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The Land-Use and Land-Cover Changes in the Este District, South Gondar Zone, Northwestern Ethiopia, in the Last Four Decades (the 1980s to 2020s)

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Abstract: Environmental transformations are the results of land-use and land-cover (LULC) changes. This study aims to investigate the LULC changes and associated factors in the Este District in northwestern Ethiopia, for the last four decades (the 1980s to 2020s). The land-use and land-cover classes were analyzed using supervised classification techniques in ERDASS IMAGINE 2015 and ArcGIS 10.3.1, categorizing the Landsat satellite images for 1984, 2000, and 2018 into six cover classes: settlement, forests-shrublands, cropland, grassland, bare land, and water body. We used a historical Google map, topo-sheets, and ancillary data to verify the classification accuracies for 1984, 2000, and 2018, respectively. The climate and demographic data were obtained from the Ethiopian Meteorological Station and Ethiopian Statistical Agency, respectively. In addition, data from key informant interviews and focus group discussions were also used to understand the local community experiences and perceptions toward LULC changes. The values of each LULC class were correlated with the demographic and climatic variables, using simple correlation analysis to evaluate the impact of demographic and climatic conditions on LULC changes. The analysis indicated that the least and largest classes of LULC in Este District were water bodies (mean cover = 1.9 km^2) and croplands (mean cover = 791.7 km^2), respectively. Cropland coverage increased by 2% in 2000, then decreased by 11% in 2018. Between 1984 and 2018, the grasslands and settlements increased by 22% and 0.5%, respectively. Half of the bare land and one-tenth of the forests-shrublands also decreased over the last four decades (the 1980s to 2020s). As a result, the original croplands and forests–shrublands classes (11% each) before 2000 were converted into new grasslands and croplands after 2018, respectively. The study indicated that precipitation, solar radiation, and population growth are the potential drivers, and the perceptions of local communities are nearly in line with the statistical analysis results. Alternative income sources, such as tourism and carbon trading and the participation in afforestation programs, could reverse the situation in the study area.

Keywords: accuracy; LULC classes; LULC derivers; Landsat images; verification

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1. Introduction

Land-use and land-cover change are aspects of the transformation of the earth's land-use and land-cover systems [1]. These processes and associated effects influence the abiotic and biotic resources of a specific region [2]. Depending on the type of derivers, every LULC modification is a switch from one form of cover to the other [3,4]. LULC changes can be explained in temporal and spatial perspectives [5]. Temporally, these changes vary from time-to-time and are not recent phenomena; they date back to prehistory [6]. Spatially, however, the changes are explained to vary from region to region and they are not confined

to a specific continent or region of the earth [7]. Many research works show that the most considerable LULC changes, especially the loss of forests, took place in most parts of sub-Saharan Africa [8].

Assessing changes in either the spatial or temporal LULC patterns is important for land management, especially forest conservation [5,9]. However, assessing these changes without the use of advanced technologies could be challenging, considering the time and financial resources it may require for remote areas [9]. The application of GIS technology assessing the LULC changes over a large area removes the constraints of the resources, despite some of its limitations [2,9].

In developing regions, such as those in sub-Saharan Africa, agricultural lands and settlements are expanding while forest–shrubland cover is decreasing in proportion to the increasing human population [10,11]. Changes in agricultural lands and settlements and forest–shrubland cover may put tremendous pressure on water [12,13], land stability [14] and biodiversity [2,15]. Ethiopia has lost its fertile land and high forest cover because of the drivers behind the rapid LULC changes [12,13,16].

The drivers of these LULC changes include population growth, demand for energy, and the shortage of arable land [17,18]. Additionally, climate change, such as the unpredictable variation in rainfall, has also impacted the LULC dynamics of the country [19,20].

The interconnection between LULC changes and population growth, climate change and variability [12,19,21], is estimated to be high in the Amhara Regional State of Ethiopia [22], which is the second highest in population among the regional states in the country [23]. A few similar large-scale research works conducted to understand LULC changes in the region have indicated that population growth and agricultural expansion are the major forces that drive LULC change [19,24]. However, studies in LULC changes are rare on a small-scale, such as in the Este District, South Gondar Zone, Amhara Region, Ethiopia. Hence, this research aims at detecting LULC changes and the associated forces behind the changes and, to evaluate the perception of local communities regarding these changes and factors in the Este District, South Gondar Zone, Ethiopia between 1980 and 2020.

2. Materials and Methods

2.1. Descriptions of the Study Area

Este District is bordered by the Simada and Lay Gaynt districts to the east, the Farta District to the north, the Andabet District to the west, and the East Gojjam Administration Zone to the south. The district extends from 37°50′00″ to 38°16′00″ E and 11°10′0″ to 11°55′0″ N. The total area of the district is approximately 1365.2 km^2 (Figure 1).

Este District is characterized by high mountain peaks and plateaus of the Guna mountain range (4062 m. a. s. l.) in the north, and hills with many slopes steadily diminishing towards the west, culminating at the Blue Nile Gorge (1200 m. a. s. l.). Although the altitude of the study area ranges from 1200 m. a. s. l. to more than 4062 m. a. s. l., the main surface area lies between 1800 and 2800 m. a. s. l. (Figure 2). Rivers, such as Saga, Gumara, and Wanka, and the tributaries of the Blue Nile river flow from the north to the south of the district (Figure 2).

According to Ethiopia's Central Statistical Agency [25], the human population in the district was estimated to be more than 211,000, of which 108,000 and 103,000 were male and female, respectively. The majority (197,000) of the population live in rural areas while the remaining small portion (14,000) live in urban areas [25].

Mekane Eyesus town is the capital city of the district. Even though the Este District population is largely comprised of youths, there is a slight decrement in the 0–4-year age group in recent times. The majority of the population (65%) is under 25 years [25].

There are three major ecosystem types in the district, namely Afroalpine, sub-Afroalpine and, Dry Evergreen Montane forest ecosystems. These ecosystems are found in the altitudinal range of high (>3200 m. a. s. l.), medium (between 1900 and 3400 m. a. s. l.), and low mountains (500 and 1900 m. a. s. l.) [26], respectively. The district produces "Teff" (*Eragrostis tef*, which is a staple cereal crop), and other crops, such as maize (*Zea mays* L.),

barley (*Hordeum vulgare* L.), wheat (*Triticum aestivum* L.), sorghum (*Sorghum bicolor* L.), peas (*Pisum sativum* L.), beans (*Faba bean* L.), and potatoes (*Solanum tuberosum* L.).

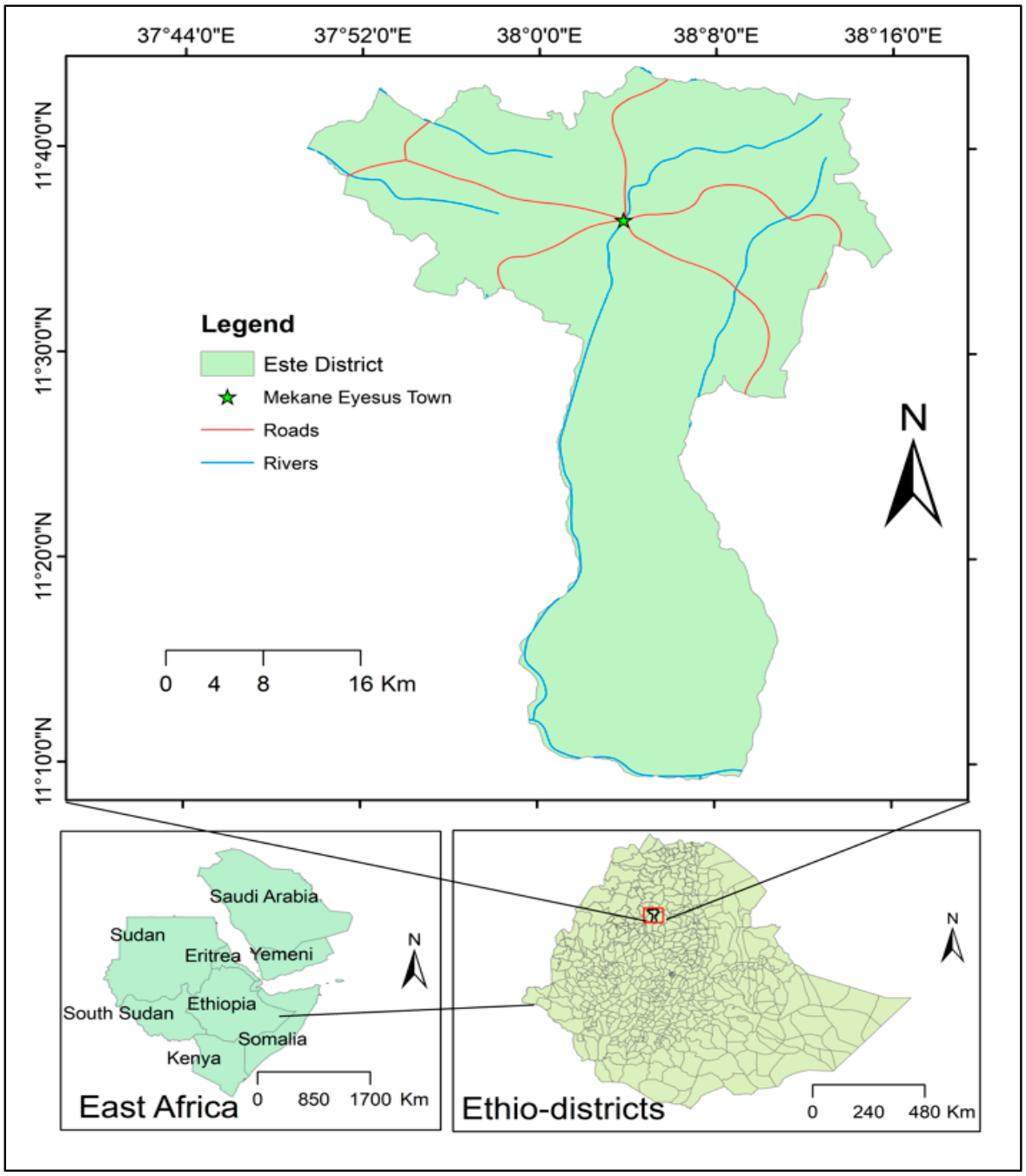


Figure 1. The location of the research area.

As the Digital Elevation Model (DEM) indicated four soil types (Eutric, Calcic, Chromic, and Luvisols) occupy nearly half the district's surface area (Figure 3). There are eight major soil types (Calcic, Chromic, Dystric, Eutric, Leptosols, Orthic, Pellic, and Vertic soils) and 12 subsoils types (Figure 4) in the district as FAO-UNESCO soil classification system [27,28].

The climate data of the district were obtained from the Ethiopian Meteorological Agency, Mekane Eyesus Station, and Global Weather Data for SWAT (https://globalweather.tamu.edu/, accessed on 20 November 2019). The climate in the study area is a unimodal type of rainfall [29]. The annual precipitation and annual mean temperature were 1331 mm and 17.4 °C, respectively (Figure 4).

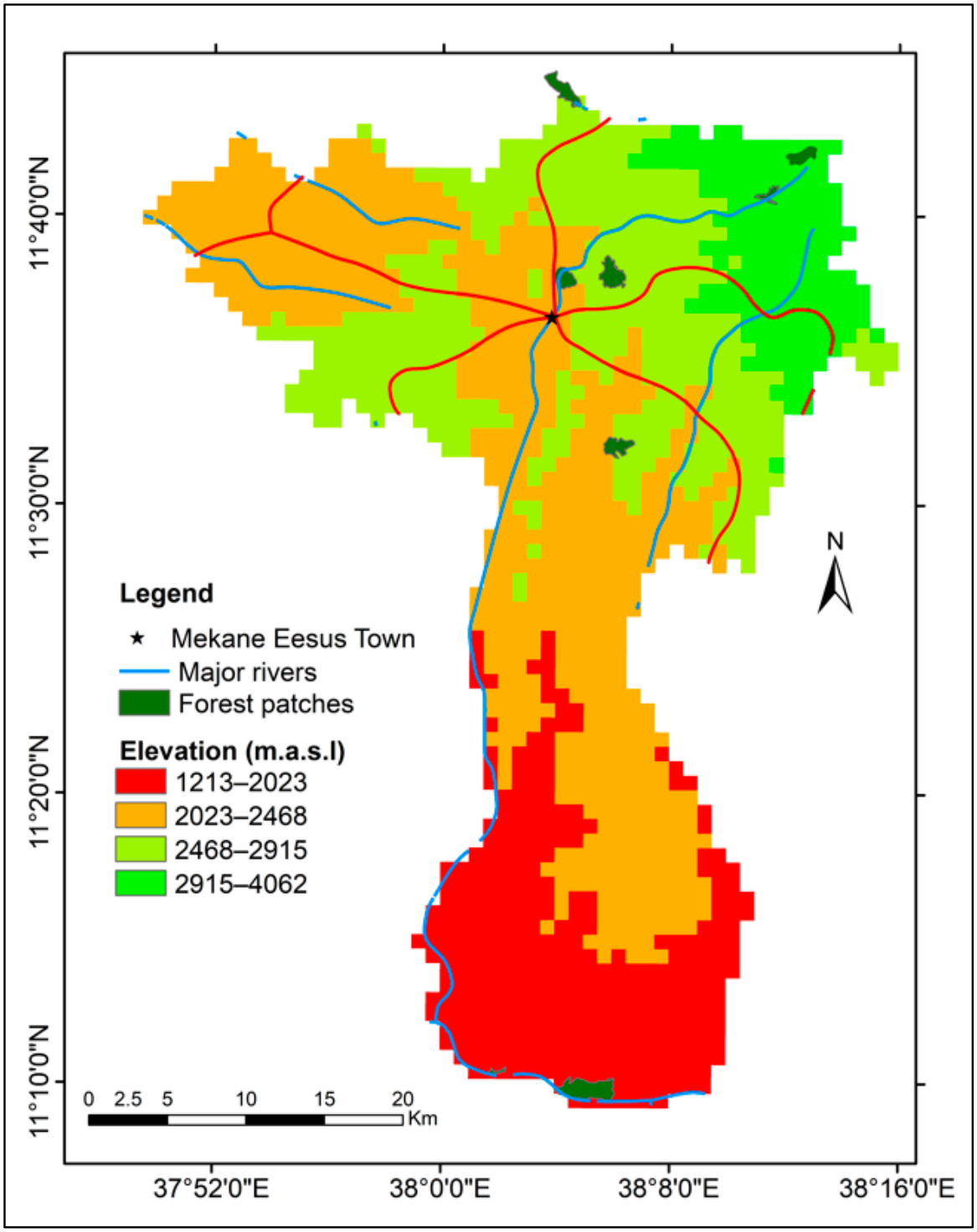


Figure 2. The elevation, distribution of roads, and rivers in the Este District.

2.2. Data Collections

Data collection and analysis were categorized into four major processes: downloading, post-classification, classification, and verification. ERDAS IMAGINE 2015 and ArcGIS 10.3.1 were used to process Landsat satellite images of the study area. We collected ancillary data, topo-sheets, and shapefiles from the field, Ethiopian map agency, and webs, such as Diva-GIS (https://www.diva-gis.org/datadown, accessed on 2 December 2019), respectively. Generally, we followed the main steps shown in the following workflow (Figure 5).

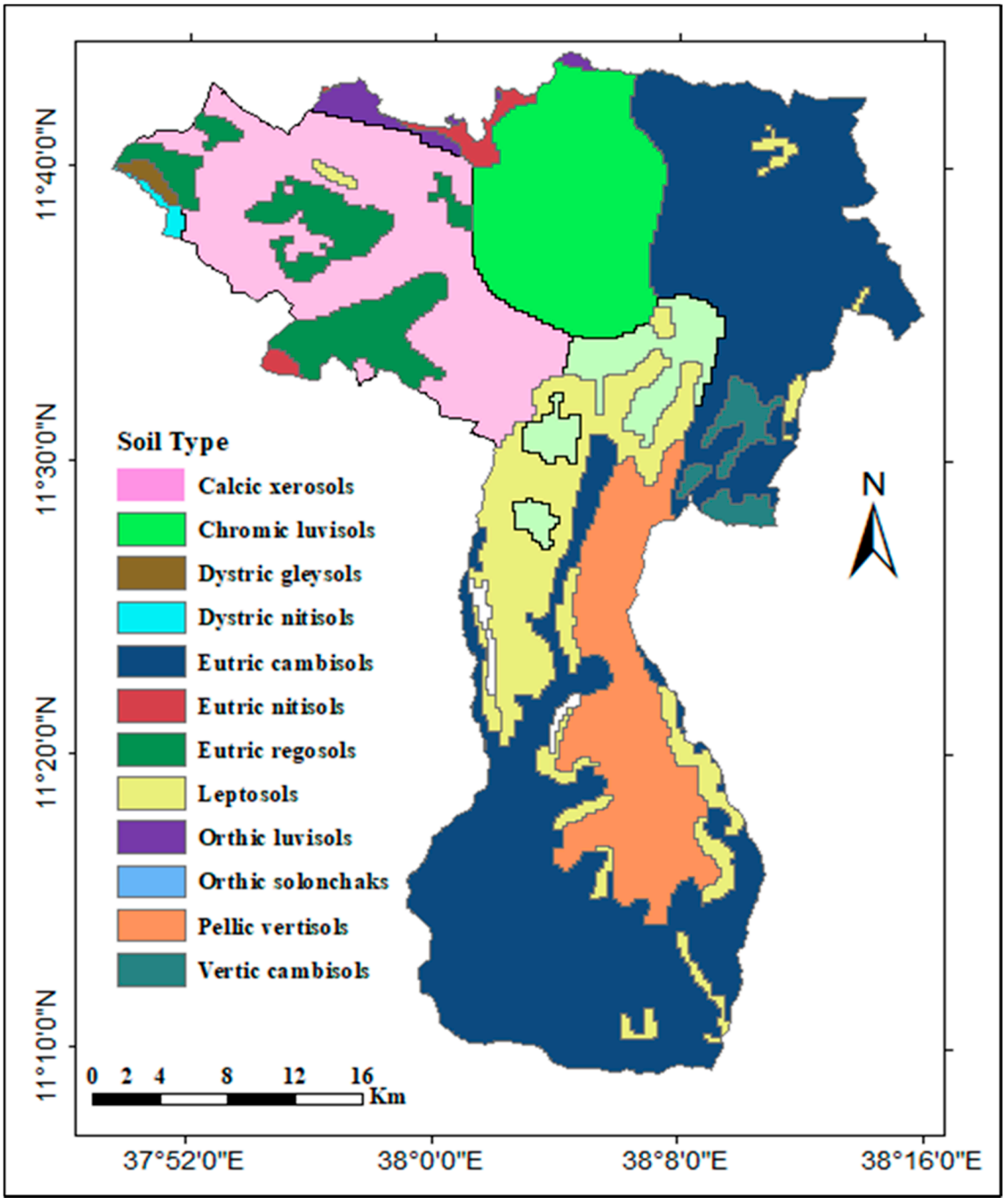


Figure 3. IUSS-WRB soil types in Este District.

Three remotely-sensed Landsat images were acquired in dry and cloud-free seasons from the Earth Explorer (http://earthexplore.usgs.gov, accessed on 9 December 2019). The following table shows the image (satellite image) source, resolution, direction, row, and image acquisition date (Table 1).

Table 1. Landsat satellite images used.

Image Sources	Resolution (m)	Sensor	Path	Row	Acquisition Date
Landsat 4–5	30 × 30	TM	169	52	8 December 1984
Landsat 7	30 × 30	ETM+	169	52	27 January 2000
Landsat 8	30 × 30	OLI	169	52	1 January 2018

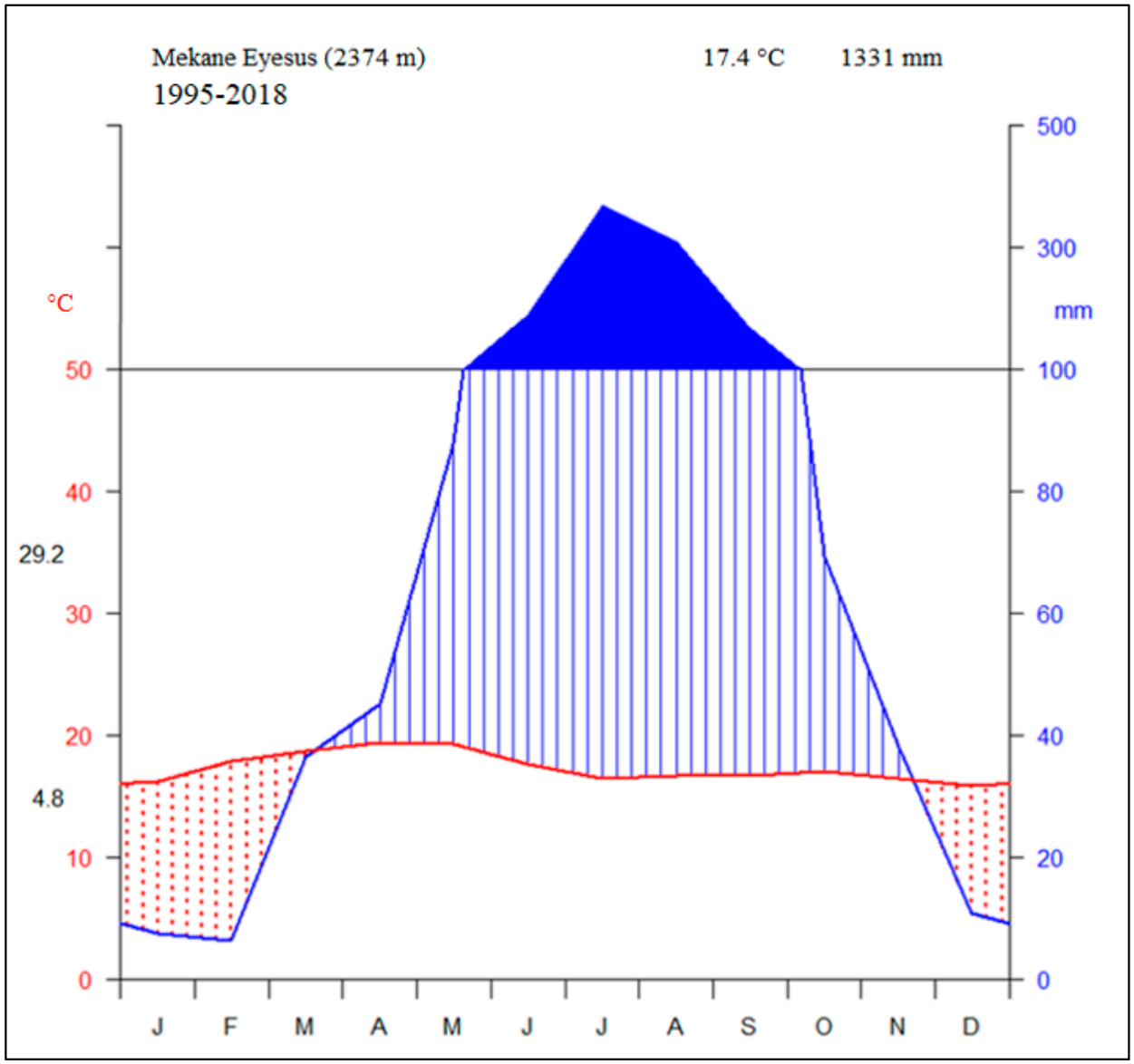


Figure 4. Climate diagram of Este District.

2.2.1. Pre-Classification

After being geometrically corrected, the satellite images were reprojected to WGS 1984 UTM, zone 37N. In the pre-classification process, two steps were performed: layer stacking and sub-setting. Layer stacking combines seven images with different bands and helps create a clear view of the image in the classification process [30]. Similarly, a sub-setting image helps to concentrate attention on a small site in the classification process [30] and is shown in the figure (Figure 6).

2.2.2. Classifications

We performed the steps following supervised classification methods to characterize the LULC changes of Este District with ERDAS IMAGINE 2015 [27,28,31–33]. The sub-set and mosaic images were classified into six classes: forests–shrublands, croplands, grasslands, settlements, water bodies, and bare lands. The classification was created based on the signatures collected from the available pixels of the area of interest (Este District). After selecting the training areas, the maximum likelihood classification algorithm was used to classify the images. Table 2 offers an overview of the land-use and cover groups identified in the research (Table 2).

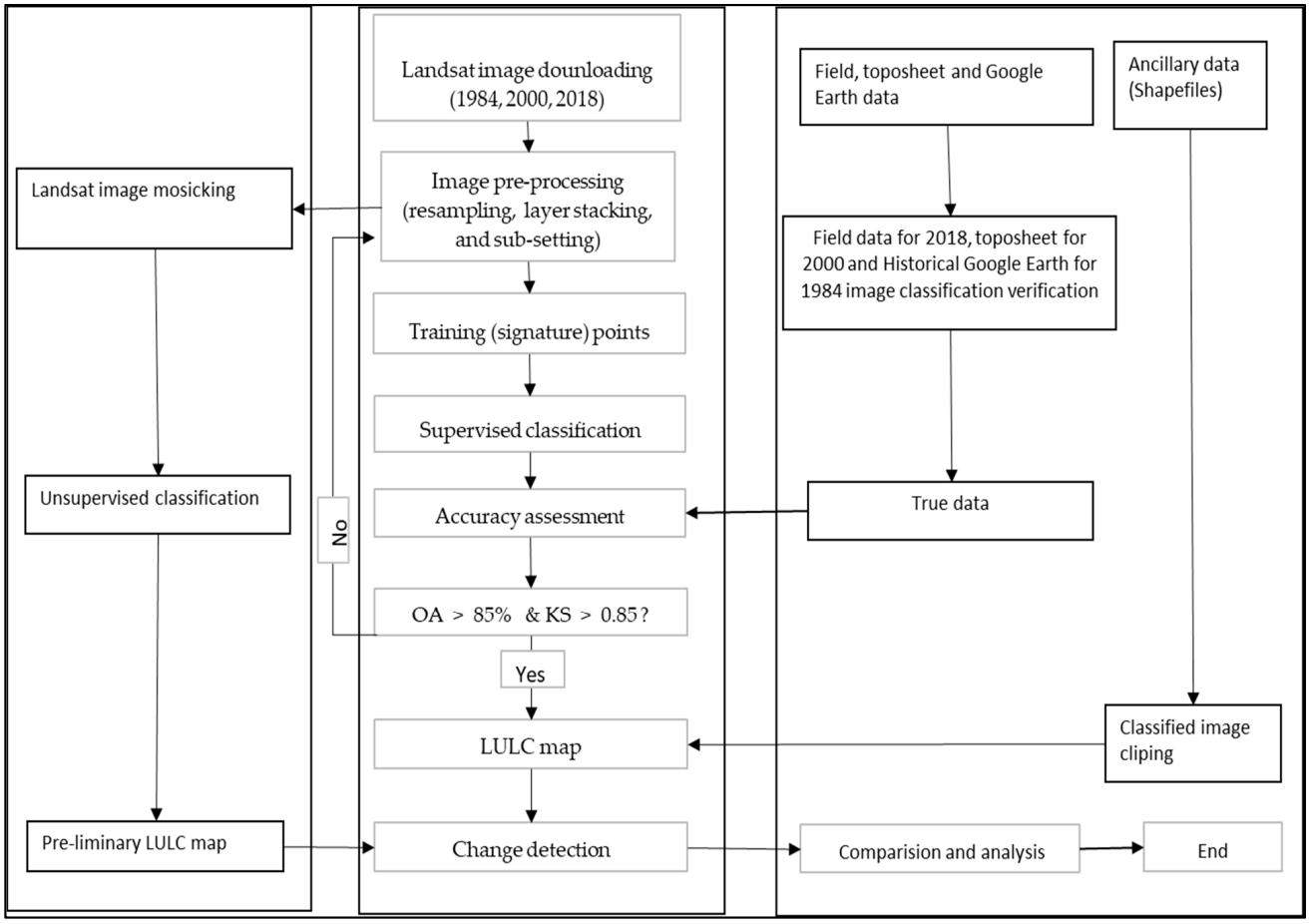


Figure 5. Flowchart of the major LULC classification and assessment methods (Notice: OA = overall accuracy and KS = kappa statistics).

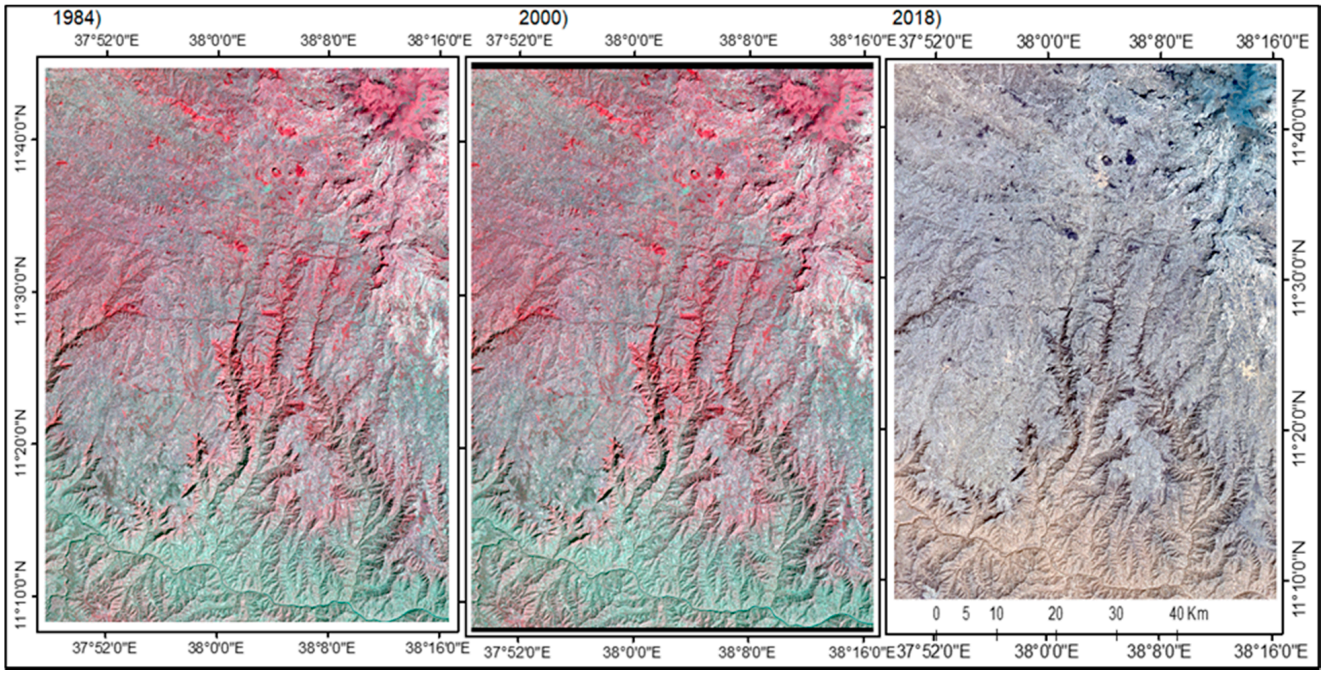


Figure 6. Sub-set image of the study area.

Table 2. Considered land-use and land-cover groups for the research in the Este District.

LULC Classes	Descriptions
Forests–shrublands	Bushlands, shrublands, and natural and afforested forest areas
Croplands	Areas cultivated with annual crops, vegetables, or fruits
Grasslands	Herbaceous vegetation, sparse trees, sparse shrubs, and grasses
Settlements	Towns, churches, rural villages, schools, and roads
Water bodies	Major rivers, such as the Nile river, ponds, and some wetlands
Bare lands	Exposed rocks and sandy areas

2.2.3. The Verification and Clipping Processes

Eight hundred and sixty training points were used: 214, 341, and 305 from fields, historical Google Earth Pro imagery and a topo-sheet for images of 1984, 2000, and 2018, respectively, following Abineh and Bogale [34] and Czaplewski [35]. The area of interest was then clipped using ArcGIS 10.3.1. The classes and values of the reference data was matched in Excel 2013, copied and pasted in Notepad, and saved as readable (ANCI format) by ERDAS IMAGINE 2015. We classified the image into land-use and land-cover types after entering the image data into ERDASS IMAGINE 2015. Before the accuracy level and kappa statistics were observed as >85% and 0.85, respectively, the classification was repeated several times to achieve the desired level of the accuracy [36]. We clipped the area of interest using ArcGIS 10.3.1. The software was used to draw the clipping process to the area of interest.

2.2.4. Causes, Derivers, and Perceptions of Population to the LULC Changes in the Study Area

Data on the population of the district for 1984 to 2018 were obtained from the South Gondar Administration Zone, Economic, and Finance Department, and the Ethiopian Central Statistical Agency, to analyze the possible association of the population growth and the extent of LULC classes.

The rate of change of the LULC values was calculated by comparing the change in the value of each LULC class with the value's change rate, with the value of the previous year. Additionally, 450 key informants (40 years old and higher) were selected to share their perceptions on the LULC changes in their area, from 10 November to 9 December 2020. The informants were chosen in two stages. First, five of the minor administrative units ("kebeles" = Amharic) were selected at random (four from dry evergreen Afromontane forests and one from Afroalpine and sub-Afroalpine ecosystems types). Second, representative households in the "kebele" and informants were chosen based on their age and recommendations from the district agricultural officers. Interviews and focus groups were then held with the key informants.

2.3. Data Analysis

The area in km^2 of each LULC class and total study area was calculated using ArcGIS 10.3.1 and Excel 2013, respectively [37,38]. The last LULC map was reclassified using ArcGIS 10.3.1 to identify the LULC class changes from 1984 to 2018. The reclassified raster image was transformed into a polygon using raster-to-polygon conversion tools. Two polygons were intersected using intersect tools (1984 with 2000, 1984 with 2018, and 2000 with 2018), and the area was measured using a geometric calculator in ArcGIS 10.3.1. Each LULC class's area was saved in a dBase file format. PivotTable in Excel 2013 was used to define the unchanged position, and was subjected to change. Intersect methods in ArcGIS were used to test the transition matrixes between the analyzed years and classes of the LULC, followed by PivotTable in Excel 2013. The importance of the change matrix is to identify the dynamics of the LULC classes [39,40]. The change, which is the lost or gained value of the changes in each LULC class of the two years, was calculated as the common values of the two years subtracted from the row total values and column total values [34]. Bar graphs and change matrix tables were produced to compare the LULC classes of the different years (1984, 2000, and 2018) using a statistical program R [41] and

MS Excel 2013, respectively. The association between the LULC and potential derivers was tested using correlation analysis in R package Hmisc [42]. In addition, the perception of the local communities towards the LULC changes was evaluated using a scale from 10 to 100% values.

3. Results

3.1. The Accuracy Assessment

Table 3 displays the accuracy values of the overall and classes of the study. The overall accuracies of old (1984), medium (2000), and current (2018) image classifications were 99.3%, 96.1%, and 91.5%, respectively (Table 3). Similarly, the Producer's Accuracy (%), User's Accuracy (%), and Kappa Statistics lied in 80–100, 88–100 and 0.90–0.99, respectively (Table 3).

Table 3. LULC class and overall classification accuracies and kappa statistics (1984–2018).

Year	Explan. Variable	Forest–Shrubland	Cropland	Grassland	Settlement	Water Body	Bare Land	OA	KS
1984	PA	100.0	96.00	100.00	100.00	100.00	100.0	99.30	0.99
	CE	0.00	4.00	0.00	0.00	0.00	0.00		
	UA	100.00	100.00	96.00	100.00	100.00	100.00	99.30	0.99
	OE	0.00	0.00	4.00	0.00	0.00	0.00		
2000	PA	98.90	100.00	95.50	87.10	90.50	97.30	96.20	0.95
	CE	1.10	0.00	5.50	12.90	9.50	2.70		
	UA	95.70	90.50	98.50	100.00	100.00	100.00	96.20	0.95
	OE	4.30	9.50	1.50	0.00	0.00	0.00		
2018	PA	80.00	95.70	93.40	91.40	94.10	100.00	91.50	0.90
	CE	20.00	4.30	6.60	8.60	5.90	0.00		
	UA	98.10	88.00	90.50	96.90	100.00	72.70	91.50	0.90
	OE	1.90	12.00	9.50	3.00	0.00	27.30		

Note: Explan. Variable, PA, CE, UA, OE, OA, and KS are the explanatory variables, producer's accuracy (%), commission error (%), user's accuracy (%), omission error (%), overall accuracy (%), and kappa statistics, respectively.

3.2. LULC Classes of Este District in the Last Four Decades

Croplands, forests–shrublands, grasslands, bare lands, settlements, and water bodies were the LULC classes identified from satellite images arranged in decreasing order (Figure 7). The dominant class was croplands (60.8%), followed by forests-shrublands (25.4%) in 1984, and continued to dominate until 2000. Croplands accounted for at least 50% of the district (51 to 62%) in 1984, 2000, and 2018 (Figure 7 and Table 4).

Table 4. Share of the LULC classes in Este District, in three analyzed years: 1984, 2000, and 2018.

LULC Classes	1984		2000		2018	
	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
Forests–shrublands	346.3	25.4	243.4	17.8	204.7	15.0
Croplands	829.6	60.8	851.5	62.4	694.0	50.8
Grasslands	122.5	9.0	216.7	15.9	424.4	31.0
Settlements	5.9	0.4	6.2	0.5	13.1	1.0
Water bodies	1.8	0.1	1.7	0.1	2.3	0.2
Bare lands	59.0	4.3	45.6	3.3	26.7	2.0
Total	1365.5	100	100	1365.5	1365.5	100

The second largest LULC class, next to croplands until 2000, was forests–shrublands (243.4–346.4 km^2~18 to 25% of the study site). In contrast, the least dominant class was the water bodies (0.1%) (Table 4). The intermediate classes were the grasslands (122.5 km^2~9.0% of the site) and bare lands (59.0 km^2~4.3%). However, after 2000, most of the forests–shrublands (150.4 km^2 or 50% of total forests–shrublands) were converted to croplands (186.0 km^2~8% of total croplands) and grasslands (5.4 km^2~5% of the grasslands) (Table 5). Although the cropland remained as the dominant LULC class, they have greatly reduced from 851.5 km^2 (62%) in 2000, to 694.0 km^2 (51%) in 2018. Forests–shrublands cover

decreased from 243.4 km^2 (18%) in 2000, to 204.7 km^2 (15%) in 2018. In contrast, grasslands and settlements increased from 216.7 km^2 (16%) and 6.2 km^2 (0.5%) in 2000, to 424.4 km^2 (31%) and 13.1 km^2 (~1%) in 2018, respectively (Figure 8 and Table 4).

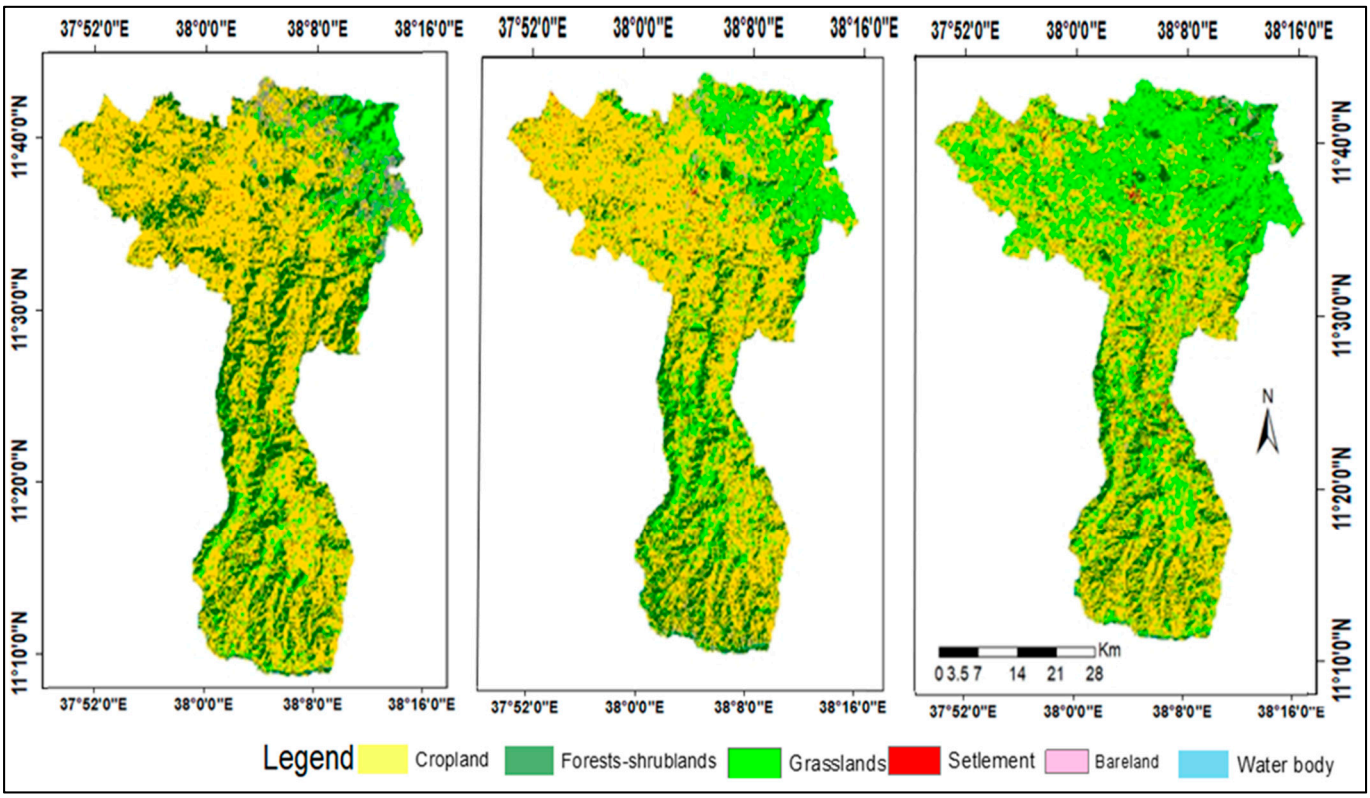


Figure 7. The study site's LULC classes for the last four decades.

Table 5. LULC change matrix between 1984 and 2000 (area in km^2).

LULC Classes		Classes of 2000						
		Grassland	Cropland	Water Body	Settlement	Forest–Shrubland	Bare Land	Total
Classes of 1984	Grassland	78.1	26.5	0.0	0.1	4.2	9.7	118.6
	Cropland	100.6	665.6	0.3	4.4	47.6	19.8	838.3
	Water body	0.0	0.2	1.2	0.0	0.4	0.0	1.8
	Settlement	0.2	3.5	0.0	0.2	0.8	0.1	4.8
	Forest–shrubland	5.4	150.4	0.1	0.3	186.0	1.0	343.2
	Bare land	28.6	15.7	0.0	0.0	0.3	12.8	57.4
	Total	212.9	861.9	1.6	5.0	239.3	43.4	1364.1

The areas (km^2) and percent cover (%) of each LULC type are shown in Table 4. During 2000, the study also identified that croplands reached their maximum (62%) (Table 4).

3.3. Land-Use and Land-Cover Change Rates in Este District

There were four trends for the LULC shift rates (increment, decrement, constant, and both increment and decrement trends). During the study periods, some land-cover classes expanded (settlement and grassland), others shrank (forest–shrubland and bare land), and others remained relatively constant (water body). The cropland increased in the first period (1984 to 2000), but decreased in the second period (2000–2018). The cropland, grassland, and settlement areas increased by 2 km^2, 8 km^2, and 0.015 km^2 per year, respectively, until 2000. On the other hand, the water body, bare ground, and forest–shrubland decreased by a rate of 0.06 km^2, 1 km^2, and 7 km^2 per year, respectively, during the same years. The increment in the cropland was at the expense of the forest–shrubland (17.5%) and some bare land (1.8%). 12:25 PMCropland increased at the expense of the forest–shrubland, some part of it (12%) changed into grassland. In the second period (2000–2018), the grassland and settlement continued to increase at a rate of 12 km^2 and 0.5 km^2 per year, and cropland

and bare land decreased at a rate of 9 km^2 and 1 km^2 per year, respectively. Some cropland changed to other LULC classes at the expense of non-cultivated and new lands, especially the forest–shrubland. The water body showed a relatively constant change. However, a significant and dynamic change was observed in the grassland and settlement (both positive change), and the forest–shrubland and bare land (both negative change) parts of the LULC changes (Table 5).

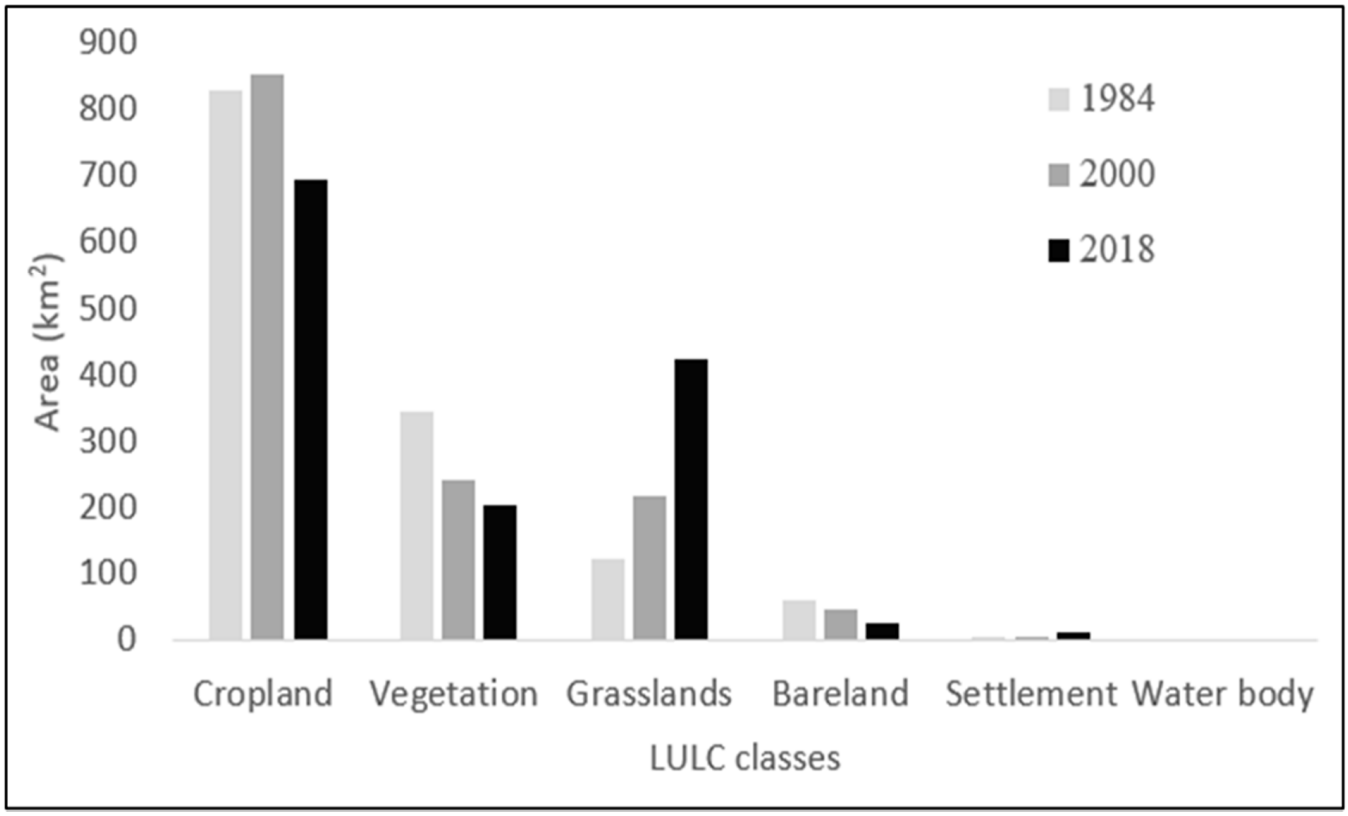


Figure 8. The relative area (km^2) of the LULC classes of the study area.

The most considerable net change (−7.6%) between 1984–2000 was in the forest—shrubland, the most being the conversion to cropland. The second (6.9%) and third (1.7%) most significant LULC changes occurred in grasslands and croplands, respectively (Table 6).

Table 6. No change, gain, loss, and net changes of LULC of Este District during 1984–2000.

LULC Classes	1984		2000							
	Cover		Unchanged		Gain		Loss		Net Change	
	(km^2)	(%)	(km^2)	(%)	(km^2)	(%)	(km^2)	(%)	(km^2)	(%)
Forest–shrubland	346.3	25.4	186	13.6	53.4	3.9	157.3	11.5	−103.9	−7.6
Cropland	829.6	60.8	665.6	48.8	196.3	14.4	172.9	12.7	23.4	1.7
Grassland	122.5	9.0	78.1	5.7	134.8	9.9	40.5	3.0	94.3	6.9
Settlement	5.9	0.4	0.2	0.0	5.0	0.4	4.6	0.3	0.4	0.1
Water body	1.8	0.1	1.2	0.1	0.5	0.0	0.6	0.0	−0.1	0
Bare land	59.1	4.3	12.8	0.9	30.6	2.2	44.7	3.3	−14.1	−1.1
Total	1365.2	100	943.9	69.1	420.6	30.8	420.6	30.8	0	0

A small portion of cropland (<2%) was changed into forest–shrubland from 1984 to 2018. However, a large amount of forest–shrubland (>11%) was converted into cropland during the same years (Table 7).

Table 7. LULC change matrix between 1984 and 2018 (area (km^2)).

LULC Classes		Classes of 2018						
		Grassland	Cropland	Water Body	Settlement	Forest–Shrubland	Bare Land	Total
Classes of 1984	Grassland	84.6	24.2	0.0	0.3	3.1	6.4	118.6
	Cropland	276.1	517.3	0.3	10.9	22.4	11.6	838.5
	Water body	0.0	0.4	1.3	0.0	0.2	0.0	1.8
	Settlement	0.7	3.4	0.0	0.3	0.3	0.1	4.8
	Forests–shrubland	12.9	152.5	0.7	0.6	173.7	2.9	343.3
	Bare land	47.2	4.4	0.0	0.1	1.7	4.1	57.5
	Total	421.5	702.2	2.3	12.1	201.4	25.1	1364.5

Similarly, a significant net change was observed in grasslands (22%) followed by forests–shrublands (−10.4%) during 1984–2018. In contrast, a minor net change was observed in the water body class (Table 8).

Table 8. Unchanged, gain, loss, and net changes of the LULC changes during 1984–2000.

LULC Classes	1984		2018							
	Cover		Unchanged		Gain		Loss		Net Change	
	(km^2)	(%)	(km^2)	(%)	(km^2)	(%)	(km^2)	(%)	(km^2)	(%)
Forest–shrubland	346.3	25.4	173.7	12.7	27.8	2.0	169.6	12.4	−141.8	−10.4
Cropland	829.6	60.8	517.4	37.9	184.9	13.5	321.2	23.5	−136.3	−10.0
Grassland	122.5	9.0	84.6	6.2	336.9	24.7	34.0	2.5	302.9	22.2
Settlement	5.9	0.4	0.3	0.0	11.8	0.9	4.5	0.3	7.3	0.6
Water body	1.8	1.3	1.3	0.1	1.0	0.1	0.6	0.0	0.4	0.1
Bare land	59.1	4.3	4.1	0.3	21.0	1.5	53.4	3.9	−32.4	−2.4
Total	1364.5	100	781.3	57.3	583.3	42.7	583.3	42.7	0	0

The interchange between grasslands and croplands was high from 2000 to 2018. About 57.8 km^2 (27.2%) of the grassland was converted into cropland, while 237.9 km^2 (27.6%) of the cropland changed into grassland (Table 9).

Table 9. LULC change matrix between 2000 and 2018 (area (km^2)) of total Este District.

LULC Classes		Classes of 2018						
		Grassland	Cropland	Water Body	Settlement	Forest–Shrubland	Bare Land	Total
Classes of 2000	Grassland	141.4	57.8	0.0	0.8	8.5	4.5	212.9
	Cropland	237.9	534.9	0.6	10.2	60.8	17.5	861.9
	Water body	0.1	0.6	0.9	0.0	0.1	0.0	1.7
	Settlement	1.8	2.7	0.0	0.4	0.2	0.1	5.2
	Forest–shrubland	10.9	95.0	0.7	0.4	130.9	1.4	239.3
	Bare land	29.6	11.3	0.0	0.2	1.0	1.5	43.5
	Total	421.5	702.2	2.3	12.1	201.4	25.1	1364.5

The most significant net shift was observed in the grassland (15%), followed by cropland (−11%) from 2000 to 2018 (Table 10).

Table 10. No change, gain, loss, and net changes in the LULC changes from 2000 to 2018.

LULC Classes	2000		2018							
	Cover		Unchanged		Gain		Loss		Net Change	
	(km^2)	(%)	(km^2)	(%)	(km^2)	(%)	(km^2)	(%)	(km^2)	(%)
Forestshrubland	239.3	17.5	130.9	9.6	70.6	5.2	108.4	7.9	−37.8	−2.7
Cropland	861.9	63.2	534.9	39.2	167.4	12.3	327	24.0	−159.6	−11.7
Grassland	212.9	15.6	141.4	10.4	280.3	20.5	71.6	5.2	208.7	15.3
Settlement	5.2	0.4	0.4	0.0	11.6	0.9	4.8	0.4	6.8	0.5
Water body	1.7	0.1	0.9	0.1	1.3	0.1	0.8	0.1	0.5	0
Bare land	43.5	3.2	1.5	0.1	23.5	1.7	42.1	3.1	−18.6	−1.4
Total	1364.5	100.0	810	59.4	554.7	40.7	554.7	40.7	0.0	0.0

3.4. The Potential Causes of the LULC Changes in Este District

The correlation analysis between the LULC classes and demography and climatic condition, showed that the most determinant factor for all the classes of LULC changes was the growth in the human population. Population exerts a significant pressure on some LULC classes (grassland, water body, and settlement, r = 0.82 and *p*-values = 0) and others (cropland, bare land, and forest–shrubland, r = −0.96 and *p*-values = 0). Of the seven environmental factors (both demographical and climatic) that were tested for their impact on the LULC changes, three variables, population growth, precipitation, and solar radiation, have been identified to strongly and significantly influence the dynamics of the LULC changes (Table 11). The grassland and settlement showed positive changes, while the bare land and forest–shrubland showed negative changes. In contrast, the cropland showed both negative and positive changes during the last four decades in Este District (Figure 9).

Table 11. The r-squared values and level of significance of the correlation between LULC classes and potential causes.

LULC Classes	Max. Temp.	Min. Temp.	Precipitation	Wind Velocity	Humidity	Solar Rad.	Population
Grassland	0.139 ns	−0.197 ns	0.581 **	0.214 ns	−0.144 ns	0.469 **	0.987 ***
Cropland	0.015 ns	0.285 rs	−0.620 **	−0.224 ns	−0.040 ns	−0.529 **	−0.850 ***
Water body	−0.033 ns	−0.292 rs	0.619 **	0.223 ns	0.061 ns	0.530 **	0.825 ***
Settlement	0.043 ns	−0.257 ns	0.617 **	0.225 ns	−0.029 ns	0.516 **	0.917 ***
Bare land	−0.171 ns	0.173 ns	−0.550 **	−0.210 ns	0.201 ns	−0.439 **	−0.999 ***
Forest–shrubland	−0.274 ns	0.076 ns	−0.441 **	−0.170 ns	0.318 rs	−0.330 rs	−0.968 ***

Note: Max. temp. = maximum temperature; min. temp. = minimum temperature; solar rad. = solar radiations; and ns, rs, **, and *** indicate not significant, nearly significant, at 0.05 and 0.00, respectively.

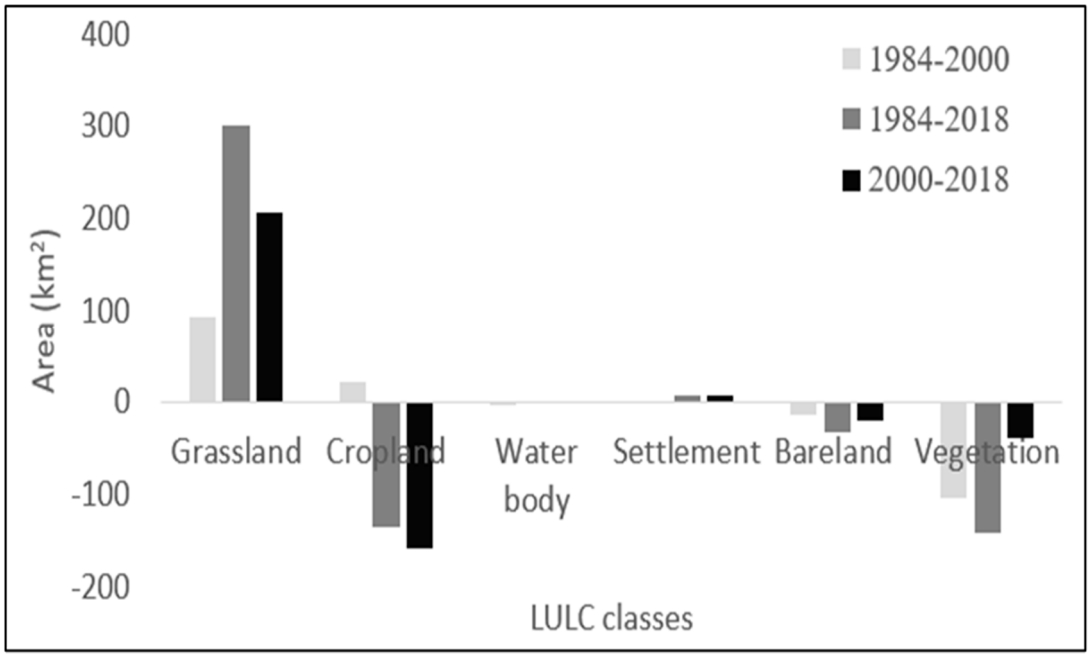


Figure 9. The overall LULC change values in Este District (1984–2018).

Compared with the remaining environmental conditions, the minimum temperature also affected the cropland and water body dynamics in the study area at a nearly significant level (Table 11).

3.5. The Experiences and Perceptions of Local People towards the LULC Changes

Participants in the focus groups and primary informants provided their personal views and impressions of the LULC changes in the last four decades. Accordingly, they stated that the expansion in the settlements and grasslands was progressive and the factors

behind the LULC changes were population growth and uncontrolled grazing in the district. According to the participants, the local people previously practiced free grazing. However, currently, they keep improved cattle varieties and practice stall feeding. The stall feeding resulted in the expansion of the settlements and grasslands in the district. The shrinkage of forest–shrubland cover in the district appears to be the clearing of forests and shrublands by the landless and jobless youth, to produce cereals and pulses in response to the growing demand for food by the rapidly growing population. There is some reconversion of old agricultural fields to grasslands for alternative income, from selling grass or feeding improved cattle for more milk production, which is in high demand (Table 12).

Table 12. Perceived causes of LULC changes by key informants and focus group discussion participants.

Cause/Derivers	Yes (%)	No (%)	Cause/Derivers	Yes (%)	No (%)
Population growth	91	9	Expansion of farmland	86	14
Enhanced cattle breeds	87	13	Conservation practices	74	26
Infrastructure expansion	81	19	Expansion of settlements	65	35
Firewood	75	25	Irrigation	55	45
Climate change	95	5	Soil erosion/degradation	95	5

4. Discussion

The results of the level of accuracy in this study, suggested that the classification process achieved its highest level of reliability of the information. Many research works agree that the accuracy of classification is acceptable if it is greater than 85 [43,44]. Classification accuracy may be influenced by a variation in the quality of images, such as cloud cover [45], and post-classification correction with ancillary data [46].

In this study, cropland, on average, accounted for more than 58% of the study area. This result is consistent with the findings of Dagnenet et al. [20], Solomon et al. [47], and Woldeamlak [48]. Hagos [49] and Tatek and Ayalew [50], indicated that croplands accounted for about 66% and 84% in Huluka and Muga water shades, respectively. Other studies conducted to determine LULC dynamics, indicated the expansion of croplands [17,19,47,48]. Still, other studies showed no change in the cropland area due to the intensification of agriculture or an increase in crop production per unit area of land [51], and the conversion of cropland into settlements [52] and grasslands to ameliorate soil fertility [53] and to feed livestock for better means of income than crops [54].

This study showed that grasslands and settlements increased considerably in the period considered (1984 to 2018). The net change in the grasslands was considerably high (15–22%) compared to the other classes of LULC. A similar study was reported from the Derekoli catchment, from 1980 to 2000 [55], the Komto forest area from 1990 to 2020 [56], the Somado watershed [57] in Ethiopia, and the Greater Accra Metropolitan area in Ghana from 1991 to 2000 [58]. The expansion of grasslands was also reported in Northern Chiba, Japan [59], and the cause of the expansion in grasslands is attributed to livestock feed, production, soil fertility, rehabilitation, and biodiversity conservation [54]. The driving force behind the expansion of settlement areas is attributable to population growth and government policies in favor of urbanization [60].

This result showed a significant and pertinent connection between population growth, precipitation, and solar radiation and land-use and land-cover classes. The literature is replete with similar findings [61]. The findings of several studies on the effect of climate change on the LULC (for example, Brandon [62], Dale [63], and Liu et al. [64]) are consistent with the findings of the current study. Additionally, nearly similar research on the experiences and perceptions of local elders on the potential drivers of LULC changes have been reported from neighboring areas, such as the Koga catchments [24] and Muga watersheds [48]. The similarity in the results may be due to the similarity in the LULC drivers [24,65].

This study can be used to understand the relative size of each LULC class and devise a plan to maintain the balance of the land's components [66]. For example, knowledge on

the current extent of forest damage is crucial for restoring deforested areas or protecting current forest cover from extra-deforestation [67]. This study can also serve as a starting point for current or future development strategies involving land resource allocation for diverse human purposes [66]. The bare land, particularly if used for settlements, and the other areas for agriculture, forest, and other land-use categories can be important for the wise use of natural resources, such as land [68].

5. Conclusions and Recommendations

In this study, the LULC dynamics study was analyzed in the Este District (in the South Gondar zone, the Amhara regional state, Ethiopia), with the objectives of identifying the major LULC classes and the dynamics in the specified classes during the last four decades (1984–2018), and analyzing the drivers of these changes. During the study period, six major land-cover classes were established for the last four decades in the study site (1984–2018). Croplands, forests–shrublands, grasslands, bare lands, settlements, and water bodies were the classes in decreasing order. The LULC changes in Este District during the last four decades showed three patterns: some classes increased, while others decreased and others did not show a clear direction of change. The grasslands and settlements expanded, while the forests–shrublands and bare lands declined, and the cropland grew in the first phase (1984–2000) but declined in the second (2000–2018). Relatively, steady-state change was observed in the water body. The dominant LULC change was mainly from forests–shrublands to croplands. Towards the end of 2018, the rate of the grassland expansion had been gradually rising in the study region. Climatic factors, such as solar radiation and precipitation, and demographic factors, such as rapid population growth, were the major forces for the conversion of forests–shrublands into cultivated land. The remaining climatic variables, such as the wind velocity and temperature, were found to have no significant effect on the LULC changes in the Este District. Moreover, the respondents shared their perceptions and experiences. They agreed that the implementation of controlled grazing and improved cattle varieties in the district resulted in the expansion of the grasslands and the decrease of croplands in the district. The growing number of improved cattle varieties increased alternative sources of income for the local community. This research suggests that the concerned body, especially the district leaders, should intervene in establishing sustainable land-use to reverse or mitigate the impacts on undesirable LULC changes, primarily by halting forests–shrublands conversion to cultivated lands.

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