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Land Use/Land Cover Dynamics in Upper Ribb Watershed, Lake Tana Sub Basin, Ethiopia

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Research Article

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ABSTRACT

Population growth causes land and water resources degradation in the Ethiopian highlands by changing the land use and land cover of the area. Land use/land cover change has been one of the factors responsible for altering the hydrologic response of watersheds. Various water resources projects planning and implementation will require knowledge of the extent of these changes on catchment hydrology. This study assesses the land use and land cover dynamics in Upper Ribb watershed. The land use land cover change analyses for three different years of 1973, 1995 and 2016 were performed using ERDAS Imagine 2014. An accuracy assessment was done for the 2016 land use and land cover classification and the Kappa coefficient, K=0.92 which indicates the perfect classification. During this study, most parts of the bush/shrubland were changed to grazing and cultivated land. The overall 43 years period (1973-2016) study shows that there was a dramatic increase in cultivated lands with 29.947%. On the other hand, bush/shrublands were decreased by 34.195% for this study period.

INTRODUCTION

Land use/cover dynamics and subsequent conversion lead to loss of biodiversity, deterioration in the physical and chemical properties of soil which causes degradation of the land [1].

Land use/cover changes are highly pronounced in the developing countries that are characterized by agriculture-based economies and rapidly increasing human populations. It is caused by a number of natural and human driving forces [2]. Natural effects such as climate change are only over a long period of time, whereas the effects of human activities are immediate and often direct. From human factors, population growth is the most important in Ethiopia [3] as it is common in developing countries. Population growth has a significant effect on land degradation, poverty and food insecurity in the northern Ethiopian highlands [4].

Some 85% of the population lives in rural areas and directly depend on the land for its livelihood. This means the demands of lands are increasing as the population increases.

Population growth causes degradation of resources particularly forests that rely on the available land. Not only have this but poor land use practices and improper management systems played a significant role in causing high land degradation. So far limited measures have been taken to combat the problems.

The knowledge how land use/cover would be changed as time goes will enable local governments and policy makers to formulate and implement effective and appropriate response strategies to minimize the undesirable effects of future land use/cover change or modifications.

This study aims application of ERDAS Imagine 2014 for classification of land use and cover change over the past 43 years in the Upper Ribb watershed. The main objective of this study was to analyze the land use and land cover dynamics between 1973 and 2016 in Upper Ribb Watershed.

Description of Study Area

The Upper Ribb watershed is located in South Gonder Zone of the Amhara National Regional State of Ethiopia. It is located with geographical coordinates of 12°35' to 13°54' north and 34°59' to 41°25'east latitude and longitude respectively (Figure 1). The Upper Ribb watershed originates from high (Guna) mountain at an elevation of 4090 m.a.s.l and drains to the northeast part of Lake Tana. It covers an area of 678.15 km^2.

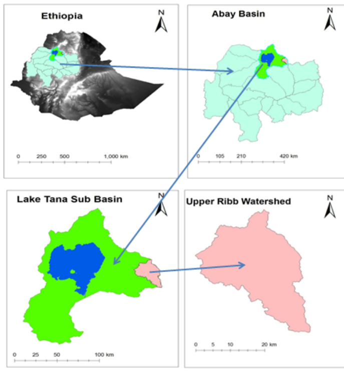

Figure 1. Location of the upper ribb watershed.

METHODS

The general methodology followed for this study consist of the following major activities.

Ground truth data (ground control points) were collected by asking the local elder man for the 1973 and 1995 years and an identification of the different types of the land cover of the study area for the recent year 2016 using GPS.

After the collection of necessary data, image classification and change detection analysis were done to identify land cover changes by processing the selected year image data.

Basically, the general methodology for the study can be described by the following flow Chart (Figure 2).

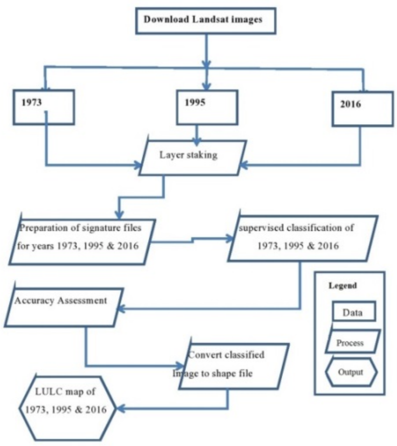

Figure 2. The framework of the methodology used.

Land use Land Cover Data Collection and Analysis

Land Use and Land Cover (LULC) data in Upper Ribb Watershed were acquired from USGS earth explorer. The major data source for land cover/use image is where free Landsat image is available. Four multi-temporal remotely sensed images were acquired for change detection for this study, including Landsat MSS/RBV 1973, Landsat TM 1995 and Landsat OLI/TIRS 2016. These images were downloaded in zipped files and extracted to Tiff format files. The satellite images used for this study were taken in the dry season. The dry season was selected since the satellite images were in

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good quality (free of cloud cover), easy for identification of cultivated lands and grazing lands. The process of detecting LULC from the satellite images was through image processing and classification of images.

LULC classes were determined based on the information acquired from previous knowledge, field observation of the sample areas and ground control points.

Image Processing

Landsat images were acquired in grayscale and a different image was downloaded for each one of the bands. By creating a composite image, the images could be displayed in color, most specifically in RGB style (Red, Green, and Blue). Displaying bands in the RGB format allows seeing different features within a scene and becoming more familiar with the scene to identify informational classes like urban areas, forests, agriculture, and water bodies. But this color may not look more natural. To display the composite image as in natural colors (a true color image) it must be combined. This was done through ERDAS Imagine by making layer stacking of images.

A layer stack is often used to combine separate image bands into a single multispectral image file. In order to analyze remotely sensed images, the different images representing different bands must be stacked. This allows different combinations of RGB to be shown in the view. After stacking the Landsat image sub-setting of upper ribb watershed satellite image was performed using the layer stacked images by the delineated watershed shapefile.

Sub-setting is the process of clipping or cutting out a portion of an image for the area or image of interest (Table 1).

Table 1. Description of Landsat images.

Acquisition date	Sensor	Resolution (m)	Producer
March 26,1973	MSS	30	United State Geological Survey (USGS)
March 21, 1995	TM	30	United State Geological Survey (USGS)
April 16 , 2016	OLI	30	United State Geological Survey (USGS)

Land Use and Land Cover Classes

Before the analysis is started, land use and land cover change studies usually need the development and the definition of homogeneous land use and land cover units. These have to be differentiated using the available data source such as remote sensing, any other relevant information, and the previous local knowledge.

Hence, based on the prior knowledge of the study area and additional information from previous research in the study area [5], seven different types of land use and land cover has been identified for the Upper Ribb watershed. The descriptions of these land use and land covers are given in Table 2.

Table 2. Land use and land cover classes.

LULC class	Description
Cultivated land	Areas used for crop cultivation, both annually and perennially. It is the area with the standing crop, tree crops, and croplands where the crops were harvested.
Bush and Shrubland	Areas with bushes, shrubs, and small trees, with little wood and mixed with some grasses. It includes plantation trees and scrubs vegetation at the fringes of forest cover and areas dominated by scattered trees.
Grazing land	Areas covered with grass used for grazing, as well as bare lands that have little grass or no grass cover. It also includes other small sized plant species.
Water bodies	Areas with surface water in the form of ponds, reservoirs, lakes, streams, rivers and its main tributaries.
Forest land	Land covered with dense trees which are mainly evergreen forest land
Urban and Settlement Area	Areas with low density to high-density residential. It comprises both dispersed rural and urban settlement areas.
Woody Savanna Land	Areas cover with wood mixed with higher grass cover including seasonal as well as permanent wetlands.

Image Classification

Image classification is the process of assigning of pixels of a continuous raster image to the different land cover classes. There are two ways to classify pixels into different categories namely supervised and unsupervised classification using ERDAS Imagine software. In unsupervised classification, the computer produces spectral classes based on the digital numbers (DN) without any direction from the user. It is used to cluster pixels in a data set into classes based on statistics only. These classes are spectral classes and their identity is not initially known until they are compared with some reference data.

In supervised classification compared with computer-controlled unsupervised classification, the users have much closer control over the classification process. In this process, they select pixels that represent patterns they recognize or can identify with help from other sources. Knowledge of the data, the classes desired, and the algorithm to be used are required before they begin selecting training samples.

In this study, the land cover map was prepared based on the pixel-based supervised classification through the procedure of First, selecting the training sites which are typically representative for the land cover classes. Thus, between 25 and 35 ground control points were collected for each land cover classes (cultivated, grazing, forest, bush/shrub, urban, savanna and water bodies) for the year 1973 and 1995 by asking local elder people of the area, and for the year 2016 from the ground truth. Then the signature files/training samples were created from those collected ground control points. Second, from the supervised classification methods, the Maximum Likelihood supervised classification algorithm was used. This is due to the fact that unlike other classifiers it considers the spectral variation within each category and the overlap that may occur among different classes [6]. The best grouping of unknown pixels was provided by the use of parameters of the maximum likelihood statistical method. In this particular study Maximum Likelihood classifier has been used in the supervised classification method.

Accuracy Assessment of Image Classification

After image classification accuracy assessment must be done to determine how well the classification process accomplished the task. This process involves generating a set of points in the classified imagery and comparing them with actual points on the ground through fieldwork. The most widely used classification accuracy is in the form of error matrix which can be used to derive a series of descriptive and analytical statistics [7]. The columns of the matrix depict the number of pixels per class for the reference data, and the rows show the number of pixels per class for the classified image. From this error matrix, a number of accuracy measures such as overall accuracy, user's accuracy, producer's accuracy, and Kappa statistics are determined. The overall accuracy is used to indicate the accuracy of the whole classification (i.e. number of correctly classified pixels divided by the total number of pixels in the error matrix), whereas the other two measures indicate the accuracy of individual classes. User's accuracy is regarded as the probability that a pixel classified on the map actually represents that class on the ground or reference data, whereas product's accuracy represents the probability that a pixel on reference data has been correctly classified. Kappa statics is a type of technique used in accuracy assessment. It expresses the agreement between two categorical data sets.

In this study, accuracy assessment was performed using the available and the Google Earth Image together with previous knowledge of the area which used as reference data to generate testing data set by generating certain random testing points. A total of 200 testing sample points were selected randomly for the recent year 2016 and accuracy assessment was done.

RESULTS AND DISCUSSION

Land Use and Land Cover Change Analysis

After the image processing and land cover detection, seven (Cultivated Land, Grazing Land, Bush, and Shrub Land, Forest Cover, Water Body, Urban and Settlement Area and Woody Savanna Land) land use and land cover classes were found for the year 1973, 1995 and 2016.

Images of March and April (1973, 1975 and 2016) were acquired when crop harvesting had already been done and farmlands appear bare.

Analysis of the 1973 land sat satellite image revealed that bush/ shrub land constituted the largest proportion of land in Ribb Watershed with a value of 65.501%, followed by cultivated, grazing and forest lands with 22.993%, 6.851% and 4.259% coverage's respectively (Figure 3 and Table 3). Urban and water covers small percentages, i.e. 0.316% and 0.080% respectively.

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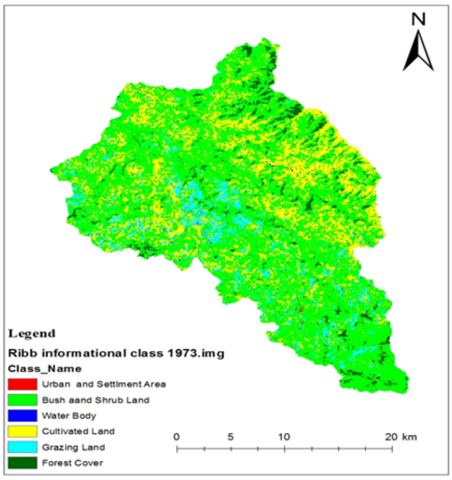

Figure 3. Land use and land cover map of the upper ribb watershed in 1973.

Table 3. Summary of land use/cover change percentage of the upper ribb watershed.

class Land cover classes	Years			Land use change detection		
	1973	1995	2016	1973-1995	1995-2016	1973-2016
Cultivated Land	22.993	55.405	52.94	+32.412	-2.464	+29.947
Grazing Land	6.851	28.405	10.297	+21.554	-18.107	+3.446
Bush and Shrub Land	65.501	13.516	31.306	-51.985	+17.79	-34.195
Forest Cover	4.259	1.775	1.57	-2.485	-0.205	-2.69
Water Body	0.08	0.363	0.412	0.283	0.049	+0.331
Urban and Settlement Area	0.316	0.537	1.406	+0.221	+0.869	+1.090
Woody Savanna Land			2.069			+2.069

According to the maximum likelihood classification of 1995 land sat satellite image in Upper Ribb Watershed (**Figure 4**), the proportion of land allocated for cultivation expanded to 55.405%. Furthermore, grazing land, urban area, and water body have increased to 28.405%, 0.537% and 0.36% respectively. However, the proportions of bush/shrubland and forest cover have decreased to 13.516% and 1.775% respectively.

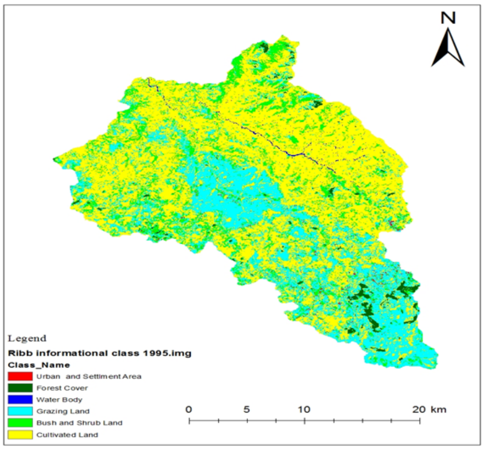

Figure 4. Land use and land cover map of the upper ribbs watershed in 1995.

The maximum likelihood classification of 2016 Landsat satellite image showed that the land cover classes (Figure 5) were also dominated by cultivated lands with 52.940%, though the value decreases as it compared from the year 1995. It is also followed by the ever-increasing bush/shrubland with 31.306% and the ever decreasing grazing land with 10.297%. This indicates that recent conservation activities were taken in the area for watershed management. But this conservation practice cannot preserve the forest cover, which is decreased to 1.570%. Other land cover classes also cover the remaining 3.887%, with woody savanna grassland 2.069%, urban and settlement area 1.406% and water body 0.412%.

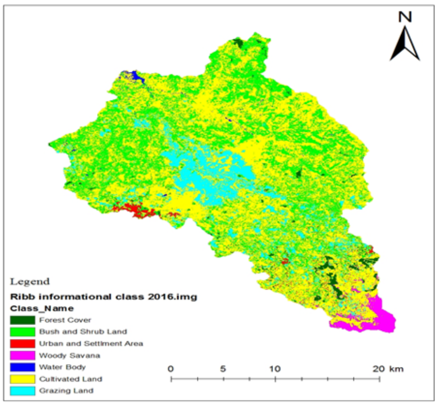

Figure 5. Land use and land cover map of the upper ribb watershed in 2016.

From Table 4 it can be observed that there was a dramatic increase of cultivated and grazing lands for the first period (1973-1995) with +32.412 and +21.554 respectively. On the other hand, bush/shrublands were decreased by 51.985% for this period. However, the bush/shrub lands show an appreciable increase during the second period (1995-2016) with +17.790%. On the contrary, the grazing land showed a significant decrease in the second period (1995-2016) with 18.107%. And also forest cover decreases for the first and second period, but the urban area, water body, and woody savanna lands were increased both in the first and the second periods. This increment of water body was due to impoundment of the Ribb dam reservoir and also the storage of Selamko reservoir in the Upper Ribb watershed. The increment of bush/shrubland and woody savanna lands in the second period were due to conservation activities taken in the area for watershed management particularly the conservation activities taken in Guna mountain were responsible for the expansion of woody savanna lands in the southern edge of the Watershed. Such recent conservation works for the expansion of bush/shrublands in the area were from preserving some cultivated lands and protecting overgrazing areas. This causes the cultivated lands to decrease in the second period though it shows slightly.

Previous similar studies in this watershed and other parts of the country also reflect similar results. For instance, Garede and Minale [5] showed the cultivated and settlement land, shrubland, and grassland coverage during 2011 were 70.43%, 14%, and 7.58% respectively for the whole ribb catchment in the northwestern part of Ethiopia. Yeshaneh [8] stated that crop field coverage in Koga watershed in 2010 was 76.83%.

Geremew [9] shows that the cultivated area was increased by 45%, while forest, grassland, shrubland, and water was decreased by 2%, 34%, 5.7%, and 4.9% respectively from 1986 to 2001.

Hadgu [10] indicating a sharp reduction of natural habitats and an increase in agricultural land in the highlands of Tigray, northern Ethiopia over a period of 41 years (1964-2005). He reported that shrubland was dominant in 1964 covering 46% of the area followed by woodland with coverage of 28% of the area. However, agricultural land was dominant in both 1994 and 2005 covering 34% and 40% respectively. The next dominant LULC types in 1994 and 2005 were shrubland with coverage of 21% and 39%.

Andualem and Gebremariam [11] reported that there was an increase of cultivated lands and a decrease of forest cover by 33.79 and 1.4 percent respectively in Gilgel Abbay watershed, northwestern Ethiopia from the periods 1986-2011.

Bewket [12] identifies agricultural conversion of 79% of the Riverine forests of the chemoga watershed within the Blue Nile basin from 1957 to 1998. Rientjes [13] also presented the agricultural land, shrubland and grassland coverage during 2001 were 62.7%, 8.9%, and 8.8% respectively for upper Gilgel Abay catchment.

Accuracy Assessment

Accuracy assessment involves generating a set of points in the classified imagery and comparing them with actual points on the ground through fieldwork. The most widely used classification accuracy is in the form of error matrix which can be used to derive a series of descriptive and analytical statistics [7]. The columns of the matrix depict the number of pixels per class for the reference data, and the rows show the number of pixels per class for the classified image. From this error matrix, the number of accuracy measures such as overall accuracy, user's and producer's accuracy determined. The overall accuracy is used to indicate the accuracy of the whole classification (i.e. number of correctly classified pixels divided by the total number of pixels in the error matrix), whereas the other two measures indicate the accuracy of individual classes. User's accuracy is regarded as the probability that a pixel classified on the map actually represents that class on the ground or reference data, whereas product's accuracy represents the probability that a pixel on reference data has been correctly classified.

In this study, an accuracy assessment was made by using a confusion matrix with 200 randomly selected points (Table 4) by using land use maps, ground truth points, and Google Earth. Great importance was given to the representation of different LU/LC classes by these randomly chosen points.

Table 4. Confusion matrixes for the classification of 2016 land use.

Classified Image	Ground Truth								User's Accuracy
	Cultivated	Bush	Grazing	Forest	Urban	Water	Woody	Total	
Cultivated	101	0	2	0	0	0	0	103	98.06%
Bush	2	31	2	1	0	0	0	36	86.11%
Grazing	1	1	46	0	0	0	0	48	95.83%
Forest	0	0	1	6	0	0	0	7	85.71%
Urban	0	0	0	0	1	0	0	1	100%
Water	0	0	0	0	0	1	0	1	100%
Woody	0	0	0	0	0	0	4	4	100%
Total	104	32	51	7	1	1	4	200	
Producer's Accuracy	97.12%	96.8%	90.20%	85.7%	100%	100%	100%	Overall Accuracy =96%	

The 2016 land use and land cover classification have shown, user's accuracy and producer's accuracy are greater than 85%, as well the overall accuracy of 96% (Table 4). These values indicate the Landsat and the methodologies used were so accurate. The Kappa coefficient also calculated, with a value of K=0.92 which indicated the classification is almost perfect since it is between 0.81 and 1.00 [14]. Thus, based on this expression the land use and land cover classification for the 2016 image in this study was almost perfect.

CONCLUSION

This study has addressed the land use and land cover dynamics in Upper Ribb watershed for over 43 years period using Landsat satellite images from USGS earth explorer. The classification of land use and land covers were performed on ERDAS Imagine 2014, which were integrated with other GIS data.

The study shows that upper ribb watershed has experienced a significant change in land use and land cover over the past 43 years. This can be recognized that bush/shrublands were significantly changed to cultivated and grazing lands with a decrease of forests throughout the study periods. The results revealed that the magnitudes of the cultivated land were increased by 29.947% and the bush/shrublands were decreased by 34.195% through the study period. Degradation of cultivable and potential areas is the major problem in Ethiopia particularly in the highlands for many years and will continue in the future except appropriate watershed management activities are taken. This is due to the topography of the watershed, high dense population and poor management practices taken in the watershed. To manage this problem, the local government and other stakeholders should implement appropriate watershed management activities. This will be done by forest resources development, protection and use strategies need to be devised to encourage the increasing/expanding bushes/shrubland.

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