



Acacia decurrens tree plantations brought land use land cover change in northwestern of Ethiopia

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Abstract

Tree plantation-based land use in Ethiopia is a crucial sustainable approach to improving community income and reducing soil resource degradation in highland areas. The study aimed to evaluate land use and cover change and examine factors driving community transition from crop agriculture to tree plantation in Fagita Lekoma district. Landsat 1986, 2002 and 2020 images were used to generate the land use maps by using the maximum likelihood algorithm of supervised classification. This study utilized field observations, focus group discussions, and key informant interviews as crucial data collection tools for socioeconomic analysis. The change detection results show that cultivated land, grassland, and wetlands are significantly declining by 22.6, 20.1, and 63%, respectively. On the contrary, forestland and settlement areas are increasing by 210 and 1,665%, respectively. Forest cover was increased by 210% in the district's study year, with the highest conversion rate of 15.1% from cultivated land to forest land in the overall study period. As a result, *Acacia decurrens* forestation is the main cause of the change of use from arable land to forest land systems. This tree plantation-based land use is also the main driving force behind shifting crop farming to tree plantation-based livelihoods because it increases economic benefits and employment opportunities, reduces soil erosion, and increases soil productivity in the area. To limit the negative consequences and raise the beneficial effects of tree plantations, systematic management of tree-based land use systems, integrated advanced land resource management, and increased economic and environmental benefits are suggested for the district.

Article highlights

- The forest land and settlement area are substantially increased on the cultivated land.
- The *Accacia decurrens* tree, a crucial monoculture tree, is expanding rapidly, causing a significant reduction in cropland's spatial coverage.
- Currently, the study area has seen an increase in income and employment opportunities following the recent LULC change.

Keywords *Acacia decurrens* · GIS and remote sensing · Land use change · Tree plantations

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1 Introduction

Ethiopia faces a hasty population increase that has brought about huge deforestation for agricultural use and the exploitation of present forests for fuelwood, fodder, and constructing substances, which ends up in the deterioration of land assets as accumulative effects [1–4]. In addition, most of Ethiopia's population is found in the highlands, in the North Central Massif and the Shewa Plateau, which are often the oldest populated areas in the country and the most exploited and polluting [5]. Fast population growth is the main cause of changes in land use leading to increased human needs for food, Fiber and fuel [5–7]. To meet these needs, vast farmlands and marginal lands have been intensively cultivated, natural forests have been severely deforested, and vast grazing lands have been overgrazed and degraded [5, 8, 9]. Lack of well-defined policies and weak institutional enforcement can also lead to improper land use [10–13].

The country's forest areas have been reduced over the past century from 40% to an estimated less than 3% of the country's land [14–17]. On the contrary, factors that contributed to accelerating the decline of natural vegetation cover in the country include the increasing level of poverty, coupled with the increase in human population, the consequent demand for forest products such as firewood, and the subsequent conversion of forests and woodlands into farmlands and settlements [7]. To reduce these problems, the government of Ethiopia has established approximately 80 protected forest areas, equivalent to a total area of 2,687,915 ha, to protect the country's forest resources. In addition, the government devised a strategy to reverse the situation by means of tree-planting activities.

Tree-planting campaigns are held annually across the country, and an administration report shows that forest coverage is increasing [18]. Moreover, rural afforestation and nature conservation programs have been practiced on farms and communal lands in Ethiopia for decades [7, 19]. These plantations are mainly composed of exotic tree species, such as *Eucalyptus* spp., *Cupressus lusitanica*, *Acacia decurrens*, and *Pinus* spp. These species have been chosen due to their fast growth and attractive economic returns [20]. As a result, the latest data on Ethiopia's forest resources recorded in the FAO's Global Forest Resources Assessment (GFRA) ranks Ethiopia among countries with forest coverage of 10–30% of total area. According to the new report by FAO [21, 22] Ethiopia's forest land covers 16.5 million ha (15.24%) of the country.

Forest plantations are a widespread economic activity in the Ethiopian Highlands, primarily due to the deterioration and access restrictions of natural forests, the introduction and dissemination of fast-growing tree species,

and the awareness of smallholders about the economic benefits of plantations. The expansion of plantations in the Amhara region is being carried out in a variety of ways, including at the private, local and national levels [19, 20]. Current trends towards expanding small-scale plantations in the country, especially in the Amhara region, show that forest plantations are being accepted as an attractive business for smallholder farmers both at the regional and district levels [23]. The economic potential of the tree species *Acacia decurrens* has led to the expansion of tree plantations not only on agricultural land but also the conversion of grassland into forest areas [1, 7, 24–26].

Understanding land use and land cover (LULC) changes is crucial for understanding human–environment interactions and historical status [7, 17, 27, 28]. Remote sensing data is a key source for studying spatial and temporal changes in land use and land cover patterns, enabling long-term analysis and classification within specific regions using the amalgamation of remote sensing and geographic information system (GIS) methods [6, 7, 24, 27, 28]. Multi-temporal remote sensing datasets aid in mapping landscape changes, aiding sustainable land planning and management. However, their scale and implications for cropland decrease and land use conversion are not well known, necessitating additional research for decision-making.

Land-use changes from farmland to *Acacia decurrens* plantations are being actively implemented in the highlands of northwestern Ethiopia, especially in the Fagita Lekoma and surrounding areas [7, 24]. Recently, through the intervention of local government and the purposeful efforts of communities, they started to cover their land with vegetation, especially *Acacia decurrens* tree plantations, as local people invested throughout the district. This expansion of tree plantations is taken as the initial issue of land use change and has implications for the farm land, environment, and economic income of the local individual communities. As a result, the main objectives of this study were to analyze the magnitude and rate of the current status of LULC change and identify the driving forces of the local communities to shift crop cultivation to tree plantation land use. This study enhances the understanding of successful restoration measures on degraded highland and arable land by revealing site-specific land use change drivers and aiding in the design of effective forest restoration and development programs in the study area.

2 Materials and methods

2.1 Geographical location of the study area

The Fagita Lekoma district is geographically located between 10.956°–11.189°N and 36.666°–37.089°E (Fig. 1).

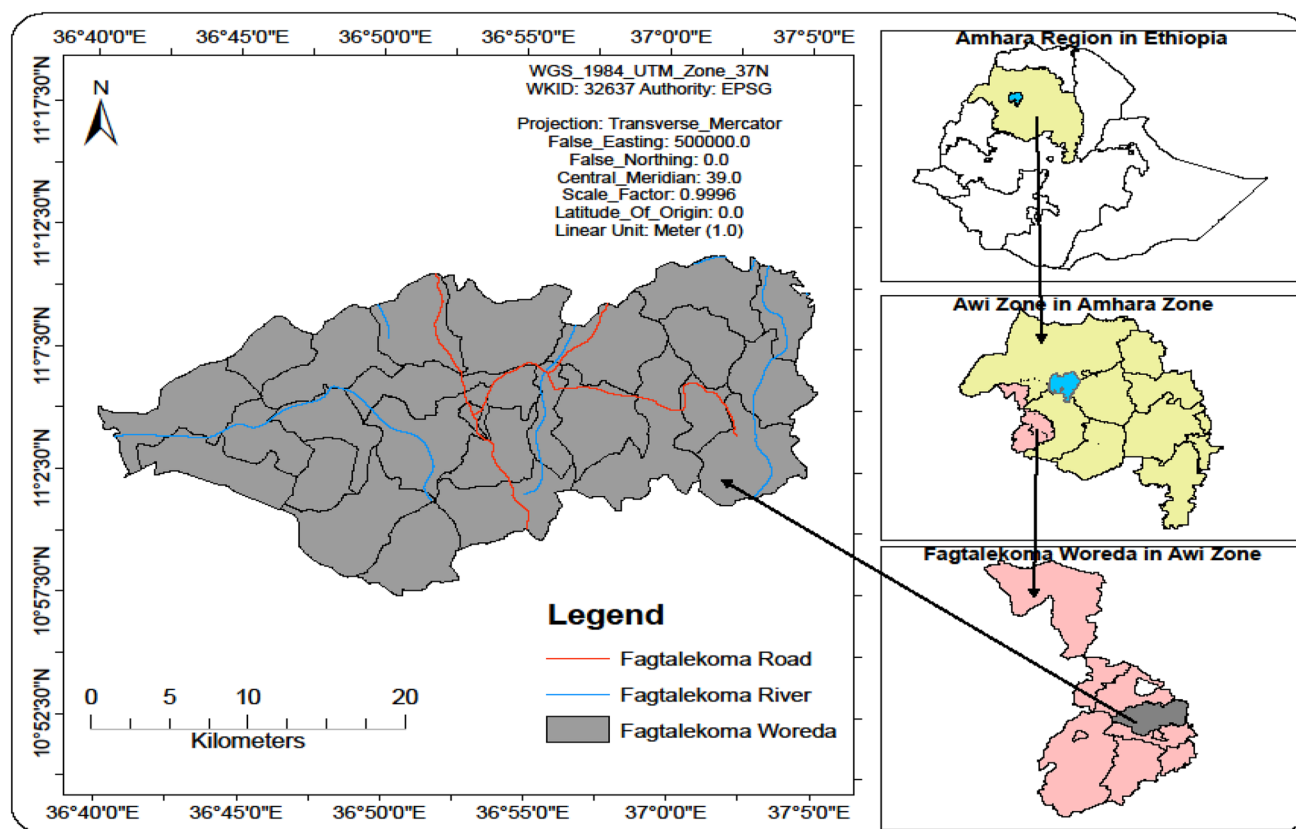
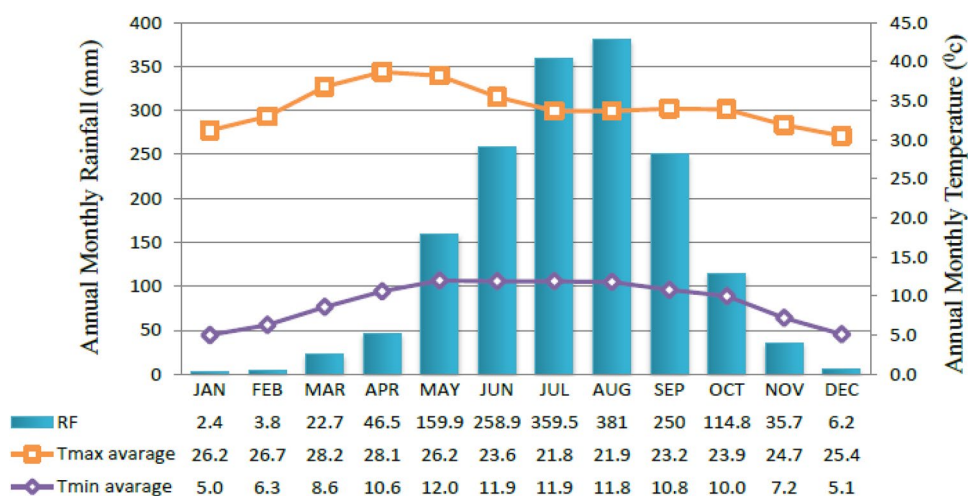


Fig. 1 Location map of Fagita Lekoma district

Fig. 2 Temperature and Rain-fall data of the study area



It's around 460 km northwest of Addis Abeba and 100 km southwest of Bahir Dar, the capital of the Amhara regional province. The total area covered by the study area is 67,679 ha. The district has two agro-climatic zones, *Dega* and *Weynadega*, which cover 16% and 84% of the total area of the study area, respectively. The research area's

altitudinal variance spans from 1880 to 2921 m above sea level. Furthermore, the relief is typically composed of 62% plains, 23% mountains, and 15% other features.

Temperature varies between the mean annual maximum of 28.2 °C and mean annual minimum of 5 °C across the elevation gradient. The average rainfall is 381 mm during the rainy season (Fig. 2).

Table 1 lists the types and characteristics of the satellite images used in this study

Data type	Year	Acquisition date	Sensor	Path & Row	Resolution	Data source
Landsat 5	1986	Jan 01	ETM	170/52	30 M	USGS
Landsat 7	2002	Jan 05	ETM+	170/52	30 M	USGS
Landsat 8	2020	Jan 16	OLI	170/52	30 M	USGS

Table 2 Description of LULC classes for the study district

LULC class	Description
Cultivated land	Includes annual rain-fed and irrigated cultivation. Land is mostly used for cereal production in subsistence farming and is mixed with bushes
Grass land	Covered mainly by grass, there is a small part of bushes and trees
Forest land	It includes both natural vegetation and planted trees. The dominant tree species in the study area are Chigegn (<i>Acacia decurrens</i>), Bahirzaf (eucalyptus), and bamboo forest (<i>Arundinaria alpine</i>)
Wetland	It represents most of the flat areas where frequent flooding occurs during the rainy season and for most of the year; the water table is at least near or above the surface
Settlement	These areas are occupied by small towns and settlements, including markets, roads, schools, clinics, and other institutions

According to the report of the district land administration, the natural vegetation is shrunk at the borders of Banja and Guangua districts and around the churches only, as they are not damaged due to religious considerations. However, the amount of man-made vegetation is increasing at an alarming rate from time to time. This expansion is for the purpose of charcoal production as an economic value, fuelwood, and other related trading activities. The geological structure in the district is dominated by Tertiary volcanic rocks and Quaternary basalts. In relation to this, Nitisols, Gleysols, and Luvisols are the major soil types and are characterized by shallow, moderate to deep, very deep in-depth, and sandy clay to clay texture types. The erodibility of these soils also varies from medium to very erodible characteristics [29]. Mixed farming systems (crop production and animal ranching, including tree plantations) are the takeover livelihoods of the district like in most parts of Ethiopia.

2.2 Satellite image data acquisition and analysis

Different types of satellite images were taken from different sensor types to cover the intended study period (Table 1). These were the Landsat Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM⁺), and Operational Land Imager (OLI) in early 1986, 2002, and 2020, respectively. The satellite images had been acquired from the United States Geological Survey (<http://earthexplorer.usgs.gov>). It was acquired in January, at this time of the clear sky season in the region with reduced atmospheric and radiometric problems.

By using Landsat satellite images, we generated a LULC map of the study area. A spatial resolution of 30 m and dry and cloudless images were used to avoid the influence of

seasonal fluctuations for this study. The Landsat images were processed using ERDAS IMAGINE® 2014 and ArcGIS® 10.4 software. Landsat images were passed through both pre-processing and post-processing phases. All image datasets were projected onto the Zone 37N and World Geodetic System 84 (WGS84) datasets of the Universal Transverse Mercator projection system. This ensures consistency between the datasets being analyzed.

In this study, Landsat images were classified using hybrid image classification methods. The unsupervised classification was first applied prior to field surveys using visual interpretation approaches to distinguish between different land use and cover types in the study area. The LULC maps for the study area were produced using pixel-based image classification using the maximum likelihood classification algorithm [30]. Supervised image classification is the suggested classification approach for decent results when correct training data are accessible in the study area [30, 31]. Comprehensive field observations and GPS control points (GCPs) sample collection were carried out in January (the same season as the image acquisition date) to select representative training sites for each LULC class (Table 2). Five LULC classes (cultivated land, grassland, forestland, wetland, and settlement) were identified from the image, and training samples were collected to be used for image classification and validation (accuracy assessment). As a result, for each year, a total of 300 GCPs were obtained, with 80% (250 GCPs) used for picture classification and the remaining 20% (50 GCPs) used for validation. Prior knowledge and Google Earth datasets were also used in 1986 and 2002. Field observations and Google Earth Pro data sets were used to collect samples for accuracy assessment for the year 2020. The ground reference point used to

evaluate accuracy is independent of the reference point used as the training sample.

The accuracy assessment matrix was engaged to calculate the accuracy of the classification since classification is imperfect until its accuracy is assessed, which also determines the quality of the map extracted from remotely sensed data. The common way to represent classification accuracy is in the form of an error matrix for user and producer accuracy assessments. An error matrix is an array of rows and columns of squares that represents the relationship between the classes of classified data and reference data [32]. The reference data used for accuracy assessment was obtained from field observations. A set of reference points has been used to assess its accuracy. To test the accuracy of an attribute, it is important to have enough samples to represent the thematic classes and ensure a good distribution on the map. All types of accuracy assessments and Kappa coefficients are calculated as follows; Eq. 1:

$$K_{hat} = \frac{N \sum_{i=1}^r X_{ii} - \sum_{i=1}^r (X_{i+} * X_{+i})}{N^2 - \sum_{i=1}^r (X_{i+} * X_{+i})} \quad (1)$$

whereas K_{hat} = Kappa Coefficient; N is the total number of values; $N \sum_{i=1}^r X_{ii}$ is detected accurateness and $\sum_{i=1}^r (X_{i+} * X_{+i})$ is coincidental correctness.

The transformation detection is carried out by considering the LULC image on a pixel-by-pixel basis [31]. Changes extracted from the observation year of the study are represented by change metrics and provide “where” and “from-to” information about the direction of the change in the reference time interval. The change calculated for each LULC class is calculated as the difference in area percentage between the last year t_2 and the starting year t_1 . Each LULC class percentage of change is calculated by using Equation 2 [33–35].

$$C = \left(\frac{A_{t2} - A_{t1}}{A_{t1}} \right) * 100 \quad (2)$$

whereas C is the percentage change, A_{t1} is the area of one land use during time t_1 . A_{t2} is the range of land use of the same type during time t_2 .

The quantification of the rate of change has been applied to generate information about the land use and cover changes in the study area. Using the rate of change between the two periods, the rate of change per year can also be computed by dividing it by the year difference between the two periods. The rate of change of each land use and land cover can be calculated by using Eq. 3 [34–36].

Rate of change in percent

$$= \frac{\text{Observed change between two years}}{\text{Rate of time intervals}} \times 100 \quad (3)$$

A mixed-methods research approach was used for this study. Because the quantitative research approach involves the generation of data in numerical terms mainly focused on the trends and patterns of land use and land cover change. While the qualitative approach is used to identify driving forces to shift crop cultivation to tree plantation and the economic importance of tree plantations through comprehensive understanding and evidence through different primary facts in study site. The socio-economic data were used to gain detailed information from the local people and experts regarding the trends in LULC changes, the driving forces of the local communities to shift from crop cultivation to tree plantation land use systems, their economic benefits, problems, and opportunities for a sustainable future tree plantation land use system in the study area.

First, according to the classification of Hurni [5], the study area was divided into two kebeles,¹ represented agro-ecologically. Second, through purposive sampling, Gafera and Nechela Kebele were purposively selected from Weynadega and Dega, respectively. To complete the survey with qualitative data, key informant interviews (KIIs) were undertaken with eight (8) farmers, one (1) development agent, and one (1) natural resource expert through a purposive sampling system. The interview was accompanied by an open-ended questionnaire at the development agent offices, churches, and farm fields. In addition, a total of two (2) focus group discussions (FGDs) were carried out in two (2) Kebeles selected from the study area. In each kebele, eight persons within the group had knowledge, experiences, and interest in the subject under discussion through connivance sampling techniques. These included older farmers (both men and women), youth, community leaders, natural resource experts, and development agents.

3 Results and discussions

3.1 Analysis of LULC change

Following the classification scheme (Table 2), cultivated land, grasslands, wetlands, forestland, and settlements were the main land use land cover categories during the study period. The results of the first study period (1986) of the district (Fig. 3) showed that cultivated land represented

¹ Kebeles are a small administrative unit in Ethiopia.

Fig. 3 LULC map of the study area, 1986

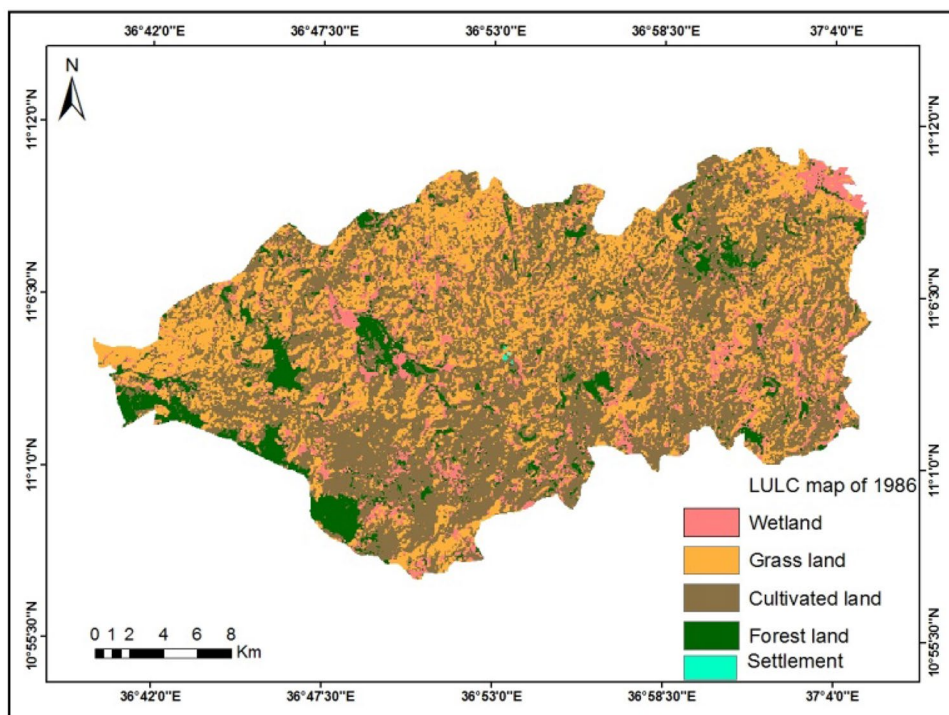
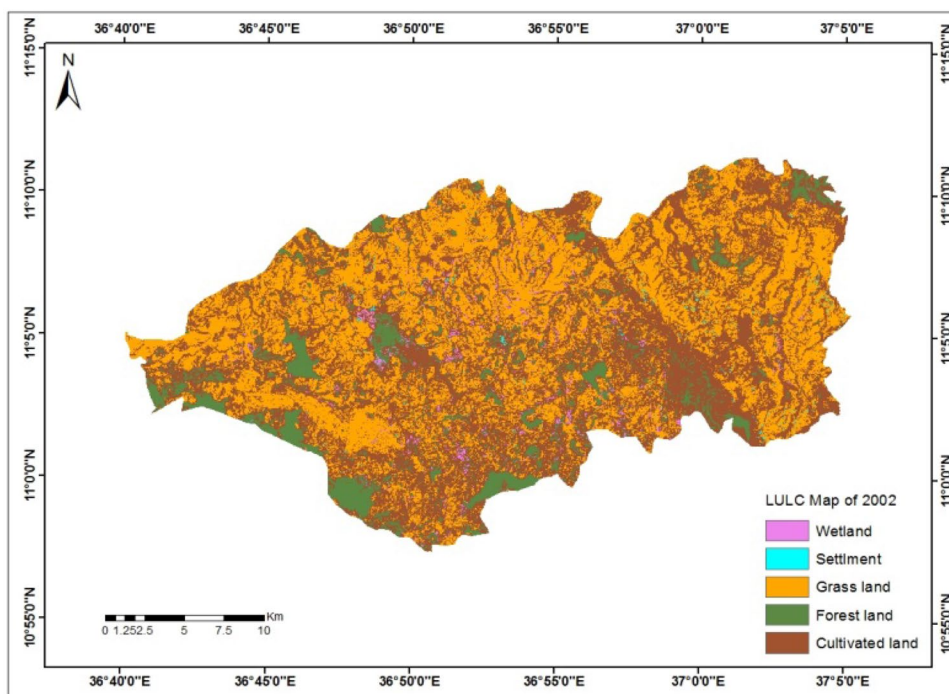
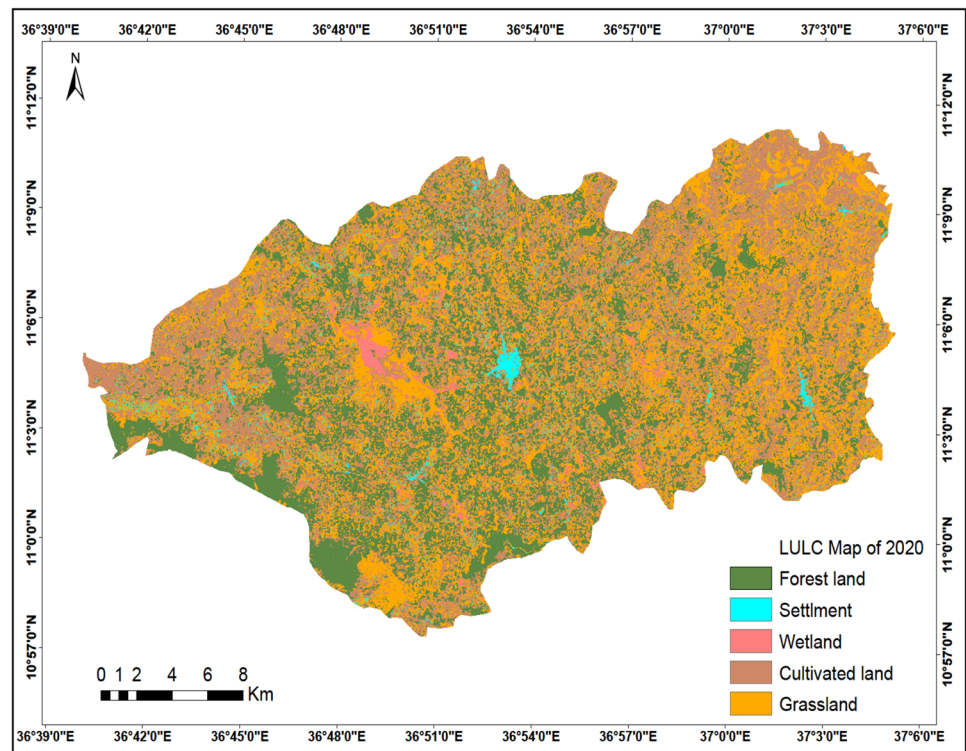


Fig. 4 LULC map of the study area, 2002



the highest proportion of land in the region, with a value of 31,038 ha, or 45.8%, followed by grasslands, which represented 28,037 ha, or 41.49%. Forestland and wetlands accounted for 9.1% and 3.5%, respectively (Table 4). Furthermore, the settlement area during this period was the smallest, with 85 ha (0.13%).

In the middle study period (2002) of the district (Fig. 4), the proportion of cultivated land assigned increased to 35,152.56 ha, or 51.89%. In addition, the area of grasslands throughout the district has decreased, covering an area (22,535.28 ha) of 33.26%. However, as compared to the baseline study year (1986), the forest

Fig. 5 LULC map of the study area, 2020**Table 3** LULC classification accuracy assessment results 1986, 2002 and 2020

Land cover class	1986		2002		2020	
	User accuracy %	Producer accuracy %	User accuracy %	Producer accuracy %	User accuracy %	Producer accuracy %
Forestland	93.3	93.3	91.7	91.7	92.3	90.5
Cultivated land	92.94	90.8	89	94.8	84	80.8
Grassland	85	91.07	88.7	84.6	92.5	88
Wetland	87.5	77.78	83.3	76.9	92.9	92.9
Settlement	85.2	87.4	83.3	90.9	77.4	92.3
Overall accuracy	89.8	89.8	86.7	86.7	87.9	87.9
Kappa Statistics	0.82	0.82	0.85	0.85	0.84	0.84

cover ratio remained stable at around 6262.74 ha, or 9.24%, while the wetland rose slightly to 3505.86 ha, or 5.17% (Table 5). Unexpectedly, the extent of the settlements changed during the second study period. In the 1986 Landsat image, it was difficult to identify the town of Adiskidam and another area of settlement. However, in the middle of the study period (Fig. 4), the town of Adiskidam achieved a decent footprint, representing only about 0.41% (280.8 ha) of the total area of the Fagita Lekoma district.

In terms of current land uses (2020) and land cover conditions in the study area (Fig. 5), the proportion of

allocated cultivated land has been significantly reduced to (24,030 ha) 35.4%. At the same time, the area of grasslands has decreased, covering an area of 22,390 ha (Table 5). However, compared to the base year (1986) and the mean period of the study (2002), the proportion of planted forest cover increased significantly, representing approximately (19,140 ha) 28.1%. Furthermore, the settlement area in the last 18 years has also increased, representing approximately 2.41% (1500 ha). Due to the area's drying up, wetlands only represent 1.3% of the 894 ha that the area covers.

Table 4 Conversion matrixes in the year between 1986 and 2002, 2002–2020, and 1986–2020

To	2002	Forestland		Cultivated		Grassland		Wetland		Settlement	
		ha	%	ha	%	ha	%	Ha	%	ha	%
From 1986	Forestland	3,260.1	4.81	2,338.2	3.45	319.05	0.47	439.2	0.7	0.9	0.001
	Cultivated	580.86	0.85	14,666.5	21.65	14,574	21.51	980.73	1.44	193.1	0.28
	Grassland	1,987.6	2.93	17,493.5	25.82	7,128.6	10.52	1,374.2	2.02	82.6	0.13
	Wetland	414.8	0.6	795.9	1.1	482.2	0.76	706.05	1.04	4.14	0.006
	Settlement	0	0	0	0	0	0	0	0	85	0.13
To	2020	Forestland		Cultivated		Grassland		Wetland		Settlement	
		ha	%	ha	%	ha	%	Ha	%	ha	%
From 2002	Forestland	3,865	5.7	871	1.34	1,328	2	41	0.06	91	0.14
	Cultivated	8,993.2	13.2	11,567	17	13,820	20.3	173	0.25	793	1.27
	Grassland	5,761.8	8.44	10,057	14.8	6,102	9	123	0.19	404	0.65
	Wetland	418	0.61	1,535	2.26	1,140	1.6	557	0.81	33	0.05
	Settlement	102	0.15	0	0	0	0	0	0	179	0.3
To	2020	Forestland		Cultivated		Grassland		Wetland		Settlement	
		ha	%	ha	%	ha	%	Ha	%	ha	%
From 1986	Forestland	3,359	4.94	867	1.3	1,889	2.8	208.8	0.31	58	0.09
	Cultivated	10,182	15.1	13,988	20.6	5,936.5	8.76	101	0.15	833	1.23
	Grassland	5,286	7.8	8,325	12.3	13,610.5	20.1	299.2	0.44	516	0.76
	Wetland	313	0.45	838	1.2	954	1.4	285	0.41	20	0.03
	Settlement	0	0	12	0.02	0	0	0	0	73	0.11

*Shaded numbers represent LULC that showed no change

3.2 Results of accuracy assessment for LULC classification

Accuracy classes are usually defined as the extent to which the classification of results matches reality, and the accuracy of a map largely determines the usefulness of the map [32, 37, 38]. To present the accuracy of the classification outcomes (Table 3), overall accuracy, user's and producer's accuracy, and Kappa statistics were computed from the error matrix for each year by using Eq. 1 [30, 31]. In this study, the accuracy assessment is performed for 1986, 2002, and 2020 classified images using ground control points collected using a topographic map from the elderly, field observations, and Google Earth Pro data sets.

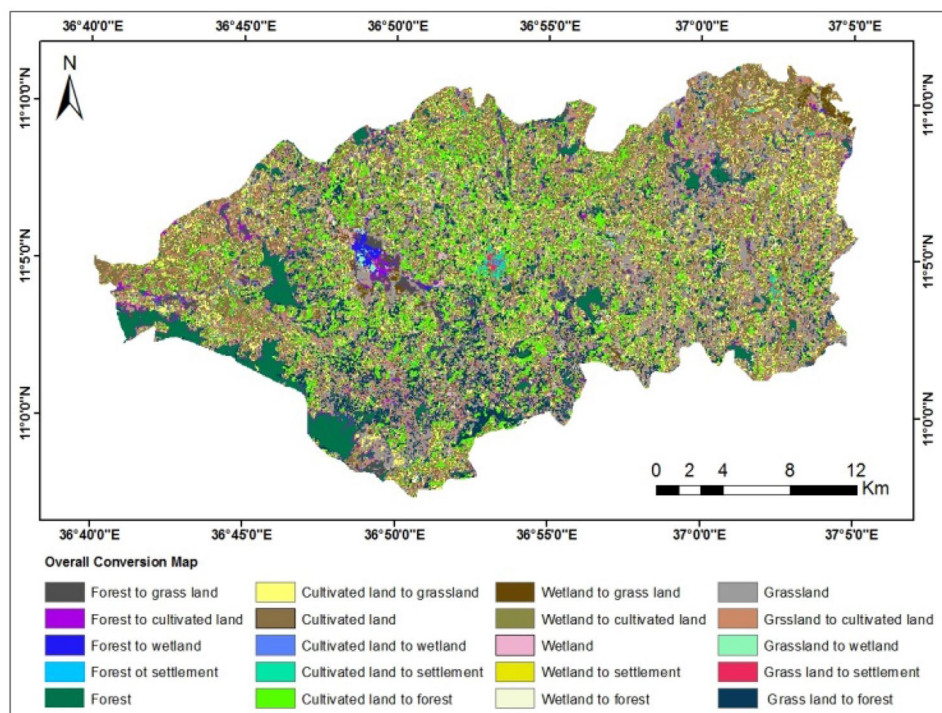
3.3 Patterns of LULC change in the study area

Agriculture has always been the most important force in the transformation of the land on this planet. Today, almost a third of the earth's surface is used to cultivate or herd livestock [4, 17, 39]. The majority of farmland is generated at the expense of natural forests, grasslands, and wetlands. It used to provide valuable habitats for species and provide valuable services to humans [9, 40].

In Table 4, the cultivated land constituted 45.8%, 51.9%, and 35.4% of the total area of the district in the years 1986, 2002, and 2020, respectively (Fig. 6). Still, cultivated land is the predominant land use system in the study area. This result agrees with the findings of [28] in the Anjeni area of the northwestern highlands of Ethiopia. And, in a related study conducted by [7, 24] in the Fagita Lekoma area, arable land was the main land use type, covering 58%, 63%, and 57% in 1973, 1987, and 2015. In 2000, 2010, and 2017, it was 46.3%, 30.3%, and 39.16%, respectively. Moreover, this result is also in line with the findings of [41] in which cultivated land was the major land-use type, covering 75.2%, 91.7%, and 96.5% for the respective years of 1957, 1987, and 2005 in the Gumara watershed of the Lake Tana basin, Northwestern Ethiopia.

In the first study period, the cultivated land increased by 4114 ha (13.3%), while it decreased by 11,122 ha (33%) in the middle study period. This outcome is also in line with the judgments of [8] at Chemoga Watershed under the Blue Nile Basin, in the study years between 1957 and 1998, there was a similar increase and decrease pattern of cultivated land, with a 13% escalation in 1957–1982 and a 2% diminution in 1982–1998.

The grassland covered 41.5%, 33.2%, and 32.9% of the total area of the district in the years 1986, 2002, and 2020,

Fig. 6 LULC Change map between 1986 and 2020**Table 5** Patterns of LULC changes from 1986 to 2020 in the study district

LULC classes	Area 1986		Area 2002		Area 2020		Change between 1986 and 2002		Change between 2002 and 2020		Change between 1986 and 2020	
	Ha	%	Ha	%	ha	%	ha	%	Ha	%	Ha	%
Forestland	6182	9.1	6262	9.24	19,140	28.1	+80	+1.3	+12,878	+206	+12,958	+210
Cultivated	31,038	45.8	35,152	51.9	24,030	35.4	+4114	+13.3	-11,122	-31.6	-7,008	-22.6
Grassland	28,037	41.5	22,535	33.2	22,390	32.9	-5502	-19.6	-145	-0.65	-5647	-20.1
Wetland	2410	3.5	3506	5.1	894	1.31	+1,096	+45.5	-2612	-74.5	-1516	-63
Settlement	85	0.13	281	0.41	1500	2.41	+196	+231	+1219	+434	+1415	+1665

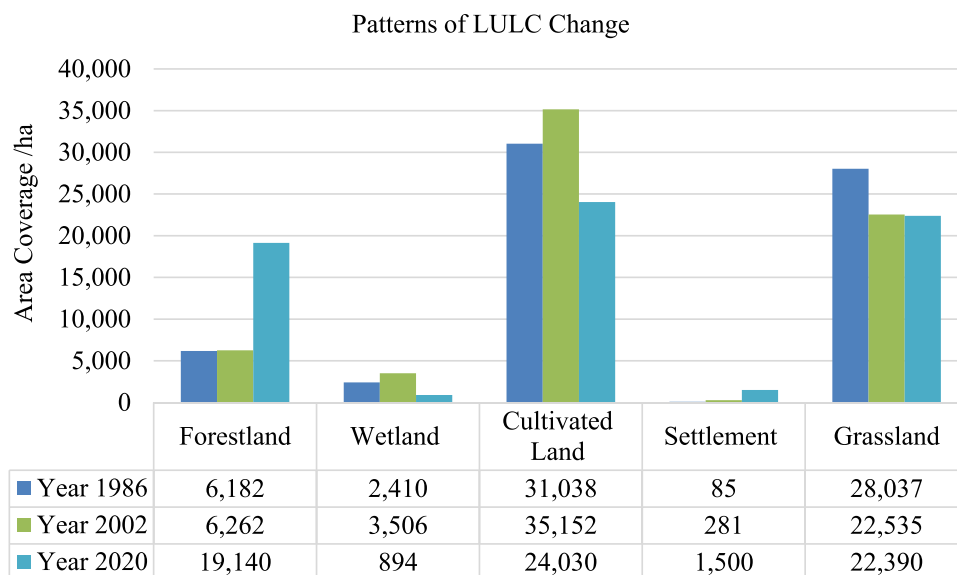
N.B. '-' indicates decrease '+' indicates increase 'ha' indicates hectares

respectively (Table 5). This is the second-largest land cover class in the study area. The result is in line with the finding of [7, 24] in Fagita Lekoma district, which stated that grassland land was the second largest land cover type, covering 15.8%, 32.3%, and 22.7% for the years 1973, 1987, and 2015, and 16.5%, 18.96%, and 25.27% for the years 2000, 2010, and 2017, respectively. During the overall study period (1986–2020), the conversion of cultivated land into grassland accounted for 8.76%. In reverse, grassland also loses 12.3% of its area on cultivated land (Table 4 and Fig. 7). Throughout the study period (1986–2020), the area coverage of grassland decreased by 20.1% (Table 5). Increasing demand for cultivated land contributed to the reduction of grasslands.

The result differs from the conclusion of [7, 28], where they presented the rising of grassland coverage during the

study period in the Anjeni area and Fagita Lekoma district, respectively, in northwestern Ethiopia. On the other hand, support from the report of [8, 41–43] shrub-grasslands showed a decrease of this land cover in Chemoga watershed between 1957 and 1998; a similar pattern of change and decreased between 1972 and 2004 in the upper Dijo River catchment; 31.1%, 23.8%, and 21.8% for the years 1973, 1986, and 2000 at Dessie Zuria district; and 2.69%, 1.36%, and 0.65% for the years 1957, 1987, and 2005 in Gumara watershed, respectively. The afforestation programs in the study area also contributed to the reduction of grassland during the second study period (2002–2020), overtaking 8.44% of the total area of the study area (Table 4). This is due to the farmers increasing attention to covering their lands and surroundings with *Acacia decurrens* trees.

Fig. 7 Shows the Patterns of land use/cover change 1986–2020 in the study area



The area under forestland cover was 9.1%, 9.24%, and 28.1% of the total area of the district in the years 1986, 2002, and 2020, respectively (Table 5). The rate of change in forestland cover was slightly different in the first study period (1986–2002), increasing by about 1.3%. While increasing by 206% between 2002 and 2020 (the second study period). During the overall study period, forestland was similarly increasing by 210% as in the first and second study periods (Table 5). The outcome is in line with the conclusion [7, 24] that was reported about the increasing forestland due to the expansion of new tree plantations in the study area. The main reason for the change in forest coverage from 2002 to 2020 was the introduction of *Acacia decurrens* plantations in the study area. This result is lower than those provided by [41, 44], who reported the reduction of forest cover in the Denki river catchment near Ankober district and the Gumara watershed of the Lake Tana basin in Northwestern Ethiopia, respectively. An attempt to recover the lost forest cover through an afforestation program was practiced in the area during the second study period. As a result, the coverage of the forest vastly increased between the years 2002–2020 (the second study period) and the whole study period (1986–2020).

Wetlands are the second-smallest land cover type in the study area, covering about 3.5% in 1986 and 5.41% in 2002. It was decreasing and would cover only 1.43% in 2020. By considering the overall study periods, 40%, 34.6%, 13.1%, and 1.5% were converted into grassland, cultivated land, forest, and settlement, respectively (Table 4). It is clearly shown in the Zimbiri area, which is the widest

wetland located on the western part of the study area. This type of land is the most productive, and it is also the most threatened by changing and degrading ecosystems on earth [45–47]. The conversion of recorded wetlands to cultivated land occurred because wetlands have the capacity to grow crops without irrigation in the winter season. The major crops that are cultivated on the wetland at the study site are potato, wheat, and maize. This LULC type is found around the plains and is mainly used for farming.

The conversion of cultivated land and grassland to the expanse of settlement area is high. During the first study period (1986–2002), the settlement areas were expanded to include cultivated land and grassland, respectively (Table 4). In 1986, the settlement area covered about 85 ha (0.13%), and in 2020, it covered 1,500 ha (2.4%) of the total study area. According to [7, 24, 41] they have reported similar results indicating population growth and the appearance of other factors.

3.4 Expansion rate of tree plantations on farmland in the study area

The possibility of switching from one land-use system to another depends on demographic changes and the economic and financial returns of the selected farm enterprises [26]. Most rural residents in the Ethiopian highlands provide more land for crop production than other land-use systems to support and feed their livelihoods. In the second study period (2002–2020), the conversion of cultivated land by 8993.2 ha (13.2%) was observed into

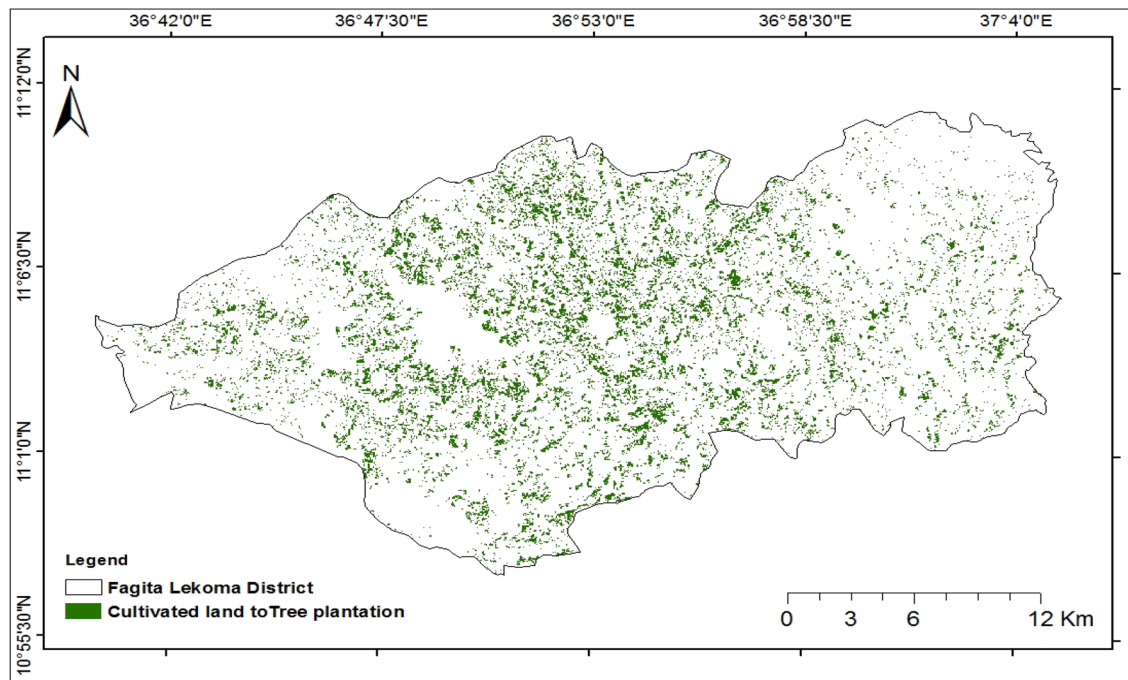


Fig. 8 Shows the spreading of the *Acacia decurrens* tree plantation on the farmland

Table 6 Annual rates of land use and land cover change in Fagita Lekoma district

LULC classes	Change between 1986 and 2002		Annual rate of change (1986–2002)		Change between 2002 and 2020		Annual rate of change (2002–2020)		Change between 1986 and 2020		Annual rate of change (1986–2020)	
	ha	%	ha/yr	%	ha	%	ha/yr	%	ha	%	ha/yr	%
Forestland	+80	+1.3	+5	+0.08	+12,878	+206	+715.4	+11.4	+12,958	+210	+381.1	+6.2
Cultivated	+4114	+13.3	+257	+0.83	–11,122	–31.6	–618	–1.76	–7008	–22.6	–206.1	–0.67
Grassland	–5502	–19.6	–344	–1.2	–145	–0.65	–8.1	–0.04	–5647	–20.1	–166.1	–0.6
Wetland	+1096	+45.5	+68.5	+2.8	–2,612	–74.5	–145.1	–4.14	–1516	–63	–44.6	–1.9
Settlement	+196	+231	+12.3	+14.4	+1219	+434	+67.7	+24.1	+1415	+1665	+41.6	+49

N.B. '–' indicates decrease ' +' indicates increase 'ha' indicates hectare 'yr' indicates year

forestland (Table 4). *Acacia decurrens* tree growers have taken the first responsibility to decrease the cultivated land in the study area (Fig. 8).

The average annual rate of change (Table 6) in forestland/tree plantation cover showed relatively no more change between the first study period (1986–2002), which accounts for about 0.08% added to the previous,

and incredibly increased between the second study period (2002–2020), which accounts for about 11.4% recorded, and the overall study period (1986–2020) was similarly increasing by about 6.2% of the total area. The increase in forestland in the study area from 2002 to 2020 (Table 4) is in sharp contrast with the trend in most rural areas of Ethiopia.

3.5 Driving forces of small holder farmers to engagement in *Acacia decurrens* tree productions

Agriculture in Ethiopia is the cornerstone of the country's economy as well as the principal livelihood of the population. Previous studies report that the livelihood dependence of the Ethiopian population on agriculture is the prominent cause for almost all forms of LULC changes [8, 27, 48, 49].

In the current this study, LULC changes analysis showed significance reduction of cultivated lands in the study area. On the other side, the forest lands and built-up areas were expanded. *Acacia decurrens* tree plantations are the major factors to change the land-use system in the study area. Following this, the investigators attempt to identify the main driving forces of local farmers strictly engaging to tree plantations. There are four major causes were identified through FGDs and KIs. Increasing the actual and potential income generation from the tree-based land-use system, the tree-based land-use system is highly compatible and adaptable with other land uses system, declining agricultural land productivity for crop cultivations and creating countless Job opportunities for the job and landless people without considering age and sex specifications is crucial four major driving forces of the communities to shifting from crop cultivations to tree plantations activities in the study area. Let's look at the details below the interactions among different variables that contribute to enforce the local communities from crop cultivations to engage tree plantations.

3.5.1 Increasing the actual and potential income generation

Forest resources are one of the financial assets and basic economic activities like animal husbandry and crop production [50–53]. Increasing fuel wood and biomass energy demand in the major cities has opened new charcoal market opportunities for the people in the study area. Expanding market opportunities will encourage communities, as

an economic incentive, to plant, protect, and manage forest resources [54]. In line with this literature, the expansion of *Acacia decurrens* tree plantations has been rapidly implemented by the serious private campaign of local farmers in the last decade in the study area [7, 55]. The farmers at the current study site have established *Acacia decurrens* woodlots to generate cash income by producing charcoal. Accordingly, the key informants and focus group participants also confirmed that, compared with other products, the income potential of plantation products is by far the most important driving factor for large-scale producer families. Due to the growing demand for *Acacia decurrens* products (charcoal, firewood, and organic ingredients), small-holder farmers planted *Acacia decurrens* trees; it is also a potential income-generating activity in the market-driven in the study area.

3.5.2 Adaptability and compatibility with other land uses

The introduction of exotic tree species, especially eucalyptus, has provided multiple socio-economic benefits and has been criticized in multiple directions for their negative ecological effects [54, 56]. However, contemporary spreading out of *Acacia decurrens* plantations is capable of numerous habits in the study area. According to the FGDs and KIs investigations, the individual landowners adopted the technique of planting *Acacia decurrens* trees together with crops such as Teff (*Eragrostis tef*), Wheat (*Triticum aestivum* L.) and green pepper (*Capsicum annum*) during the first growing season. After the crop harvest, the farmers let the trees grow and the tree plantation had an excessive survival rate. The plantations are ready for harvest 5–6 years after planting. Farmers uproot the tree at harvest time so that the cereal crops can be grown for one to two years before the area is replanted with *Acacia decurrens*. In addition, local development officials acknowledged that the shallow rooting nature of the species rapidly decomposed and restored devastated farmland. These are also another reason for the rapid expansion of forestland in this study area.



Source: Photos taken by Authors during the field survey, 2020

3.5.3 Declining agricultural land productivity

Northwestern highlands of Ethiopia have a long history of settlement and rainwater farming practices [5, 54].

The Northwestern Highlands of Ethiopia have a long history of settlement and rainwater farming practices [5, 54]. The prolonged settlement, poor agricultural practices, free grazing, and deforestation have resulted in severe soil erosion and land degradation [3, 57]. According to the expressions of natural resource experts, the soil of the study district was particularly acidic and degraded before starting tree plantations because of soil erosion and overexploitation of farmland for extraordinary crop production, like that of the various highland regions of Ethiopia. This result is supported by [10, 25], where soil acidity is the cause of the decline in agricultural productivity and dissatisfies the households food consumption in the study area. These forces farmers to grow tree plants that can tolerate soil acidity, restore soil fertility, and generate additional income and jobs for households.

3.5.4 Job opportunities

According to KIIs and FGDs, many young people, including farmers, were previously unemployed and involved in illegal activities in the Fagita Lekoma district. Furthermore, they are temporary laborers who have migrated in huge numbers to the Kolla area. However, because of these “golden trees” its history has resulted in significant employment opportunities for people of all genders and ages. According to the KIIs’ real evidence, if future land use is properly planned, this is a very good employment creation possibility for young people. *Acacia decurrens* growers engage several family members in the planting, harvesting, charcoal production, transportation, and storage processes. In addition, there are numerous agents for the *Acacia decurrens* plantation and advertising system, such as the sale of the complete plantation to charcoal marketing.

3.6 Economic benefits of tree plantations for local communities

The economic benefits of growing trees are allegedly higher than those of cultivating annual crops [20, 58].

The farmers are well aware of the multiple socioeconomic advantages of *Acacia decurrens* compared to Eucalyptus globulus and another tree species commonly planted in the study area [26]. One major goal of the *Acacia decurrens* plantations is to generate income by selling charcoal. Farmers were fortified to plant *Acacia decurrens* due to its fast growth, its use as fuel wood, its potential to be used for charcoal, its role in soil fertility maintenance, and the marketability of this species [7, 20, 24, 25]. Smallholder tree planting has provided occasional employment possibilities for jobless youths and women. FGDs and KIs confirmed that the tree plantations land use provided more income than the solely cultivated land use system. Similarly, [7] reported to *Acacia decurrens* that the intercrop land use system provided 1.3 times more income than the single *Teff* land use system in the study area. The mixed land use system with pastures and *Acacia decurrens* provided farmers with an income 11 times higher than the pure pasture land use system. Therefore, smallholder farmers obtained the highest income from the *Acacia decurrens* land-use system only, followed by agricultural or grass-based land-use systems. This is one of the major reasons that motivated local farmers to change the land use system from a crop-based land use to a tree plantation-based land use.

3.7 Opportunities and threats of the *Acacia decurrens* tree plantations

According to interviews with key informants, the expansion of tree plantations on degraded landscapes plays a major role in creating more jobs for landless youth and providing opportunities to diversify livelihoods, as discussed in terms of economic benefits. *Acacia decurrens* is favored by smallholder farmers due to its fast growth and good adaptability to different land-use systems in the study area. Trees are planted after clearing or on agricultural lands that have been used for other purposes. This is a new agroforestry production system that shows the potential to maximize benefits by incorporating fast-growing plants into annual crops in the study area.

In contrast to the benefits of *Acacia decurrens* tree plantations, the threats of the introduction of *Acacia decurrens* might also lead to a decrease in agricultural cumulative production as it leads to a reduction in arable land, as noted above. According to the explanation of the district cadastral department (2020), the major problem facing farmers in the study area is the lack of arable land and the decrease in agricultural production. This is demonstrated by having to import grain from neighboring districts to provide their food security. Currently, population pressure is high, so the need for additional land is increasing. Because the growing of tree plantations is competing for land, it requires more land than other land use systems to

provide relevant income. Presently, due to the severe land shortages, some smaller administrative units in the district donate land to landless youth on community-owned land by organizing themselves into small business groups.

Moreover, farmers are covering their fertile and irrigable lands with trees to gain the highest profits from the tree plantations than from their annual crop productivity. KIs revealed that farmers and charcoal makers noticeably perceive that the smoke of charcoal is dangerous for human health, mainly for people who make charcoal in conventional ways. Tree plantation is a long-term investment that requires capital until it matures for harvest. Therefore, it makes it hard for poor smallholder farmers to use it and forces them to rent their land to wealthy people.

4 Conclusion and recommendations

In the study area, the production of *Acacia decurrens* trees is mainly extended to farmers' arable land due to the attractive economic income from tree production compared with crop production. The results show that the area of cultivated land has been reduced by 22.6% compared to the previous coverage. The surfaces of grasslands and wetlands were declined by 20.1% and 63%, respectively, throughout the research period. The rates of plantation forest cover, on the other hand, increased by 210%. Furthermore, the settlement area rose by 1665% during the research period, following a pattern comparable to that of forest land. The pattern of land use and land cover has changed, showing a tendency to increase forest land due to afforestation. A large amount of cultivated land and grasslands were reduced and turned into tree plantations and settlement areas. Arable land productivity decreased prior to this change due to extensive cultivation, which has highly degraded soils, leading to the introduction of tree plantations as a replacement for agriculture. *Acacia decurrens* expansion is the most preferred tree species. The other has increased the level of income and enabled soil restoration through reducing soil erosion and regulating water availability. The new multifunctional agroforestry systems with *Acacia decurrens*, crops, and/or animal grazing have created new job opportunities for landless people of all ages and sexes in the study area. Farmers and charcoal makers are exposed to the smoke of charcoal, which is the main threat to their environment. The threat is mainly derived from the charcoal produced using conventional methods. The local rules and communities may consider the introduction of appropriate processing options to provide environmentally sustainable solutions, adding value to the *Acacia decurrens* timber produced in the area.

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Author contributions TE has made a great contribution starting from the naming of the research, data acquisition, collection, entry, coding, and analysis, result interpretations and discussions. MA, He spent a lot of time on the critically revising the theme of our research and the advised overall activity of this paper.

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Declarations

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Consent to participate Not applicable.

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