
**INTERNATIONAL
SOIL AND WATER
CONSERVATION RESEARCH**

**Land Use-Land Cover dynamics of *Huluka* watershed,
Central Rift Valley, Ethiopia**Hagos Gebreslassie¹**Abstract**

Land Use-Land Cover (LULC) dynamic has of human kind age and is one of the phenomena which interweave the socio economic and environmental issues in Ethiopia. *Huluka* watershed is one of the watersheds in Central Rift Valley of Ethiopia which drains to Lake Langano. Few decades ago the stated watershed was covered with dense acacia forest. But, nowadays like other part of Ethiopia, it is experiencing complex dynamics of LULC. The aim of this research was thus to evaluate the LULC dynamics seen in between 1973 – 2009. This was achieved through collecting qualitative and quantitative data using Geographic Information System (GIS) and Remote Sensing (RS) technique. Field observations, discussion with elders were also employed to validate results from remotely sensed data. Based on the result, eight major dynamic LULC classes were identified from the watershed. Of these LULC classes, only cultivated and open lands had shown continuous and progressive expansion mainly at the expense of grass, shrub and forest lands. The 25% and 0% of cultivated and open land of the watershed in 1973 expanded to 84% and 4% in 2009 respectively while the 29%, 18% and 22% of grass, shrub and forest land of the watershed in 1973 degraded to 3.5%, 4% and 1.5% in 2009 respectively. As a result, land units which had been used for pastoralist before 1973 were identified under mixed agricultural system after 2000. In the end, this study came with a recommendation of an intervention of concerned body to stop the rapid degradation of vegetation on the watershed.

Key Words: GIS, RS, Land use, Land cover

1 Introduction

Globally, Land Use-Land Cover (LULC) change is as old as human kinds (Turner et al., 1993). But, the current rate of changes is not the same as to what was at the beginning. Dramatic increase in rate of change has been seen in the past few centuries (Lambin and Geist, 2006). Most of the registered LULC changes were the result of the practices done to satisfy the immediate needs of human being (Turner et al., 1995; Brandon and Bottomley, 1998; Serneels and Lambin, 2001; Sherbinin, 2002). These rapid LULC changes exert detrimental and adverse impacts on the environment and livelihood. For example, Kalnay and Cai (2003) assumed LULC as the most important factor to climate changes. Lambin and Giest (2003) have also described its negative impact on socio-economic of rural population. Meyer and Turner (1994) described its impact on physical resources like water, soil and land quality. LULC change can also affect the global and local bio-diversity (Chapin et al., 2000).

In Ethiopia, LULC changes were registered at local level that adds up to the changes at national level. Most of these changes were from the natural forest to agricultural land and was due to human intervention (Woldeamlak, 2002; Daniel, 2008). Specifically, a few decades ago central rift valley to which *Huluka* watershed belongs was covered with open forests of acacia trees which had been providing good opportunity to increase the economic sources such as livestock raring and crop production and in reducing soil erosion (Motuma, 2006). But, through time, the status of acacia forest becomes degraded. This research

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was therefore aimed at evaluating the nature and trend of land use-land cover changes of the watershed during the last four decades.

2 Materials and methods

2.1 Area description

Huluka River is one of the perennial rivers in Arsi Negele district and drained into Lake Langano from southeastern ward. All the area draining in the main river that ends at Lake Langano is defined as *Huluka* watershed. *Huluka* watershed stretches over 218 square km starting from the rift valley plain at the Lake Langano to the peak of southeastern escarpment “*Duru*” mountain. The entire site is located geographically 7° 16.4' to 7° 30.7' N and 38° 47.7' to 38° 44.3' E. The average elevation is 1,977 m.a.s.l. *Huluka* watershed is found in Ethiopian central rift valley system and located 235 km south of Addis Ababa, the capital of Ethiopia (Fig. 1).

Average annual temperature varies from 10 – 25 °C. Moreover, the Langano metrological station classified the whole area to have bimodal rainfall distribution, i.e., in the period July to October (wet season) and March to June (small rain season). About 83% of the soil in the watershed is sandy loam whereas 9% is sand soil (EARO, 2002). Andosols soil type covers about 52.2% of Arsi Negele, while Nitosols cover the remaining 47.8% (ORS, 2004). So, the textural class and soil type of *Huluka* watershed fall in the above soil description.

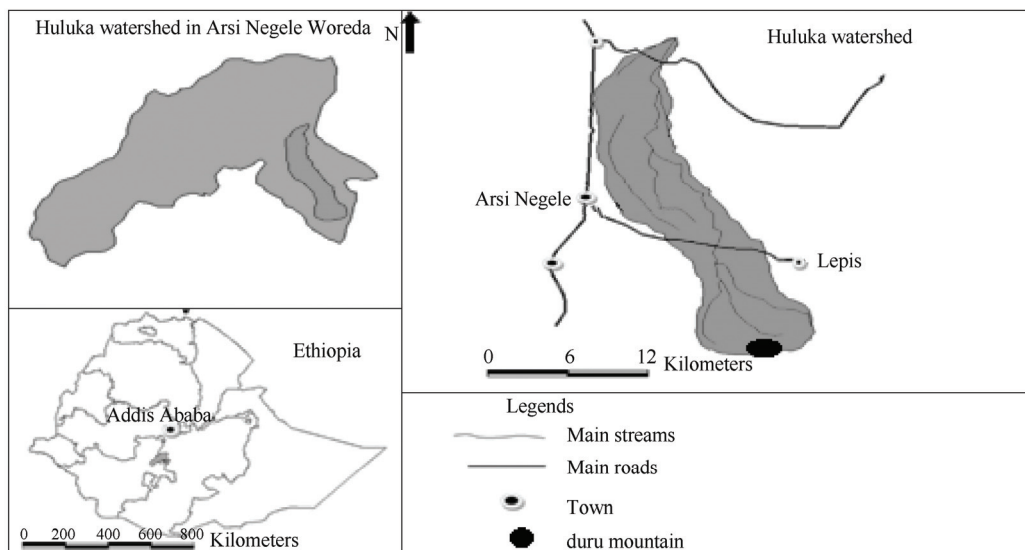


Fig. 1 Location of *Huluka* watershed

2.2 Methodologies

The major source of LULC data was mainly multi temporal satellite images and topographic maps. Five dates of remotely-sensed land sat images acquired in dry season (Table 1) was collected from different sources. These images procured were processed using image processor ERDAS IMAGINE 8.4 software and Arc view GIS 3.2 software.

Table 1 Satellite images used

Land sat Types	Path and Row	Date of Acquisition	Spatial Resolution (m)
<i>Landsat-MSS</i>	180/055	1973-01-30	57 × 57
<i>Landsat-MSS</i>	181/055	1973-01-31	57 × 57
<i>Landsat-TM</i>	168/055	1986-01-21	28.5 × 28.5
<i>Landsat-ETM⁺</i>	168/055	2000-02-05	28.5 × 28.5
<i>Landsat-ETM⁺</i>	168/055	2009-12-03	28.5 × 28.5

2.2.1 Pre-classification processing

Four sheets of 1:50,000 scaled topographic maps where *Huluka* watershed is laid were first collected from Ethiopian Mapping agency and scanned to computer compatibility. But, the scanned topographic maps were distorted in reference to the ground position. Thus, they were first geo-referenced by taking four GPS points which were easily identified locations like churches and then re-projected to WGS 1984-Universal Transversal Mercator (UTM), zone 37N. Finally, the four sheets of geo-referenced scanned topographic maps were connected to each other keeping their continuity with the Mosaic process of ERDAS 8.4 software and it was from this topographic map that the watershed boundary digitized manually in Arc view GIS 3.2 software.

The satellite images were geometrically corrected in reference to the geo-referenced topographic map and re-projected to the WGS 1984-Universal Transversal Mercator (UTM), zone 37N. In this study, rectification was very important to make all the satellite images and scanned topographic maps readable each other by dis-considering the slight errors during geometric correction. As the study area was small, higher order of transformation was not required. Therefore 1st-order transformation which was expressed by the equation of a plane $(t+1)(t+2)/2$ was used. "t" was the order of the transformation which was 1 in this case. The minimum GCPs requirement according to this formula was "3". The rectification process was accomplished by taking 4 easily identifiable Ground Control Points (GCP). The spatial resolutions of MSS, TM and ETM⁺ were different. So, it was important registering to uniform spatial resolution. This was done through the re-sampling process in the ERDAS software. The spatial resolutions of each image were brought to 30 m by 30 m pixel size.

2.2.2 Classification

Several studies (e.g. Abrams et al., 1996; Congalton, 1991), stated the importance of developing a classification system which suit to the study area and to the objective of the study. Therefore, hybrid (un-supervised and supervised) classification system was used to classify all satellite images with ERDAS IMAGINE 8.4 software. The maximum likelihood classification were applied for image classification after selecting 104, 51, 40 and 80 training areas on MSS 1973, TM 1986, ETM⁺ 2000 & ETM⁺ 2009 land-sat images, respectively. Training sites were identified based on the information obtained from field observations, discussion with elders, topographic maps, from image interpretation as well as aerial photograph from Google earth.

2.2.3 Post Classification

Accuracy of the classification was done by taking 60 random points. The points were traced using GPS and identified their past Land Cover class from the knowledge of elder people. Finally the error matrix system has been used to compare the ground truth with the classified land cover classes. This was done to all classified satellite images (MSS 1973, TM 1986, ETM⁺ 2000 and ETM⁺ 2009). Finally, complete matrix and change of classes were automatically generated from the classified satellite images (Table 2).

Table 2 Description of considered land cover classes and interpretation keys from the used satellite images (Woldeamlak, 2002)

Land cover	Description	Key	
		Tone	Texture
Cultivated land	This category includes areas under crop and land under preparation. Unless mapping scale allows, physical boundaries are broadly defined to encompass the main areas of agricultural activity and are not defined on exact field boundaries. The class may include small inter-field cover types (e.g. hedges, grass strips, small windbreaks, etc.) as well as farm infrastructure.	Invisible white	Smooth
Wood land	Areas with sparse trees mixed with short bushes, grasses or are on open areas.	Red	Coarse
Open land	Open lands have included rocky areas, rural roads and bare lands free of any use.	Light dark	Medium coarse
Grass land	Grass lands are those areas which are predominantly covered with grass. Areas covered with grass with some scattered trees and pastures are assumed as grass land.	Light White	Medium coarse
Shrub land	Areas covered with small trees, bushes and shrubs, mainly ranged from closed canopy to open canopy areas are considered as shrub land.	Light red	Medium coarse
Continuous NF	Are areas covered with naturally grown closed stand of trees forming continuous canopy.	Very deep red	Coarse

Land cover	Description	Key	
		Tone	Texture
Fragmented NH	It is forest area which is highly intervened by human being. Due to the interferences they are not canopy closed.	Deep red	Coarse
Plantation forest	It is land which is completely covered with manmade trees planted with regular arrangement.	Light-deep red	Smooth

2.3 Data analysis

The summary statistics such as area of land cover in each image and conversion matrixes were automatically generated from the ERDAS 8.4 software. The conversion matrix was analyzed by paring two images. MSS 1973 was paired ETM⁺ 2009. Moreover, to see the details matrixes, pairing were done between MSS 1973 and TM 1986, TM 1986 and ETM⁺ 2000, and ETM⁺ 2000 and ETM⁺ 2009. The change of land cover from the base date of image during the stay until the next date of image was automatically generated by over laying classified land cover map over the next classified land cover map. The estimated conversion of one land cover class to other land cover class was compared with the total estimation of land cover conversion of respective pair of years for each land cover. The rate of land cover change was calculated for the three periods from 1973 – 1986, 1986 – 2000 and 2000 – 2009 using following formula

$$\text{Rate of land cover changes (\% yr}^{-1}\text{)} = [(B-A)/A_t] \times 100 \quad (1)$$

where A = previous land covers area (ha); B = recent land cover area (ha); t = number of years between A and B .

3 Result and discussion

3.1 State of land cover

In *Huluka* watershed eight major land cover classes were identified in each date of satellite image. The land cover classes and coverage in each date of image are given below (Table 3):

Table 3 Coverage of each land cover classes in each date of image

Land cover type	Land cover in each year of image							
	1973		1980		2000		2009	
	ha	%	ha	%	ha	%	ha	%
Cultivated land	5525	25.3	8199	38.6	12735	58.3	18142	83.1
Wood land	1184	5.4	1208	5.5	1559	7.1	215	1.0
Open land	83	0.4	52	0.2	492	2.3	797	3.7
Grass land	6407	29.4	5036	23.1	2512	11.5	772	3.5
Shrub land	3913	17.9	5054	23.2	3284	15.0	1014	4.7
Continuous NF.	1741	8	1569	7.2	779	3.6	3	0.0
Fragmented NF.	2973	13.6	677	3.1	454	2.1	319	1.5
Plantation forest	5	0.0	35	0.2	17	0.1	4	0.0

The rows in Table 3 show temporal variations of land cover classes and the columns show the spatial variation of land cover classes. Only about 25% of *Huluka* watershed was under cultivated and open lands by the year 1973, while the remaining 75% was covered by the other land cover classes. Later on, cultivated land dominates the other land cover classes. For example cultivated land in 1986 has increased by about 13% in 13 years gap. In reverse to this, the fragmented natural forest decreased by 11%. In the successive period i.e. 1986–2000, cultivated land has shown an increase of about 20% while grass land and shrub land dropped about 20%. In the last date of satellite image, in 2009, the classification referred that about 83% of *Huluka* watershed was under cultivated land (i.e. more than triple of the 1973). The other change was on open land that showed a considerable expansion and holds about 3.7% of the study area in 2000–2009. In 1973 as it is illustrated in land cover map (Fig. 2), it was on the gentle slope at and around the outlet of the watershed (northern part) where the

cultivated land concentrated while the remaining part of the watershed was at least under grass land. But, through time cultivated land expand toward the upper slope of the watershed (southern part) and then after 2009 the majority part of the watershed came under cultivation except very small part of the watershed in the upper slope.

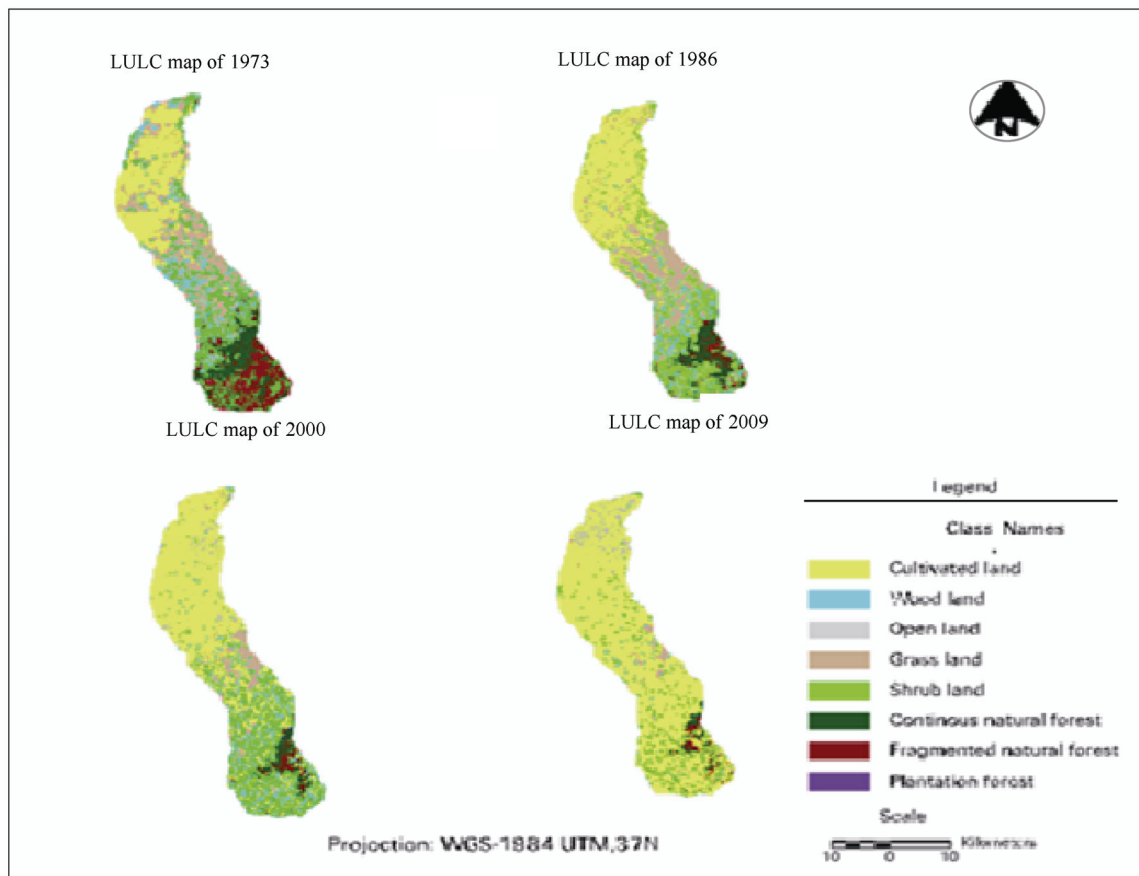


Fig. 2 Land cover map of 1973, 1986, 2000 and 2009

The result of this study has revealed conversion of one land cover class to other land cover class in *Huluka* watershed. In areas like rift valley which was under high population, it was unthinkable to expect and find land cover which remains stable in time respect. But, what should be mattered was the direction of the change. Starting from 1973 to 2009 and even on ward, a dominant one way LULC conversion was seen in *Huluka* watershed. That was from grass, shrub and natural forests to cultivated lands. The transitions of different LULC to cultivated land were in two types. The first one was the deliberate and direct conversion of many LULC classes to cultivated land. For example, shrub and grass lands were directly converted to cultivated land. The second type of conversion to cultivated land was a step by step conversion. For instance, continuous natural forest was converted to fragmented natural forest and then to woodlands and shrub lands and finally converted to cultivated land. Such step by step conversion of the LULC classes to cultivated land may be related to the extraction of forestry related uses like extraction of fuel wood and construction woods. In this style of conversion, the intention farmers were not converting in to cultivated land. Instead, it was after a time that farmers converted it in to cultivated land.

The continuous conversion of different LULC classes to cultivated land in *Huluka* watershed has squeezed shrub land and natural forests in to very small area on the very steep slopes and periphery of river valleys of the watershed which were very difficult for cultivation only. The conversion of LULC was location dependent. For instance, on the upper slope of the watershed (southern part) a slight change of LULC was observed as opposed to above direction of LULC change. For example, around the foot of *Duru* ridge (southern part of the watershed), there was a practice of fallowing of cultivated land and planting eucalyptus trees. As a result some conversion of cultivated land to grass, shrub and plantation forest lands was indicated. Whereas in the gentle slope (northern part of the watershed), there was no significant fallowing cultivated land. Instead there was intensification of the

agricultural practices such as irrigation practice. Intensification of agricultural practices was related to the acute shortage of land on the gentle slope. The other possible reason was unsuitability for cultivating. In line with this Gessesse and Kleman (2007) reported moisture and terrain as possible variables to alter the pattern and trend of LULC change.

3.2 Rate of land cover change

The rate of land cover change was not mono directional that was some of the land cover classes were expanding through time while others were shrinking from time to time. The detail is displayed in Fig. 3.

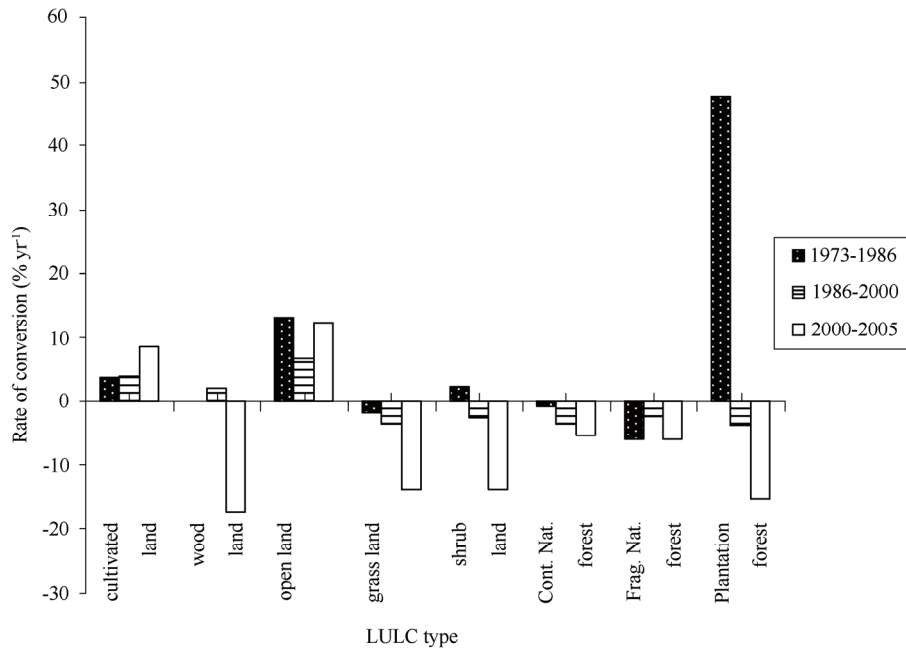


Fig. 3 Rate of each land cover change in each period: the up warded bars indicated expansion rate while the inverted one indicates the shrinking rate, it is a relative expression of each land cover as compared to its originals (on the base year of each period)

Fig. 3 shows continuous progress in the rate of cultivated land expansion. It increased from 3.7% in 1973–1986 to 8.5% in the last period considered (2000–2009). The other land cover class which has shown continuous expansion was open land. In reverse to this, grass and shrub lands have shown continuous shrinking in the last 36 years. The degrees of shrinking these land cover classes have shown an increase from the earlier period up to the latest period. More over continuous shrinking has also seen in the natural forests. Besides to this and according to the discussions with the respondents it was within the first period when good plantation practice have seen in the upper part of the watershed around *Duru* ridge by Arusi Negele forest enterprise. In summary, it was during the first period (1973–1986) when the low rate of conversion in almost all land cover was seen while the higher rate of land cover change was in 2000–2009.

The rapid expansion of cultivated land at the expense of grazing and shrub lands imply the increase of local community's interest on producing annual crops instead of livestock production. Efrem et al. (2009) and Kebede (1998) indicated that the change of the local community's economic source in the Central Rift Valley of Ethiopia from pastoralist to permanently settled crop producing practice in 1960s. From this time on ward, farmers shifted their source of economy to ward producing annual crops. To increase the crop production, farmers have been increasing the size of cultivated land. Of course this could have been achieved by intensifying agricultural practices on the existing cultivated land. But, this was not introduced to the *Huluka* watershed.

The other cause of rapid conversion of other LULC to cultivated land was the reduction of land productivity. As a result of climate change and continuous soil erosion, the productivity of land can decline from time to time. To compensate the reduction of yield, farmers believed increasing the size of cultivated land for annual crop production as a right solution achieved by clearing the natural vegetation which would have been important in

mitigating the climate change and soil erosion had it been used sustainably. In addition, according to (Cohen, 1987) the rapid population increases the migration of people from the central high lands found to be causes for the expansion of cultivated land. Moreover, the rapid expansion of cultivated land could be attributed to the land tenure system. Most of the land covers other than the cultivated land are communal land (Tolera, 1996) that allowed free access and then developed a sort of competition among farmers to gain more uses from the common land. Increasing fuel wood collection for sell, converting into cultivated land and leaving more livestock can be mentioned.

According to Meyer and Turner (1994), the rapid loss of vegetated land covers has influenced to the human life directly and indirectly. For example, shortage of fuel and construction woods and reducing the availability of water are common problem observed in the area. Moreover, gully erosion is worsening from time to time as the vegetation status changed. Especially, soil erosion by gully was highly influenced by the type, extent and quantity of cover (Morgan, 1996). Lands with good vegetation cover could not susceptible to gully. This could be related to the capability of the vegetation in intercepting falling raindrops. In addition, the roots are important in inhabiting the channeling of land flowing water. Therefore, the expansions of cultivated land can worsen gully erosion.

3.3 Relation of land use and land cover

The major land uses in Huluka watershed were directly or indirectly related to agriculture and forestry practice. The agriculture related land uses are producing annual crop and livestock production. The forestry related land uses were related to fuel wood collection, construction wood and timber production. The relation between land use and land cover is described in Table 4.

Table 4 Relation of land cover and land use

Cover	Land use type							
	a	b	c	ab	ac	bc	d	
Cultivated land	***	**	–	*	–	–	–	
Wood land	**	**	–	***	***	–	–	
Open land	–	–	–	–	–	***	**	
Grass land	–	***	–	**	*	–	–	
Shrub land	–	***	–	**	**	–	–	
Continuous NF.	–	*	**	***	***	–	–	
Fragmented NF.	–	*	**	***	***	–	–	
Plantation forest	–	*	***	**	**	–	–	

Where a = crop production, b = grazing, c = timber production, ab = source of fuel, ac = construction wood production, bc= settlement, d= transport.

NB. The more the number of stars indicates the more intensity of that land use type.

As can be seen from Table 4, cultivated lands were primarily used for annual crop production (eg. maize, teff, wheat and etc.). Grass and shrub lands were mainly used to graze livestock. Fuel and construction wood were mainly collected from the available natural forest lands, while timber products were from plantation forest lands. Though the main purposes of each land cover classes in Huluka watershed was as stated in the above, they do have also other alternative uses. For example, cultivated lands used as graze livestock after the crop harvested in the off-season. Moreover, the cultivated lands with scattered trees can be used as source of fuel-wood. Grass and shrub lands provide some additional uses to the local community other than the main use stated in the above. For example, the scattered trees in grass lands and the bushes in shrub land can be used as fuel wood. Even, there was a possibility of using the matured trees to produce construction woods. Though limited natural forests are commonly used to forestry related uses (fuel wood, construction wood and timber production), they also interfered with the livestock from nearby farmers.

4 Conclusion

Huluka watershed has identified with eight major dynamic land cover classes during the period (1973–2009). The LULC change in *Huluka* watershed during the last four decades was dominated by one way transition. The dominate LULC transition was mainly from grass, shrub and acacia forest lands to cultivated land. The expansion rate of cultivated land in *Huluka* watershed has been showing progressive increase up to the end of

2009. However, this could not be expected after 2009 due to the shortage of other LULC that can be converted to cultivated land. The conversions of forested land in to cultivated land in Huluka watershed were step by step and direct style. The conversion of vegetated land to cultivated and open lands were attributed to the factors shifting of the local community from livestock rearing farming system to crop production farming system and rapid population increases. The consequences of the rapid vegetation degradation in the area were sever expansion of rills and gullies which contribute a lion share on declining agricultural production. Moreover, respondents agreed that the soil displaced from the watershed has impact on Lake Langano. Finally this study urges an intervention from concerned body looking into sustainable land use management by reversing the common direction of LULC change seen in the area.

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