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Drivers and Implications of LULC Dynamics in Hazara and Its Impacts on Cereal Crops

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In order to generate and give useful information to policymakers and development practitioners regarding the scale and trends of land use/land cover change (LULCC), it is necessary to have a firm grasp on its trajectories and extents. This research details the causes, effects, and implications of LULCC in the Finchaa catchment on long-term sustainable land management. The land use maps and change quantifications were created using data from Landsat photos taken in 1987, 2002, and 2017. The photos were classified using a supervised classification method and a maximum likelihood classifier. The socioeconomic survey combined key informant interviews, focus groups, and transect walks. Over the previous three decades, forestland, rangeland, grazing land, and swampy regions have shrunk while agricultural land, commercial farm, built-up, and water bodies have expanded. Lack of good catchment management practices in the name of "intensive agriculture" has long been a source of trouble for the region. Increasing erosion and sedimentation of surrounding water bodies is a consequence of increased farming on steep hillsides. The observed LULCC in the research area was the result of a combination of biophysical, socioeconomic, institutional, technological, and demographic variables. The main effects of LULCC in the Finchaa catchment are a decrease in agricultural yield, loss of biodiversity, prolonged aridity and drought, land and soil degradation, and a decrease in water resources. The long-standing gap between catchment area supply and demand for both land and water has been exacerbated by socioeconomic changes and population growth. Risk management will require watershed management policies that are more holistic and interconnected.

Keywords: Drivers; Finchaa; Land use/land cover; Sustainable; Watershed Management

Introduction

Among the many factors that affect biophysical systems at all sizes, land use/land cover change (LULCC) is a significant one. Because of the ways in which land use and land cover (LULC) are linked to the most fundamental features and processes of our world, they are a primary source of anxiety. Land productivity, biodiversity, land degradation, the hydrological cycle, and environmental conditions are all processes that are affected by these factors [1]. Reduced ecosystem services are a direct result of LULCC, which disrupts natural systems' ability to provide for human needs and increases the vulnerability of people and resources to climate change, socio-economic crises, and political problems [2]. There has also been a rise in both domestic and international LULCC [3]. Historically, sustainable development and poverty alleviation initiatives have had less sway due to a lack of acknowledgment of the value of the natural environment for human well-being [4]. Nonetheless, there is a strong connection between natural environments and poverty, which has a knock-on effect on sustainability and development. The sustainability of the farming system, food production, revenue, and employment are all threatened by the depletion and degradation of land and water resources [5]. The poor, who depend mostly on land and natural resources, will suffer greatly as a result. Estimates put the annual cost of agricultural and pasture land degraded by LULCC and poor land management practice at $300 billion USD [6]. The highest proportion of the worldwide price tag for degraded land is borne by Sub-Saharan Africa (22%). Women and the poor are disproportionately affected by land degradation, according to a research from the Food and Agriculture Organization (FAO) [7]. Research into LULCC has exploded in popularity in recent years [8]. It has been demonstrated through research that LULCC has been particularly severe in the Ethiopian highlands. To meet the needs of a growing population, a number of factors, including intense agricultural expansion, urbanization, and the harvesting of forest products, are speeding up with time [9]. Yet, some research have found contradictory tendencies in LULCC. In the Somodo watershed, which is located in southwestern Ethiopia, for instance, agricultural land has decreased while grassland has expanded [10]. Grassland and shrubland have been expanding in the northern highlands, as observed [11].

Anthropogenic and biophysical causes combine to set in motion the LULCC process [12]. Social, economic, biophysical, and political issues all play a role as LULCC catalysts [13]. It has been reported that the key drivers of LULCC in Ethiopia are the human and animal population, different agricultural practices, urbanization, the occurrence of drought, and poor land-use planning. Yet, causes and effects might vary greatly from one region to the next. In the Afar and Somali regions, for instance, overgrazing and charcoal production are major causes, while in the southwest of the country, forest grabbing for investments (coee and tea plantation and, agriculture), settlements, poor law enforcement, shifting cultivation, and land tenure policy have been major causes. On the other hand, there is a dearth of knowledge and understanding about the complexity of the change drivers and their ramifications in some areas. Insufficient research has been conducted at the national level to determine the full scope of the causes, effects, and implications of LULCC. A wide range of biophysical, socioeconomic, and environmental stresses are exerted on the upper Blue Nile Basin, which is home to a wide range of natural resources, including land, vegetation, genetic diversity, and water [14]. The rate of soil erosion and nutrient depletion, as well as the fluctuation of the climate, are among the key stressors, together with the increasing human population and the resulting destruction of habitats and other natural resources. Thus, the recent intense LULCC has been a challenge to the planned sustainable development in various parts of Ethiopia, including the study area. Ethiopia has an abundance of water, although this has had only a minor impact on the growth of the country's economy. Since water resource development is so crucial to the country's economic and social growth, it is a top priority [15]. Yet, the efficiency with which future and current construction projects are administered will determine the water resources' usefulness in advancing sustainable development. The majority of Ethiopia's hydroelectric power, sugar, and ethanol all come from the Finchaa watershed. In contrast to neighboring regions, however, the catchment has seen comparatively little multidisciplinary and independent study. Finchaa catchment in LULCC has only had a small number of research [16]. Without taking into account the actual spatio-temporal LULCC, Ayana et al. [17] conducted a study on the effects of land use and management techniques on surface runoff and sediment output using hypothetical scenarios. Tefera and Sterk [18] primarily focused on studying the LULCC induced by hydroelectric dam building in the Finchaa watershed, while Kebebew [19] evaluated the state of the LULCC in the Finchaa catchment by considering solely downstream of the reservoirs. The mechanisms behind this, such as spatial-temporal LULCC and their impact on the entire Finchaa watershed, are unknown, however. Consequently, it is necessary to have a spatially accurate and up-to-date time series of land resource information for the catchment. To better understand the causes, mechanisms, and patterns of the changes at indifferent spatial and temporal scales[20] is the most essential activity in LULCC studies. Comparing and contrasting different parts of the watershed to determine which are at risk or amenable to change requires an understanding of the spatio-temporal trends of LULCC within a larger socio-ecological system at watershed scale. This allows for more proactive measures to maintaining water resources and land health by providing detailed insight into the status of the watershed and providing evidence-based interaction between the local people and the watershed. This research aims to learn more about the LULCC in the Finchaa catchment and how its magnitude and temporal variability affects the area. The specific goals of this research are to I examine the transitions between landuse and landcover categories and the LULCC associations with slope, (ii) identify the major driving factors and explore the implications of the LULCC in Finchaa catchment, and (iii) analyze the changes in landuse/landcover over the last 30 years (1987-2017).

Materials and Methods

Study Area

The research took place in the Finchaa sub-basin of the upper Blue Nile Basin in Ethiopia's Oromia Regional State. The coordinates for the Finchaa sub-basin are 9°100–10°000 North, 37°000–37°400 East, with a total area of 3,781 square kilometres. The catchment has a wide range of elevations, from 851.2 to 3213 metres above sea level, giving it a highly topographic profile. There are extensive irrigable fields downstream, as well as great hydropower potential, in this region [21]. Fincha, Amerti, and Neshe are the three watersheds that make up this sub-basin. The detail studyarea description is shown in Figure 1.

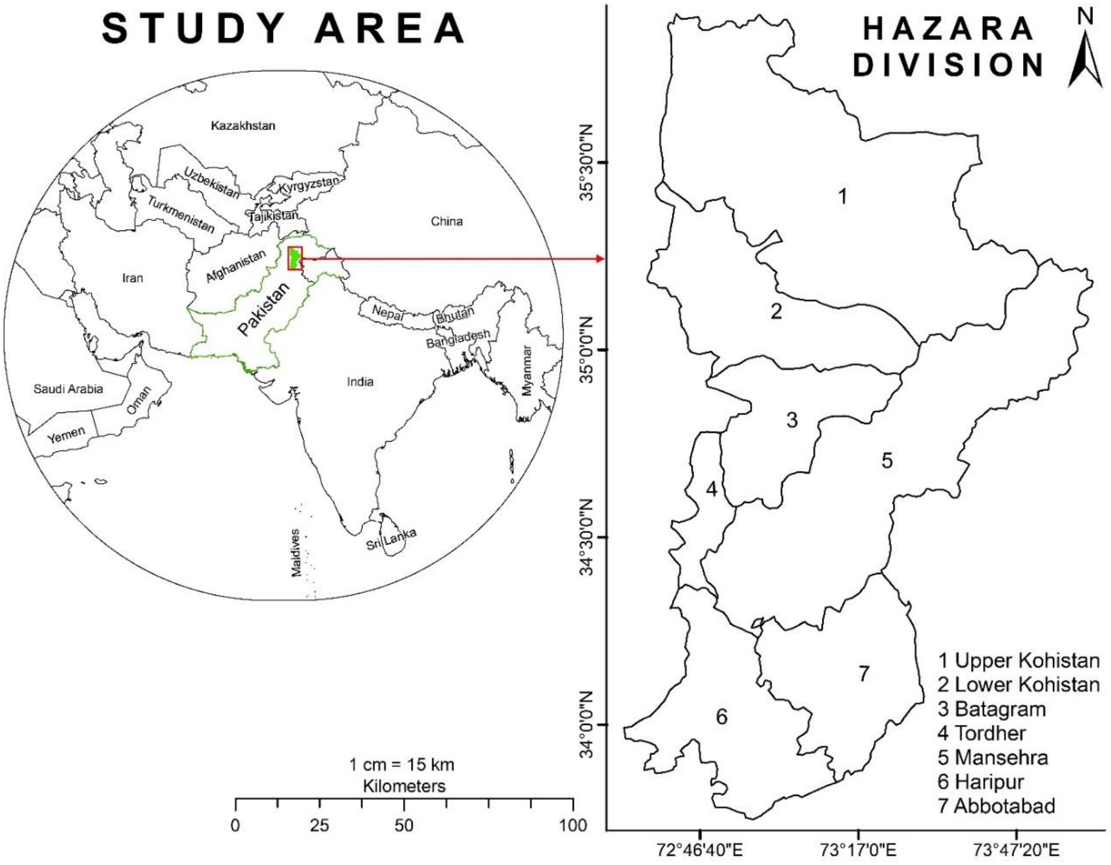

Figure 1. Map of the study areas

The ecosystems and land uses in the Finchaa sub-basin are important to the national economy. They include forest, commercial agriculture, wetland, and lake ecosystems. Because of its downstream relationship to the Nile basin, the sub-basin has also been a focus of international and national hydro-politics. Annual precipitation in the Finchaa catchment varies from around 1367 mm to about 1842 mm, with the lower amounts occurring in the northern lowlands and the higher amounts above 1500 mm happening in the southern and western highlands of the sub-basin. The watershed receives its majority of its annual rainfall, around 1604 millimetres, throughout the months of June, July, and August. [22]. The monthly average temperature in the watershed ranges from 15.50 to 18.62 _C.

Data Sources and Methodology

Spatial Data

This investigation made use of Landsat pictures, a DEM, and data collected in the field. Using a 30 m DEM from the USGS's Earth Explorer (https://earthexplorer.usgs.gov/), the watershed was defined, and slope maps were created, for the area under investigation. In-field observations were made with a Global Positioning System (GPS), Landsat composites, and Google Earth to acquire Ground Control Points (GCP) for use in image classification and accuracy testing. For this study, we used USGS images from https://landsatlook.usgs.gov/, namely two sets of Landsat Thematic Mapper (TM) imagery and one set of Landsat 8 Operational Land Imager and Thermal Infrared Sensor (OLI-TIRs) image (Table 1). Whole photos for a given year covering the entire catchment on the same day were not available for the watershed due to extent and quality concerns. As a result, the Landsat photos for the same season were gathered using a variety of different pathways and rows. The acquisition dates were chosen during the same season each year to lessen the impact of seasonal changes in vegetation pattern and distribution.

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

Acquisition Date	Satellite Image	Sensor	Spatial Resolution	Used Bands	Sources
April 2000	Landsat TM	TM	30	1–5, 7	USGS
April 2022	Landsat8 OLI	OLI-TIRs	30, 15	1–7, 9, 8 *	USGS

Path/row = 150/035, 150/036, 150/037. * 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.

Socio-Economic Data

To gain a better grasp of local resources, resource utilisation, citizen participation in policymaking, and community perspectives on emerging trends and pressing concerns, we conducted a socioeconomic study [23]. Socioeconomic surveys can be conducted in a number of ways depending on their intended use, but in this case, researchers relied on key informant interviews (KIIs) and focus group discussions (FGDs). Three typical sub-watersheds were chosen for FGD and KII based on agro-ecological parameters and proximity to reservoirs in the catchment. The municipalities of Horro, Jima Geneti, AbayChomen, and Guduru are all included in the areas serviced by these smaller watersheds (Figure 1). The corresponding author and several agricultural specialists conducted the fieldwork. Seven focus group discussions were conducted altogether; two in the upper and lower sub-watersheds, and three in the middle. Seven community members are chosen to take part in each FGD. Experts in Natural Resources management, land use administration, and Environment and climate change participated in 22 KIIs that were held at the District and Zonal levels.

Each municipality's useful GIS data was compiled. Both the KIIs and the FGDs made use of free-form questions to elicit responses from participants about the most notable changes in LULC and its associated biophysical, institutional, socioeconomic, and demographic factors. In order to learn about the management's point of view, assess the efforts made towards resource management, and identify the obstacles they face, they organized discussions on the practices and rules that govern land management in their region. Land deterioration was also discussed, along with the most pressing problems that need fixing. The goals of the interviews and discussions were to learn about the history and current state of LULCC, to pin down the underlying causes of the shifts, and to assess the effects of LULCC on local economies, communities, and ecosystems. Transect walks, field walks, and informal interviews with individuals in their farms/fields were utilized to gain a better understanding of the most prominent issues seen in the watershed and resource management practice. Farmers were questioned about the altered terrain and the factors that led to the changes. The farmers were also prompted to talk on how the shifts in their environment, livelihood, and lifestyle had affected them. Farmers were also questioned on the societal and economic effects of their farming practices on the shift in land usage. The situation in the watershed was observed in the field using pre-made checklists, and key areas were photographed to supplement the study. Table 2 shows the eight groups of land use/land cover types that were determined with the help of field observation, information from specialists, and an examination of documentation from national and regional agencies. This study's LULCC analysis is based on these categories.

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.
S Forest	Sparsely located trees with brush and shrub form types, bushes, woodlands, grasses, mixed rangelands, and transitional forests (less dense forests) were included.
T Forest	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.
Soil	Sand, bare soil, baren soil.
Water bodies	Areas that are completely inundated by water like lakes and major rivers.
Snow	Area under snow.

Data Analysis

Using the use of Landsat image processing, classification, and post-processing, we were able to analyze and quantify the spatio-temporal dynamics of the LULC from 1987 to 2017. Geometric and radiometric corrections were performed during pre-processing of images before analysis. The image processing for LULC classification in this study only made use of six TM spectral bands (bands 1-5 and 7) and eight Landsat 8 OLI spectral bands (bands1-7 and 9). Using the use of the Principal Component Analysis (PCA) tool in ERDAS, a 15-m spatial resolution layer (band 8) from OLI was combined with multispectral bands with a 30-m spectral resolution. The OLI picture was just pan-sharpened so that it would be easier to see details and understand what was going on.

Each pixel was assigned a category based on the known ground truth using the maximum probability parametric rule. In order to accurately classify images using maps with fewer than 12 categories, 50 samples are required, as stated in [24]. Following the advice, 50 reference samples were used for picture classifications across all classes. Data for the two years

(1987 and 2002) were gathered from Google Earth as points of reference. The following are the broad steps taken throughout the picture classification process. At first, we had to pick some places to do our training [25]. The processed photos were utilized to build polygons for a certain spectral class, allowing for the polygon sampling approach to be used to sample the training sites. During this procedure, we used a variety of banding schemes, image enhancing techniques, and color compositions to isolate and analyse surface elements in the photos. Each band is a group of data files for a certain region of the electromagnetic spectrum, and their combination was chosen based on their usefulness in detecting the study's aspects. Histogram analysis was used to assess the retrieved signatures from the sample, and several approaches were tried until a unimodal distribution was attained. Then, all signatures inside a given class were selected and combined into a single one. Cumulated (merged signature) data was utilized in a supervised classification process to generate a land cover map. The images were classified based on their contents using the class signatures generated from the training data sets.

Accuracy Assessment

Generating a collection of points from the classified image and comparing their locations with those of points whose locations were established by the ground truth data and matching coordinates from the original maps was the method used to evaluate the accuracy of the classification [26][27]. The data sets used here were sampled at random. A group of points was picked at random. Accuracy was not evaluated using data utilized during classifier training. As a result, an error matrix was constructed using data from 460 randomly generated locations [28]. The 2017 points of reference were gathered from the corresponding Google Earth, original Landsat photos, earlier reports and maps, and field observation for 1987 and 2002. We were able to calculate the historical LULC with the help of data gleaned through interviews and focus groups [29][30]. This data included the locations of forests, pasture land, and water supplies. High-resolution Google Earth was utilized to better identify the land-use classes than the low-resolution historical maps for 1987 provided from the Ethiopian Mapping Agency. Other research utilized a similar method in areas of Ethiopia [31] and Italy [32] where historical maps were inadequate. The overall accuracy, user accuracy, producer accuracy, and kappa statistics were calculated from the error matrix [33]. Most kappa coefficients will be between 0 and 1. Strong agreement is indicated by a kappa value of 0.8 or above, moderate agreement by a value between 0.4 and 0.8, and poor agreement by a value of 0.3 or lower, as stated by Viera and Garrett [34][35].

Land Use/Land Cover Change Analysis Once the land cover classifications were derived, Arc Geographic and Information System (ArcGIS10.1) 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:

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

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

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 the1987–2002and 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.

Result and Discussion

Table 3 shows the confusion error matrix and Kappa statistics for the accuracy of classifying the LULC maps from 1987, 2002, and 2017. Overall, the accuracy of the 1987 map was 81.7%, the 2002 map was 85.4%, and the 2017 map was 89.7%. Kappa values ranged from 0.78 to 0.83 to 0.88 for the 1987, 2002, and 2017 maps, respectively. According to the Kappa figures, the years 2002 and 2017 had the highest degree of agreement, while 1987 had the best degree of agreement.

Table 3. Accuracy of land use/land cover maps for 2000, 2022.

	LULC	Built up	Soil	Crop	S Forest	T Forest	Water	Snow	Row Total	User Accuracy (%)
2000	Built up	92	8	0	0	0	0	0	100	92.00
	Soil	6	89	5	0	0	0	0	100	89.00
	Crop	0	1	87	8	4	0	0	100	87.00
	S Forest	0	0	9	84	6	1	0	100	84.00
	T Forest	1	0	4	6	89	0	0	100	89.00
	Water	0	0	0	0	0	93	7	100	93.00
	Snow	0	0	0	0	0	4	21	25	84.00
	Column Total	99	98	105	98	99	98	28		
	Producer's Accuracy (%)	92.93	90.82	82.86	85.71	89.90	94.90	75.00		
	Overall Classification Accuracy (%)	88.8								
	LULC	Built up	Soil	Crop	S Forest	T Forest	Water	Snow	Row Total	User Accuracy (%)
2022	Built up	88	12	0	0	0	0	0	100	88.00
	Soil	4	91	5	0	0	0	0	100	91.00
	Crop	0	2	89	7	2	0	0	100	89.00
	S Forest	0	0	9	84	6	1	0	100	84.00
	T Forest	1	0	3	4	92	0	0	100	92.00
	Water	0	0	0	0	0	95	5	100	95.00
	Snow	0	0	0	0	0	2	23	25	92.00
	Column Total	93	105	106	95	100	98	28		
	Producer's Accuracy (%)	94.62	86.67	83.96	88.42	92.00	96.94	82.14		
	Overall Classification Accuracy (%)	89.92								

Analysis of Finchaa Catchment's Land Use and Land Cover Changes across Time and Space The watershed is dominated by agricultural areas, which accounted for 36.27 percent of the area in 1987, 42.64 percent in 2002, and 51.86 percent in 2017. (Table 4). Commercial farms and urban and built-up regions both saw growth between 1987 and 2017. In 1987, 0.12% of the total area was urban and built-up; by 2002, 0.27 percent; and by 2017, 1.91% of the total area was urban and built-up. Wetlands and bodies of water occupied 3.57 percent and 4.31 percent of the watershed, respectively, in 1987; 3.12 percent and 5.94 percent, in 2002; and 2.49 percent and 6.0 five percent, in 2017. Sugar cane cultivation first appeared in the catchment's lowland parts around 1994, following the development of a sugar factory there. Around 4577.5 hectares (1.38%) of land was used for commercial farming in 2002. The sugarcane plantation was expanded so that the firm could meet its goal of doubling sugar output. In addition, the new plantation was set up in the area just below the Neshe hydropower station in about 2012. The farm was increased in 2017 to a total area of 18372 hectares (5.55 %). Land used for forest, range, and pasture made up 21.55 percent, 20.63 percent, and 13.55 percent of the catchment in 1987, respectively. In both 2002 and 2017, the majority of LULC was comprised of forest, range, and grazing land. The greatest reduction occurred in forest and rangeland between 1987 and 2002 and between 2002 and 2017, whereas the greatest gain occurred in agricultural land. The LULCC increased more rapidly between 2002 and 2017 than it did between 1987 and 2002. Figure 2 depicts the prevalence of LULCC throughout a 30-year time span. Continuous decline was seen in forested, grazing, range, and swampy areas, while continuous growth was shown in agricultural, commercial farm, and urban and built-up areas.

Table 4. LULC area coverage, status, and changes between 2000 & 2022.

LULC Types	Area				Change (Gain/ Loss)	
	2000		2022		2000 - 2022	
	sq km	% Age	sq km	% Age	sq km	% Age
Built Up	482.36	2.8	2204.73	12.7	1722.37	357.07
Soil	5219.62	29.9	1458.08	8.4	-3761.54	-72.07
T Forest	789.22	4.5	1068.49	6.1	279.27	35.39
S Forest	3134.39	18.0	5370.88	30.8	2236.49	71.35
Crops	505.43	2.9	1386.00	8.0	880.56	174.22
Water	231.28	1.3	598.37	3.4	367.09	158.72
Snow	7065.52	40.5	5341.26	30.6	-1724.26	-24.40
Total	**17427.81**	**100**	**17427.81**	**100**		

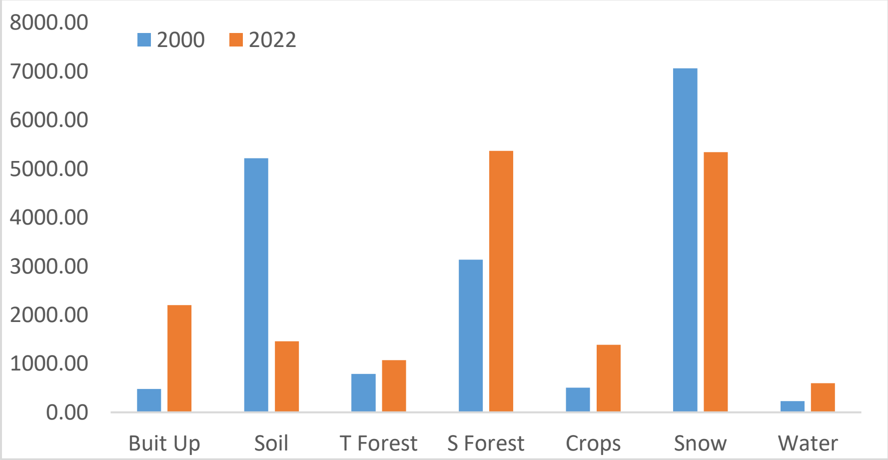

Figure. 2: LULC distribution

Pathways of Change and Transition Across LULC Domains

Finchaa saw complex LULC transitions, as evidenced by the LULCC analysis.

The LULC matrix was created for the decades between 1987 and 2002 and between 2002 and 2017. Areas gained, lost, maintained, and traded between LULC kinds were determined using the matrix (Table 5). The rangeland class experienced the greatest decline between 1987 and 2002, followed by the forest land class and the grazing land class. The least damage was found in urban and built-up areas, followed by water and swampy terrain. Rangeland had the biggest loss, followed by forest land and agricultural land, while urban and built-up areas showed the lowest loss, followed by marshy area and water bodies, between 2002 and 2017. Agricultural land, followed by rangeland and forest land, had the greatest increase between 1987 and 2002, while urban and built-up land, followed by water bodies, showed the smallest increase. Waterbodies, marshy areas, and urban and built-up areas had the lowest growth rates between 2002 and 2017, followed by agricultural land, then rangeland, and finally grazing land.

Table 5. LULC change transition matrices for 2000-2022.

LULC Classes		To 2022								
		Built Up	**Crops**	**S Forest**	**Snow**	**Soil**	**T Forest**	**Water**	**Grand Total**	**Loss**
From 2000	**Buit Up**	**235.38**	120.33	105.01	4.64	15.41	0.49	1.03	482.29	246.91
	Crops	102.50	**241.45**	147.38	4.60	5.27	3.92	0.26	505.37	263.92
	S Forest	192.36	460.18	**2237.50**	7.15	20.20	219.13	1.27	3137.79	900.29
	Snow	588.57	14.22	211.50	**5260.36**	458.74	86.55	443.38	7063.33	1802.97
	Soil	1060.59	545.36	2398.69	61.26	**926.84**	142.26	83.74	5218.74	4291.90
	T Forest	6.80	4.25	239.86	1.06	1.41	**533.51**	2.30	789.19	255.67
	Water	19.41	0.06	30.58	2.10	30.07	82.59	**66.29**	231.11	164.82
	Grand Total	2205.62	1385.85	5370.51	5341.17	1457.94	1068.46	598.27	17427.81	
	Gain	1970.24	1144.40	3133.01	80.81	531.10	534.94	531.98		

The diagonals (written in bold) indicate 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.

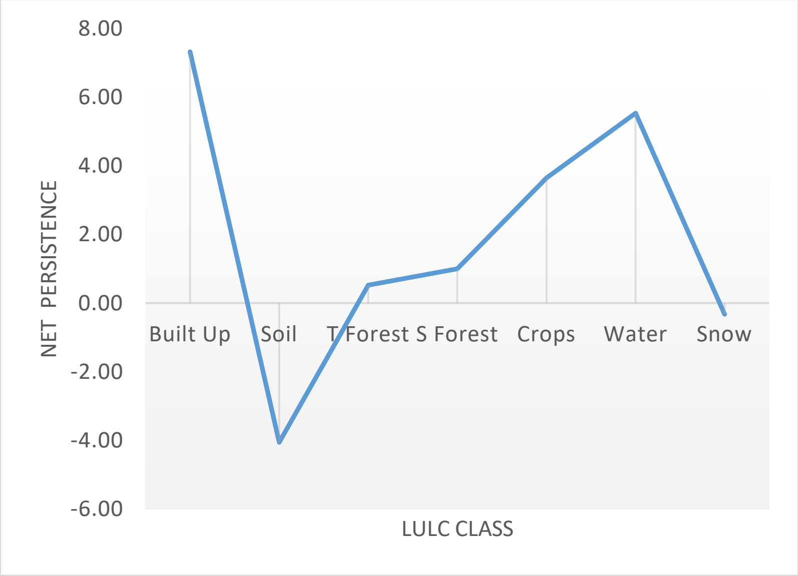

Figure. 4: LULC Persistence

The largest net change to persistence ratio for the study periods of 1987–2002 and 2002–2017 was found for the diagonals of each class, urban, and built-up area. The LULC class with the highest net change to persistence ratio is the least persistent one. Urban and built-up areas had the lowest persisting LULC class in the Finchaa catchment, followed by rangeland, while agricultural land and grazing land had the highest persisting LULC class. For the period from 2002-2017, the LULC classes with the lowest persistence were urban and built-up areas and commercial farms, whereas the LULC classes with the highest persistence were water bodies and agricultural lands, in that order.

Conclusion

Satellite image interpretations have yielded quantifiable spatial and temporal evidence demonstrating that Finchaa has suffered considerable LULCC since 1987. Rangeland, grazing grounds, and swampy area all shrank between 1987 and 2017, whereas agricultural land, commercial farm land, and urban and built-up areas all expanded. Both the change trajectories and the transition matrix used to evaluate the flow of information between categories in LULC systems shed insight on the most important dynamics and internal transformations that occur within these systems. The ratio of net change to persistence is highest in urban and built-up regions and lowest in agricultural land throughout the period between 1987 and 2002. In general, the least stable LULC classes have the highest net change to persistence ratios. The spatial distribution of LULCC demonstrates that agriculture and settlement have been expanding, while forest and swamp areas have been shrinking, along all slopes. No slope type has escaped the reduction in rangeland; only the hilly slope types have fared better. Major drivers of LULCC have been recognized as agricultural expansion, urbanization and infrastructural development, timber and woodworks, resettlement, unregulated grazing, and insufficient environmental considerations. Human actions have environmental, social, economic, biophysical, and institutional consequences, all of which contribute to LULCC. The principal impacts of LULCC experienced by the community are the decrease in agricultural productivity, the loss of biodiversity and habitat, the poor and declining profitability of farmers, the degradation of land and soil, the depletion of water resources, and the prolonged aridity and drought. Important natural resources, such as dwindling forests, are in jeopardy due to the increasing cultivation of land on steep slopes and in flood-prone areas. Urgent action is needed to address these issues of land and soil degradation. What's more, natural resources management's longevity is crucial to the catchment's three reservoirs. This study's qualitative and quantitative analysis of the LULCC's motivations and impacts could aid decision-makers by providing data for integrated watershed management and planning. The catchment's natural resource is important and should be protected with the rehabilitation of the degraded lands. This helps mitigate some of the negative outcomes brought on by the catchment's complicated environmental dynamics.

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