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SPATIO-TEMPORAL IMPACT OF SOCIO-ECONOMIC PRACTICES ON LAND USE/ LAND COVER IN THE KASSO CATCHMENT, BALE MOUNTAINS, ETHIOPIA

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Abstract: This study aims to identify the driving forces and implications of the temporal and spatial dynamics of land use and land cover in the Kasso catchment, Bale Mountains (Southeastern Ethiopia). Aerial photographs (1965 and 1973) and satellite image (SPOT5 2007) were interpreted and analyzed using GIS tools. Socio-economic surveys, focus group discussions, and field observations were also used to determine the causes and effects of these land use and land cover dynamics. It was found that agriculture and settlement land had increased by 24%, whereas natural forest, woodland, bush land, and grassland declined by 80.74%, 68.08%, 63.02% and 17.65%, respectively. Agricultural expansion and population growth were the two major driving forces behind the land use and land cover dynamics. Environmental and local livelihood implications included forest cover degradation, soil erosion and fertility decline, stream volume and livestock size decline, and scarcity of firewood and construction materials. These in turn contributed to food insecurity, particularly in some low-income households, as well as hindering the sustainable livelihoods of the study area in general. Therefore, we suggest that there is a need to protect the fragile environment, and to adapt and implement sustainable land management practice to promote sustainable livelihood in the area.

Keywords: *Land use/land cover change analysis, ecosystem; land management; remote sensing; socio-economic factors*

I. INTRODUCTION

Society's demand for land resources and the expansion of technological, managerial, and institutional capacity have significantly altered the vegetation, soil, and topographic features of the environment on a global scale (Turner and Meyer, 1994). The most significant historical change in land cover across the planet has been the expansion of agricultural lands (Houghton, 1994). Much of this agricultural land has been converted from natural forests, grasslands, and wetlands, which provide valuable habitats for species and ecosystems crucial to the survival of humankind (Millennium Ecosystems Assessment, 2003). It is spectacular land use and land cover led that the global forest area has decreased from about 53 million square kilometers in 1700 to about 44 million square kilometers at the beginning of the 21st century. It is estimated that, in the same period, the area covered by savannas and grasslands has decreased globally from 30–32 million square kilometers to 12–23 million square kilometers (Lambin and Geist, 2006). Recent finding also revealed that the growing global population and associated increase in demand for food has attributed to increase agricultural area to nearly 40% of the earth's ice free land surface of which had previously covered by natural vegetation (Ramankutty et al.,2008; Ellis et al.,2010).

The trends of LULC dynamics on earth depend on the level of a country's economy and technology. At global scale, LULC change trend in developed countries has been that natural vegetation cover has increased, encroaching over land that was formerly cultivated. In contrast, in most developing countries, natural vegetation has lost ground to the rapid expansion and intensification of lands under cultivation (Achard et al., 2002). Evidences indicate that (World Bank, 2001) in most developed nations in the second half of the 1990s, there was a positive afforestation rate (of 0.1% annually). However, during the same period, most developing nations (especially those with natural tropical forests) experienced annual deforestation rate of 0.5%, or greater. Angelsen and Balcher (2005) reported that the loss of natural forests in developing countries provides cause for concern, as the loss negatively affects the livelihood of people who are dependent on forests for their survival. Current data indicated that global net forest loss during the period 2000-2010 was 3.2 % per year and the corresponding figure for Africa exhibited a net forest loss of 10% and in contrast Europe showed a gain of 1.6 % (Earth Policy Institute, 2012)

LULC dynamics are the result of a complex interaction between several biophysical and socio-economic conditions, which may occur on various temporal and spatial scales (Reid, 2000). These dynamics have potential local and regional consequences, including loss of soil fertility, increased soil erosion, reduction of biological diversity, hydrological changes, and a modification of local climatic conditions **(**Egeru et al., 2010).

As is the case in other developing countries, Ethiopia is experiencing a high rate of deforestation, although during the period 1994 to 2004, the rate declined from 150,000–200,000 hectares (EFAP, 1994) to 14,100 hectares per year (FAO, 2007). Mulugeta (2004) estimated the annual deforestation rate for Ethiopia to be 0.8%, while, at the same time, the increase in plantation forests was 0.18%. Clearing natural vegetation for agriculture, fire wood, and grazing are the immediate causes of LULC changes in Ethiopia (Kassay, 2004).

An analysis of the LULC pattern of an area reflects the past and present status of resource conditions and exploitation (Mohammed, 2006). Therefore, it is important to understand these dynamics to be able to predict how they will affect human society, both today and tomorrow (Efrem et al., 2009). An accurate evaluation of trends of LULC dynamics enables us to identify the major driving forces behind these trends, as well as their ecological and socio-economic impact. This in turn provides a sound basis for the sustainable management of natural resources and thus a projection of future LULC trajectories (Giri et al., 2003).

Although there was no officially published information on trends of LULC at the national level, several researches have been undertaken on LULC changes in the northwestern (Woldeamlak, 2002), northeastern (Abate, 2011; Asmamaw et al., 2011), eastern (Mohammed, 2006, 2011), and south central (Muluneh, 2003) parts of the country. Nevertheless, there is significant variation in terms of the level of analysis, purpose, and outcome of these studies. In addition, there are also differences in terms of the geographical location and characteristics of these case studies. The spatial heterogeneity thus leads to variability in the presentation of the causes and processes of LULC dynamics. Therefore, area-specific information on LULC dynamics is essential for land-use planning aimed at appropriate resource management and maximizing the productivity of agricultural and non-agricultural land, on both local and regional levels (Daniel, 2008).The over all purpose of this research paper is to fill a research gap in available knowledge and scientific information about the magnitude and rate of LULC dynamics in the Kasso catchment. The study focuses on a 42-year period (1965–2007) and integrates RS and Geographical Information Systems (GIS) techniques. The study aims to: (1) study the patterns of LULC dynamics in the Kasso catchment of the Bale Mountains between 1965 and 2007; and (2) identify and discuss the major driving forces of LULC dynamics, as well as how these changing dynamics have affected the livelihood of the local community and their immediate environment.

II. METHODOLOGY

II.1. The study area

The Kasso micro catchment area is located between 7° 1’ 10” N and 7° 8’ 10” N latitude and between 39° 49’ 45” E and 39° 58’ 15” E longitude. The catchment is located about 12 km west of Robe town, which is the Capital of the

Bale Zone. The road distance of the study area is approximately 415 km from Addis Ababa, the national capital of Ethiopia (Fig. 1). The altitude ranges between 2,480 and 3,250 meters above sea level (m.a.s.l). The area covers 175.95 km^2 and forms a part of the Bale Mountains, Southeastern Ethiopia. It is bounded by smaller watersheds in the north and south, mountain hills in the west and Shaya river in the east and north east directions. The absence of aerial photographs for periods 1965 and 1973 has distorted the normal shape of the catchment in the south and west directions. As part of Bale Mountains, the study area shows great variation in physiographic units and is characterized by a gradually rolling terrain towards the northern and southeastern lowlands bordering Shaya stream, a tributary of the Weybi River that drains to the Indian Ocean. The area is dissected by valleys and numerous permanent and seasonal streams that rise from the wetter and cooler mountains. In general using NRCS slope classification guide (NRCS, 1993), the slope gradient of the Kasso catchment can be classified as a slightly flat slope (0 to 7%), a gentle slope (7 to 15%), and from a slight to a steep slope (15 to 60%).

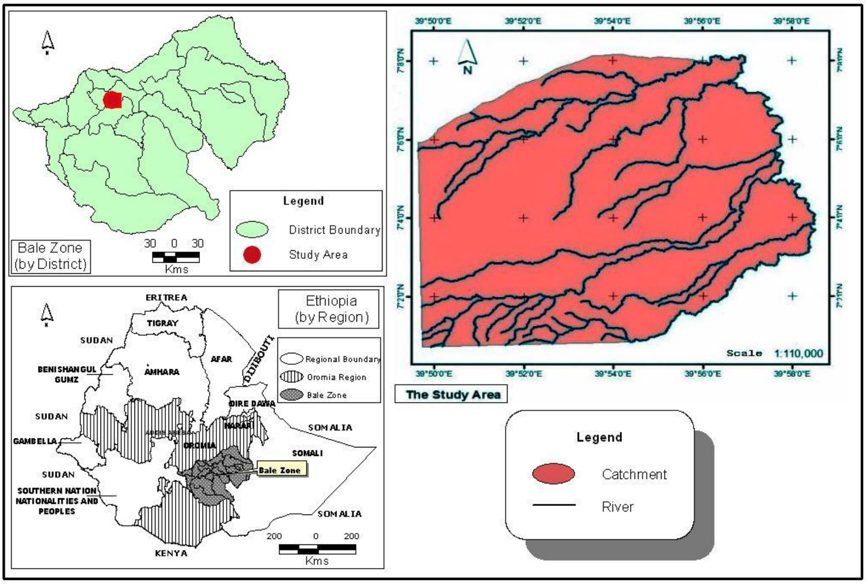

Fig. 1 National, regional and zonal location of the Kasso catchment (EMA, 1973)

The long-term (1973–2007) (EMS, 2012) climatic data record indicates that the Kasso catchment area experienced a mean annual temperature and a mean annual total rainfall of 14.72° C and 743.46 mm, respectively. The lowest temperature occurs during the annual dry season (November to February). The rainfall pattern follows a bimodal distribution.

A significant proportion (>62%) of the annual rainfall occurs between June and September. This is the major annual rainy season, with a peak in August. The months of March, April, and May form a relatively minor rainy season, accounting for about 35% of the total mean annual rainfall of the Kasso catchment (Fig 2).

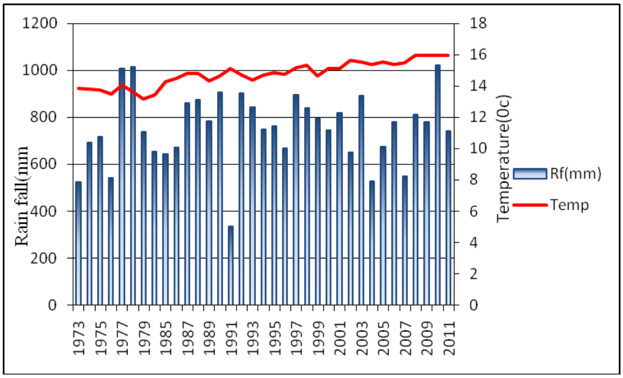

Fig. 2 Mean annual rainfall and temperature characteristics of the Kasso catchment (Ethiopian Meteorological Service, 2012)

Field survey indicates that topographic irregularities determine the natural vegetation cover of the Kasso catchment. Accordingly, distribution of vegetation across the landscape ranges from grassland to afro-alpine. Afro- and sub-afro-alpine vegetation prevails above 3,000 m.a.s.l. In the montane forest zone, *Junipers procera (*locally referred to as *Hindessa*) is the dominant forest tree type. As one moves up to the zone of sub-alpine forest, *Hagenia Abyssinia (*locally known as *Hexoo*) forest dominates. In the afro-alpine zone, *Erica arborea* vegetation is the most common forest type. Short bushes and trees are also found along rivers and the sides of valleys. Forest plantations, mainly *Eucalyptus globulus*, are also common around homesteads.

The total human population of the Kasso catchment was 9,783 and 20,208 in 1983 and 2007, respectively, and increased to 20,911 in 2011. This gave a corresponding population density of 55.60, 114.84, and 118.85 persons/km^2, rrespectively. Such a high population density may exert pressure on local land resources. A subsistence mixed agriculture, consisting of crop growing and animal rearing, forms the main economic base of the study catchment. Cereal crops, such as barely (*Hordeum vulgare*), wheat (*Tiriticum vulgare*), oats (*Avena salive*), and *tef* (*Eragrostis tef*) are the major cultivated crops.

Other crops include chick pea (*Cicer arietinum*), flax (*Linum usitatisssimmum*), potatoes (*Solanum tuberosum*), onion *(Allium cepa*), and cabbage (*Brassica oleracea*). Farming expands up towards the steeper slopes, higher altitudes, and natural forests.(S-DARDO, 2011).

II.2. Data acquisition and analysis

Two sets of aerial photographs, from 1965 and 1973 (1:50,000), and the latest available SPOT-5 (2007) satellite imagery were used to collect spatial-temporal data for the analysis of the LULC dynamics of the Kasso catchment. These sets of data sources were obtained from the Ethiopian Mapping Agency (EMA, 1973). The topographic map of the Goba area (where the Kasso catchment is mapped at scale of 1:50,000) was scanned and digitized to delineate the boundary of the study area and to extract relevant information, including contours. The aerial photographs of 1965 and 1973 were scanned at a resolution of 1200 dots per inch (DPI) and saved in Tag Image File Format (TIFF).

With carefully selected Ground Control Points (GCPs) on the topographic map (1:50,000), each set of aerial photographs (1965 and 1973) were geo-referenced according to the Universal Transverse Mercator (UTM) zone 37 projection parameters using ERDAS Imagine version 9.2. The root mean square (RMS) error was significantly less than half (0.5) a pixel. The geo-referenced aerial photograph images were mosaicked and clipped to fit the delineated study area using the ERDAS software. Thereafter, a visual stereoscopic interpretation of the various features on the aerial photographs was completed based on a visual interpretation of the elements on the photograph images, including tone, texture, shape, size, and pattern. After the recognition and the interpretation of the various LULC features, a classification of LULC types was performed using the aerial photographs. Accordingly, six main LULC categories were developed for subsequent spatial-temporal LULC dynamics analysis using modified Anderson et al. (1976) classification scheme (Table 1).

In this classification, natural and plantation forest trees were considered as forestland. The reason for this was that, as a result of the enhancement of plantations in natural forests, it was difficult to differentiate one from the other at a scale of 1:50,000. Similarly, it was difficult to separate scattered rural dwelling units from agricultural land. For this reason, these two activities were grouped into the agricultural rural settlement LULC category.

An additional input data source was the SPOT-5 satellite image of 2007, which was originally geo-referenced and corrected for any sensor irregularities by the EMA, the dataset provider. Thus, the image was adjusted to the 1:50,000 scale topographic maps of the study area. The images of the area of interest were then clipped based on the frame of the boundary of the study catchment area. We used a similar image interpretation approach to that of the aerial photographs. The classes identified on the aerial photographs and satellite images were verified in the field to check the accuracy of the researchers' interpretation and classification. The LULC categories were then digitized on screen and delineated according to the established legend. Finally, maps depicting the LULC pattern of the study area for 1965, 1973, and 2007 were produced at a scale of 1:50,000.

Table 1 Brief description of classified LULC types of the Kasso catchment, Bale Mountains, Southeastern Ethiopia

Land use/cover type	Description
Agricultural rural settlement land	Area is covered with annual and perennial crops and rural dwelling units
Grassland	Area is predominantly covered by grass and scattered short bushes
Bush land	Vegetation cover is mixed with diverse types of species grown mainly along valleys and streams
Afro-alpine-scrub	Predominantly contains short trees, grown mainly at over 3,000 m.a.s.l., mainly containing *Erica arborea* types of plants
Woodland	Open stands of trees disturbed by human activities for construction, firewood, and other purposes; predominantly contains *Juniperus procera*
Forestland	A combination of natural and plantation forests

The extent and trends of each LULC class change were calculated using Arc GIS software for the respective periods of the study. Thus, change detection matrices for two periods (1965 to 1973, and 1973 to 2007) were produced using post-classification comparison techniques, which involved overlaying and comparing the successive LULC maps from which the transformation matrices were analyzed.Although LULC changes may be observed directly in the field and using remote sensing data sources, an investigation into the causes and consequences of the changes across a range of spatial and temporal scales generally requires an integration of natural and social scientific methods, such as interviews with land users and experts knowledgeable in the field (Ellis et al., 2001). Hence, as supplementary information, we conducted a socio-economic survey of households between December 2011 and February 2012. The purpose of the survey was to acquire data that would assist in explaining the socio-economic and demographic conditions of rural households and communities, as well as the causes of the LULC dynamics and their effect on local livelihood and the environment. Therefore, we selected a random sample of 100 households from each of the three elevation classes of the catchment area (lower, middle, and upper).

The categories of the elevation were based on local context including topography, dominant human activities and types of crops grown with help of extension experts. Agro-ecological (elevation) was preferred due the fact that elevation ranges may cover large areas and accommodate more people than slope for socio-economic survey of sampled households. In addition, complementary focus groups and key informants were selected from village leaders and experts to provide a qualitative understanding of the causes and effects of the LULC dynamics. We also repeatedly conducted field observations to assess the status of land resource management practices in the study catchment area.

III. MAIN RESULTS

III.1. Patterns of LULC dynamics

III.1.1. Agriculture and rural settlement land

Agriculture and rural settlement land remained the predominant LULC type during the entire study period, covering 62% (10,800 ha), 67% (11,739 ha), and 76% (13,417 ha) of the total area in 1965, 1973, and 2007, respectively (Table 2). The trends showed a consistent expansion of agriculture and rural settlement land over the four decades being analyzed (1965–2007). Accordingly, there was an increase of 7.62% (939 ha) between 1965 and 1973, and 14.29% (1,678 ha) between 1973 and 2007. This gradually expanded towards the upper and steeper slope gradients of the catchment area (Fig. 5, 6, and 7).

Table 2 Areas of LULC in different study periods in the Kasso catchment

Land use/cover classes	1965		1973		2007	
	ha.	%	ha.	%	ha.	%
Agriculture and rural settlement	10,800	62	11,739	66.72	13,417	76.25
Grassland	3,037	17.26	1,499	8.52	2,501	14.22
Afro-alpine scrub	589	3.35	608	3.46	591	3.36
Bush land	1,809	10.28	2,709	15.4	669	3.8
Woodland	1,225	6.92	989	5.62	391	2.22
Forestland	135	0.77	50	0.3	26	0.15
Total	17,595	100	17,595	100	17,595	100

As the change detection analysis results revealed, this observed consistent expansion was attributed to the conversion of grassland, bush land, woodland and forestland into agriculture and rural settlement lands at different stages. For instance, between 1965 and 1973, the agricultural and rural settlement LULC category exhibited a net gain of 7.62% (939 ha) from grassland (Table 4). Similarly, between 1973 and 2007, the same category achieved a considerable net gain (1,678 ha), of which bush land covered 12.54% (1,473 ha), woodland 1.3%

(149 ha), grassland 0.26% (29 ha) and forestland 0.22% (24 ha) (Table 5). However, conversion of agriculture and rural settlement land to other LULC classes was relatively insignificant. Generally, throughout the study period (1965–2007), agricultural and rural settlement land cover increased by 24% (2,609 ha), with an annual average rate of expansion of 0.57% (Table 3 and Fig. 3-7).

Table 3 Rate of LULC dynamic (1965–2007) in the Kasso catchment

Land use/ cover classes	1965–1973			1973–2007			1965–2007		
	Total change		Annual change	Total change		Annual change	Total change		Annual change
	Ha	%	%	ha	%	%	ha	%	%
Agriculture and rural settlement	939	7.62	0.95	1,68	14.29	0.42	2,61	24	0.57
Grassland	–1.54	–50.64	–6.33	1,00	66.84	1.97	–536	–17.65	–0.42
Afro-alpine scrub	18	3.23	0.4	–16	–2.63	–0.8	3	0.51	0.01
Bush land	900	49.75	6.21	–2,04	–75.3	–2.21	–1,14	–63.02	–1.5
Woodland	–237	–19.27	–2.4	–598	–59.56	–1.75	–834	–68.08	–1.62
Forestland	–85	–62.96	–7.87	–24	–48	–1.41	–109	–80.74	–1.92

Table 4 Land use/cover change matrix for 1965 and 1973

Change from/to		Land use/land cover for 1973 (ha)							Changes in 1973	
								Class	Area	
1965		Ag/set	GL	AF	BL	WL	FL	Total	ha	%
	Ag/set	10,495	1,038	0	100	102	4	11,739	931	8.7%
	GL	72	1,107	0	249	69	2	1,499	–1,538	–50.6%
	AF	0	14	589	0	4	0	608	18	3.22%
	BL	122	807	0	1,415	286	79	2,709	900	49.8%
	WL	111	68	0	45	764	0	989	–237	–19.35%
	FL	0	3	0	0	0	47	50	–85	–62.9%
Class	Total	10,800	3,037	589	1,809	1,225	135	17,595		

Ag/sett=Agriculture and settlement; GL=Grassland; AF=Afro-alpine; BL=Bush land; FL=Forestland

III.1.2. Grassland

Grassland was the second largest LULC class type after agriculture and settlement land cover, covering 17.26% (3,037ha) and 14.22% (2,501ha) of the total area in 1965 and 2007, respectively (Table 2). However, the category showed a loss and a gain due to seasonal factors of the LULC dynamic during the entire study period. For instance, grassland cover exhibited a negative change, declining by 50.64% (1,538 ha) between1965 and 1973 with an annual declining rate of 6.33%. During this period, around 31.81% (966 ha), 18.37% (558 ha) and 0.46% (14 ha) of grassland was converted into agricultural and settlement land, bush land and afro-alpine vegetation, respectively. However, this trend was reversed in the period between 1973 and 2007, increasing by 66.84% (1,002 ha) (Table 3).

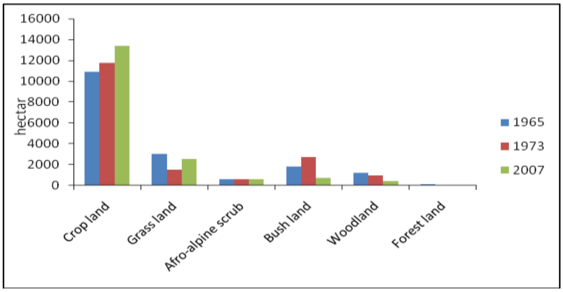

Fig. 3 Trends of the LULC dynamics in the Kasso catchment

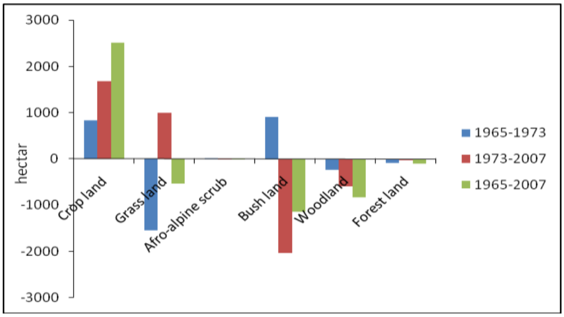

Fig. 4 Rate of change in the LULC dynamics in the Kasso catchment

The main reason behind the latter change was the conversion of an appreciable portion of bush land (43%; 662 ha), woodland (22%; 348 ha), and a small area of afro-alpine vegetation (1%; 18 ha) to grassland. This mostly occurred in the middle and upper slopes, but also in a few pockets of land in the lower slopes bordering the river courses (Table 5). During the same period, about 1.93% (29 ha) of grassland was converted to agriculture and settlement land. In general, the LULC dynamic trends showed a decrease of 17.65% (536 ha) of grassland cover between 1965 and 2007, with an average decrease of 0.42% (11.90 ha) per year (Table 3 and Fig. 3, 4, 7).

III.1.3. Woodland

Woodland covered 1,225 ha (6.92%) of the total area of the study catchment in 1965. However, trends shown by the LULC dynamics analysis indicated that there was a significant decline in woodland cover over the study period: from 6.92% (1,225 ha) in 1965 to 5.62% (989 ha) in 1973 and to 2.22% (391 ha) in 2007 (Tables 2 and 3). The change detection matrix results showed that about 19.27% (237 ha) of woodland shifted to bush land between 1965 and 1973. A similar pattern was observed in the subsequent analysis period. Of the total area converted, 59.56% (598 ha) changed to other LULC types, and 34.66% (348 ha), 14.83% (149 ha), and 10.06% (101 ha) changed to grassland, agriculture and settlement, and bush land, respectively, between 1973 and 2007. However, only about 0.89% (9 ha) of agriculture and settlement land was shifted to woodland (Table 4). Generally, the overall woodland cleared and transferred to other LULC categories during the two consecutive study periods was 68.08% (834 ha), with annual decline of 1.62% (19.62 ha) (Tables 3, 4, and 5, and Fig. 4, 5, 6, and 7).

Table 5 Land use/land cover change matrix for 1973 and 2007

Change from/to		Land use/land cover classes for 2007 (ha)							Changes in 2007	
								Class	Area	
1973		Ag/set	GL	AF	BL	WL	FL	Total	ha	%
	Ag/set	11,141	570	2	1,529	150	24	13,417	1,678	14.29
	GL	541	867	21	722	350	0	2,501	1,002	–66.84
	AF	0	4	585	2	0	0	591	–17	–2.63
	BL	56	56	0	418	139	0	669	–2,040	–75.3
	WL	1	2	0	38	350	0	391	–589	–59.56
	FL	0	0	0	0	0	26	26	–24	-48
Class	Total	11,739	1,499	608	2,709	989	50	17,595		

Ag/sett=Agriculture/ settlement; GL=Grassland; AF=Afro-alpine; BL=Bush land; FL=Forestland

III.1.4. Afro-alpine Schrub

Afro-alpine scrub vegetation is located above 3000 m.a.s.l. and forms part of the Bale Mountains National Park (BMNP). *Ericaceous* shrub is the dominant Afro-alpine vegetation type in the study catchment area. Compared to other land cover types, afro-alpine vegetation was the least disturbed by the human-induced LULC dynamic (Table 3). Its low accessibility, cold climatic condition, and the protection afforded by its location within the BMNP have probably contributed to the low level of influence of human activities. However, similar to other LULC classes, afro-alpine vegetation also demonstrated gains and losses. There was initially an increase of 3.23% (18 ha) between 1965 and 1973. This was due to the conversion of 0.46% (14 ha) of grassland and 0.13% (4 ha) woodland to afro-alpine scrub.

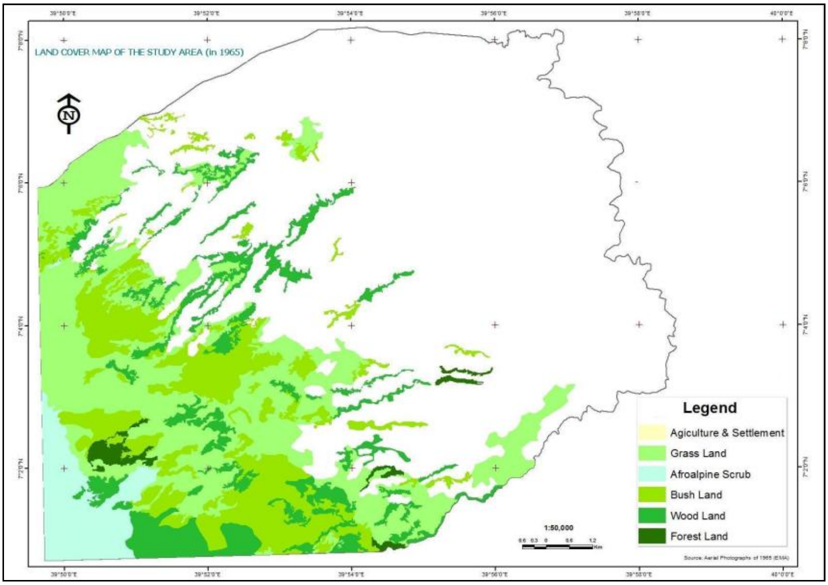

Fig. 5 Land use/cover map of Kasso catchment, 1965

However, in the following analysis period (1973 to 2007), the area decreased by 2.63% (17 ha), mainly transformed into grassland. Generally, this land cover class observed a slight increase (0.01%) over the study period (1965 to 2007). This slight increment might have been the result of the regeneration of previously affected vegetation as a result of a strong restriction on livestock encroachment, firewood collection, and fire control. In addition, few pockets of enclosed grassland on steep slopes were attributed to the relative increment of afro-alpine vegetation cover class.

III.1.5. Bush Land

The pattern of change in bush land cover showed both gain and loss trends. For instance, it increased by 49.03% (900 ha) from 10.28% (1,809 ha) in 1965 to 15.4% (2,709 ha) in 1973 (Table 2), mostly at the expense of grassland (30.31%; 558 ha), agriculture and rural settlement land (1.98%; 22 ha), woodland (13.13%; 241 ha), and forestland (4.31%; 79 ha) (Table 4). In contrast, the trend reversed in the second study period, declining by 75.3% (2,040 ha) between 1973 and 2007 (Table 3 and Fig. 4).

That is a significant amount of bush land cover was converted to agriculture and rural settlement land (54.37%; 1,473 ha), grassland (24.58%; 666

ha), and afro-alpine scrub vegetation (0.07%; 2 ha) (Table 5). Isolated trees observed standing alone in the bush land is also evidence of the transformation of forest and woodland to bush land. However, in the same period, 3.72% (101 ha) of woodland was converted to bush land. The overall trend showed a decline of bush land cover by 63.02% (1,140 ha) in the 42-year analysis period, with average rate of decline of 1.5% (27.14 ha) per year (Table 3, Fig. 3 and 4).

III.1.6. Forestland

Evidence collected during the local household survey revealed that there was appreciable forest cover in the catchment area in the past. However, as the present study indicated, forestland cover was the least among the LULC classes (Table 2), and was on the verge of completely disappearing. Field surveys demonstrated that remnant stands of natural forests are confined to religious sites, along rivers and streams (upper slope positions), and on peaks of hills, where crop cultivation is difficult. This indicates the severity of forest degradation over the past decades for diverse reasons.

The analysis of LULC dynamic trends over the 42-year period showed forestland cover of 0.77% (135 ha), 0.3% (50 ha), and 0.15% (26 ha) in 1965, 1973, and 2007, respectively (Table 2).

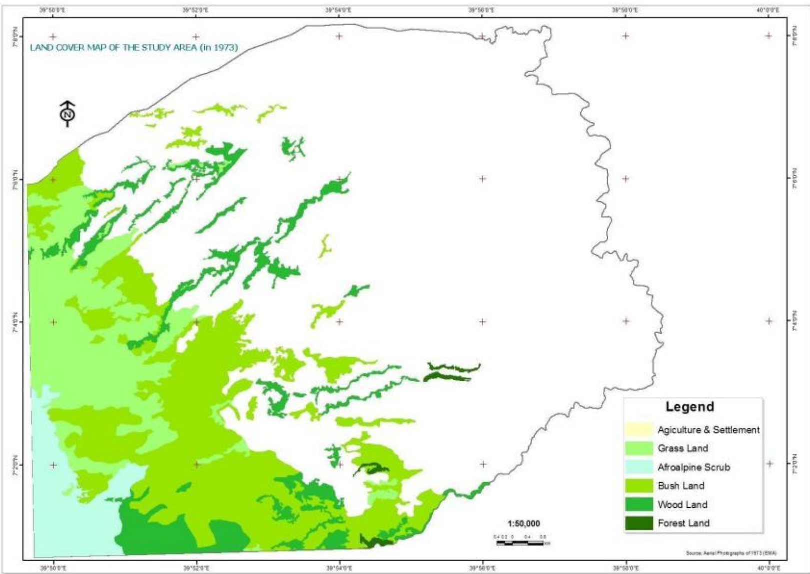

Fig. 6 Land use/cover map of the Kasso catchment, 1973

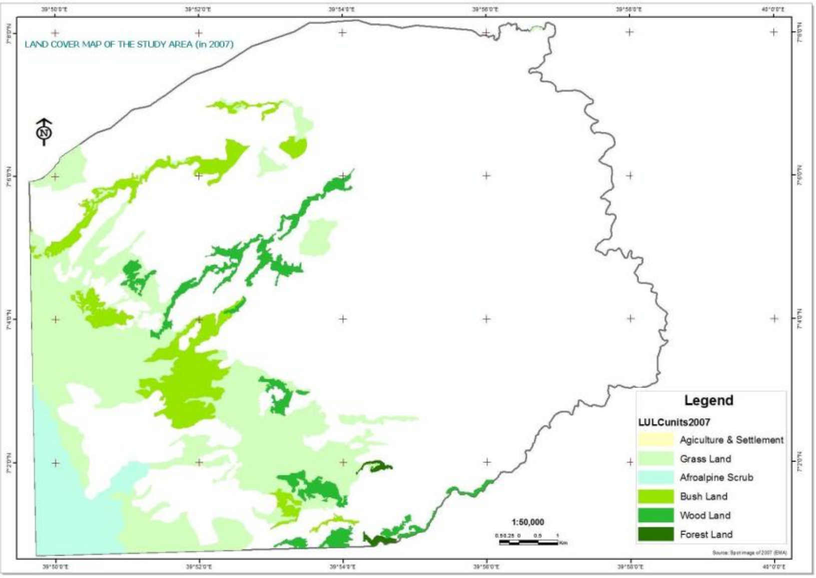

Fig. 7 Land use/cover map of Kasso catchment, 2007

Generally, during the entire study period (1965–2007), natural forest coverage decreased by 80.74% (109 ha), with an annual decline of 1.92% (2.5 ha) (Table 3, and Fig. 3 and 4). During this 42-year period, almost 80.74% of forestland had been transformed to other land cover types, such as bush land (58.51%; 79 ha), agriculture and rural settlement (20.74%; 28 ha), and grassland (1.48%; 2 ha) (Tables 4 and 5). The change analysis results showed that the largest proportion of forestland was converted to bush land. This implies a continuous and exhaustive thinning of forestry resources for diverse uses, particularly for construction, firewood, and agricultural tools, which eventually led to the degradation of forest to bush land and other LULC classes.

III.2. Causes of LULC Dynamics in the Kasso Catchment

III.2.1. Agriculture and Rural Settlement Land Expansion

The analysis of LULC dynamic trends has indicated a substantial change in the landscape in the Kasso catchment during the 42-year study period (1965–2007). About 75.6% (Table 6) of the respondents stated that agricultural expansion was the main driving force of the LULC dynamics in the study area. Elders (79 to 82 years) stated that, around 50 to 60 years ago, much of the study area was covered by forest, mainly consisting of *Rapine semien*, *Juniperus procera*, *Hagenia* *abyssinica*, and *Podocurpus gracilor*. These forests were essential to protect the fragile mountain slopes from erosion and to serve as a reservoir for natural forest exploitation. However, much of the natural vegetation has been fragmented and degraded by human disturbance, such as clearing for agriculture and extraction for fire wood and construction. Today, only few remnants of *Juniperus procera* and *Hagenia abyssinica* are scattered along streams, in the farmlands, the tops of hills, and religious sites. Other elders (above 83 years) from Kasso village pointed out that there were no agricultural and human activities along the river valleys and the upper part of the catchment in the 1930s and 1940s (Fig. 8). In support of these observations, change detection analysis results indicate that, during the 42 years, about 2,615 ha of vegetative cover was converted to agricultural and settlement land. This included 55.49% of bush land (1,451 ha), 38.05% of grassland (995 ha), 5.35% of woodland (140 ha), and 1.07% of forestland (28 ha). As a result, the low-lying plain was completely converted to agriculture and settlement land, while the middle and upper sections of the catchment area are also under human and livestock pressure (Fig. 8 and 9).

Fig. 8 Expansion of crop land

Fig. 9 Settlement expansion in side forestland (photos by Hussien, 2012)

Thus, it is possible to conclude that agriculture and settlement land has played a significant role in changing and modifying the landscape of the Kasso catchment area over the four decades. The increasing demand for crop production as a source of food and income, as well as other associated socio-economic factors, have contributed to the persistent expansion of agriculture and settlement over time. Moreover, the 1975 land reform, which allowed a household to be as big as 10 ha, the establishment of state farms and farmers cooperatives, as well as the current encouragement of extensive and intensive farming to ensure food security has also caused agricultural land cover to expand.

III.2.2. Demand for fuel wood and construction materials

The majority of sample households (73.3%) of the present study area use wood for cooking, heating, and light. This has contributed to the destruction of natural forests and the subsequent conversion of forestland to crop, settlement, and/or grassland.In addition, observations of market centers and informal discussions with experts have revealed that the majority of nearby urban areas, such as Goba, Robe, and Dinsho, as well as other smaller towns, were largely dependent on natural forests for cooking, in terms of firewood and charcoal (Fig. 10). The main source of these forestry resources was the Kasso catchment forest. The increasing size of rural settlements has also caused a deterioration in forestry resources. Moreover, the expansion and sprawl of nearby urban centers has resulted in natural forest degradation through exploitation for construction materials and demand for urban land. This implies that there is still strong human pressure on the remaining indigenous forests, not only from within, but also from outside the catchment area.

Fig. 10 Fire wood delivery to nearby Goba town (photo by Hussien, 2012)

III.2.3. Population growth

Available population data indicates that the rural population of the catchment area has increased from 9,783 in 1984 to 20,208 in 2007 (Sinana-Dinsho District Office, 2011). This is an increase of 106% during this period. As a result, the population density increased from 55.6 people /km^2 in 1984 to 114.85 people/km^2 in 2007. This high population density implies significant human pressure on the available natural resources (soil, water, and natural vegetation) in the catchment area, and is severe where people depend heavily on these resources. Consequently, the land resources have shrunk, both in quality and quantity. A significant number of respondents (58.1%) also confirmed that the population growth and the associated land scarcity is major factor in degradation of the forests (LULC dynamic) in the Kasso catchment area (Table 6).

They argue that a bigger population needs more food, shelter, and firewood. In Ethiopia, these are only obtainable by turning of forestland into agricultural and settlement land. Cleaver and Schreiber (1992) have also revealed that rapid population growth is often responsible for the breakdown in communal land management, failure of resource control, local “tragedies of the commons.”

Table 6. Causes of LULC dynamics in the Kasso catchment area

Causes of land use/cover changes	Frequency	Percent
Agricultural and settlement expansion	65	75.6
Firewood consumption	54	62.8
Land tenure	47	54.4
Poverty	43	50
Population growth	50	58.1

Hence, population growth and an increased population density are considered to be the main demographic factors causing the LULC dynamic, as a result of improper use and over-utilization of land resources in the Kasso catchment area (Fig. 11).

Fig. 11 Cultivation of a steep slope (photo by Hussien, 2012)

III.2.4. Poverty

Poverty is one of the major contributing factors to land degradation, including deforestation. When people lack access to alternative sources of livelihood, there is a tendency to exert more pressure on fewer land resources (Belay, 2002; Nayak; Dianah, 2007). Over 50% of interviewed household heads reported that poverty is one of the causes of the LULC dynamic and land degradation, particularly deforestation (Table 6). During the field survey, it was found that there were many households with large families living on small farms (<1 ha), as well as new households who have no farmland. With no alternative, tthese poor and landless (mostly youth) were the most dependent on forest resources for survival, often engaging in selling firewood, charcoal, illegal logging, and even using the forest as a source of food. Over-cultivation of limited farmland without adequate agricultural input also depletes the soil fertility. Therefore, poverty has meant that people have damaged their rural land resources. They pointed out that scarcity of farmland, landlessness, declining agricultural productivity due to low agricultural inputs and over cultivation, and a decline in the number of livestock were among the major sources of poverty in the study area.

III.2.5. Villagization policy

The villagization programs that took place in the 1970s and 1980s in the catchment area led to the destruction of forests to open new agricultural and settlement land. The hundreds of homes in Kasso village were good evidence of the extent of the forest destruction. For example, there were about 934 dwelling units in 1973 (EMA, 1973). This figure grew to 2,084 homes in 2007 (Kasso village office survey). This increase in the number of human dwelling units was at the expense of the natural vegetation, which was used for construction material and residential space. Moreover, the concentration of the human and animal population in the village center also caused gullies and soil compaction.

III.2.6. Absence of forest tenure policy enforcement

Key informants explained that, since the natural forest resources are either public or state owned, there was little effort to control and protect these resources. They also added that most of the local community did not feel or perceive the forest to be their own property, and so felt little responsibility when destroying it simply to meet their immediate needs, rather than thinking about the future. These negative impacts could be attributed to a lack of awareness and poverty. However, a lack of enforced policies and regulations on natural forest protection, poor management and development of forests, and the absence of these documents at a community level have also contributed to forest destruction. Although Ethiopia has a forest policy (MoARD, 2007), this is not fully implemented or enforced at a grass roots level, including the present study area. In fact, local authorities are reluctant to enforce the stated rules and regulations on illegal natural forest users. Thus, land degradation could be the result of land held as common ground, without strong rules governing its access (Jolly and Torry, 1993). According to local people perception, there was free access to the natural forests of the Kasso catchment area to anybody, both insiders and outsiders, which eventually led to its destruction and in consequence the occurrence of environmental and socio-economic problems in study area and its surroundings.

III.3. Socio-economic and environmental implication of LULC dynamics in the study catchment area

III.3.1. Scarcity of firewood

Local communities explained that destruction of the forest ecosystem for diverse uses has negatively affected the services it provides to their catchment area and surrounding villages and towns. One of these effects is a scarcity of firewood and construction materials. This particularly affected low-income households, because they were directly or indirectly dependent on forest resources for their livelihood. As a result, rural women have been forced to walk long distances for firewood. This reduces the time available for farming and household activities. Moreover, the scarcity of firewood increased the price of available firewood, to the point where is no longer affordable for some households. This situation caused many households to turn to animal dung and crop residues as an alternative source of fuel. However, the removal of biomass from the fields in turn reduced the organic matter being added to the soil, which would otherwise have improved the soil structure and soil fertility. This may critically affect agriculture and agricultural productivity as one of the major sources of food insecurity in developing countries such as Ethiopia. Similarly, the shortage of construction materials compelled households to depend largely on less durable and easily affected *Eucalyptus* trees for house construction and agricultural tools.

III.3.2. Animal feed shortage

Farmers pointed out that the available grassland has been declining over time as a result of agriculture and settlement expansion. It was found that there was a decrease of about 17.65% of grassland over the 42 years. Field observations indicated that the expansion of cropland has meant that grassland is now non-existent on the lower slope gradients of the catchment area, which has severely impacted livestock herding. Accordingly, animals could not get enough feed, which has negatively affected both the size and quality of livestock. A large number of respondents (90.79%) explained that the declining size of livestock has adversely affected their livelihood. For instance, the socio-economic problems associated with the decrease in livestock quantity and quality include a decline of household income from the sale of live animals, loss of draught animals, a scarcity of milk and milk products, and a lack of animal manure to replenish the soil fertility. This in turn has repercussions on ensuring food security and on improving the living conditions of the rural community in general.

III.3.3. Implications of soil erosion

The removal of natural vegetation cover for different uses, particularly for crop production associated with the irregularity of the landscape, has exposed the study catchment to soil erosion. The study revealed that most farmers (80.23%) were aware of soil erosion on their fields. The opinion of local land users and expert evaluations indicated that about 25% of the middle slopes and 20% of the upper slopes of the catchment were severely affected by soil erosion.

The clearing of natural vegetation cover for various uses, cultivation of steep slopes (Fig.11), inappropriate farming systems, and the absence of soil conservation and fertility management practices were the perceived human-induced causes of soil erosion. The clearance of vegetation cover in turn exacerbated run-off and soil erosion on steeper slopes, caused gullies on several cultivated and grassland areas at the foot of the hills/mountains (Fig. 12), as well as water logging in the low-lying farming areas.

Fig. 12 Gully erosion in the Kasso catchment area (Photo by Hussien, 2012)

Local land users identified sheet erosion as the most common form of soil erosion in the cultivated lands of the study area. Although it was not quantified in this research, about 66.28% of respondents recognized severe soil erosion on their fields, which was mainly attributed to LULC dynamics and inappropriate land management practices. On low-lying slopes, soil depletion due to repeated cultivation and water logging in summer were common agricultural problems. The LULC dynamic, especially deforestation, not only causes the physical removal of soil, but also accelerates the deterioration of the basic soil properties, which leads to a decline in soil fertility. According to farmers, this decline, severe soil erosion caused by deforestation, and intensive cultivation of steep slopes has resulted in a decline in agricultural production and productivity. This forced farmers to put more land under cultivation to increase agricultural produce, which in turn may lead to more land degradation.

III.3.4. Hydrological impact

The LULC dynamic significantly modifies the hydrological aspect of the watersheds, affecting water resources and the environment on a local and global scale (Batra *et al*., 2007). This change of the LULC pattern, such as deforestation and subsequent cultivation, could reduce the infiltration rate and percolation of rainwater to recharge streams, springs, and underground water. Overgrazing caused by shrinking of grazing land causes compaction, which may lead to reduced infiltration rates. Information obtained from interviews with household heads, focus groups, and elders confirmed that the volume of locally available streams and rivers and their flow patterns have decreased over time. According to local farmers, rainfall patterns have shown variability in both time and amount, and this has significantly affected the cropping patterns and calendar, as well as the seasonal pattern of streams. For these and other related reasons, the volume of available surface water has decreased, and many springs and streams have dried out. Thus, the LULC dynamic affects water resource availability. Owing to this effect, in dry seasons, household families and livestock are forced to travel long distances, on average for two hours a day, to access water. They are also forced to use open well water, which made them vulnerable to water borne diseases. The decrease in the volume of streams has also reduced the capacity of supplementary irrigable land for food crop production.

Local farmers, and particularly elders in the study catchment area, underlined the observations of the changes in climate over time. The climate change was verified by a number of physical/ecological and socio-economic indicators. The physical indicators expressed by farmers included: the drying up of the wetland and its conversion to cropland; livestock diseases, probably linked to vector borne diseases; a decrease in the growing period from six to four months; the cultivation of short-matured crops, mainly in higher, cool altitudes; the decrease in stream volume; and the duration and amount of rainfall. The socio-economic factors considered to be climate change indicators include the long distance people need to travel to fetch water and drinking water for animals, as well as the cultivation of warm temperature crops in cool temperature zones and the shift from rearing cattle to goats.

Results of meteorological data collected over 31 years (Ethiopian Meteorological Service database, 2012) confirm the community's perception of the relative changes in the climate in their area. The data analysis showed that the mean annual minimum, average, and maximum temperatures continuously increased by coefficients of 0.086, 0.058, and 0.025, respectively, in the period between 1973 and 2007 (Fig.13).The mean annual minimum and average temperature revealed more change, which could have a significant effect on warming the microclimate. In addition, a rainfall data analysis showed that the annual amount of rainfall was irregularly decreasing, with a negative trend line coefficient (–0.41). Hence, this change in annual temperature and rainfall was indicative of local climate changes (Fig. 13 and Fig. 14).

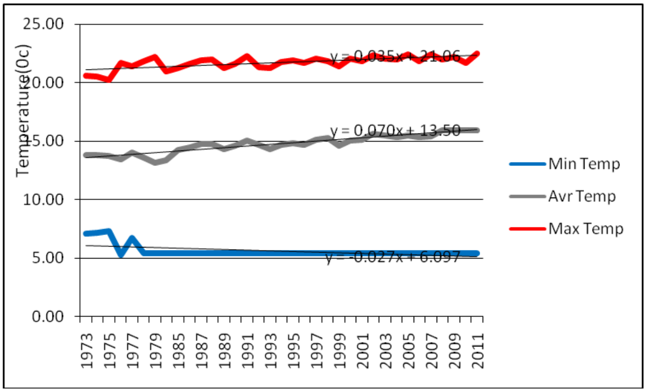

Fig. 13 Temporal variations of temperature (Ethiopian Meteorological Service, 2012)

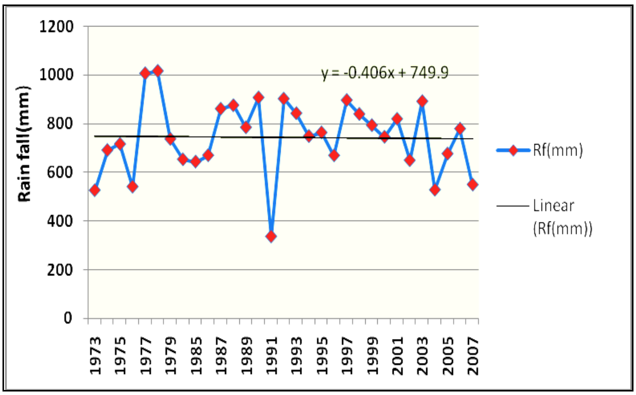

Fig.14 Temporal variation of rainfall (Ethiopian Meteorological Service, 2012)

III.3.5. Degradation of biodiversity

The rich biodiversity of the Kasso catchment area and the parts of the national park is under human pressure for various purposes, including agriculture, livestock grazing, fire wood, and settlement expansion. As a result, the conversion of natural vegetation, including forests, woodland, bush land and grazing land to land used for agriculture and settlement has meant significant environmental change, including biodiversity loss. For instance, local people reported that, in the past, there were elephants and buffalo in the study catchment area, as well as other parts of the Bale Mountains area. In addition, elders have asserted that there was a variety of vegetation species, such as *Agamsa* (*Carrisa Edulis*), *Tullaa* (*Rapanea Simen*), *Egersa* (*Olea Africana*), and *Leemman* (*Arundinaria alpina*) that have many uses, including medicinal value to the local community. However, today, some of these wild animals and plant species are near extinct, and others are either non-existent or the animals have migrated to other locations because of the removal of their habitat.

IV. CONCLUSION

This study analyzed the dynamics and driving forces of LULC between 1965 and 2007 in the Kasso catchment area, Bale Mountains (Southeastern Ethiopia). As major input, the study used remote sensing and socio-economic data sources. We identified agricultural and settlement land, grassland, bush land, afro-alpine, woodland, and forestland as major LULC categories. The results revealed that almost all recognized LULC classes exhibited significant and consistent LULC transformation between 1965 and 2007. While agricultural and settlement land expanded by 24%, forestland, woodland, bush land, and grassland declined by 80.74%, 68.08%, 63.03% and 17.65% over the analysis period, respectively. The existence of this LULC dynamic was attributed to socio-economic factors, namely population growth, agricultural expansion, poverty, land scarcity, and related land tenure policy factors.

The changes in LULC have socio-economic and environmental consequences across various geographical regions. In the study area, farmers are aware of the environmental changes and identified several implications of these changes in their area. Declining available natural forests, an increase in soil erosion, local hydrological changes (e.g., a decrease in available water volume and streams) and a decline in available grazing land were some of environmental consequences described by local land users. In addition, the environmental change effects of these LULC dynamics on the socio-economic/livelihood of the local community and its surroundings included a shortage of firewood and construction materials and a decline in agricultural productivity and the size of livestock.

Conservation and management of natural resources in the study area are not adequate to mitigate the problem of local land degradation. As a result, the livelihood of the local community and the normal function of the ecosystem are under threat. Thus, sustainable land management is the base needed to remove unsustainable practices and to create a sustainable environment for all concerned. Therefore, overall watershed management is essential to ensure an environment that will result in sustainable natural resource management and development in all dimensions of the study catchment area.

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