Population, Land Use, and Land Management for Surface Runoff in the Upper Nile Basin Area of Ethiopia. *Mt. Res. Dev.*, **2005**, *25*, 147–154,doi:10.1659/0276-4741(2005)025[0147:TIOCIP]2.0.CO;2.

28. Yalew, S.; Teferi, E.; Van Griensven, A.; Uhlenbrook, S.; Mul, M.; Van Der Kwast, J.; Van Der Zaag, P. Land Use Change and Suitability Assessment in the Upper Blue Nile Basin under Water Resources and Socio-Economic Constraints: A Drive towards a Decision Support System. 6th International Congress on Environmental Modelling and Software, Leipzig, Germany, 1–7 July 2012

29. Arsano, Y. Ethiopia and the Nile Dilemmas of National and Regional Hydropolitics, University of Zurich: City, Country, 2007.

30. Awulachew, S.B.; Yilma, A.D.; Loulseged, M.; Loiskandl, W.; Ayana, M.; Alamirew, T. *Water Resources and Irrigation Development in Ethiopia*; International Water Management Institute: Colombo, Sri Lanka, 2007.

31. Ayana, A.B.; Edossa, D.C.; Kositsakulchai, E. Modeling the Effects of Land Use Change and Management Practices on Runoff and Sediment Yields in Fincha Watershed, Blue Nile. *OIDA Int. J. Sustain. Dev.*, **2014**, 7, 75–88.

32. Kebebew, Z. GIS and Remote Sensing In Land Use Land Cover Change Detection in Finchaa Valley Area , East Wollega, Addis Ababa University: City, Country, 2005.

33. Tefera, B.; Sterk, G. Hydropower-Induced Land Use Change in Fincha'a Watershed, Western Ethiopia: Analysis and Impacts. *Mt. Res. Dev.*, **2008**, *28*, 72–80,doi:10.1659/mrd.0811.

34. Murayama, Y.; Estoque, R.C.; Subasinghe, S.; Hou, H.; Gong, H. *Land-Use/Land-Cover Changes in Major Asian and African Cities*; 2015; *92*. Page or doi

35. Daba, M.; Rao, G.N. Evaluating Potential Impact of Climate Change on Hydro - Meteorological Variables in Upper Blue Nile Basin . A Case Study Fincha Sub - Basin. *J. Environ. Earth Sci.*, **2016**, *6*, 48–57.

36. Dibaba, W.T.; Miegel, K.; Demissie, T.A. Evaluation of the CORDEX Regional Climate Models Performance in Simulating Climate Conditions of Two Catchments in Upper Blue Nile Basin. *Dyn. Atmos. Ocean.*, **2019**, *87*, 1–14,doi:10.1016/j.dynatmoce.2019.101104.

37. Liswanti, N.; Shantiko, B.; Fripp, E.; Mwangi, E.; Laumonier, Y. Practical Guide for Socio-Economic Livelihood, Land Tenure and Rights Surveys for Use in Collaborative Ecosystem-Based Land Use Planning; CIFOR: Bogor, Indonesia, 2012.

38. Lillesand, T.M.; Kiefer, R.W.; Chipman, J.W. *Remote Sensing and Image Interpretation*, 5th Ed.; John Wiley and Sons, Inc: NewYork, NY, USA, 2004.

39. ERDAS. *Erdas Field Guide*; Lecia Geosystems GIS &Mapping: Norcross, Georgia, USA, 2013.

40. Senbeta, F. Community Perception of Land Use/Land Cover Change and Its Impacts on Biodiversity and Ecosystem Services in Northwestern Ethiopia. *J. Sustain. Dev. Africa*, **2018**, *20*, 108–126.

41. Tilahun, A.; Teferie, B. Accuracy Assessment of Land Use Land Cover Classification Using Google Earth. *Am. J. Environ. Prot.*, **2015**, *4*, 193–198,doi:10.11648/j.ajep.20150404.14.

42. Gashaw, T.; Tulu, T.; Argaw, M.; Worqlul, A.W. Evaluation and Prediction of Land Use/Land Cover Changes in the Andassa Watershed, Blue Nile Basin, Ethiopia. *Environ. Syst. Res.*, **2017**, *6*, 1–15,doi:10.1186/s40068-017-0094-5.

43. Tadele, H.; Mekuriaw, A.; Selassie, Y.G.; Tsegaye, L. Land Use / Land Cover Factor Values and Accuracy Assessment Using a GIS and Remote Sensing in the Case of the Quashay Watershed in Northwestern. *J. Nat. Resour. Dev.*, **2017**, *07*, 38–44,doi:10.5027/jnrd.v7i0.05.

44. Pulighe, G.; Baiocchi, V.; Lupia, F. Horizontal Accuracy Assessment of Very High-Resolution Google Earth Images in the City of Rome, Italy. *Int. J. Digit. Earth*, **2015**, *9*, 342–362, doi:10.1080/17538947.2015.1031716.

45. Viera, A.J.; Garrett, J.M. Understanding Interobserver Agreement : The Kappa Statistic. *Fam. Med.*, **2005**, *37*, 360–363.

46. CSA. Summary and Statistical Report of the 2007 Population and Housing Census; Central Statistical Agency: Addis Ababa, Ethiopia, 2007.

47. CSA. Central Statistical Agency: Population Projection of Ethiopia for All Regions At Wereda Level from 2014–2017; Central Statistical Agency: Addis Ababa, Ethiopia, 2013.

48. Tolessa, T.; Dechassa, C.; Simane, B.; Alamerew, B. *Land Use/Land Cover Dynamics in Response to Various Driving Forces in Didessa Sub-Basin, Ethiopia*; Springer: Amsterdam, Netherlands, **2019**, 1–14, doi:10.1007/s10708-019-09990-4.

49. Hassen, E.E.; Assen, M. Land Use/Cover Dynamics and Its Drivers in Gelda Catchment, Lake Tana Watershed,Ethiopia. *Environ. Syst. Res.*, **2017**, *6*, 1–13,doi:10.1186/s40068-017-0081-x.

50. Gashaw, T.; Tulu, T.; Argaw, M.; Worqlul, A.W. Modeling the Hydrological Impacts of Land Use/Land Cover Changes in the Andassa Watershed, Blue Nile Basin, Ethiopia. *Sci. Total Environ.*, **2018**, *619–620*, 1394–1408,doi:10.1016/j.scitotenv.2017.11.191.

51. Terfa, B.K.; Chen, N.; Liu, D.; Zhang, X.; Niyogi, D. Urban Expansion in Ethiopia from 1987 to 2017: Characteristics, Spatial Patterns, and Driving Forces. *Sustainability*, **2019**, *11*, 1–21,doi:10.3390/su11102973.

52. Midekisa, A.; Holl, F.; Savory, D.J.; Andrade-Pacheco, R.; Gething, P.W.; Bennett, A.; Sturrock, H.J.W. Mapping Land Cover Change over Continental Africa Using Landsat and Google Earth Engine Cloud Computing. *PLoS ONE*, **2017**, *12*, 1–15,doi:10.1371/journal.pone.0184926.

53. Matlhodi, B.; Kenabatho, P.K.; Parida, B.P.; Maphanyane, J.G. Evaluating Land Use and Land Cover Change in the Gaborone Dam Catchment, Botswana, from 1984-2015 Using GIS and Remote Sensing. *Sustainability*, **2019**, *11*, 1–21.

54. Mucova, S.A.R.; Filho, W.L.; Azeiteiro, U.M.; Pereira, M.J. Assessment of Land Use and Land Cover Changes from 1979 to 2017 and Biodiversity & Land Management Approach in Quirimbas National Park, Northern Mozambique, Africa. *Glob. Ecol. Conserv.*, **2018**, *16*, 1–17,doi:10.1016/j.gecco.2018.e00447.

55. Res, C.; Otieno, V.O.; Anyah, R.O. Effects of Land Use Changes on Climate in the Greater Horn of Africa. *Clim. Res.*, **2012**, *52*, 77–95,doi:10.3354/cr01050.

56. Hailemariam, S.N.; Soromessa, T.; Teketay, D. Land Use and Land Cover Change in the Bale Mountain Eco-Region of Ethiopia during 1985 to 2015. *Land*, **2016**, *5*, 41,doi:10.3390/land5040041.

57. Müller-Mahn, D.; Gebreyes, M. Controversial Connections: The Water-Energy-Food Nexus in the Blue Nile Basin of Ethiopia. *Land*, **2019**, *8*, 2–20,doi:10.3390/land8090135.

58. Coffel, E.D.; Keith, B.; Lesk, C.; Horton, R.M.; Bower, E.; Lee, J.; Mankin, J.S. Future Hot and Dry Years Worsen Nile Basin Water Scarcity Despite Projected Precipitation Increases Earth's Future. *Earth's Futur.*, **2019**, 7,967–977, doi:10.1029/2019EF001247.

59. Wakjira Takala; Tamene Adugna; Dawud Tamam. The Effects of Land Use Land Cover Change on Hydrological Process of Gilgel Gibe, Omo Gibe Basin, Ethiopia. *Int. J. Sci. Eng. Res.*, **2016**, *7*,8.