DETECTING AND QUANTIFYING LAND USE/LAND COVER DYNAMICS IN WADLA DELANTA MASSIF, NORTHCENTRAL HIGHLANDS OF ETHIOPIA

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Abstract
For sustainable land management and increased agricultural productivity, detailed and accurate information on land resources, including on land use/land cover dynamics, is required. A study was conducted in Wadla Delanta Massif to investigate land use/cover dynamics over the last four decades (1973-2014) using satellite images (1973 MSS, 1995 TM and 2014 ETM+). Global positioning system, topographical maps of 1:50,000 scale for ground verification, ArcGIS 10.2 software and ERDAS imagine 10.0 processing and analysis, supplemented with field work were used. Six land use/land cover (LU/LC) types i.e. forest, shrub, grazing, cultivated, bareland and riverbeds were identified. The results showed that there were remarkable spatiotemporal changes in LU/LC. Bareland and riverbeds increased from 17.2 to 32.30% and 1.68 to 2.61% respectively. Forest and shrub lands decreased drastically from 3.98 to 0.47% and 34.86 to 24.26% in 1973 and 2014, respectively. Agricultural and grazing lands also slightly decreased from 33.78 to 32.70% and 8.5 to 7.66% in 1973 and 2014, respectively. From 1973 to 2014, the forest, shrub, grazing and agricultural lands decreased by 90.3, 31.5, 10.08 and 3.36%, whereas the bare lands and riverbeds increased by 89.88 and 57.54%, respectively. The major contributing factors for such variations are population growth and associated needs, land tenure system, incompatible farming system, and lack of alternative energy sources. An integrated approach should be put in place in order to alleviate the current constraints and, improve agricultural productivity and food security in the study area.

Key Words: *GIS, Image classification, Remote sensing, Supervised classification*

Introduction

Land use/land cover (LU/LC) is dynamic in nature and is a key factor for understanding the interaction between anthropogenic activities with the environment. Knowledge about the nature of LU/LC change and their configuration across spatial and temporal scales is consequently indispensable for sustainable land management and

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decision making processes of comparing the current status with past events (Burnnett *et al.*, 2003). It occurs at all scales, from global, regional, local and microscopic ones. Changes can have dramatic, cumulative impacts. Land use and land cover changes are of concern to a wide variety of stakeholders, scientists, and citizens (Reis, 2008; Manandhar *et al.,* 2009).

In many instances, the terms land use and land cover tends to be exchangeable. However, there are differences. Land use refers to the human activities that take place on land or make use of land for various purposes. For example, is the land being used for commercial, industrial, recreational or agricultural purposes? It refers to the economic use to which land is put. On the other hand, land cover refers to the physical materials on the surface of a given parcel of land, such as vegetation, trees, water, or large buildings surrounded by a lawn, or other features that cover the land (Longley *et al.,* 2001; Hartemink, 2010).

Peoples' existence on the earth and their practice of modifying the landscape has had a profound effect on the natural environment (Zelalem, 2007). Due to the impacts on land management practices, economic health and sustainability, and social and political processes, changes in LU/LC are rapidly increasing, and causing adverse impacts and implications on local, regional and global scales (Prakasam, 2010). Thus, pressures to further convert or manage natural resources for human needs and attaining more of the global net primary productivity also increased (Reis, 2008; Alemayehu and Olafur, 2011). For this dynamic situation, accurate, meaningful, update and reliable information on land uses is essential for the analysis of environmental processes and understanding the problems if the living conditions are to be improved or maintained at the current levels (Selcuk, 2008). Thus, such a study will be used for land use planer and natural resource managers as a precursor to formulate and implement effective and appropriate strategies and sound plans for their own future action.

The contemporary business in this modern nation needs to have substantial information on many complex interconnected aspects of its activities to make decisions. Land use is the only aspect in this regard. Knowledge about LU/LC has also become highly significant as the nation plans to overcome uncontrolled development and deteriorated environmental quality (Hartemink *et al*., 2008; Selcuk, 2008). The main causes of LU/LC dynamics are linked to different policy issues, physical factors (slope, altitude and other), proximity factors (nearest road, settlement and other infrastructure) and other socioeconomic factors that have direct impacts on population and local level resource use patterns (Fenglei *et al.,* 2007). All have a significant power on natural ecological functions and lead to a decline of agricultural productivity, land degradation, destruction of forests, extinction of wildlife habitats and desertification (Gete, 2008; Abbas, 2010; Gol *et al.,* 2010).

Of the challenges facing the earth over the next century, the population is projected to increase by 50% and it is likely that there will also be an increase in the global standard of living (Mustard *et al.,* 2004). Anthropogenic process affects many parts of the earth's system

vis-à-vis climate, hydrology, global biodiversity and fundamental sustainability of lands (Zelalem, 2007). Through conversion and intensification of natural resources, human beings have caused an intimidation or wilderness effects in the balance of natural ecosystems (Fenglei *et al.,* 2007). As a consequence, LU/LC change is gaining recognition as key driver of environmental change.

One of the immediate challenges facing Ethiopia today is land degradation, particularly loss of vegetation cover and soil erosion which significantly contribute to low agricultural productivity (Abate, 2011). The agricultural sector in Ethiopia is being increasingly challenged with the pressure from fast growing population and diminishing natural resources (Rahdary *et al.*, 2008). Among the driving factors, high growing population accompanied with sedentary agriculture, population settlement, increased industrialization and sociopolitical instability are the most significant determinants which resulted in substantial deforestation, loss of biodiversity and undesirable changes (Diress, 2010; Menale, 2011). Due to high human and livestock population pressure, agricultural practices are pushed to rugged topography which exacerbates land degradation (Daniel, 2008).

The biophysical and socioeconomic conditions in Ethiopia have great contribution for resource deprivation. Diress (2010) and Menale (2011) revealed that during the second half of the 20th century, significant LU/LC dynamics occurred in the Ethiopian highlands. From the 1970s to 1980s, there had been a substantial decline of shrub, grazing and forest lands, and expansion of cultivated lands. By the same token, Wolde *et al.* (2007), Abate (2011) and Alemayehu and Olafur (2011) revealed that between the 1980s and 2000s the decline of shrub and forest lands continued with some improvement of vegetation cover in certain areas, and expansion of cultivated land also continued to very steep slope and marginal lands. This has led to the occurrences of recurrent drought, extensive flooding and damage on agricultural lands in Ethiopia in general and the study area in particular.

One of the prime prerequisites for better use of land is information on existing land use patterns and changes in land use through time. According to WAOR (2013), the general land classifications of the study area are plateau and plains (30%), mountainous (30%), gorges (36.5%) and other land features (3.5%). Knowledge of the present land distribution and area of such kind of classification is required for legislators, planners, regional and local governmental officials to determine better land use policy, to project utility demand, to identify future development pressure points and areas, and to implement effective plans for regional development.

In Ethiopia, limited numbers of studies have been conducted on LU/LC changes. Large areas, which were once under vegetation cover are now changed to cultivated land and have exposed to soil erosion resulting into environmental degradation and serious threat to the land (Amare, 2007). The north central highlands of Wello in general and the Wadla Delanta Massif in particular have seriously suffered with ecological degradation and over carrying capacity of

people and livestock. The area has been one of the origins where people settled earlier, as a result, land degradation and drought are common phenomena (Belay, 2002; Zelalem, 2007).

There have been very limited studies of similar topic at the study area. Therefore, this study focused on the LU/LC dynamics at the Wadla Delanta Massif in the north central highlands of Ethiopia. The objective of the study was to generate spatiotemporal data on LU/LC dynamics and land cover maps to show the overall situation of the area and to provide basic information for policy makers and resource managers who are responsible to take on mitigation measures in the area. It was conducted at the Wadla Delanta Massif in northcentral highlands of Ethiopia to detect and quantify the rates and extents of LU/LC dynamics from 1973-2014.

Materials and Methods
Description of the Study Area

The study area is found at the Wadla Delanta Massif, north central highlands of Ethiopia which is located at 11° 23′ 30.74″ to 11° 50′ 52.45″ latitudes and 38° 58′ 30.30″ to 39° 27′ 44.78 longitudes with altitude that ranges from 1500 to 3819 meters above sea level at the bottom of the valleys (Gosh Meda) and the tip of the mountain (Mekelet), respectively. It is located at about 499 km to the north of Addis Ababa, capital city of Ethiopia, and 98 km to the northwest of Dessie town in South Wello Zone (Figure 1). According to WAOR (2013), the total area of the District is 105,678 ha, stretching from lowland to highland, much of it being in the mid-altitude ranges dominantly plateau plains. Average land holding size is one hectare per household (0.75 ha for crop production and 0.25 ha for grazing). Among the total area of the District, 24025 ha was covered by this study along toposequence which was mainly situated in plain areas with altitude between 2600 to 3500 masl in the North , Northwest and West from the center of the District town (Wegel Tena).
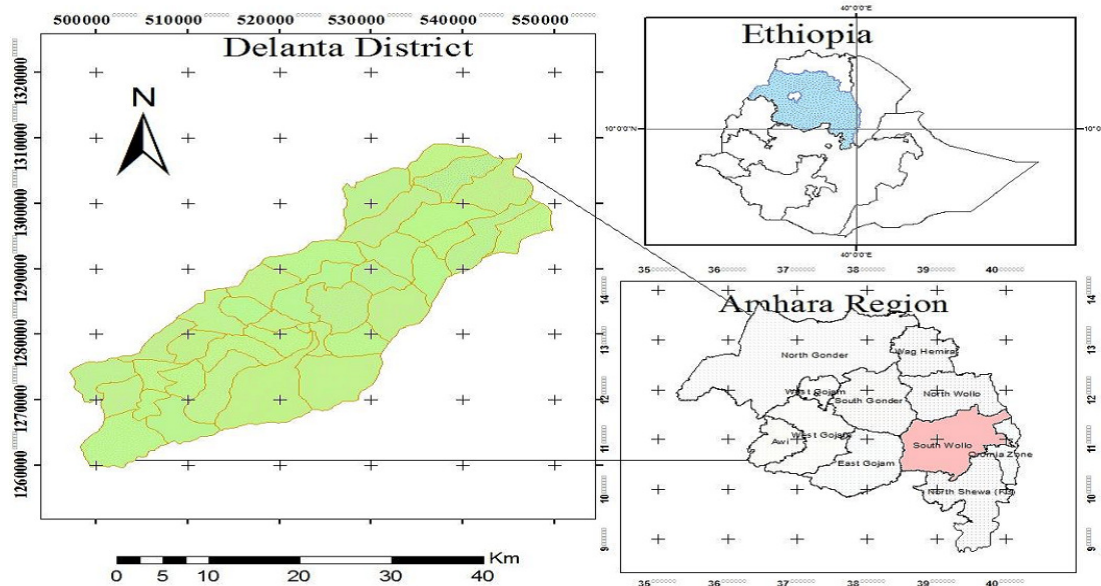

Figure 1: Location map of the study area

Geomorphology and Topography of the Study Area

The major landforms of the study area comprise extensive plateaus, chains of hills with mountainous ridge, river-valleys and very deep gorges at the boundary. Almost it is oval in shape with dendritic drainage pattern, steep ridges, and numerous convex hills at the plain area and gorges at the boundary. About two-third of the study area embracing altitudes range between 2100 to 3500 masl are highly populated (ref.). The remaining one-third of the area is mainly located along the river valleys on the east, southeast, north and northwest escarpments. The topography of the highland plateaus especially, those elevated above 3000 m which are dominated by hills (Figure 2). According to WAOR (2013) reported, the general classification of the area was about 30% mountainous, 30% plains, 36.5% gorges and 3.5% other land features.

Geology and Soils of the Study Area

Geology of the study area was characterized by the trap series of tertiary periods, similar to much of the central Ethiopian highlands (Mohr, 1971). According to Dereje *et al.* (2002), the area is covered by Oligocene rhyolite and very thick ignimbrite units encompassing predominantly of alkaline basalt with numerous inter-bedded flow of trachyte. The granite, gneisses and basalt rock types exist in the area forming part of the basement complex and most of the soils are basaltic parent material. Soils of the study area are greatly influenced by topography with high surface runoff during the main rainy season. The soils are classified as Mazi-Pellic Vertisols, Mazi-Calcic Vertisols, Haplic Cambisols and Mollic Leptosols (Nahusenay *et al.,* 2014).
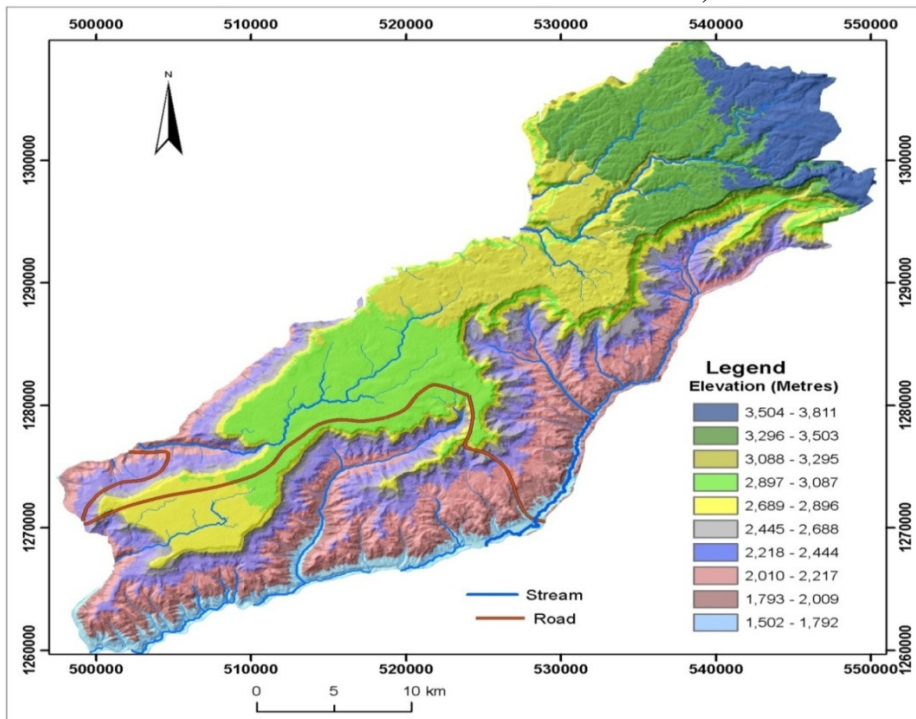

Figure 2: Elevation map of the study area

Climate and Land Use Systems of the Study Area

The traditional agro-climate classification of the study area falls in all of the categories that basically correlated with elevation. These are Kolla, Woina-dega, Dega and Wurch. The climate of the area is characterized by dry seasons (from October to February cold-dry and March to June hot-dry) and wet season (from mid-June to September). The rainfall pattern is bimodal with peak periods from mid-July to early September. For fifteen years (1999-2013) mean annual rainfall is about 812 mm of which 60-70% is received in summer (*Kiremt)* and 30-40% in the spring (*Belg)* seasons. The land use systems are both private (farming land) and communal (grazing land) land holdings which can be identified through land use patterns. Cultivated and grazing lands are the major land use types in the area which accounts for 21.6% and 8.2%, respectively. Among the total area, the largest proportion (45%) of the land is currently unutilized and the remaining (25.2%) is covered by shrub/bush, and natural and plantation forests.

Data Sources and Materials

For this study, different datasets were organized and used from satellite imageries and topographic maps. ERDAS Image 10.0 and ArcGIS 10.2 software for analysis and mapping were utilized. Moreover, the 1:50,000 topographic map was scanned, geo-referenced and merged to obtain a consistent set of baseline information. These maps allowed the verification of LU/LC delineation using additional point information and linear features vis-à-vis contours, roads and rivers. The dates of all images were chosen to be as closely as possible in the same cropping season and from comparable climatic conditions. This enhances the interpretation as the spectral reflection of land cover is easier to compare (Table 1).

Table 1: Data sources and materials

Satellite Image Data				
Data type	Sensor	Acquisition date	Spatial resolution	Path/row
Landsat	MSS	1973-01-31	57×57 meter	168/52
Landsat	TM	1995-01-05	30×30 meter	168/52
Landsat	ETM$^+$	2014-01-21	30×30 meter	168/52

ETM$^+$ = Enhancing thematic mapper plus; MSS = Multispectral Scanner; TM = Thematic mapper

The Landsat TM sensor (1995) provided several improvement over the MSS sensor (1973) including: higher spatial and radiometric resolutions, finer spectral bands with seven (as opposed to four in MSS) spectral band, which permitted the data for the branch to be automatically co-registered as they were acquired. The ETM$^+$ and TM were collected using a 30 meter ground resolution cell except for the thermal band with 120 m resolution (Table 1).

Remotely Sensed Imagery and Pre Processing

Changes in land cover were measured using time series of satellite data with a band combination of 4, 3, 2 and channels 3, 2, 1. All images were geo-referenced with essential annotations; re-projected to the new Adindan UTM Zone 37 N

Datum and were all re-sampled to a common nominal spatial grid of 30 m resolution using the nearest neighbor technique. This was to facilitate the operations that would be required for the change detection analysis. The root mean square errors of re-sampling and re-projection of the images were less than 0.5 pixels, equivalent to approximately 7–15 m.

Image Processing and Classification

Assessment of LU/LC dynamics was done by adopting a classification scheme for the Landsat images and carrying out a supervised classification. For this reason, the maximum likelihood classifier for the spectral classification of the landsat images was used. It is the most widely adopted parametric classification algorithm (Currit, 2005). The training data for supervised classification were gathered using pixel reflectance of each identified LU/LC class. The classification method assumes that statistics for each LU/LC class is normally distributed and thus groups pixels into a specific class that has maximum probability (Jensen, 2007). Taking into account the spectral characteristics of the satellite images and existing knowledge of land use of the study area, six LU/LC classes were identified and classified for three periods.

Post Classification Processing and Assessment

The post-classification refinement was developed and applied to reduce classification errors. It requires

$$r = \frac{\Delta A}{nA_o} \times 100$$

where: r = Growth rate; ΔA = Change in area extent between 1973 and 1995, and 1995 and 2014; n = Number of years (interval between 1973 and 1995, and

rectification and classification of each remotely sensed image. Through this framework the misclassified pixels of maximum likelihood classification were re-evaluated and correctly reclassified. To further process the images, pixels were assigned to categories based on their reflectance characteristics with range of 28, from 0 (black) to 255 (white), having digital number of 8 bits. In classifying the sample set, the maximum likelihood classification method was adopted with supervised classification based on the knowledge of the study area.

A combination of information collected from the field, topographic map and local people knowledge and satellite images was used in the analysis of LU/LC change. The area comparison for the three period series of images was analyzed based on the LU/LC change statistics in identifying the percentage change, trend and rate of changes. These analyses were carried out to find the rate and pattern of changes that occurred in the study area. The rate of change could be achieved by subtracting the total area of 1973 from 1995, and 1995 from 2014 with multiplying by 100, which could be positive (increasing) or negative (decreasing). The following equation is adapted from Jinadu (2004) who he worked on urban expansion in Abuja and gave the difference in area extent and the growth rate of each land use. His formula was expressed by:

1995 and 2014); and A_0 = Area extent of the base year (1973 and 1995).

Accuracy Assessment

In parallel to the remote sensing work; field work was carried out to collect data for Ground Control Points

(GCPs). The field data were collected by measurements. During these field trips, both GCPs and the Area of Interest (AOI) of study area were selected, demarcated and measured by Global Positioning System (GPS). To evaluate the accuracy of the classification system, 1020 reference test pixels were identified and confusion matrix was used. Confusion matrix indicates the nature of the classification error. The accuracy assessment was performed for the 2014 LU/LC map which was adopted by a stratified random sampling method.

In this study, the overall accuracy, producers and users accuracy and Kappa coefficient analysis were considered to perform classification accuracy assessment based on error matrix analysis using the simple descriptive technique. The overall accuracy is defined as the sum of correctly classified pixels (diagonals) divided by the total number of randomly generated reference pixels (points) used for the assessment in the error matrix and Kappa coefficient. The error matrix is expressed in terms of user's accuracy and producer's accuracy while Kappa coefficient is a measure of the interpreter agreement (Foody, 2002). The producer's accuracy and user's accuracy can be calculated based on confusion matrix including overall accuracy and Kappa coefficient (Congalton and Green, 1999). They are used to estimate the accuracy of each individual class. The producer's accuracy results from the total number of correctly classified pixels in a class divided by the total number of reference pixels available for that class. This measure shows that the probability of a reference pixel correctly classified. In contrast, the user's accuracy is defined as the total number of correctly classified pixels in a class divided by the total number of pixels that were allocated to that class. This value provides information about the probability that the classified pixels from LU/LC map accurately matches with the referenced data of that class on the ground (Jensen 2005). The Kappa coefficient, which is one of the most popular measures in addressing the difference between the actual agreement of classified map and chance agreement of random classifier compared to reference data, was also calculated. As stated by Lillesand *et al.* (2004), Kappa coefficient explains the proportionate reduction in error generated by classification process compared with the error of completely random classification which can be expressed by the following equation:

$$\mathrm{K}hat = \frac{\mathrm{N}\sum_{i=1}^{\kappa}\mathrm{X}_{ab} - \sum_{i=1}^{\kappa}\left(\mathrm{X}_a \times \mathrm{X}_b\right)}{\mathrm{N}^2 - \sum_{i=1}^{\kappa}\left(\mathrm{X}_a \times \mathrm{X}_b\right)} \qquad (2)$$

where, K*hat* = Kappa coefficient; N is sample size; $\sum_{i=1}^{k}\mathrm{X}_{ab}$ is observed accuracy and

$\sum_{i=1}^{k}\left(\mathrm{X}_a \times \mathrm{X}_b\right)$ is chance accuracy
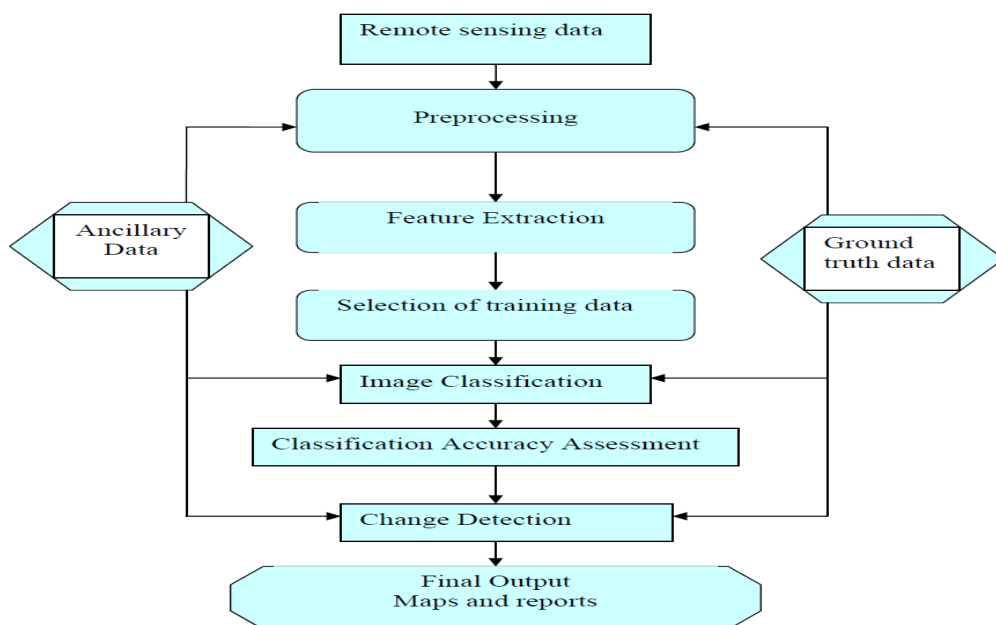
Figure 3: Flowchart of procedure for deriving LU/LC data and change of detection from remotely sensed data

Results and Discussion
Land Use/Land Cover Changes

The results of this study showed that the forest and grazing land covers over the years showed irregular trends (decrement and increment), whereas the agricultural land was vice versa.. This might be due to the plantation of Eucalyptus. The shrub land showed, during all the three consecutive years, a regularly decreasing trend especially during 2014 where there was a drastic decrement by 31% as compared to the previous land coverage, whereas the bareland and riverbed showed frequent increment for all the consecutive years. The increment of bareland and riverbed from 1973 to 1995 were by 36 and 43%, and from 1995 to 2014 by 39 and 10%,

respectively. For the last four decades, the barelands/open spaces were increased by 88% and riverbed by 57% of the total area (Table 2). This might be due to subsequent cultivation and the occurrence of repeated drought accompanied with unwise use of land resources, which led to degradation of significant area of land.

As results in Figure 4 indicated, in 1973 about 69% of the total area was covered by shrub and agricultural lands, which contained the largest share of LU/LC types, whereas 19% of the land is covered by bare lands and riverbeds, and the remaining 13% was covered by forest and grazing lands indicating that much of the area was covered by green vegetation in 1973.

Table 2: Area coverage of land use/cover classification (1973-2014)

| Land use/cover	1973		1995		2014		1973-1995		1995-2014		1973-2014	
	Area		Area		Area		RAC		RAC		RAC	
	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%
Agriculture	357.0	33.8	375.9	35.6	345.4	32.7	19.0	5.3	-30.6	-8.1	-11.6	-3.2
Grazing land	89.8	8.5	53.1	5.0	81.0	7.7	-36.7	-40.9	27.8	52.4	-8.9	-9.9
Forest land	42.0	4.0	2.8	0.3	4.9	0.5	-39.2	-93.3	2.1	76.1	-37.1	-88.3
Shrub land	368.5	34.9	353.4	33.4	256.3	24.3	-15.2	-4.1	-97.1	-27.5	-112.3	-30.5
Bare land	181.8	17.2	246.3	23.3	341.6	32.3	64.5	35.5	95.2	38.7	159.8	87.9
Riverbed	17.7	1.7	25.3	2.4	27.7	2.6	7.6	43.0	2.4	9.6	10.0	56.7
Total	1056.8	100	1056.8	100	1056.8	100						

RAC = Rate of area change
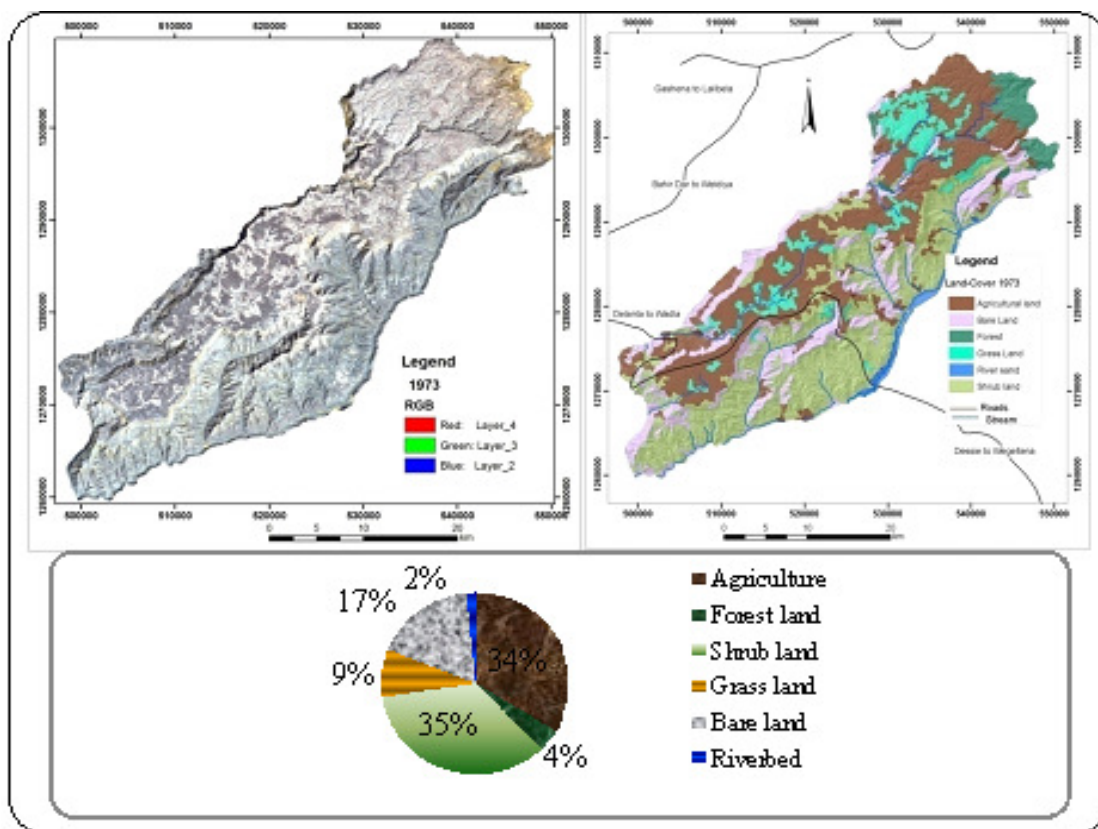
Figure 4: Landsat-MSS image of land use/land cover in 1973

The 1st Landsat image false color composite before processing; the 2nd Landsat classified subset image; and the 3rd Area coverage and percentage of land use/land cover in 1973.

As Figure 5 shows similar trends as that of 1973 period LU/LC classes. The cultivated and shrub lands accounted the greatest share of LU/LC classes, which covered 69% of the area. On the other hand, the area coverage of forest and grazing lands diminished in proportion, which accounted for only 5 and 0.3%, respectively. The fastest growth of cultivated land up to 36% might be

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attributed to the conversion of forest, shrub and grass lands to agricultural land as a result of rapid population growth. Moreover, there was an expansion of bare land from 17.2% in 1973 to 23.31% in 1995 due to the severity of drought in Wello area during this period.
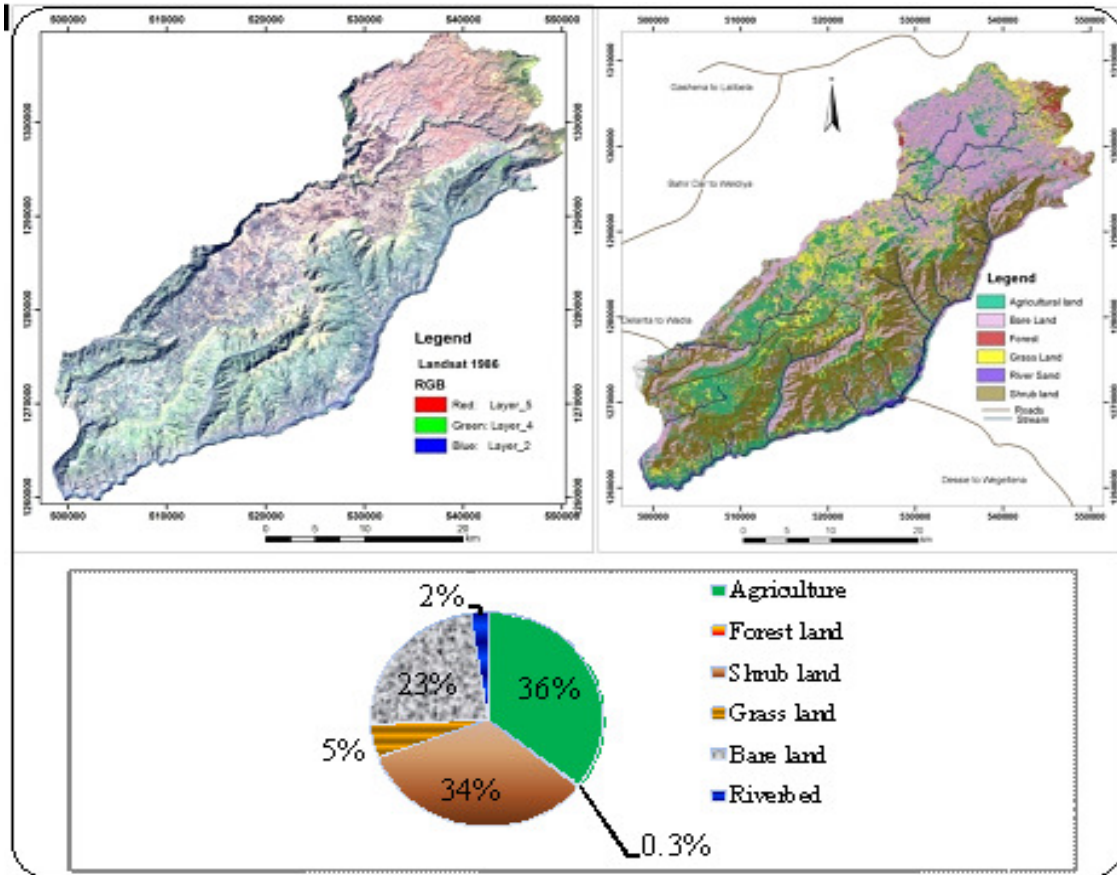

Figure 5: Landsat-TM image of land use/land cover in 1995

The 1st Landsat image false color composite before processing; the 2nd Landsat classified subset image; and the 3rd Area coverage and percentage of land use/land cover in 1995.

As to the results indicated in Figure 6, the greatest share of the study area was covered by cultivated and bare lands, which accounted for 33 and 32%, respectively, while the shrub land covered 24%. The smallest area was covered by forest, riverbeds and grazing lands accounting for about 0.5, 3 and 8%, respectively of the total area. Agriculture covered the largest area in 2014, which indicates the continuous conversion of other land cover types into cultivated land.
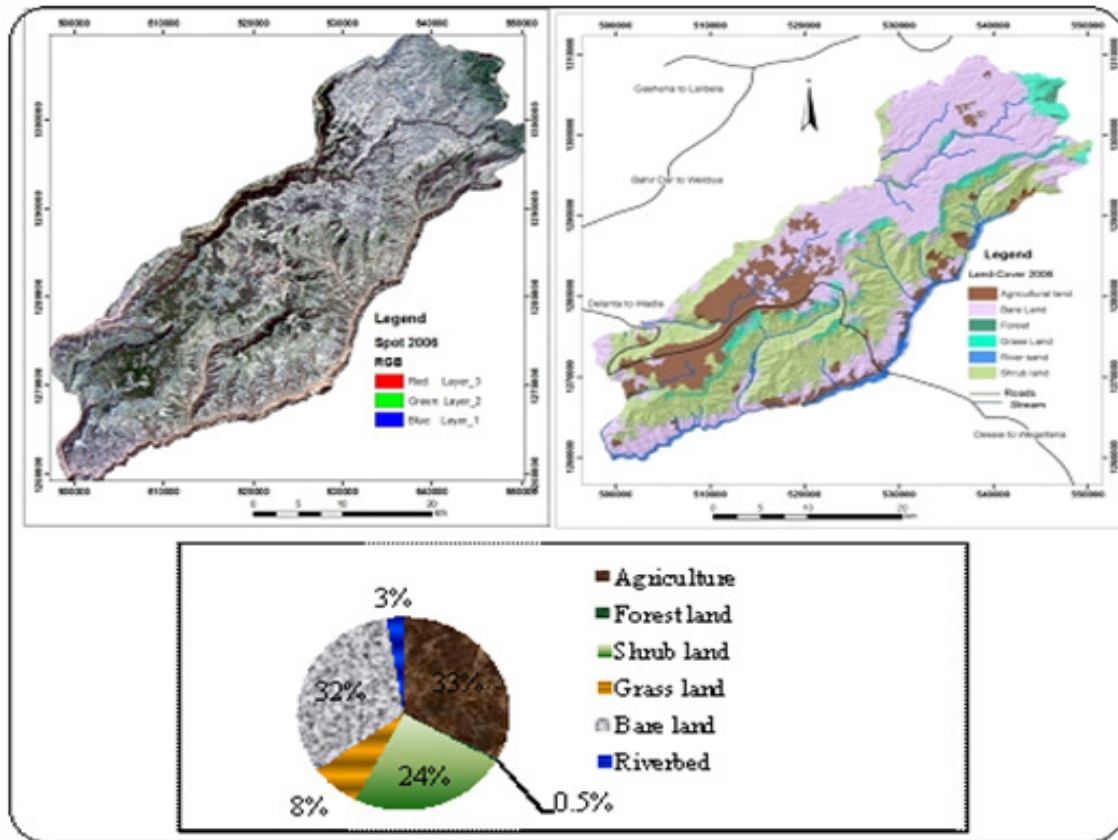
Figure 6: Landsat-ETM+ image of land use/land cover in 2014

The 1st Landsat image false color composite before processing; the 2nd Landsat classified subset image; and the 3rd Area coverage and percentage of land use/land cover in 2014

Analysis of the Extent, Trend and Rate of Land Use/Cover Change

The results of the LU/LC analysis indicate that, in all periods, bare/open space and riverbed areas showed an increasing trend, while the rest showed decrements in area coverage. For the period 1973-1995, the cultivated, bare and riverbed showed an increment by 0.24, 1.6 and 2.0%, respectively, while the rest showed decrements. In the second time span (1995-2014), except for agriculture and shrub lands, the rest showed increments (Table 3). The expansion of cultivated land at the expense of other land use/cover types was also indicated in various reports based on similar studies conducted in different parts of the country (Kebrom and Hedlund, 2000; Belay, 2002; Gete, 2008).

Table 3: Extent, trend and growth rate of LU/LC change for a period 1973-2014

Land use Category	1973-1995			1995-2014			1973-2014		
	Area change (km^2)	Rate of change (km^2/yr)	(%)/yr	Area change (km^2)	Rate of change (km^2/yr)	(%)/yr	Area change (km^2)	Rate of change (km^2/yr)	(%)/yr
Agriculture	18.76	0.85	0.24	-30.36	-1.52	-0.43	-11.6	-0.28	-0.08
Grazing land	-36.69	-1.67	-1.86	27.83	1.39	2.76	-8.86	-0.21	-0.24
Forest land	-39.21	-1.78	-4.24	2.13	0.11	4.00	-37.08	-0.88	-2.15
Shrub land	-15.2	-0.69	-0.19	-97.09	-4.85	-1.45	-112.29	-2.67	-0.75
Bare land	64.54	2.93	1.61	94.8	4.74	2.03	159.34	3.79	2.14
Riverbed	7.6	0.35	1.96	2.31	0.12	0.48	9.91	0.24	1.37

In the last four decades, more land was degraded and abandoned, and the forest cover decreased. The rate of change in the first time span period was faster and higher than the second time span. The overall changes showed that the bare and riverbed areas were increased by 2.14 and 1.37% per year, respectively, while forests, shrub, grazing and cultivated lands (to some extent) were reduced. The observed trends of increasing bare and riverbed areas and decreasing forest land in the area could be due to population growth which forced farmers to till and expand their lands to greater extent than what they were doing before to cope up with the conditions and to sustain their life and the occurrences of recurrence drought especially on the upper topography areas i.e. *Angot* and the surroundings.

This finding was consistent with the finding of Kebrom and Hedlund (2000), who reported that forest coverage of the Kallu District was diminished by 51% from 1958-1995. The reduction of forest and shrub lands and theirs modification to other lands was fast and visible phenomenon; and contrasting with Woien (1995) and Crummey (1998) who reported that a substantial increase of forest biomass in Wello region as a whole is observed at present than what was in the 1930s. The patterns showed the tendency towards covering more land with annual crops, while tree plantations became lesser at the expense of shrub-grazing lands.

Accuracy/Validation of the Classification Results

The overall accuracy derived from the stratified random sampling method for the 2014 classified images showed 88.43% with an overall Kappa statistic of 0.8619 for Landsat 2014 ETM$^+$ image. This means that 88.43% of the LU/LC classes are correctly classified. The report derived from the accuracy assessment cell array shows that the classification has resulted in more than 88% accuracy. In terms of producer's and user's accuracy, all classes were over 83% accurate (Table 4).

Kappa coefficient of more than 0.8619 for each classified image. Considering the categories accuracy, the stratified random sampling method provided high accuracy assessment in forest and shrub lands with an accuracy of > 90%. It also provided high accuracy of 88.02, 87.88, 87.12 and 85.48% for agriculture, grazing, riverbed and bare lands, respectively. As per Jensen (2005) and Lillesand *et al* (2004), the Kappa values of more than 0.80, between 0.40 and 0.80 and the values less than 0.40 indicate that there is good, moderate and poor classification performance, respectively. Based on this judgment, this study has showed high accuracy assessment for the map of 2014.

Table 4: Accuracy assessment of the 2014 land use land cover classification

Land use type	Agriculture	Grazing	Forest	Shrub	Bare	Riverbed	Row total	CE	UA
Agriculture	**169**	11	0	0	6	5	191	11.52	88.48
Grazing land	8	**145**	0	3	12	6	174	16.67	83.33
Forest land	0	0	**133**	13	0	0	146	8.90	91.10
Shrub land	5	0	11	**154**	0	0	170	9.41	90.59
Bare land	2	6	0	0	**159**	10	177	10.17	89.83
Riverbed	8	3	0	0	9	**142**	162	12.35	87.65
Column total	192	165	144	170	186	163	**1020**		
OE	11.98	12.12	7.64	9.41	14.52	12.88			
PA	88.02	87.88	92.36	90.59	85.48	87.12			

Overall Accuracy = 88.42% with a Kappa Coefficient (K_{hat}) of = 0.8619; OE = Omission error; CE = Commission error, PA = Producer accuracy and UA = User accuracy (UA).

Land Use/Cover Change Drivers

Land use/cover changes are not only the cumulative effects of nature but also results of a number of interacting variables and processes. The distribution of various LU/LC types are primarily controlled by natural (slope gradient, soil depth, terrain configuration, drought and famine) and anthropogenic factors (Daniel, 2008; Diress, 2010; Abate, 2011). Population pressure, land tenure, farming systems and demand for sources of energy are among the major anthropogenic driving forces in the study area.

Population Pressure

According to the CSA (1994) census, the total population of the study area was 117,762, and the 2007 census showed that the population was 128,547. It increased by 9.2% as to the 2007 census (CSA, 2008). Such rapid population growth in the area has exerted pressure on the existing limited land resources through increasing demand for food, fuel, construction materials, and other necessities. The considerable increases in demand for food has resulted in an expansion of croplands through infringe untilled areas, including forests, shrub and marginal lands.

Most of the interviewed Key informants (83.5%) responded that agriculture was significantly expanded during the *Derg* regime and some of the respondents (14.5%) also pointed out that the expansion of agriculture also took place during the Ethiopian People Revolutionary Democratic Front regime. The expansion of croplands toward forest, shrub and marginal areas, including continuous and over cultivation, has resulted in deforestation and soil degradation. Results have showed that during the analysis period the degraded land was increased by 2.52% per year. This was mainly attributed to human induced factors mainly high population growth. As a result, the reduction of fallowing lands, soil exhaustion, cultivation of shallow and steep slope soils, over exploitation of forest and grazing lands have worsen the prospects for future agricultural growth.

Land Tenure System

Another major factor driving changes in the study area is the changing land tenure policy. Traditionally, before 1975, the land was owned by a few landlords, and this system made it possible to practice landless community, which ensured sustainable land resource production as well as survival of ecological unit. However, the tenants (*chisegna*) and petty landowners (*gebar*) did not have their own land. This gave

birth to the 1975 revolution and the land reform proclamation in which the landless people got their own land without land ownership certificate.

As a result of government policy of ensuring security of land tenure to facilitate development, a few landlords owned land and subdivided among individual ranches which created new households. In consequence, the land fragmentation, and eroded land tenure security created a condition whereby farmers lost interest in land improvements. After the downfall of the Military Government in 1991, the land tenure again changed in which subdivision of individual farms took place for the second time. The results of the field interviews revealed that these land tenure changes have affected societal acuity and land use systems.

Nowadays, the land tenure system of Ethiopia including the study area is uncertain about farmers' security of rights to the land which focused on community short term needs rather than long visualization. All these have contributed to the current ecological damage, over intensive land uses and poor land management practices.

Another problem of the land tenure system was land fragmentation. Information from the interviews revealed that the majority of the community have less than one hectare of land (Table 5) which are found at various locations. A farmer has two or more part of a set of land in the study area. This land fragmentation has drawbacks on land management, time wastage and intensive/extensive cultivation.

Table 5: Plot size distribution by Agro-ecology

Plot size	Upper		Middle		Lower		Total	
	NRP	%	NRP	%	NRP.	%	NRP	%
< 1 Timad*	2	16.7	3	18.8	0	0.0	5	12.5
One Timad	3	25.0	3	18.8	2	16.7	8	20.0
2-3 Timads	6	50.0	8	50.0	5	41.7	19	47.5
4-5 Timads	1	8.3	2	12.5	4	33.3	7	17.5
> 5 Timads	0	0.0	0	0.0	1	8.3	1	2.5
Total	12	100	16	100	12	100	40	100

* 1*Timad* = approximately 0.25 hectares, and NRP = Number of respondents

The results indicated that about 20% of the households have utmost one *Timad* (0.25 ha). The majority of the respondents have 2-3 *Timads* (48%). The rest of the respondents were categorized below one (12.5%), from 4 to 5 (17.5%) and above five (2.5%) *Timads*. Generally, 87% of the respondents have less than one hectare of land. In terms of agro-ecology, peasants in middle elevation have less farm plots than the upper and lower elevation areas. This has something to do with high population pressure.

Therefore, land degradation and soil fertility are expected to decrease more rapidly in such type of plots due to more exploitation.

Farming system

The farming system is an influential factor which leads to change LU/LC complex. It involves subsistent traditional and mixed type crop and livestock husbandry. The expansion of croplands has resulted in the destruction of forest and shrub lands as well as grazing areas. Similarly, the expansion of croplands into

grazing lands has led to the decline of livestock production.

Nowadays, most part of the land in the study area, which is suitable for crop production, is already cultivated. For the future, the only option to increase crop production is to use croplands more intensively. Due to shortage of land, farmers are obligated to shift from extensification to intensification by increasing labor and other inputs. However, farmers do not have access to fertilizers due to their prohibitively high prices. The farmers did not use their available supplies of manure and crop residues on fields, rather they have used them as fuel and to feed livestock. As a result, there is no return of organic matter to restore the fertility of land used for growing annual crops. This has resulted in declining soil fertility and a drop in agricultural productivity. In most highland parts of Ethiopia, livestock production goes side by side with crop production and is the major source of plough power and source of cash income in the study area.

According to WAOR (2013) report and the focal group discussion of the key respondents, the livestock production showed a decreasing trend due to shortage of feed, diseases and selling. Nevertheless, most of the farmers in the area did not have any oxen, some had only one ox and a few farmers had two oxen per household. This has created serious problems for efficiency of farming activities. The crop residues (100%), Hay (70%), grazing (60%) and weeds (55%) are the main livestock feed sources in the area (Table 6). The shortage of livestock fodder is primarily attributed to the drought and shortage of rain. Following shortage of livestock feed, over population and unbalanced carrying capacity, small farmland holding per family that limits presence of crop residues; poor livestock management like free grazing is applied. All these have contribution for LU/LC changes in the area.

Table 6: Sources of livestock feedings by agro-ecology zone

Feeding types	Upper		Middle		Lower		Total	
	NRP	%	NRP	%	NRP	%	NRP	%
Crop residues	12	40	16	53	12	30	40	100
Grazing	10	30	6	18	8	33	24	60
Hay	9	36	12	48	7	25	28	70
Weeds	6	26	11	48	5	23	22	55
Sorghum stall	0	0	3	4	11	79	14	35
Others*	5	13	6	15	7	39	18	45

Source: Based on Field Survey; NRP = Number of respondents; *a = *Attella* (by- product of local beer), guassa (type of grass), chopped *kosheshilla and beles (thorn and cactus)*, root of *sama*, salt, hillside grazing, browse, grain, *etc.*

Sources of Energy

Animal dung (100%) and fuel wood (80%) have been the most important energy sources (biofuels) in the study area (Table 7). The increasing demand for fuel wood in the absence of alternative sources of energy has led to the destruction of forest and shrub as well as the use of crop residues and animal dung for fuel rather than using as sources of organic fertilizer to replenish soil fertility. Similar findings were reported by Gete (2008), about 95% of the biomass is obtained from fuel wood, cattle dung and crop residues. One of the immediate impacts of the thinning and

destruction of the shrub land is shortage of fuel wood and construction materials for the rural community. This condition forces farmers not only to travel very long distances to collect wood, but also increasingly burn crop residues and organic manure for cooking and heating. This has led to the decline in soil fertility and productivity of croplands as the action leads to depletion of organic matter in the cultivated soils.

Table 7: Source of household energy consumption

Energy types	Upper		Middle		Lower		Total	
	NRP	%	NRP	%	NRP	%	NRP	%
Animal dung	12	30	16	40	12	30	40	100
Wood	8	25	13	41	11	34	32	80
Crop residue	4	18	7	35	9	46	19	49
Bush	3	19	5	34	7	47	15	37
Gas/ kerosene	8	31	10	39	8	30	26	64

Source: Based on Field Survey; NRP = Number of respondents;

Conclusions

Over the last four decades, significant change in land use/land cover has occurred in the study area. The overall changes showed that the bare and riverbed areas increased, while the forest, shrub, grazing and cultivated lands reduced in area coverage. The rate of change in the first period was faster and higher than the second period. The major contributing factors include population pressure, land tenure, incompatible farming system, and lack of alternative energy sources. An integrated approach should be followed in order to alleviate the current constraints and ensure sustainable use of the limited land resources in the study area.

Acknowledgement

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