



Impact Assessment of Land Use/ Land Cover Change on Soil Erosion and Rural Livelihood in Andit Tid Watershed, North Shewa, Ethiopia

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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Case Study

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ABSTRACT

Land use, which is use of land by human for different purposes, is influenced by two broad sets of forces human needs (socio-economic) and environmental features and processes (biophysical). The study was carried out at Andit Tid watershed one of SCRP research unit founded in 1982, located on 39° 43'E 9°48'N. This research has aimed to assess the trend and main driving force of land use and land cover change (LULCC) within the catchment / watershed during the last two decades and its impact on soil erosion. Structural questioner was used to collect social data from 8% of the total household. Landsat 5 and Landsat 8 Enhanced Thematic Mapper (ETM) and supervised image classification used to identify land use/ land cover change of the study area for 1994 and 2014 years, respectively. TESTMAIN and SPSS version 16 Statistical software's were used for Soil loss calculation and social data analysis, respectively. The result indicates that, there is expansion of cultivated land by 11.33% (44.55ha) while reduction in natural shrub lands by 7.3%

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(35.73ha). The main driving forces of land use land cover change are high number of family member, small land holding size and minimum asset own per household, lower educational level of the household, the household mainly occupied on agriculture and there is lack of animal feed. This change forced farmers to collect cereal crops based on suitability area, sale livestock, use organic and inorganic fertilizer and use improved variety due to low crop productivity. The LULC change has an impact on decline soil fertility, cause serious soil erosion problem with in farmland/watershed. The result also indicated that soil loss reached 3655 ton per annum from the watershed. Therefore, proper handling and land use system need to be implemented, rainwater harvesting structures and soil and water conservation practice need to be encouraged in order reduce soil loss.

Keywords: Land use; soil erosion; household; change.

1. INTRODUCTION

Land is the foundation resource for nearly all human uses. Human use of land resources varies from place to place depending on the production objectives and the biophysical capability or suitability of the land itself. Land use, which is use of land by human for different purposes, is influenced by two broad sets of forces human needs (socio-economic) and environmental features and processes (biophysical) [1]. Land cover changes influence the biogeochemistry, hydrology, and climate of the earth. Studies that assessed land cover changes at the global scale mostly focused on: deforestation, cropland expansion, dry land degradation, urbanization, pasture expansion, and agricultural intensification [2]. Land use/land cover change is a key driver of global change [3] and has significant implications for many international policy issues [4]. In particular, land use/land cover (LULC) changes in tropical regions are of major concern due to the widespread and rapid changes in the distribution and characteristics of tropical forests [5,6]. However, changes in land cover and in the way people use the land have become recognized over the last 15 years as important global environmental changes in their own [7].

The traditional management of land-based resources, coupled with a growing interest and reliance on various products and services from those resources poses a challenge for managing the natural resources. Changes in land use and land cover conditions and agricultural water management practices in irrigation could be responsible for the problems associated with hydrological resources of the Lake Tana Basin [8]. Inappropriate allocation and utilization, lack of capacity to develop and use poorly accessible water resources, loss of water due to its seasonality and run off are some of the problems associated with the water resources in the basin.

Therefore, producing more food under conditions of increasing water scarcity and without creating further environmental degradation is a challenge being faced [9].

To understand how LULC change affects and interacts with earth systems, information is needed on what changes occur, where and when they occur, the rates at which they occur, and the social and physical forces that drive those changes [10]. The information needs for such a synthesis are diverse. Remote sensing has an important contribution to make in documenting the actual change in land use/land cover on regional and global scales from the mid-1970s [11]. [12] investigated the changes in LULC over a period of 16 years in southwestern Nigeria using remote sensing and GIS techniques and deriving factors behind the changes and the adverse effects of these changes on the livelihood of the people and the local environment. In Andit Tid watershed it is obvious that there is land use as well as land cover change, large portion of the study area is covered by cultivated land, but in some areas covered by artificial forest (eucalyptus plantation). Hence understanding impacts of land use land cover change on the livelihood and soil erosion in this area is needed for optimal management of natural resources in the area. Therefore to explore and understand the impact of land use land cover on soil erosion, it is also important to assess the trend of LULC change within the catchment / watershed, to assess the main driving force of LULC change in the study area and to analyze the relation of LULC change with soil erosion.

2. MATERIALS AND METHODOLOGY

2.1 Description of the Study Area

The watershed for this research is one of the catchments of the Soil Conservation Research

Programme (SCRIP) of the Amhara Regional Agricultural Research Institute (ARARI), which is called Andit Tid. The watershed initiated in 1982 by the Institute of Geography of the University of Bern (Switzerland). Hence in the study area there is huge amount of collected and available data for the last 25-30 years. Accordingly Andit Tid is situated in the area of northern Shewa (39°43'E and 9°48'N) and covers a total area of 481 ha, and the altitude of the catchment ranges from 3040 to 3548 meter above sea level [13].

2.2 Social Survey Sampling Procedure and Data Collection

To collect the required social data for the study individual interview and focus group discussion was conducted. Accordingly 25 households (8%) of the total households (161) were randomly select and interviewed with structured questioner. Focus group discussions was also made with the development agents (DAs), the watershed community members and PA leaders to supplement and cross check the data obtained through the household individual survey.

2.3 Soil Erosion

Annual soil erosion data was obtained and determined from river discharge record and climatic data collected by SCRIP/WLRC over the last 20 years.

2.4 Land Use Land Cover Change Data Collection and Processing

The land use land cover of study area was made based on LandSat5 Thematic Mapper (TM) and LandSat8 Enhanced Thematic Mapper (ETM) for 1994 and 2014 years, respectively and supervised image classification used. Then the images geometrically corrected to Universal Transverse Mercator (UTM) coordinate system. Resolution 30 m by 30 m, path number 168 Number of rows 53 and 6 Bands were used.

Data on the type and characteristics of the past and present land use and land cover change were generated from Landsat satellite imagery of 1994 TM (Thematic Mapper), and 2014 Landsat 8 at 30 m spatial resolution for both satellite imageries. On top of that, Topo sheets with scale of 1:50,000 were scanned and used for geo-referencing the Landsat satellite images. Field observations, interviews and discussion with the land users were also employed to substantiate the information.

Landsat satellite image contain a detailed record of features on the ground at the time of exposure. In order to obtain the desired information from the series of satellite images, interpretation should proceed on a systematic way. The pre-image interpretation phase was done based on visual interpretation in relation to the study area. Once the overall aim was defined, the level of details and the categories of land use/cover that needed to be distinguished were determined. Interpretation and analysis of satellite images has been made in the remote sensing departments of Ethiopian Mapping Agency (EMA) following the procedures given below:

- a) The 1994 satellite image(TM) for the study is acquired and band combination of 4,3,2 infrared, red and green wavelength of the electromagnetic spectrum were selected respectively to get the best information on land use land cover features from the image. The study area was clipped out from the combined image using the subset tool of ERDAS 2010 software.
- b) The satellite images of each year were geo-referenced into a map coordinate system using the Universal Transverse Mercator (UTM) projection using clearly observed and selected control points on 1:50,000 topographic map using ERDAS 2010 with 0.5 Root Mean Square (RMS) error.
- c) In order to extract the study area and fix the area of interest (AOI) the satellite images of each year were transferred from Tiff (tagged image file format) into image format using ERDAS (Environmental research design and analysis system) 2010 software. Since the satellite images were changed into image and each image had to be rectified and referenced into UTM (Universal Transverse Mercator) coordinates because the coordinates were discarded when the image was imported from Tiff format to image format.
- d) The identification and classification of land use/land cover types from the satellite images require intensive use of spectral band combination for visual verification, because the satellite images were black and white in the first place and they were combined to get a meaning full color of the land use land cover features. The visual interpretation of various features on the characteristics of satellite images, i.e. tone, texture, shape, pattern, shadow,

association and aspect as well as location of the features was done with the support of field verification of each land use/cover features.

However, the satellite image was interpreted with the aid of field collected ground truth using global positioning system (GPS) and ERDAS 2010 software. Moreover, supervised classification, using the maximum likelihood classifier was used to classify the satellite images and generate distinct land use/cover types. The maximum likelihood algorithm is the most powerful classification methods when accurate training data is provided and one of the most widely used algorithm. Training data or spectral signatures for the supervised classification were established from the previous knowledge of the area, and with the help of other supporting data sources such as satellite images, topographic maps and interviews with elderly people of the area.

The classification result was assessed to its accuracy and the accuracy assessment task was done using ERDAS 2010 by selecting 20 random points from both classified images and the ground truth data which were collected using handheld GPS and the accuracy of the classification found to be 80% with the kappa statistics of 0.75 which is acceptable for classification using Landsat imageries.

In order to prepare an output map, these classified coverage features were transferred in to Thematic Map using ArcGIS 10.

The land use land cover change statistics of the area between 20 years is calculated using the following formula and the output is presented in table.

$$\text{The rate of change} = \frac{Y2-Y1}{N} \quad (\text{Eq.1})$$

Where

Y1= the Area in hectare of the land use feature in the oldest year (1994)

Y2= the area in hectare of the land use feature in the recent year (2014)

N= the time interval in years between the two imageries (1994-2014)

2.5 Data Analysis

In addition to image data analysis, the socio economic data as well soil erosion data were analyzed using SPSS version 19 and TESTMAIN software, respectively.

3. RESULTS AND DISCUSSION

3.1 Land Use and Cover Change at Andit Tid Watershed

As shown in Fig. 1, there is spatial image difference and land use system at Andit Tid watershed between 1994 and 2014.

As shown in Table 2 and Fig. 1, cultivated land was increased from 113.85ha to 169.29ha during the last 20 years. This encountered about 11.33 percent or 55.44 ha increment than other land use system. Shrub land were reduced highly and by 7.3 percent or by 35.73ha. On the other hand, forest land, grass land, and wood lands were also reduced by 10.17ha, 5.67ha, and 3.87ha, respectively between 1994 and 2014 land use system of the study area. In Ethiopia agricultural land expansion was taking the leading on land use land cover change. Studies conducted at Humera, Metama and Gambela parts of Ethiopian drylands are agricultural lands were increased by 20.77%, 44.64% and 244% and woodlands were decreased by 41.69%, 43.71% and 57.82%, respectively [14].

3.2 The Main Driving Force (causes) to LULCC

From Table 3 the result shows that, the mean numbers of family of the study area is 5.48 per household. This indicated that the asset distribution and land holding between family members is 9,240 ETB and 0.314 ha, respectively. This is an implication for the main cause of land use land cover change in the study area. According to a survey made in Amhara region, 12.8% of the rural households have no access to land [15]. Hence, it will be imperative to look for other options of addressing the growing shortage of land and landlessness. A survey conducted in Ethiopia by [16] stated that, among the main factors affecting forest cover are high population growth, lack of awareness, low income and poverty, educational background, highly dependent on agriculture (crop production).

On the other hand most (76 percent of the respondent) household leaders of the watershed are illiterate and read and write only. Knowledge and awareness gap between community lead to improper land use system. Most of the community members (96 percent) in the study area are occupied on agriculture productivity. This causes the diversification of agricultural lands than improving productivity per unit area.

Table 1. Producer, user and overall land accuracy of the classification (1994-2014)

LULC classes	Reference total	Classified total	Number correct	Producers accuracy	Users accuracy
Wood land	5	7	5	100.00%	71.43%
Forest land	3	3	2	66.67%	66.67%
Crop land	4	2	2	50.00%	100.00%
Shrub land	3	2	2	66.67%	100.00%
Grass land	5	6	5	100.00%	83.33%
Total	20	20	16		

Overall Classification Accuracy = 80.00%; Overall Kappa Statistics = 0.7531

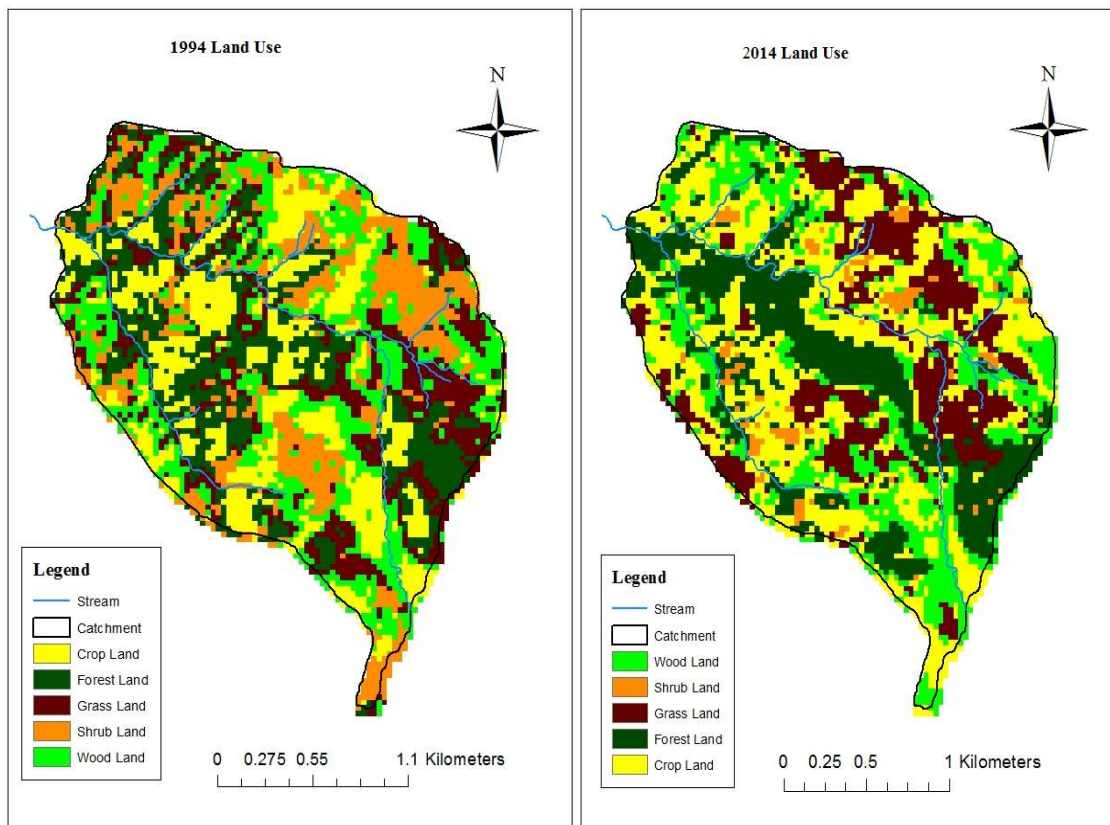


Fig. 1. 1994 and 2014 land use system Andit Tid watershed

Table 2. Land use and land cover change at Andit Tid watershed between 1994 and 2014

Land use type	1994		2014		LULC	
	Area (ha)	%	Area (ha)	%	+/- (ha)	(+/- %)
Cultivated land	113.85	23.27	169.29	34.61	+55.44	+11.33
Forest land	96.57	19.74	86.4	17.66	-10.17	-2.04
Shrub land	88.65	18.12	52.92	10.82	-35.73	-7.30
Grass land	88.92	18.18	83.25	17.02	-5.67	-1.16
Wood land	101.16	20.68	97.29	19.89	-3.87	-0.79
Total	489.15	100.00	489.15	100		

3.3 Impact of LULC Change on Household Livelihood and Soil Erosion

As shown in Table 5, 56 percent of the respondent farmers were forced to adjust their crop selection criteria base on their land suitability for specific cereals (barley and wheat) for long period time. From farmers' point of view, they are not preferable to grow crops for household consumption, high market demand and high yield crops.

As shown in Table 6, the farmland soil fertility status of most farmers infertile and moderately fertile. This leads to 84 percent of the respondent crop failure encountered, 88 percent forced to use organic and inorganic fertilizer and improved crop variety to gain affordable yield for their household consumption. 52 percent of the

respondents were sale their livestock in order to compensate low crop production. The other impact of land use and land cover change in the study area there is lack of animal feed, this leads to reduction of shrub lands and grass lands.

Land covered by vegetation or herbaceous tree/shrub species reduce the occurrence of erosion because it reduces the kinetic energy of the rain storm and the surface run off. However in the study area there is high erosion problem on farmlands (88%). It has a severe problem loss of top soil from their farmland. The erosion type caused by land use land cover change is mostly sheet and rill erosion 36.4% and 54.5%, respectively. In order to reduce soil erosion problem the government and SCRIP projects implement huge soil and water conservation practices.

Table 3. Household number, asset owned and land holding size of the study area

Causes of land cover change	N	Descriptive statistics				
		Minimum Statistic	Maximum Statistic	Mean Statistic	Std. Error	Std. Dev. Statistic
HH Number	25	2	10	5.48	.366	1.83
Asset Owned (ETB)	25	\$464	\$124,585	\$50,638	\$5,600	\$28,002
Land Holding (Ha)	25	0.5	3.0	1.72	0.13	0.66

Table 4. Education, occupation and feeding system of the study area

Labels	Description	Frequency	Percent	MSE
Education	Illiterate	5	20.0	0.210
	Read and write	14	56.0	
	Primary (1-4 grade)	2	8.0	
	Junior (5-8 grade)	3	12.0	
	High school (9-10 grade)	1	4.0	
Occupation	Agriculture	24	96.0	0.120
	Trade	1	4.0	

Table 5. Crop selection criteria

Crop production	Suitability to the area		Household consumption		High demand (sale)		High yield		Not yet practiced	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Cereals	14	56	10	40	1	4	-	-	-	-
Vegetable	4	16	5	20	11	44	1	4	4	16
Fruit trees	-	-	-	-	3	12	-	-	22	88
Pulses	1	4	18	72	3	12	1	4	2	8
Oil crops	2	8	4	16	8	32	-	-	11	44

3.4 Impact on Annual Precipitation and Sediment Loss of Andit Tid Watershed

According to respondents, following transformation in land use and land cover over the study areas, the climatic condition has changed significantly. They replied that a trend towards a shorter rainy season that starts later

and finishes earlier with intensive pattern as compared to the old times. The automated installed rain-gauge data in study area supported the respondents' idea as shown in Fig. 2 which ranges from 1278 mm to 1894 mm per annum. On the other hand the annual river station discharge rate range from $1.01 \times 10^6 \text{ m}^3$ to $5.2 \times 10^6 \text{ m}^3$ and annual sediment loss of the watershed ranges from 436 ton to 3566 ton (Fig. 3).

Table 6. Impact of land use land cover change on crop productivity and Input use at household

Labels	Description	Frequency	Percent	MSE
Fertility status	Fertile	4	16.0	0.133
	Moderate	14	56.0	
	Infertile	7	28.0	
Crop failure encounter	Yes	21	84.0	0.075
	No	4	16.0	
Organic fertilizer use	Yes	22	88.0	0.066
	No	3	12.0	
Inorganic fertilizer use	Yes	22	88.0	0.066
	No	3	12.0	
Improved crop variety use	Yes	22	88.0	0.066
	No	3	12.0	
Selling agricultural products	Cereals	4	16.0	0.103
	Vegetable	3	12.0	
	pulses	3	12.0	
	Livestock	13	52.0	
	Wood products	1	4.0	
	None	1	4.0	
Feed shortage**	Yes	14	58.3	0.103
	No	10	41.7	

** Number of respondent (N) =24 having livestock

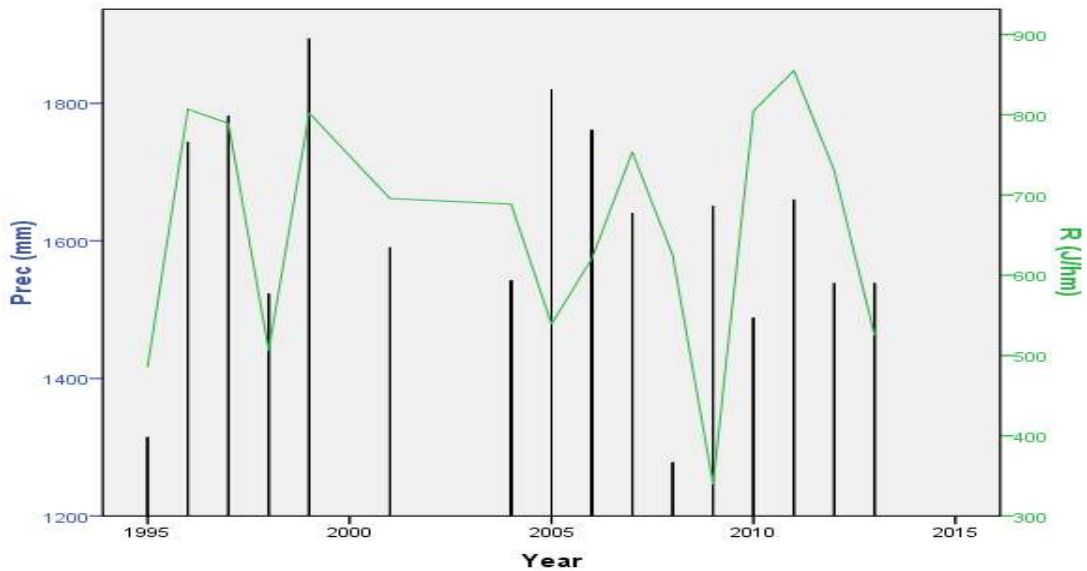


Fig. 2. Annual precipitation and rainfall erosivity (R) of the study area 1994-2013

Table 7. Impact land use land cover change on soil erosion

Labels	Description	Frequency	Percent	MSE
Soil erosion problem	Yes	22	88.0	0.066
	No	3	12.0	
Seriousness**	Very sever	6	27.3	0.201
	Sever	9	40.9	
	Moderate	5	22.7	
	Some	2	9.1	
Erosion type**	Sheet erosion	8	36.4	0.160
	Rill erosion	12	54.5	
	Splash erosion	1	4.5	
	Gully erosion	1	4.5	
Source of erosion**	Upper/top part	11	50.0	0.204
	Middle/central	5	22.7	
	Bottom/lower	5	22.7	
	Some parts	1	4.5	
Erosion pattern**	Highly increased	9	40.9	0.232
	Moderately increased	9	40.9	
	Moderately stabled	4	18.2	
	Highly increased	-	-	
Erosion Impact**	Yield reduction	8	36.4	0.105
	Removal of top soil	14	63.6	
	Increase Input	-	-	
Maintenance of SWC	Yes	22	88.0	0.066
	No	3	12.0	

** Number of Respondent (N) = 22

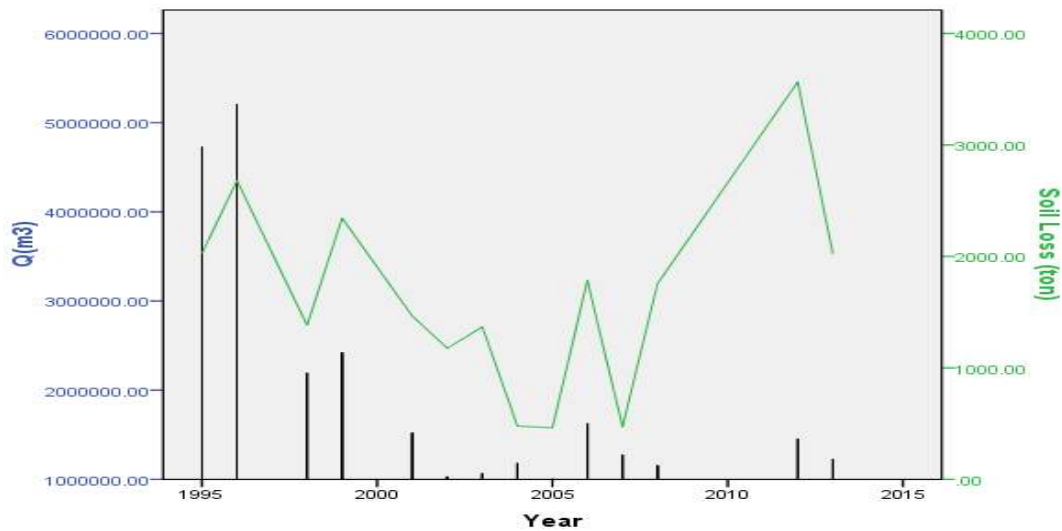


Fig. 3. Annual river discharge and soil loss of the study area 1994 -2013

4. CONCLUSION

Land is the foundation of nearly all resource use by human while its utilization varies from place to place depending on biophysical capability or suitability of the land by itself. Inappropriate management of land resources, coupled with a

growing interest and reliance on various products and services from those resources poses a challenge for managing the natural resources. Understanding the LULC change with the earth system by different modern applications system was crucial to generate information how land use and land cover change affect the land

productivity and livelihood status of the community. In the study area (Andit Tid watershed) it is obvious that there is land use as well as land cover change, while scientific evidence on LULC change scanty. Large portion of the study area is covered by cultivated land, but in some areas covered by artificial forest (eucalyptus plantation).

This study confirms that, the watershed is highly affected by land use land cover change between 1994 and 2014. During these two decades agricultural land (cultivated land) was increased by 11.33% while other land use was decreased. The result demonstrated that, the main driving force for land use land cover change are; poor land use system, and high number of family member verses low asset owned and small land holding size per household, and the community highly dependent rain-fed agriculture (96%) than other off-farm activities, and lack of awareness, adverse climatic condition (frost) and erratic rainfall.

LULC change that had seen in the watershed indicates that, farmers were forced to use local cereal varieties than improved cereals and other cash crops. Reduce fertility status, high and sever erosion pattern, frequent crop failure, use higher amount inputs, selling of their products (especially their livestock) and feed shortage for their animals' are the main impact caused by LULC change in the watershed while they try to construct and maintain their farmland by soil and water conservation structures.

Land use system, lack of soil and water conservation measure and rainfall pattern lead to crop failure and loss of top soil in the watershed. Therefore, at least at household level rainwater harvesting structures should be constructed in order to reduce crop failure, to increase irrigation options for vegetables and fruits, and to minimize soil erosion. Awareness creation on land use land cover change, provision of climate smart new improved crop varieties and cash crops must be done by research centers and development organizations. The watershed needs proper land use system by avoiding allocation of new farmland and further study on land use system analysis is required.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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