International Journal of Environmental Sciences Vol. 4 No. 2. 2015. Pp. 81-88

Full Length Research Paper

Multitemporal Land Use Land Cover Change and Dynamics of Blue Nile Basin by Using GIS and Remote Sensing Techniques, North-Western Ethiopia

Moges Kidane Biru[1], Amare Sewnet Minale (PhD) [2], Alemu Bezie Debay[1]

[1]Department of Natural Resource Management and Water Resource and Irrigation Management, Ambo University, Ambo, Ethiopia.

[2]Department of Geography and Environmental Studies, Bahir Dar University, BahirDar, Ethiopia.

Corresponding Author: Moges Kidane Biru

Abstract

Geographic Information System and Remote Sensing techniques are effective for assessing past and present land use and land cover dynamics of watershed. This study analyzes land use and land cover dynamics of Koga watershed for the past 40 years. For this study georeferenced Landsat images of MSS (1973), TM (1986), ETM+ (2001), and OLT (2014) were used. Additionally household socioeconomic survey and key informant interview were used to define types of land use land cover in the watershed. After unsupervised and supervised classification method, post classification computed to evaluate the classification accuracy. The rate and dynamics of LULC maps between 1973 -1986, 1986-2001 and 2001 and 2014 interval of years were computed and interpreted. The results of remote sensing and GIS analysis revealed that in 1973 more than 60% of the land is covered by cultivation land, the forest coverage of the watershed for 40 years range from 3.6 to 10.1% in 2001 and 1973 respectively. The highest conversation of other LULC to cultivation land occurred between 1973 and 2001, whereas because of expansion of Eucalyptus tree in marginal cultivation lands and 765.3ha conversion of cultivation to Koga reservoir; cultivation land decreed from 23123.6ha (77.5%) to 19116.1 (64.1) in 2001 and 2014 respectively. In 2014 classification year Koga reservoir covers 1580.2ha (5.3%), of which 48.2%, 35.2%, 4.5%, 6.6% and 4.9% of the water body convert from cultivation, grass, bush, built up and forest land respectively. In order to make relevant natural resource management and planning of an area, one has to therefore, properly consult situations of the past and present, i.e. socio-economic and biophysical aspects of the watershed.

Key words: *GIS, Koga Watershed, Post-Classification, Remote Sensing, Supervised Classification.*

Introduction

Land is the one of the major natural resource which supports economic, social, welfare and various other human activities. (Mueller and Zeller, 2002; Azene, 2001). *Land represents earth surface that provides and grow food, stores water and it is a basic physical resource for urban and industrial development and a range of social and cultural activities* (FAO, 2002). Every parcel of land on the earth surface is unique in terms of land cover it possesses and on the way it is used. (Sanderson *et al*., 2002; Eleni, *2013;* Geist and Lambin, 2001). Land use and land cover have different physical meanings but yet they have closely linked characteristics of the Earth's surface (Getachew, 2011).

Land use is usually defined *as the purposes of the land for which, humans use the land and its resources to fulfill once need.* Land cover is *the habitat or any type of vegetation present, such as forest, grass and agriculture area* (William, 2000; Agarwal *et al*., 2002). FAO, (2000) stated land cover *as the observed biophysical cover on the earth's surface*." and land use as *the arrangements, activities and inputs that people under-take on a certain land cover type*. Land use and land cover change is locally pervasive and globally significant ecological dynamics and has become paramount importance to the study of global environmental change (Vincy *et al,* 2004; Wolterl, 2006; Paree*t al*, 2008).

Changes in land use (human use applied to these attributes) and land cover (biophysical characteristics of the earth surface) has been in the past, at present and will continue at a faster pace in future (Lambin, 2003). In developing country like Ethiopia where land is a major source of economic welfare for the people shows a continuous and intensive change in terms of use and cover (Eleni, 2013; Amare, 2013; Amare and Kameswara, 2012). In Ethiopia, the availability of natural resources as well as their dynamics and management vary considerably from area to area (Zeleke and Steenhuis, 2005).

Land use and land cover dynamics affects most of environmental factors such as physical and chemical characteristics of soil, climate parameters, topography and vegetation distribution pattern (Asmamaw, 2013). It also reflects the importance of land as a key and

finite resource for most human activities including agriculture, industry, forestry, energy production, settlement, recreation, and water catchment and storage (Emiru, 2009). In addition to impact of land use and land cover change in environment, it has a high and continuous impact on crop production which leads to food insecurity (Abdo, 2008).Therefore, Land use and land cover change and dynamics is central issue that requires thorough scientific investigation for sustainable land use planning and development (Lambin, 2003) and represents a vibrant and dynamic area of research.

Land use and Land cover has increasingly become a key research priority for national and international research programs examining global environmental change (IGU, 1998). Because of traditional land management (Azene, 2001) coupled with a growing population interest and reliance on various products and services on natural resources there is massive clearance of forest ecosystem resulting in poor agricultural soil and water resource management practices thereby causing hydrological resource problem in Blue Nile basin in Ethiopia (EFAP, 1993; Azene, 2001).

This study provides empirical evidence to show the past land use and land cover change and dynamics recovered in Koga Blue Nile, which further can be used in formulation land use planning and policy for the watershed. Studying past and present history of dynamics helps in understanding future land use land cover projection trend and extent, which can be used in developing effective environmental management policies and strategies (Agarwal *et al*., 2002).

Materials and Methods

Description of the study Area

The study was conducted in Koga watershed in Tana Basin, Blue Nile Ethiopia. The watershed is located at latitudes of 11°9.7' and 11°30'N and Longitudes of 37°02' and 37°18'E; covering a total area of 29589 ha of land including Koga Reservoir and irrigation project in 2011. Koga River and Koga reservoir are the largest source of water for the watershed; Koga River is originated from Wezen Mountain and is a tributary of Gilgel Abay River and drains to Lake Tana.

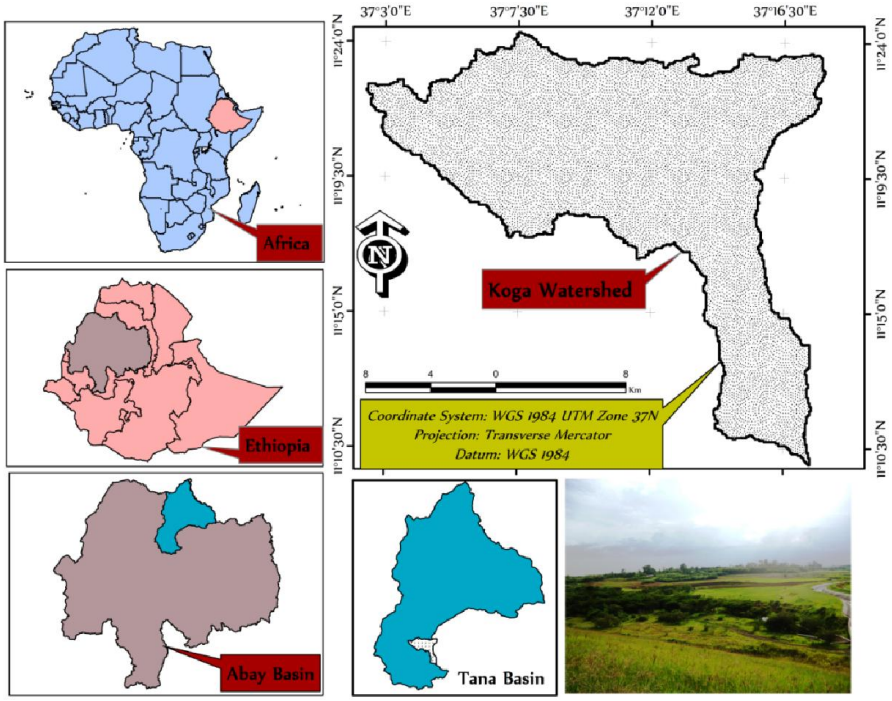

Fig 1: Map of the Study Area

The watershed has bimodal distinct seasons commonly known the dry called Bega and wet season called Keremite. The Dry season starts from November to May, while the Wet season covers the remaining part of the year, in this season characterized as a high rainfall season. Crop Cultivation is the major basis of livelihoods of almost all the people in the watershed; some of the watershed communities also engaged in animal husbandry and labour economic activity in the woreda main city. With regards to the agricultural practice the watershed is divided into two; the highly land crop cultivation characterized by rein fed and small scale labour intensive agricultural practice, whereas the lower watershed area practice various types of irrigation system after the construction of Koga dam reservoirs that start operation in 2011.

Attitudinally Koga watershed is located at 1887 to 3119 m asl; the lowest elevation point found at the mouth of Wotete Abay and the highest elevation located at Wozen Mountains. The regional geology comprises extensive flow type, volcanic (extrusive) rock; which were deposited during the Paleocene-Oligocene-Miocene (Tertiary) period of geological time (according to the woreda agricultural

office). The Ashangi family comprises the older volcanic material, which was formed by accumulation of lava and debris from fissure volcanic rock eruption.

Data Sources and Collection Method

To study trends and dynamics remote sensing and ground data was used for the past 40 years. A total of four land sat satellite image, Digital Elevation Model 30m by 30m and 120 ground control point used based on 30 ground point for each land use and land cover class was used. These four referenced images were obtained from Ethiopian Mapping Agency at the same dry season; avoiding a seasonal variation between the images vegetation pattern and distribution. For 1973 a black and white aerial photos were obtained from Ethiopian Mapping Authority (EMA).

Field survey and structured questioners used to collect the demographic and socio-economic data of the watershed. The demographic and socio-economic data used to assess the underlying factors of land use and land cover change process. The land use land cover change map of the watershed is correlated to the information collected from the questioners to study factor triggering the change.

Table 1: The Acquisition Dates, Sensor, Path/Row and Resolution of Land Sat Images

No	Sensor	Path and Row	Spatial Resolution	Date of Acquisition	Source
1	Land Sat 1 MSS	182/52	57 x 57 m	01/02/1973	USGS
2	Land Sat 5TM	170/52	30 x 30 m	20/02/1986	USGS
3	Land Sat 7 ETM^{+}	170/52	30 x 30 m	13/02/2001	USGS
4	Land Sat 8 OLS	170/52	30x 30 m	06/01/2014	USGS

Data Analysis

The contribution of land use and land cover type on the recorded change in the study area is the primary determinant factor. In order to clearly assess the changes of land use and land cover in the watershed, determination of type and size of classes is significant. Accordingly, based on the information's obtained from the key informants past knowledge, visual interpretation of remotely sensed satellite image and using field observation over all seven land use and land cover classes were identified for this study.

Classification of the four land use and land cover map has both pre-processing and post classification techniques. Before the classification accomplished correcting the data for sensor irregularities and atmospheric noise was performed using ERDAS IMAGINE 10 software. To facilitate supervised classification; unsupervised classification and aerial photo image fusion was done. For each land use and land cover classes signature was prepared using training area and significant spearability is obtained. After supervised classification was obtained accuracy assessment were done by comparing the classified image with 120 ground control points collected during field survey.

The comparison of land use and land cover statistics is assisted to identify the amount of changes per hectares, percentages, extent, and rate of changes between 1973 and 2014. Observed change was simply calculated by subtracting the recent data from the former/previous one (i.e. 1973-1986, 1986-2001 and 2001-2014). Geographical extent of each land use and land cover type was computed for each time interval and changes in the trend dynamics of different periods were traced. Land use land cover conversation rate and extent were computed in terms of percentage and area change. The land cover conversion matrix analysis was conducted in ERDAS IMAGINE 10.

Results and Discussion

Land Use and Land Cover Changes From 1973-2014

The land use and land cover history and dynamics statistical summary of Koga watershed was presented for 1973, 1986, 2001 and 2014 using map figures and tables. Land use and Land cover dynamics in Koga watershed is analyzed from multi-temporal Land Sat images for the last 40 years (1973 and 2014). Each land use and land cover class defined using information from key informant's, agricultural office, and field survey of the area; the result contacted with the above bodies and reach an agreement, table 2 shows the land use and land cover class of the watershed and their descriptions. The Water body of the watershed is only used from 2014 land use and land cover map because the reservoir water conservation start in 2011.

Table 2: The Study Land use and land cover class types and their descriptions

No	Land Use and Land Cover Class	Description

1	Built-up areas	Include resident area educational, health, and socio-economic facilities and shops.
2	Cultivation Land	This category encompasses areas allotted for crops production (both annual/seasonal and perennial), dispersed rural settlements, and homesteads.
3	Grass land	Grasslands are non-woody areas where the vegetation is dominated by grasses and herbs with nil or little proportion of shrubs.
4	Bush land	Areas covered with sparse woody plants mixed with shrubs, bushes, and grasses. It is a low-density forest forming vegetation.
5	Forest Land	Land covered with dense trees which includes ever green forest land, mixed forest and plantation forests.
6	Wet Land	Land use land cover which remains water logged and swampy throughout the year.
7	Water Body	Koga Reservoir

As stated by Alemayehu (2010) and Amare (2013) after studying the land use land cover of Ethiopian high lands and Gelgele Abay, Ethiopia respectively; that agriculture mainly crop cultivation has a very long history and has had much publicized and support43% of the national GDP. The total area under cultivation had increased by 1.6 % in 2011/12 to reach 13.9 million hectares (UNDP, 2014). The same result found in studying and land use and land cover of Koga watershed in 1973 classification map (shown in table 3). Cultivation lands cover most of the watershed area, accounted for more than 60% of the total watershed area at all four classification years.

In the time series analysis of the land use and land cover maps during the period of 1973–2001 was significantly characterized by the expansion of the Cultivation and Built ups. The cultivation land expanded into much of the forest land and bush land. There has been an appreciable increase in the area of cultivation land, wet land, built up or settlements and water body during the period of 1973–2014 with a concomitant shrinkage in the area of bush land, grass land and forest land (Table 3).

Table 3: land use and land cover classes and extent from 1973 – 2014

LULC Name	1973		1986		2001		2014	
	Area(ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Forest Land	3015.8	10.1	2966.0	9.9	1088.4	3.6	2492.3	8.4
Wet Land	110.5	0.4	112.7	0.4	190.3	0.6	198.4	0.7
Built Ups	1034.6	3.5	1345.1	4.5	2144.5	7.2	3280.2	11.0
Bush Land	2522.4	8.5	790.8	2.6	623.3	2.1	1734.2	5.8
Grass Land	5061.7	17.0	6030.1	20.2	2675.3	9.0	1443.5	4.8
Cultivation Land	18100.1	60.6	18600.0	62.3	23123.6	77.5	19116.1	64.1
Water Body	-	-	-	-	-	-	1580.2	5.3
Total	29845	100	29845	100	29845	100	29845	100

The results indicates a series of Land use and land cover dynamics for the last 40 years (1973-2014). In this regard, the trend has shown a tendency towards more land being brought under cultivated and built up area. The land use and land cover map of 1973 used as a base map to study dynamics occurred in the watershed. The 1973 land use land cover map illustrates that most of the land are primarily covered by cultivated land which accounted to 18100.1ha (60.7%) of the total watershed area. The land which is covered by grass land and forest land occupies an area of 5061.7 and 2990.8ha of land with percentage of 17.0 and 10.1 respectively. The smallest portion of the watershed land was covered by bush, wetland and built ups areas that account 8.5, 0.4 and 3.5 % respectively of the watershed.

Similarly, in 1986 land use land cover classification, the majority share was covered by cultivated land, which accounts an area of 18600ha (62.3 %). While an estimated 6030.12ha of land was covered by grass land which shows a major increment during 1986, it has increased from 968.42 ha from 1973 map, whereas bush land decrease to 790.8 ha of land. The classification map of 1986 shows a slightly increments of wet land and built ups to 112.7 and 1345.14 ha respectively. Forest land in 1986 shows a slight decrease and recorded 2966.01 ha which account 9.9 % of the total land use and land cover. The least land use and land cover recorded in 1986 by studying land sat TM is wet land which account 0.4 % of the total land area (112.7 ha).

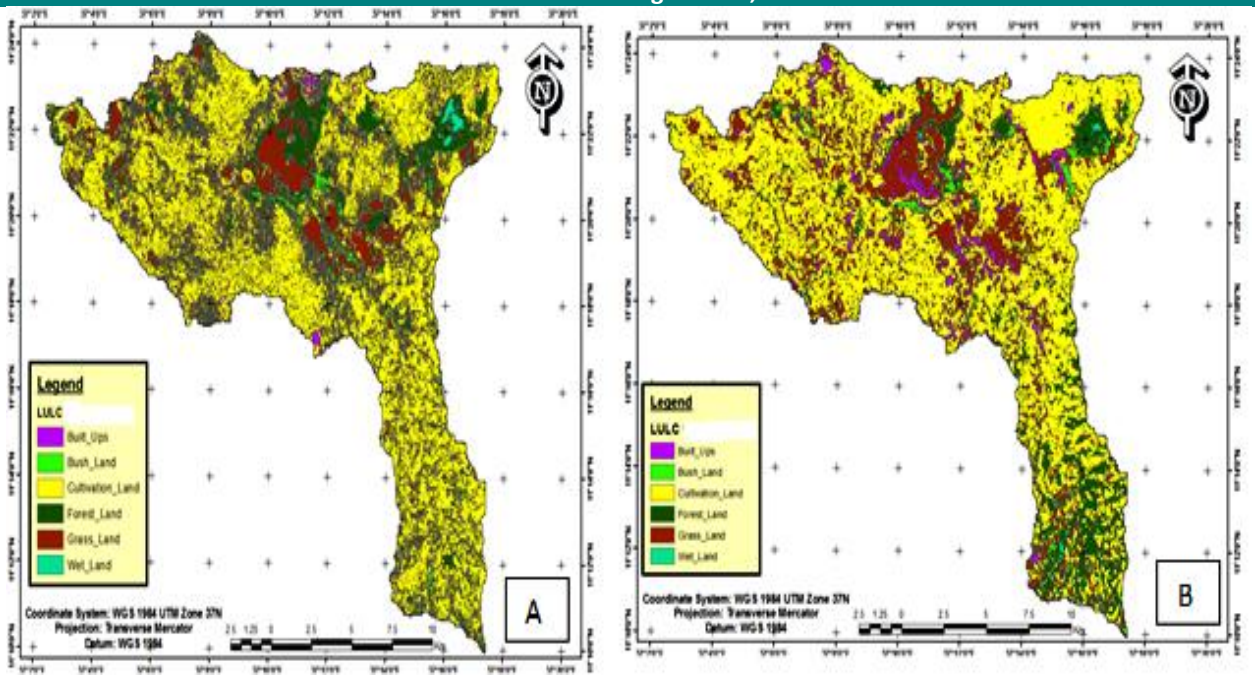

Fig 2: Land use and land cover Map of the Koga Watershed 1973 (A) and 1986 (B).

From the analysis of the Landsat of 2001 supervised classification result indicate that a massive increment of cultivated land and degradation of forest land is recorded. Cultivation land in 2001 year comprises 77.5% of the total landscape, and forest land decreased to 3.6 %. Another class of land that decreases is bush land and grass land to 623.34 and 2675.25 ha respectively. Wetlands appeared to have increased upto 0.6 % cover of the total landmass, but built ups area increased to 7.2% with 2144.52ha of land in the watershed. This is mainly attributed to population growth resulting in an increased demand for new cultivation land and settlement areas which in turn resulted shrinking of other types of land use land cover of the area.

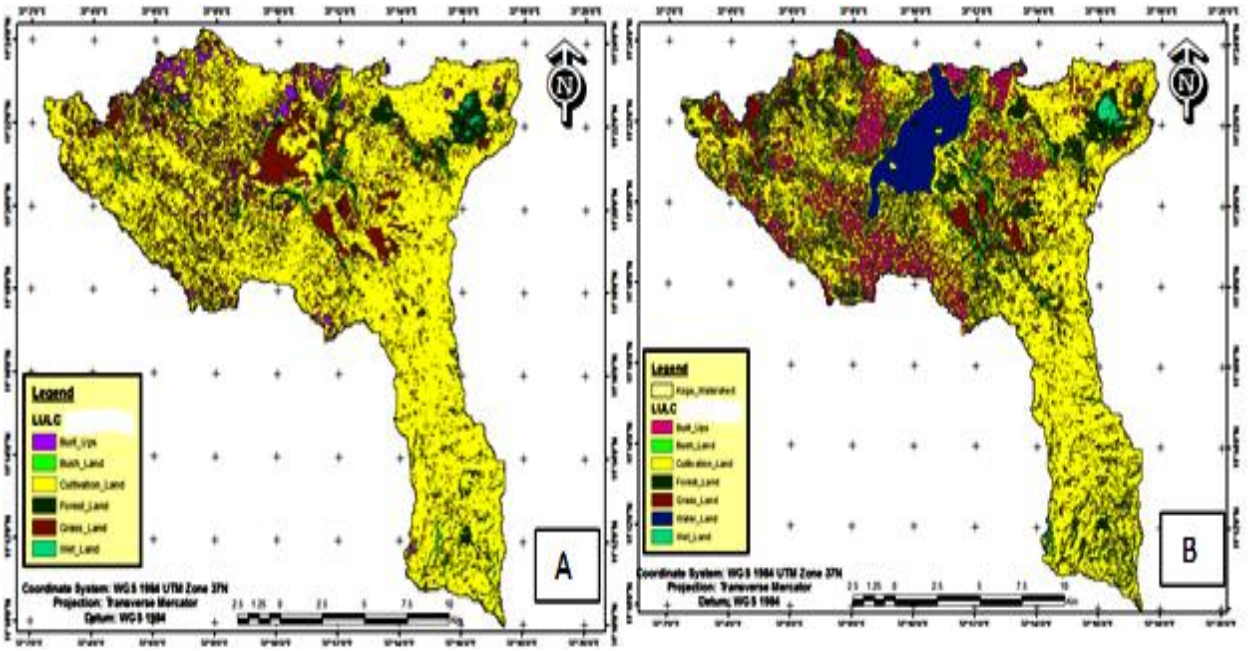

Fig 3: Land use and land cover Map of the Koga Watershed 2001 (A) and 2014 (B).

The land use and land cover map of 2014 shows that the highest share of land was covered by cultivated and built ups, which covered 19116.1 ha (64.1%) and 3280.19 ha (11.0) of the total area of the watershed. Bush land, grass and forest areas covers 1734.15 ha (5.8%), 1443.45 ha (4.8%) and 2492.31 ha (8.4%) respectively. The land use land cover changes that have recorded in Koga watershed had shown continuous expansion of cultivated land in order to meet the increasing food demands of the growing

population. The land use land cover cultivation land expands at the expense of forest, grass and wetlands. In the watershed, there was expansion of forest land from 2001-2014.

Unlike other studied in the region forest land of Koga watershed happens to increase from 2001 classification map to 2014. The study area in 2014 particular year shows a high amount of cultivation land converted to Eucalyptus tree plantation because of the framers perception over the economic advantage of Eucalyptus. During field survey the following picture is taking as an evidence that even if the local government official at Kebele and Woreda agricultural office level try to stop the expansion of Eucalyptus plantation on cultivation land most of the farmers try to convert the cultivation area to Eucalyptus year by year.

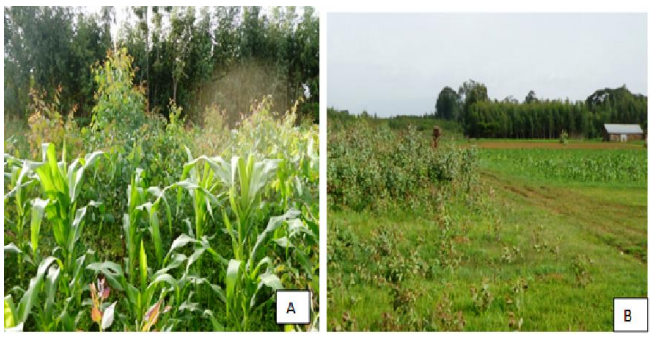

Fig 4: Mixed plantation, Maize and Eucalyptus in one field (A) and Expansion of Forest in Cultivation land (B)

Generally, during the 2001 and 2014 period of the study recorded afforested mainly of Eucalyptus trees. By an increase of population in the area; there is also an increasing demand of fire wood and house constriction material. As a consequence there was an expansion of forested areas to cultivated lands and, in general, land cover changes in the forest and built up area were quite significant in the watershed. Consequently, the expansion of forest to agriculture land has may result reduction of crop production the lower part of the watershed.

Analysis of Land Use and Land Cover Dynamics (Rate and Pattern)

In order to obtain the information of land use and land cover dynamics in terms of pattern and rate conversion, post-classification analysis was carried out in ERDAS IMAGINE 10 using classification images of 1973, 1986, 2001 and 2014.

Table 4: Extent and Rate of LULC Change between; 1973-1986, 1986-2001 and 2001-2014.

LU and LC Class	Area(ha)				Observed change between (in % change).		
	1973	1986	2001	2014	1973–1986	1986- 2001	2001-2014
Forest Land	3015.8	2966.01	1088.37	2492.31	-1.65	-63.31	128.99
Wet Land	110.5	112.7	190.26	198.433	1.99	68.82	4.30
Built Up	1034.6	1345.14	2144.52	3280.19	30.02	59.43	52.96
Bush Land	2522.4	790.781	623.34	1734.15	-68.65	-21.17	178.20
Grass Land	5061.7	6030.12	2675.25	1443.45	19.13	-55.64	-46.04
Cultivation	18100.1	18600	23123.6	19116.1	2.76	24.32	-17.33
Water				1580.23			
Total	**29845**	**29845**	**29845**	**29845**			

Empirical evidence from table 4 shows that bush and forest land was main land use and land cover types which decreased by 68.65% and 1.65 % rate of change between 1973 and 1986 classification years. In a contrary built up of the watershed increased 1345.14 ha from 1034.6 ha between 1973 and 1986, and the increased rate reached 30.02%. Comparing 1986 and 2001 land use and lands cover map reviled that the watershed was under intensive land use and land cover changes than that occurred from 1973 to 1986 classification year. In this particular period the forest, bush and grass land decreased by 63.31, 21.17 and 55.64% respectively. But built ups and cultivation land of the watershed show an increment in coverage with 59.43 and 24.32 % respectively.

In accordance with the trends from the past, the cultivated land during 2014 land use land cover map found to decrease from 2001. The pattern of land use land cover distribution in 2001to 2014 also follows the pattern from 1986 to 2001 except that forest land increase from 1088.37 ha to 2492.3 ha by 129 % of the total watershed area. This improvement in forest and bush land cover could be attributed to the implementation of a watershed management program through coordinated efforts of Koga Dam project along with the Mecha Woreda Bureau of Agriculture and other partner institutes and the participation of the community at large. But expansion of forest land to cultivation land would have impact on agricultural product; should be solved in future. The study period between 2001 and 2014 also witnessed an increase rate of built ups area at which the physical expansion of the settlement areas in the watershed increased. For instance, the built-up land increased by 52.96% with 4.41% rate of change every year.

Fig 5: Part of Koga Dam Water Body and Dam Intake Tower

Classification Accuracy Assessment

To assess the classification accuracy, confusion matrix was developed and interpreted. The overall accuracy and over all kappa coefficient is 87.86% and 0.85 respectively. The overall accuracy gives the overall results of the confusion matrix. It is calculated by dividing the total number of correct pixels (diagonals) by the total number of pixels in the confusion matrix. Monserud (2002) suggested the use of kappa coefficient value less than 0.4 as poor, 0.4-0.55 % fair, 0.55-0.7 % good, 0.7-0.85 % very good and greater than 0.85 % as excellent classification result. Thus according to this classification efficiency in terms of kappa coefficient ranges, classification for this study denotes very good agreement.

Conclusion

Expansion of intensive agriculture and rapid rate of population growth in Koga watershed fuel land use and land cover dynamics. Koga watershed is one of the water tower high lands of Blue Nile basins, which have a potential amount of land for irrigation system. Based on the land use land cover classification results, the forest area has been reduced from 3015.8 ha to 1088.4ha between 1973 and 2001. The cultivation land coverage of the watershed in 1973 is 18100.1ha but this figure increase to 23123.6ha which covers 77.5% of the watershed area in 2001. But the coverage shows a slight decline to 19116.1ha in 2014 because of expansion of Eucalyptus plantation. Because of an increasing demand of fire wood and house constriction material and economic advantages of Eucalyptus tree over crops the forest coverage increase to 2492.3 ha at an average rate of 8.4 % per year in 2014.

Between 2001 and 2014 classification years a total of 3.31% of cultivation land is changed to a water body because of the construction of Koga Dam. Other land use land cover classes converted to water body are forest land, bush land and grass land which accounts 7.34%, 11.05% and 20.87% respectively. This study revealed that the effects of human activities are immediate and often radical, while the natural effects take a relatively longer period. The difference in increase by households and land cover change indicates the pressure on forest and bush land. Hence, between 1973 and 2014; 40 years in the watershed the built up area increase from 1034.6ha to 3280.2ha. This implies that population pressure and limited income diversity is believed to be one of the major driving forces for the change of land use land cover. In order to make relevant natural resource planning and management, one has to therefore, properly consult situations of the past and present, i.e. socio-economic and biophysical aspects of the watershed.

Acknowledgment

We would like to extend acknowledge to Bahir Dar University Geospatial Data and Technology for providing us financial support. The authors are grateful to the Abbay and Tana Basin administration and Koga watershed farmers who participated in this research as a whole. We would like to thank reviewers for their comments on the manuscript.

References

Abdo, K. (2008). Assessment of Climate Change Impacts on the Hydrology of Gilgel Abbay Catchment in Lake Tana Basin, Ethiopia. (Unpublished Thesis). Master of Science in Geo-information Science and Earth Observation, Specialisation: Integrated Watershed Modelling and Management.

Agarwal, C., Green, G., Grove, J., Evans, T. and Schweik, C. (2002) A Review and Assessment of Land-Use Change Models: Dynamics of Space, Time, and Human Choice. General Technical Report NE-297. Newtown Square, Pennsylvania: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. Page:61

Alemayehu M, (2010). Synthesis of Research on Land Use and Land Cover Dynamics in the Ethiopian Highlands. UNU-Land Restoration Training Programme Keldnaholt, 112 Reykjavik, Iceland.

Amare, S and Kameswara R. (2012) Impacts of land cover/use dynamics of Gilgel Abbay catchment of Lake Tana on climate variability, Northwestern Ethiopia, Journal Applied Geomaticvs. 4:155-163. DOI 10.1007/s12518-012-0092-2.

Amare, S. (2013) Retrospective Analysis of Land Cover and Use Dynamics in Gilgel Abbay Watershed by Using GIS and Remote Sensing Techniques, Northwestern Ethiopia, International Journal of Geosciences, 4 (7): 1003-1008.

Asmamaw, A. (2013). Assessing The Impacts of Land Use and Land Cover Change on Hydrology of Watershed: A Case study on Gilgel–Abbay Watershed, Lake Tana Basin, Ethiopia. Dissertation submitted in partial fulfillment of the requirements for the Degree of Master of Science in Geospatial Technologies. Universidade Nova.
Azene, B (2001). Status and Dynamics of Natural Resources in Ethiopia. In: Taye Assefa, editor. Food Security through Sustainable Land Use: Population, Environment, and Rural Development Issues for Sustainable Livelihoods in Ethiopia. Addis Ababa, Ethiopia: NOVIB Partners Forum on Sustainable Land Use, pp. 165–184.
EFAP [Ethiopian Forestry Action Program] (1993). Ethiopian Forestry Action Program: The Challenge for Development. Volume2. Addis Ababa, Ethiopia: Ministry of Natural Resources Development and Environmental Protection.
Eleni, Y. (2013). Identifying Land Use/Cover Dynamics In the Koga Catchment Ethiopia, from Muli-scale Data, and Implications for Environmental Change. ISPRS International Journal of Geo-Information, 302-323.
Emiru, W. (2009). Hydrological Responses to Land Cover Changes in Gilgel Abbay Catchment, Ethiopia. Master of Science in Geo-information Science and Earth Observation, Specialization: Integrated Watershed Modelling and Management ITC, Enschede.
FAO. (2000). Land Cover Classification System (LCCS): Classification Concepts and User Manual.
FAO. (2002). Land-Water Linkages in Rural Watersheds Case Study Series: Food and Agriculture Organization of the United Nations. Rome, Italy.
Geist, H. and Lambdin E. (2001) What Drives Tropical Deforestation? A Meta-Analysis of Proximate and Underlying Causes of Deforestation Based on Sub National Case Study Evidence, LUCC International Project Office, LouvainlaNeuve.
Getachew, F. (2011). Analysis of Land use/Land cover Changes in the Debre-Mewi Watershed at the Upper Catchment of the Blue Nile Basin, Northwest Ethiopia. Journal of Biodiversity and Environmental Sciences, 1 (6), 184-198.
Hurni, H. (1990). Degradation and Conservation of Soil Resources in the Ethiopian Highlands. in African Mountains and Highlands: Problems and Prospective. (B. M. Hurni, Ed.) African Mountains Association, 51–63.
IGU [International Geographical Union] (1998). Land use/cover change. Land Use Policy 15 2:165–166.
Lambin, E. (2003). Dynamics of Land-Use and Land-Cover Change in Tropical Regions. Annual Review of Environment and Resources, 28, 205– 241.
Mueller, D.and M. Zeller (2002) Land-Use Dynamics in the Central Highlands of Vietnam: A Spatial Model Combining Village Survey Data with Satellite Imagery Interpretation. Agricultural. Economics. 27:333–354.
Pare, S., Soderberg, U., Sandewall, M., Ouadba, J.M., 2008. Land use analysis from spatial and field data capture in southern Burkina Faso, West Africa. Agriculture Ecosystems & Environment 127, 277e285.
Sanderson, E., Redford, K., Vedder, A., Coppolillo, P. and Ward, S. (2002) A Conceptual Model for Conservation Planning Based on Landscape Species Requirements. Landscape and Urban Planning 58: 41–56.
Shiferaw, B. and Holden, S. (2001). Farm Level Benefits to Investments for Mitigating Land Degradation: Empirical Evidence from Ethiopia. Environment and Development Economics 6: 335-358.
United Nations Development Progeramme. (2014). Ethiopia: Country Economic Brief. Available date.http://www.et.undp.org/content/dam/ethiopia/docs/Country%20Economic%20Brief%201%20final%20for%20web.pdf.
Vincy, M., Brilliant R., Pradeepkumar, P. and Riju, S. (2004). GIS-Based Land use Land Cover Change Characterization in the Humid Tropical Meenachil River Basin, Kerala, South India.
William,B.(2000).Agricultural and Small Watershed Hydrology:Watershed Characteristic. Retrieved.615, 2013,fromegr.msu.edu:http://www.egr.msu.edu/~northco2/WshedChar.html.
Wolter, E. (2006). Land Use Land Cover Change in the U.S. Great Lakes Basin 1992 To 2001 J. Great Lakes Res. 32:607–628.
Zeleke, G. and Steenhuis, T., (2005). The Broken Link in the Agricultural Production System in Ethiopia and its Impacts: Natural Resources Engineering and Management, Cornell University, Ithaca, USA.