**Land Use/Land Cover Dynamics and its Environmental Impacts in Kulfo Watershed, Gamo Highlands, South Western Ethiopia**

**Abstract**

Gamo highland have experienced drastic cover dynamics of land resource resulted from historic settlement, heavy concentration of human and livestock population, and obsolete farming practices. The aim of this study was to examine the dynamics of the land use/land cover and its consequent environmental impacts in Kulfo watershed located in South Western Ethiopia. Historic spatial and socio-economic data were used in GIS and Remote Sensing environment to analyze and map the research data. The result of this study revealed that the Land use/ cover change analysis conducted in three periods (1986, 1999 and 2017) showed a remarkable dynamics and modification over varying cover types. In 1986 the dominant land use land covers were cultivated land (42%) followed by pasture land (23%) and forest land (18.3%). After 32 years (2017), cultivated land (71%), shrub land (7.5%) and bare lands (6.2%) were the three dominant land uses/cover types in the study area. During the study period, cultivation encroached to marginal steep slopes (with gradient more than 60%) and mountain grasslands where once used as a place of celebrating traditional festivals and grazing lands. Such a dramatic change in three-decade period has further increased degraded lands and raised erosion vulnerable areas to 97.2%, the resultant effects of which has greatly threatened the livelihood of communities in the watershed. The land use in the study watershed is not as of the land capability, excess forest, shrub and grasslands were unnecessarily brought under agriculture. Therefore, it is recommended that land has to be used as per its capability and conservation measures shall give attention to erosion prone areas.

**Keywords**: Land use/cover, Environmental impacts, GIS, Remote sensing

## 1. Introduction

Land is a primary asset for the survival and development of human being. It supports the livelihood of most people in agrarian country like Ethiopia, where majority of its population depends on it for subsistence. In developing countries, a high proportion of income, employment, and export earnings stems from agricultural production. Access to land is the basis for economic and social life in both rural and urban areas.

Studies noted that changes in land-use/cover affect patterns and dynamics of catchment biophysical and socio-economic processes, which have direct impact on livelihood of the local communities (Taddese, 2001; Kidanu, 2004). Land use change and excessive human pressure on the marginal lands resulted to loss of soil productivity, reduction in crop yield and livestock number, and human carrying capacity. Climatic change, land resource depletion, loss of soil fertility and depletion of fuel-wood resulted from ever-increasing population are blamed as the main threat to sustainable environment and seasonal food shortage among the mountain people (Amede, 1986). Similarly, in the study area Population pressure, cropland scarcity, soil erosion, declining pastures and deforestation are the major land related problem.

The negative effect of population pressure over natural environment was forwarded by scholars like, Kumer (1988) in Nepal, Bilsborrow (1991) in Guatemala. They assumed that over-uses of natural resource and degradation are the consequences of population pressure. Literatures have critically commented the impact of population pressure on environment and agricultural production. For instance, Roger (1992) in Bamboutos mountains, Western Cameroon; Yongnian et al. (2003) in the upper reaches of the yellow river, China, and Vagen (2006) in the highlands of Madagascar.

In the Ethiopian context, studies conducted by Gashaw et al. (2014) and Temesgen et al. (2014) on land use/ cover has reported the expansion of cultivated land into forest lands. Similarly, several studies have also reported deforestation and expansion of cultivation into hill slopes and marginal areas as a major cause of land degradation (Bewket, 2003; Zeleke and Hurni, 2001). Furthermore, numerous studies have reported concomitant findings (Belay, 2002; Woldeamlak, 2003; Temesgen , 2013). Though there are limited efforts made in Southern Ethiopia, the study by Abiyot et al. (2013) and Degefa (2007) in agroforestry system of Gedeo zone are among limited contribution in the region.

In the study area, agriculture is a major land use, net sown area accounts for more than 80 % of total area of the watershed. Traditional crop–livestock mixed farming is the basis of livelihood of local communities and backbone of rural economy. Expansion of agricultural land use into grassland coupled with ecosystem degradation which aroused from traditional farming; over grazing and related factors are the causes of cover change in the watershed. Thus, the aim of this study was to examine the land use land cover dynamics and its Environmental Impacts.

## 2. **Materials and Methods**

### 2.1. Description of the Study Area

Kulfo watershed is located in Gamo highland, which is part of the Southwestern highlands of Ethiopia. Astronomically, it lies between 5°58' 5''N to 6°15'31''N latitude and 37°18'12''E to 37°36'19''E, longitude covering about 434.7 km$^2$ (Figure 1). It falls in four former districts of Gamo Zone, namely Bonke, Arbaminch Zuria, Dita and Chencha. The altitude ranges between 1180 m (on the shores of Lake Chamo) to3384 m above sea level (on the peaks of Mt. Bale or Gughe). Its topography is characterized by plateaus and undulating landscape dissected by hills in the northern part and dominated by rift valley plains and Lakes in the southern part.

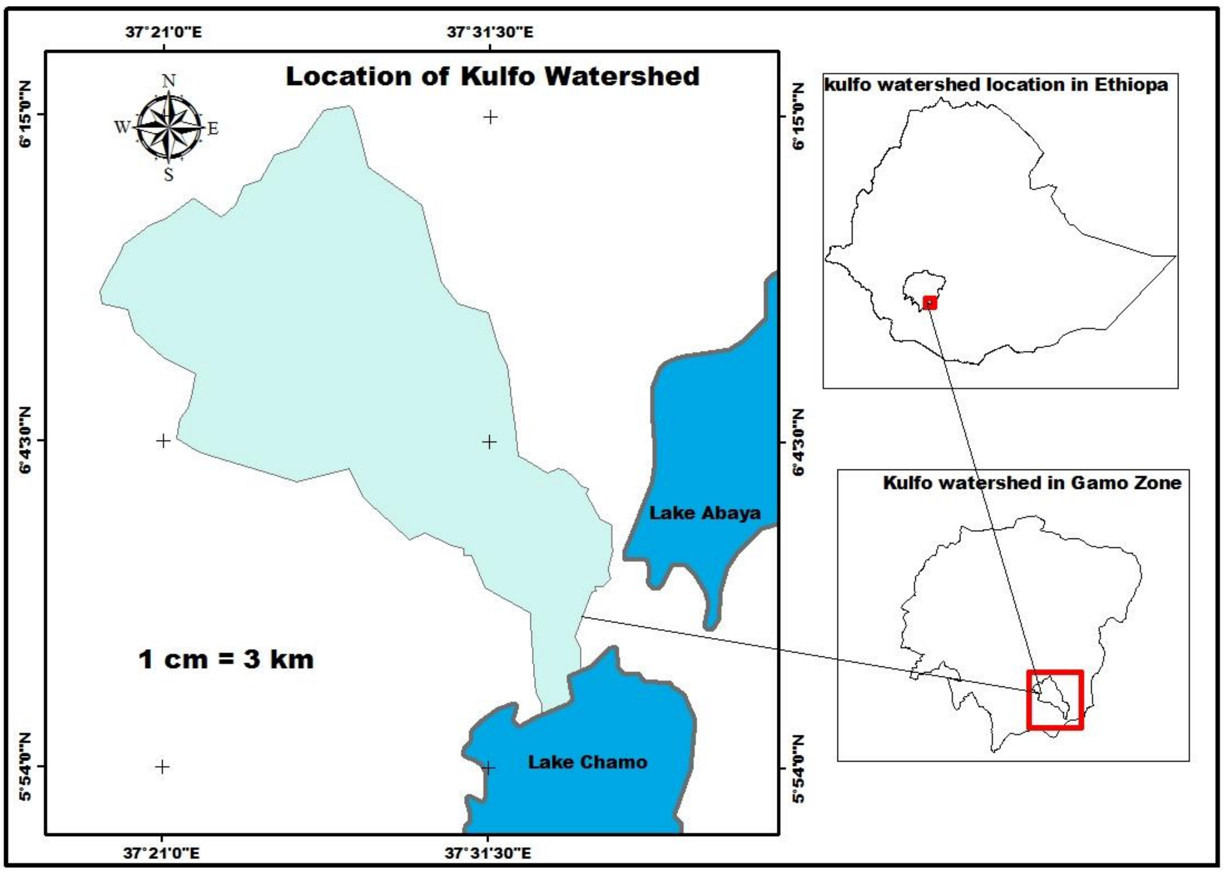


Figure 1: Location Map of Kulfo Watershed

Agro-ecologically, the watershed is characterized in four traditional agro ecological zones, namely Kolla (20.9%), Weyna Dega (35.9 %), Dega (37.4%) and High Dega, cold high mountain area (5.8%). The rainfall pattern is bimodal with the mean annual rainfall of 1390 mm in the northern plateaus and 959 mm in the southern plains. Furthermore, the mean annual temperature is 16.7 $^{O}$C and 31 $^{O}$C in the northern and southern parts respectively.

According to FAO classification of Soil, the dominant soils are orthic acrisols (59.9%), dystric nitisols (13.4%), eutric fluvisols (11.3%), dystric fluvisols (9.5%) and others, such as leptosols, eutric nitisols and chromic vertisols (5.9%). Seed farming integrated with livestock farming and perennial farming complex are the dominant source of livelihood in the upper and lower parts of the watershed respectively. Potato (solanum tuberosum L.), barley (Hordeum vulgare L.) and enset (Enset ventricosum (Welw) in the uplands and banana, maize and different vegetables are commonly grown in the down streams. Human and livestock population of the watershed were estimated to be 315,731 (of which 50.3% are female) and 77,258 (TLU) respectively.

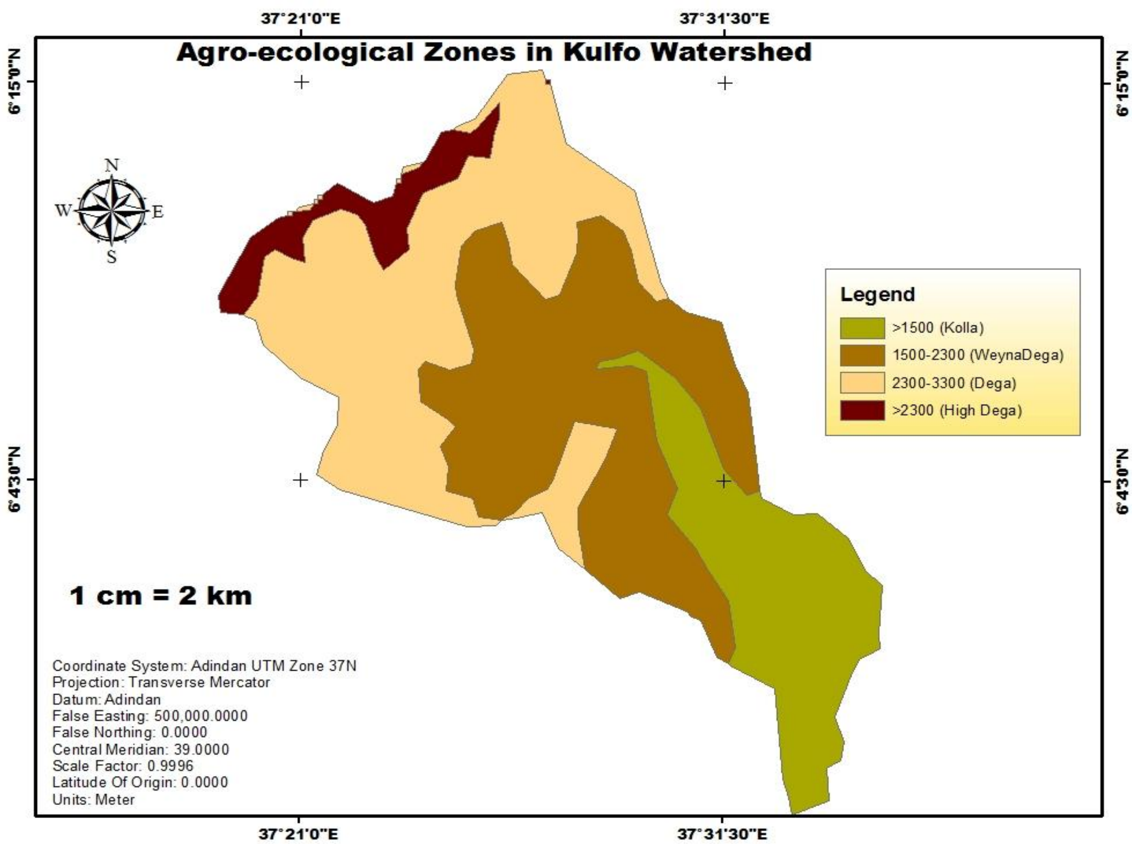


Figure 2: Agro-ecological zones of Kulfo watershed

Seed farming integrated with livestock farming and perennial farming complex are the dominant source of livelihood in the upper and lower parts of the watershed respectively. Potato (solanum tuberosum L.), barley (Hordeum vulgare L.) and enset (Enset ventricosum (Welw) in the uplands and banana, maize and different vegetables are commonly grown in the down streams. Human and livestock population of the watershed were estimated to be 315,731 (of which 50.3% are female) and 77,258 (TLU) respectively.

In the upstream the minimum and maximum temperature varies between 14.3 $^{O}$C and 18.4 $^{O}$C. The annual mean temperature of the area is 16.7 $^{O}$C, which showed a slight annual variation (CV= 7.7%). The downstream areas got minimum (15.4 $^{O}$C) and maximum (31.6$^{O}$C) temperature in December and April months respectively. In this part of the watershed temperature condition is highly variable (CV= 50.2%) and showed a decreasing pattern from north to south (Figure 3). The study watershed experienced two rainfall patterns. They are Belg, little rain season (March to May) and Kiremt (June, July and August), which is main rainy season. The fluctuation of rainfall in these seasons may impact on growing period and reliability of rainfall (Figure 3).

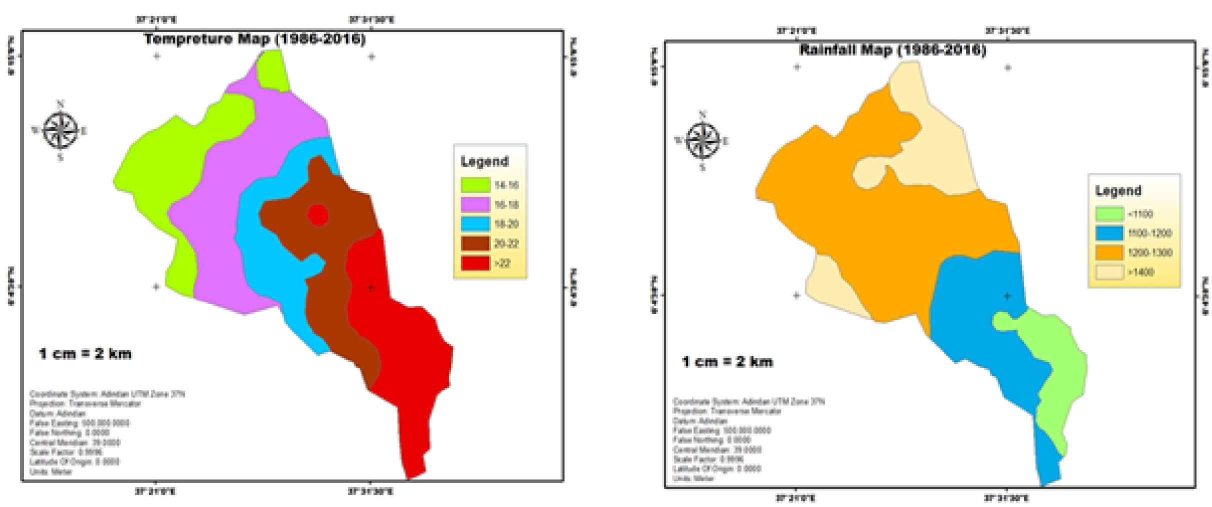


Figure 3: Temperature and Rainfall map of Kulfo watershed

## 2.2. Methodology

Land use/ land cover data of three periods (1986, 1999 and 2017) were investigated using GIS and Remote Sensing technology. GIS has been efficient and powerful tool in providing reliable information on natural resource classification and land use/ cover quantification and mapping over space and time (Roy et al., 1991; Campbell, 1997). To map and quantify cover data, Landsat imagery acquired on 7 Feb 1986, 12 Jan 1999 and 8 March 2017 (path 169/row 053) were used.

Then pre-processing of satellite images were carried out using color composites in RGB transformation. A false color grid composite image was developed using EDADAS virtual GIS environment to classify land use/ cover types. Then to get the major land use/ cover classification first unsupervised and next supervised classifications were used. For verification purpose ground truth data were collected from randomly selected sites using Geographic Positioning System, GPS. Furthermore, high resolution images were used (from Google earth) as a source of data for inaccessible localities. Following these procedures, using maximum likelihood classifier both spatial and temporal land use/ cover maps were determined (Lilles and Kiefer, 1999).

Then accuracy assessment of land use and cover layers were carried out by comparing sample land use/ cover class of the classified layer and the percentage layer. Thus according to Lilles et al. (2004) overall accuracy was computed by dividing sum of correctly classified values (diagonals) over total number of randomly generated reference values of the error matrix. The same author noted that the minimum level of accuracy in the identification of land cover categories from remote sensor data should be at least 80%. The classification accuracy of the study area was comparable with the aforementioned findings and hence our accuracy assessment estimate was more accurate and reliable.

To know the percentage of change of the same land use/ cover class between two times was computed using:

$$\text{Change (\%)} = \frac{(A_{tn} - A_{tn}\text{-}1)}{A_{tn}\text{-}1} * 100$$

Where, $A_{tn}$ is area of specific land use/ land cover class at time $t_n$, $A_{tn}$-1 is area of the same land use/ cover class at time $t_n$-1, Change (%) is percent change in the area of specific land use/ land cover class between times $t_n$ and $t_n$-1.

In addition, soil, climate, demographic and socio-economic data were used for this the study. The analysis was undertaken using narration and descriptive statistical technique, in addition to figures and tables.

## 3. Result and Discussion

## 3.1. Land Use/Cover Dynamics (1986-2017)

Land use/ cover change analysis conducted in three periods (1986, 1999 and 2017) showed a remarkable dynamics and modification over varying cover types. In 1986 the dominant land use land covers are cultivated land (42%) followed by pasture land (23%) and forest land (18.3%). After 32 years (2017), cultivated land (71%), shrub land (7.5%) and bare lands (6.2%) are the three dominant land uses/ cover types. The analysis further revealed that in the studied periods cultivated lands showed annual increment by 2.2 % at the expense of pastureland and forest covers (Table 1 and Figure 4). This was probably due to fast annual population growth (2.9%) in the watershed. This finding was comparable with the reports of Kebrom and Hedlund, which reported an increase of 2.4 % for Kalu district, in northern Ethiopia. And it was also well agreed with the findings of Minta et al. (2014); Dercon and Hill (2009) and Belay (2002) which was conducted in Northern and central Ethiopian highlands.

In the downstream the development of urbanization was paramount, transforming large areas of bush lands into settlements. Between 1986 and 1999 studied period the annual dynamics was 2.8%, while it was 7.5% in the consecutive period, i.e., between 1999 and 2017. Furthermore, urbanization is not only expanded at the expense of bush land but also it negatively damaged woodlands, riverine vegetation through fuel wood, grass fetching and logging.

Table 1: Land use/ cover dynamics in Kulfo watershed (1986, 1999 and 2017)

| Land use/ cover type | 1986 Area (ha) | % | 1999 Area (ha) | % | 2017 Area (ha) | % | 1986-2017 Change/year ha | Change/ year (%) |
|---|---|---|---|---|---|---|---|---|
| Crop land | 18,218.7 | 42 | 23,884.7 | 55 | 30,868.5 | 71 | 395.3 | 2.2 |
| Forest | 7,997.7 | 18.3 | 5,432.9 | 12.5 | 2,048 | 4.7 | 185.9 | -2.3 |
| Grass land | 9,997.2 | 23 | 6,472.7 | 15 | 2,123.1 | 4.9 | 246 | -2.5 |
| Shrub Land | 4,781.3 | 11 | 3,422.5 | 7.8 | 3,234.2 | 7.5 | 48.3 | -1.0 |
| Bare Land | 1,705.8 | 4 | 3,187.9 | 7.3 | 2,682.9 | 6.2 | 30.5 | 1.8 |
| Settlement | 765 | 1.7 | 1,065 | 2.4 | 2,509 | 5.7 | 54.5 | 7.1 |
| **Total** | **43,465.7** | **100** | **43,465.7** | **100** | **43,465.7** | **100** | | |

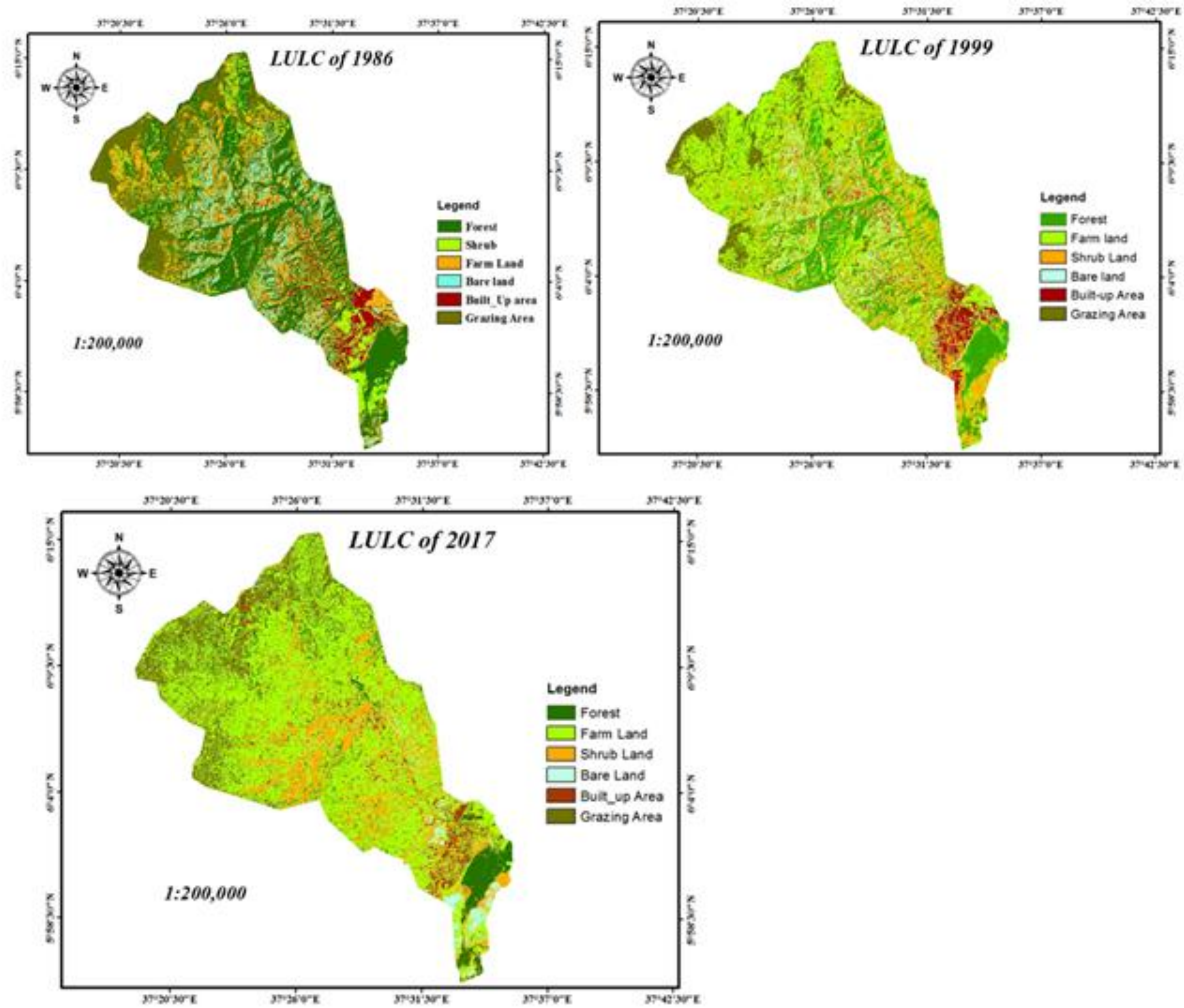


Figure 4: Land use/cover maps of Kulfo watershed (1986, 1999 & 2017)

In study watershed, croplands and bare lands are the two land use types that showed significant increment in the studied period, which shared 71% and 6.2% of the total area of the watershed respectively. Previous studies conducted by Dame (2016) in Girar Jarso District in Northern Shewa, by Ebrahim and Mohamed (2017) in Gelda watershed and Gashaw et al. (2017) in Andassa watershed also reported similar findings. From the normal circumstance it is clear that steep slope farming along with continuous tillage without proper management measures would exacerbate degradation of soil nutrients in the area. The assertion was concomitant to research results of Hurni et al. (2005) which was conducted in Andassa catchment of Northern highlands of Ethiopian.

### 3.2. Transitions between Land Use/Covers types

As it is shown in the conversion matrix (Table 2 & 3) a sizeable portion of forest lands, bush lands and pasture lands were transformed into crop land and settlement land. This was primarily a result of cultivation of densely covered grasslands and forestlands. Thus, cultivation of grasslands and forestlands has destroyed soil structure, increased soil erosion, and triggered degradation and flooding of low-lying farms by sediments and gravels which were brought from the upstream.

Table 2: Matrix of land use/cover conversion from 1986 to 1999

| Land use/ cover type | Cultivated | Forest | Grassland | Shrub land | Bare land | Settlement | Total area (1999) |
|---|---|---|---|---|---|---|---|
| Cultivated | **18005.6** | 2463.9 | 246.4 | 3106.4 | 62.4 | 0 | 24,101.9 |
| Forest land | 63.4 | **5108.5** | 109.3 | 92.4 | 59.3 | 0 | 6,280.7 |
| Grass land | 11.7 | 28 | **5959.7** | 17.8 | 455.5 | 0 | 6,019.9 |
| Shrub land | 8.6 | 171.1 | 1927 | **1223.4** | 92.4 | 0 | 3,996.6 |
| Bare land | 27.4 | 121 | 1723 | 290 | **1026.5** | 0 | 2,001.6 |
| Settlement | 102 | 105.2 | 31.8 | 51.3 | 9.7 | **765** | 1,065 |
| Total area (1986) | 18,218.7 | 7997.7 | 9997.2 | 4781.3 | 1705.8 | 765 | 43,465.7 |

Table 3: Matrix of land use/cover conversion from 1999 to 2017

| Land use/ cover type | Cultivated | Forest | Grassland | Shrub land | Bare land | Settlement | Total area (2017) |
|---|---|---|---|---|---|---|---|
| Cultivated | **23169.7** | 2267 | 3484.8 | 1513.4 | 433.6 | 0 | 30,868.5 |
| Forest land | 41.6 | **2018.3** | 18.5 | 17.5 | 22.4 | 0 | 2,048 |
| Grass land | 43.6 | 21.6 | **2539.1** | 27.4 | 1.3 | 0 | 2,123.1 |
| Shrub land | 6.8 | 974.5 | 19.2 | **1384.9** | 800.2 | 0 | 3,234.2 |
| Bare land | 4.2 | 91.3 | 150 | 69.3 | **1836.5** | 0 | 2,682.9 |
| Settlement | 618.8 | 60.2 | 261.1 | 410 | 93.9 | **1065** | 2,509 |
| Total area (1999) | 23,884.7 | 5432.9 | 6472.7 | 3422.5 | 3187.9 | 1065 | 43,465.7 |

Resulted from age old farming practices and progressive encroachment of cultivated lands into steep marginal lands, the growth of bare land was paramount (6.7 %) in the years between 1986 and 1999. But in the successive period (between 1999 and 2017) the trends showed a declining trend (1.6 %). This could be attributed from nation wise campaign of watershed management measures that dramatically increased the use of mechanical and agronomic soil and water conservation measures particularly in the degraded landscapes. But resulted from uplands degradation and riverine deforestation sedimentation and flooding were great environmental problem in the downstream. (Figure 3).The downstream degradation not only affected banana plantation, which was the lifeline of the livelihood of the communities but also increased turbidity of the Lake water, since Lake buffer areas were badly encroached by horticulture farms. This finding was in line with Bewket (2003) who reported down-stream sedimentation caused by up-stream degradation in Chemoga watershed, upper Blue Nile basin, Northwestern Ethiopia.

### 3.3. Land use/ cover dynamics in relation to slope category

When observing 1986 land use/ cover data, steep landscapes (>30%) covered by annual crops were 59.5% and this figure raised to 59.8% in 1999 and reached to 60.4% in 2017 cropping year. Steep terrain (> 30% slope) is not recommended for cultivation of cereal crops, but such a landscape is kept for forest cover or perennial crops (Zeleke and Hurni, 2001). In the same period, the area occupied by forest cover was badly dwindling from 57.2% to 53.6% and 36.3% in three successive years (1986, 1999 and 2017) respectively. These results explained that forest cover was largely encroached by annual crops, which badly exposed the landscape to human induced degradation and threatens the habitats of the wildlife. According to the group discussion response of natural resources management experts of Bonke district, the increase of croplands into marginal steep terrains could be explained by fast newly emerging farming households in the area.

In the studied periods the expansion of annual crops in the gentle slope (<30%) was not significant as compared the steeper terrain. Its area was declined from 40.5% to 40.2% and 39.6% in the successive studied periods. Such a decrease in the crop lands could be explained by the encroachment of banana farms and eucalyptus lots in to the crop lands. This was probably resulted from the increasing demand of fruit products (banana avocadoes, and mango) at the national market and the growing demand of eucalyptus tree for construction purpose. But the trend was contrary for the forest land i.e., it showed a significant increment from 42.8% in 1986 to 46.4% and 63.7% in 1999 and 2017 respectively (Table 4).

Table 4: Land Use/Cover Changes in relation to slope category in the watershed

| | | Areal Coverage in different slope categories (%) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Land use/cover | < 5% | 5-10% | 10-20% | 20-30% | 30-40% | >40% | Total (area ha) |
| **1986** | Cultivated land | 3.6 | 3.5 | 17.4 | 16 | 19 | 40.5 | 18,218.7 |
| | Forest land | 4.8 | 6.8 | 16.8 | 14.4 | 18.5 | 38.7 | 7,997.7 |
| **1999** | Cultivated land | 3.5 | 3.2 | 18.5 | 15 | 18.3 | 41.5 | 23,884.7 |
| | Forest land | 6.3 | 4.7 | 17.4 | 18 | 20.3 | 33.3 | 5,432.9 |
| **2017** | Cultivated land | 1.9 | 6.4 | 21.3 | 10 | 17.9 | 42.5 | 30,868.5 |
| | Forest land | 18 | 9 | 9.2 | 27.5 | 19.2 | 17.1 | 2,048 |

### 3.4. Environmental impacts of land use/cover change

Population of the study area was increased at an average rate of 2.9 % per annum over 2009’s (CSA, 2010). Based on 2017 land use/cover data, the average farm holding in the study watershed was 0.16 ha per person or 1.78 ha per household (average household size was 7). This was far behind sustainable average holding of 2.5 hectare per household in the Ethiopian condition. In response to accelerated population growth, additional grasslands, forestlands and even mountain peaks are converted into cropland, where there is no more extra space is left for further expansion (Figure 5).Thus, mountain peak cultivation without sustainable soil and water management measure as practiced in the study watershed further triggered soil erosion by reducing water infiltration rate and aggravated runoff in the steep slopes. The process of land degradation that was prevailed in the upstream was not uncommon in the downstream, where banana & vegetable farms in the low lying areas are frequently inundated and flooded by gravel deposition (Figure 6).

If the present rate of population growth cannot be curtailed by positive measures, the land use data suggested that within two-decade period there remaining landscape will be converted into settlement and croplands, which is the other environmental challenge for livestock sector of economy in the catchment. Gete (2000) in his study conducted in the northwestern highlands of Ethiopia strongly commented the effect of population dynamics on land resource degradation.

Figure 5: Steep slope cultivation in Kulfo watershed (particularly in Zigiti area)

In the mountainous landscape like the study area, the presence of livestock is important for the supply of manure or dung (traditionally called *pito*) for *enset*/ cereal fields and supplement protein deficient staple food kocho. Livestock statistics in Kulfo watershed was estimated to be 200,020 (district agriculture departments, 2018). When observing the aggregate stocking level, livestock size (36.4 TLU per hectare) was more than the carrying capacity of the study area. According to FAO (1986), area of grazing land required per total livestock unit (TLU) is 1.5 hectares. If we consider FAO's estimate, the total area of pasture land required to the number of livestock unit in the study area should be 115,886.6 hectares. This is more than fifty folds (54.6) from what is currently available in the study area (2123 ha). Therefore, in order to support the present livestock population Kulfo watershed need additional 113,763.8 ha of grazing land.

From the ongoing analysis it was evident that the grass lands in the study area was over-stocked and deteriorated beyond the carrying capacity, which could be the major cause for severe range land degradation and soil erosion. In response to decreasing grazing lands, the size of sheep, equines and cattle per household was sharply diminished and they are forced to stay on bare land. Unavailability of fodder for livestock could directly or indirectly affect quality and quantity of livestock production, and reduce animals for plowing and transportation and thereby impacts animal dung/ manure, which was the source of traditional soil improvement measure. These all factors can negatively threaten the status of food security and household income of the community in the watershed.

Figure 6: Siltation and Gullies formation in lower part of kulfo watershed

According to the field observation in the upper part of the watershed such as Haringa, Gugula, Wusamo, Kacha Kashaso and Gana karerevealed that due to the scarcity of grazing land communities in the neighboring in these Kebeles are frequently clashing over the scarce pasture resource and such conflict remains great security and ecological challenge among the communities in Mt. Gughe area.

## Conclusion

According to this study, the land use/cover analysis showed that there is an increasing trend during the studied period (1986-2017). Croplands have been increased by 70.3 % whereas Forest, shrub and grasslands showed a decreasing trend. Mainly forest lands, bush lands and pasture lands were transformed into crop lands and settlement lands. This was primarily a result of cultivation of densely covered grasslands and forestlands. Thus, cultivation of grasslands and forestlands has destroyed soil structure, increased soil erosion, and triggered degradation and flooding of low-lying farms by sediments and gravels which were brought from the upstream. In the downstream of the watershed, the development of urbanization was paramount, transforming large areas of bush lands into settlements. Between 1986 and 1999 studied period the annual dynamics was 2.8%, while it increases to 7.5% in the consecutive period, i.e., between 1999 and

2017. Furthermore, urbanization is not only expanded at the expense of bush land but also it negatively damaged woodlands, riverine vegetation through fuel wood, grass fetching and logging.

In the study area, cultivation encroached to marginal steep slopes (with gradient more than 60%) and mountain grasslands where once used as a place of celebrating traditional festivals and grazing grounds. Such a dramatic change in three-decade period has further increased degraded lands and raised erosion vulnerable areas to 97.2%, the resultant effects of which has greatly threatened the livelihood of communities in the watershed. Therefore, it is recommended that Land has to be studied to provide its maximum yield. Sustainable land management that significantly supports rural and urban development is a prerequisite for long-term use of the land and thereby improves the livelihood of the communities in the watershed.

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