LAND USE/COVER CHANGE AT INFRAZ WATERSHED, NORTHWESTREN ETHIOPIA

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ABSTRACT

Land cover is the physical and biological cover of the surface whereas land use covers the results of human activities for the exploitation of it. The land cover and landuse change is caused by both, natural and anthropogenic factors. The objective of this study was to detect land cover/use changes in Infraz Watershed. The study has used ArcGIS10 and ERDAS IMAGINE10, landsat images of 1973, 1986, 1995 and 2011 and socio-economic data to analyze land cover and landuse changes of Infraz watershed. The study has found that due to the population increase and improper agricultural activity bush and wetlands have declined whereas farm and settlement lands expanded between the study years. About 1044 wetlands and 6338.7 ha of bush lands were lost and converted to cultivated and farm lands, grass lands and forest covers which were increased by 6685.3, 357.7 and 338.3 ha between the study periods respectively. There is an urgent need to limit the population growth rate and implementing land use policy in the Infraz watershed.

Keyword: Infraz watershed, land cover/use, population increase, landsat images, classification

INTRODUCTION

Land cover is the physical and biological cover of the surface of land, whereas land use is the result of human activities such as agriculture, forestry and building construction that alter the land surface processes (Mueller & Zeller, 2002; Foley *et al*., 2005). The conversion of natural land to cropland, pasture, urban area, reservoirs, and other anthropogenic landscapes represent a form of human impact on the environment (Ramankutty *et al*., 2002; McGranahan *et al*., 2005). Roughly 40% of the Earth's land is affected by agriculture, and 85% has some level of anthropogenic influence (Sanderson *et al.*, 2002). Deforestation, wetland drainage, and grassland degradation have all amounted to a globally significant alteration of the land cover. Large scale environmental phenomena such as land degradation and desertification, biodiversity loss, habitat destruction and species transfer are consequences of land use changes by converting natural land covers (Amare, 2013; Amare & Kameswara, 2012; Meyer & Turner, 1995).

Land use/cover and its dynamics are important factors that affect ecosystem conditions and functions. In the past 40 years, land use cover change (LUCC) dynamics have been considerably impacting/changing the biogeochemical cycle leading to modifications in surface atmospheric energy exchanges, carbon and water cycle, soil quality, biodiversity, ability of biological systems to support human needs and, ultimately the climate at all scales

(Overmars & Verburg, 2005). Changes in land use/cover accelerate soil erosion rates causing soil degradation and constituting important pollution of water bodies and impact on aquatic ecosystem (Rompaey & Dostal 2007). Obviously, the relative amounts of particular types of land use/cover in a watershed usually affect water quality. There are many connections between land surface characteristics and the hydrological cycle (Morse *et al*., 2003).

Although, there are no agreements on factors which cause land cover/use changes, some studies suggested that demographic dynamics contribute more than any other process to land cover changes (Amare, 2013; Mather & Needle, 2000) while others suggested the superiority of economic factors (Geist & Lambdin, 2001). Some socio-economic factors of land cover change include demographic changes, poverty, tenancy insecurity, non availability of market and credit facilities. Poor people, as they live hand to mouth, cannot afford to invest in resource conserving practices. They plough hillsides and overgraze land because they cannot wait for the rangelands to recover. These practices of the poor could lead to increased land degradation and worsen the poverty as well as accelerate land cover changes (Scherr, 2000; Markandya, 2001; Biru, 2007). Tenure security is a critical variable in the management of natural and environmental resources, soil conservations, and water as well as wildlife management. A study conducted by Michael & Dwinght (1998) in Gambia. Kenya, Ghana and Rwanda revealed that tenure security is a precondition for any land management. If some markets are poorly developed, farmers' production decisions and their investment in land will be discouraged and this, in turn, affects land cover changes (Singh *et al*., 1996). Lack of well defined policies, their implementation and weak institutional enforcement may facilitate changes in land use/cover. On the other hand, restoration of land use/cover is possible, if there are appropriate land use policies in place (Amare, 2011) which might have significant influence on land use/cover change.In Ethiopia some micro level studies from aerial photographs and satellite images have revealed agricultural land expansion at the expense of other land uses. These studies, confirmed the significant increase in cultivated and settlement lands at the expense of forest, wetlands, riparian vegetation, grasslands and open spaces (Amare & Kameswara, 2012; 2011; Nyssen, 2004). Similarly, the studies by (Amare & Kameswara, 2012; 2011) in Gilgel Abbay catchment have shown continuous decline of forest, wetlands and expansion of farm and settlement area between 1973 - 2008. The simultaneous upward surge in both, human and livestock populations would, therefore, bring the depletion of the biological resources. Institutional issues like political, legal, economic, and traditional affairs and their interaction with individual decision making are important in explaining land use/cover changes (Lambin & Geist, 2003).

Land cover changes in watershed systems can cause local, measurable changes in watershed systems. Studies have indicated that the land cover/use change is also related to hydrological and climate changes at global, regional and local scale. It is also responsible for releasing greenhouse gases to the atmosphere and increases the release of carbon dioxide to the atmosphere caused by deforestation, especially when followed by the expansion of agriculture (Christy *et al*., 2006; Ezber *et al*., 2007; Nunez *et al*., 2008). It is, therefore, essential to detect land cover and use change accurately, at an appropriate scale, and in a timely manner in order to better understand their impacts on watershed and its systems.

Application of remotely sensed data has made it possible to study the changes in land cover and landuse in less time, at low cost and with better accuracy (Loca, 2013). Geographical Information System (GIS) provides suitable platform for geospatial data analysis, update and retrieval (Chilar, 2000). Remote sensing technology and geographic information system (GIS) provide efficient methods for analysis of land cover/ use changes. Timely and accurate land cover change detection provides the foundation for better understanding relationships and interactions between human and natural phenomena to better manage and use resources.

The basic premise in using remotely sensed data is that, changes in land cover must result in differences in radiance values that must be large enough with respect to radiance changes (Mas, 1999).

This study, therefore, attempted to gain a better understanding of land cover/use changes, by taking the Infraz watershed as an assessing area. This is because Infraz watershed is major source of drinking water for Bahir Dar City. The two springs (Arekie and Lome), are the major sources of drinking water for Bahir Dar City and they are located in Infraz watershed. There are also many springs and wetlands in the watershed which has made the research very important. The accurate information on land cover changes and the forces and process behind is essential for designing a sound environmental planning and management. Thus, the specific objectives to be realized under this study is to detect land cover and landuse status with special reference to its causes and evaluation of their consequences through time in Infraz watershed. Hence, the objective of this study was to detect the past and present trends of land cover/use changes in Infraz Watershed.

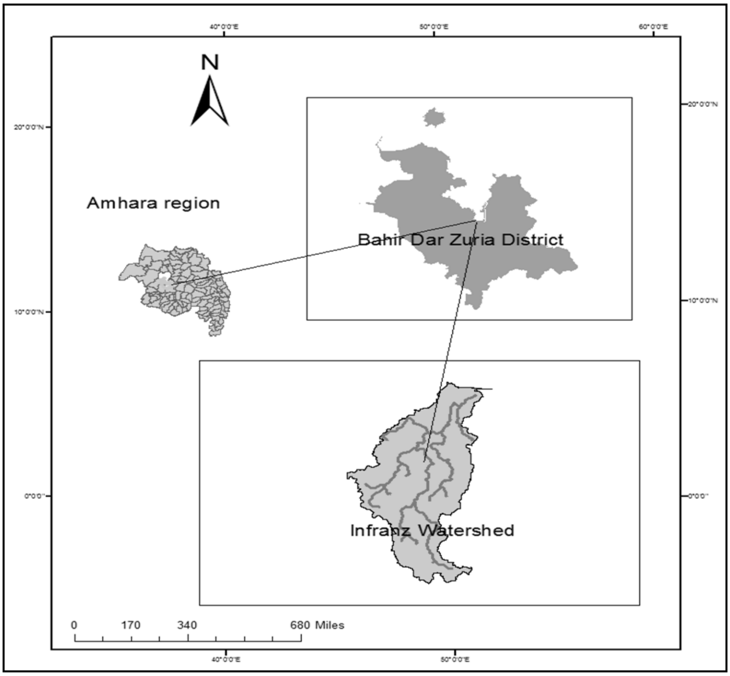
MATERIALS AND METHODS

Study Area

Infraz watershed is a collection of small seasonal streams and few perennial streams originated from hills which separate Gilgel Abbay watershed from Lake Tana to the southern part of the catchment. It is located in vicinity of the Lake Tana to its southern part and covers about 257.8km^2 area. The area comprises of sedimentary, effusive and intrusive rocks which were formed during Tertiary Volcanic eruptions. Recent alluvium and lake sediments cover the banks of the lower reaches of the main Lake Tana emissaries (SMEC, 2007). They are composed of fine sediments, partly of marsh environment, which usually are represented by clays (Mesfin, 1972; Kazmin, 1973). Luvisols are generally fertile soils because of their mineralogy relatively high nutrient content and presence of weathered minerals. Since the watershed is situated around the lake most areas of the course are covered by wetlands. The wetlands of Enfraz Springs are located at a distance of 15 km northwest of Bahir Dar. There about 44 wetlands in the catchment scattered in the watershed. The soil of the wetland belongs to the zone of Lithic Leptosols and Chromic Luvisols. *Infraz watershed agro-ecology falls into 'Woina Dega' (warm 1500-2500m) and the elevation ranges from 1777-2110m* (Fig.1.).

The mean annual rainfall and temperature for the watershed is 1448mm and 19.2°C, respectively. The main rainy season which accounts for around 70-90% of the total annual rainfall occurs from June to September. Two distinct seasons, dry and wet seasons are recognized. The dry season starts from November to May, while the wet season covers the remaining part of the year, when most of the precipitation takes place (Amare & Kameswara, 2012). Agriculture is the basis of livelihoods of almost all of the people in the watershed. Agriculture is characterized by rainfed, traditional, small scale, subsistence orientated and labour intensive activity. It is mixed farming, where the rural people depend on both, crop and livestock production for their living. However, the increasing demand for food for growing population has become a serious problem in the watershed. As the result of this, most of the land which was either wetland or covered by forest and woodland has been changed into agricultural land. There are about 32,036 people (CSA, 2007) and the crude density is about 124 persons/km^2.

Fig. 1: Study area map



Research Methods

Land cover and land use changes: The maps used for comparing the land use and land cover changes include, topographic maps of 1: 50000, SRTM images of 30 m resolution and landsat images of 1973, 1986, 1995 and 2011 and GPS points collected from the field and Google Earth. The software used for GIS analysis includes ArcGIS10 and ERDAS IMAGINE10 along with the GPS and its software Garmin. Land use and land cover patterns for 1973, 1986, 1995 and 2011 were mapped by the use of Landsat MSS (Multispectral Scanner), Landsat Thematic Mapper data (Table 1). At first, images were transferred to a common UTM and geo-referenced to datum that Ethiopia has already selected by WGS-84. The images were enhanced using histogram equalization to improve the image quality. The land cover and use change of Infraz Watershed was analyzed for the last 38 years. Pre-classification methods were applied to correct the data from sensor irregularities and unwanted sensor or atmospheric noise etc.

Table 1: Image types, sources and their descriptions /*Source: http://glovis.usgs.gov*/

Data Type	Acquisition Date	Number of Bands	Path and Rows	Spatial Resolution (m)
Landsat MSS	01-02-1973	4	182p 52r	57 X 57
Landsat TM	08-03-1986	7	170p52r and 169p 52r	28.50 X 28.50
Landsat TM	17-03-1995	7	170p 52r	28.50 X 28.50
Landsat TM	08-03-2011	7	170p 52r	28.50 X 28.50

The land cover/use change detection involves the application of multi-temporal datasets to quantitatively, the rate and magnitude of change Extracting information from images is known as image classification. Land cover and land use classification involves quantifying temporal effects using multi-temporal data sets. It is the process of sorting pixels into a finite number of individual classes, or categories of data, based on their data file values (Verbyl, 2004). If a pixel satisfies a certain set of criteria, the pixel is assigned to the class that corresponds to those criteria. This study has applied both unsupervised and supervised classification algorithms. First unsupervised classification was applied to identify the major land covers of the watershed. By using this result and collecting GPS points supervised image classification approaches were conducted.

Detection and classification of images for the present study was assisted by ground truth points collected from watershed. A supervised signature extraction with the maximum likelihood algorithm was employed to classify the Landsat images. Both, statistical and graphical analyses of feature selection were conducted, and bands 4 (near infrared), 3 (red), and 2 (green) were found to be most effective in discriminating each class and thus used for classification. Comparison site data were collected by means of on-screen selection of polygonal training data method and alarm masking method in ERDAS imagine software. The comparison sites were chosen for each image to ensure that all spectral classes constituting each land use and land cover category were adequately represented in the practice statistics.

Accuracy Assessment

A set of reference pixels representing geographic points on the classified image is required for the accuracy assessment. Randomly selected reference pixels lessen or eliminate the possibility of bias (Congalton, 1991). In this study, the assessment was carried out using ground control points from field observations as the major sources of reference data and set of reference points have to be generated to assess accuracy. About 120 GCPs were collected from field using GPS. The Kappa statistic was then calculated from these points for 2011 image.

Based on the information obtained from the field and by the assist of spot image of 2005 of the study area the land units of the study area were fixed. The major land classes were: forest, agriculture and settlement areas, bushland, grass lands and wetlands. The landsat imageries used in these analyses is low in its resolution. Because of this the major land use classes were considered , some land unite such as agriculture and settlements were merged and the swamps, ponds, riparian vegetation and marsh areas were also considered as one unit (Table 2).

Table 2: Descriptions of the land cover and land use units

No.	Land Cover Class	Description
1	Forest	Tree-covered land where trees cover density is greater than 10% and planted eucalyptus trees.
2	Bushland	Areas with sparse trees mixed with short bushes, grasses and open areas; less dense than the forest with little useful wood, mixed with some grasses
3	Grassland	Land predominately covered with grasses, forbs, grassy areas used for communal grazing.

4	Farm and settlement	Areas used for crop cultivation, both annuals and perennials, and the scattered rural settlements that are closely associated with the cultivated fields.
5	Wetlands	Wetlands include areas that waterlogged and swampy in the wet season, and dry in the dry season, perennial marshy areas and riparian vegetations.

The geographical extent (in ha) of the each land use type was digitally computed for each time period and the changes in the extents of different land use types for different periods were traced. The change in area on those land covers have been obtained by ERDAS Imagine10 and the calculation formula was as follows:

$$\Delta \text{ A } (\%) = 100 \text{ (at2 – at1 / at1)} \qquad (1)$$

where, Δ A is percent change in the area of a land use type between initial time (t1) and final time (t2); at1, is the area of the land use at t1 time; at2 is the area of the same type in t2 time. The land cover conversion matrix used to analyze the source and destination of each cover type was prepared. The land cover conversion matrix analysis was conducted in ERDAS IMAGINE10. A Conversion comparison map was prepared and each land cover change values were analyzed in Excel sheet to clearly show the source and destination of cover types in table and graphs of cover change dynamics. Using classification result of two-time remote sensing images and conversion matrix model, formula land use conversion matrix can be obtained through cover analysis. Movement direction of certain type of land and resources of newly increased area of certain type can be seen clearly by matrix like below.

$$\begin{bmatrix} (& A_{11} & A_{12} & - & - & - & A_{1n} &) \\ (& A_{21} & A_{22} & - & - & - & A_{2n} &) \\ & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \\ (& A_{n1} & A_{n2} & - & - & - & A_{nm} &) \end{bmatrix} \qquad (2)$$

Where: Aij is the area of conversion from i type of land use in k time to j type of land use in k+1 time.

Socio-economic and population data: The demographic information of Bahir Dar Zuria District was taken from the Ethiopian Central Statistical Authority (CSA). The 1984, 1994 and 2007 census data for Bahir Dar Zuria District was considered as indicator of change in population in the watershed. Using this data, changes in population growth and demographic dynamics were computed for the watershed. In order to compute the population growth rate and future projections for the population of the study area, the following exponential model was adopted: N = N0 rt (3), Where N = Size of the population (present); N0 = Size of the population of previous census; r = growth rate; and t = time period (in years) between the present and the previous census years. And r = {ln (N/N0)} / t (3). From the Infraz watershed, the socioeconomic survey was conducted, by drawing samples from watershed and by using focal group discussions, interviews with local knowledgeable individuals (farming, livestock, forestry, etc.), questionnaire method and direct observations. Sampling for the socioeconomic survey of the watershed area was done in two stages. The first stage involved in the selection of the sample sites/villages, while the second stage involved in selecting the individual households from the selected village. The total sample sizes were 120 households withdrawn by systematic random sampling techniques.

RESULTS

Land Cover Types and their States in Infraz Watershed

The land cover/use state of Infraz Watershed was presented for 1973, 1986, 1995 and 2011 (Fig. 2 and Table 3).

State of Forest: The forest cover extent and its proportion in the years 1973, 1986, 1995 and 2011 in the Infraz watershed was 1492.4 ha, accounting for 5.9% of the total area in 1973.The forest cover had shown dramatic increase in 1986 study time. This was related to the establishment of Bahir Dar City as the regional capital increased demand of wood for construction and firewood. Its cover was increased to 12.2% in the year 1986 and declined to 5.1% and 7.3% for the years 1995 and 2011 respectively (Table 3). This was related to planting of eucalyptus as a source of construction and fire wood with development of Bahir Dar as regional capital at the early times and later replacement of eucalyptus by chat on the following years.

State of Bushland: Land covered by wood and bushland (BL) in the Infraz watershed was 17362.2 ha, accounting for 68% of the total area in 1973. The BL cover extent and its proportional share in the years 1986, 1995 and 2011 were 49.6%, 47.4% and 43.2% respectively (Table 3). During these periods about 63.5% of bush and wood lands were converted to farm and settlement and other land cover types (Table 3). This was because of high demand for agricultural land for the ever increasing population in the watershed and growth of Bahir Dar Town.

State of Grassland: Land covered by grassland (GL) in the Infraz watershed was 595.8 ha, accounting for 2.3% of the total area in 1973. The GL cover extent and its proportional share in the years 1986, 1995 and 2011 were 10.0%, 9.7% and 3.7% respectively. During the study time, about 338.3 ha of area were gained from other land cover. From interview and focus group discussion this area was obtained from dried wetlands and cleared bushland.

State of Wetlands: Land covered by Wetlands (WL) in the Infraz watershed was 1580.1 ha, accounting for 6.2% of the total area in 1973. The WL cover extent and its proportional share in the years 1986, 1995 and 2011 were 4.0%, 3.0% and 2.1% respectively. Majority of the land cover was converted to farm land, grass land other land types. The wetlands during the study period had shown continuous decline.

State of Farm and Settlement Lands: Land covered by farms and settlement lands (FSL) in the Infraz watershed was 4491.8 ha, accounting for 17.6% of the total area in 1973. The FSL cover extent and its proportional share in the years 1986, 1995 and 2011 were 24.2%, 34.8% and 43.8% respectively. The land cover of FSL had shown continuous increase in the watershed.

Fig. 2: Land cover and use maps of Infraz Watershed in 1973, 1986, 1995 and 2011

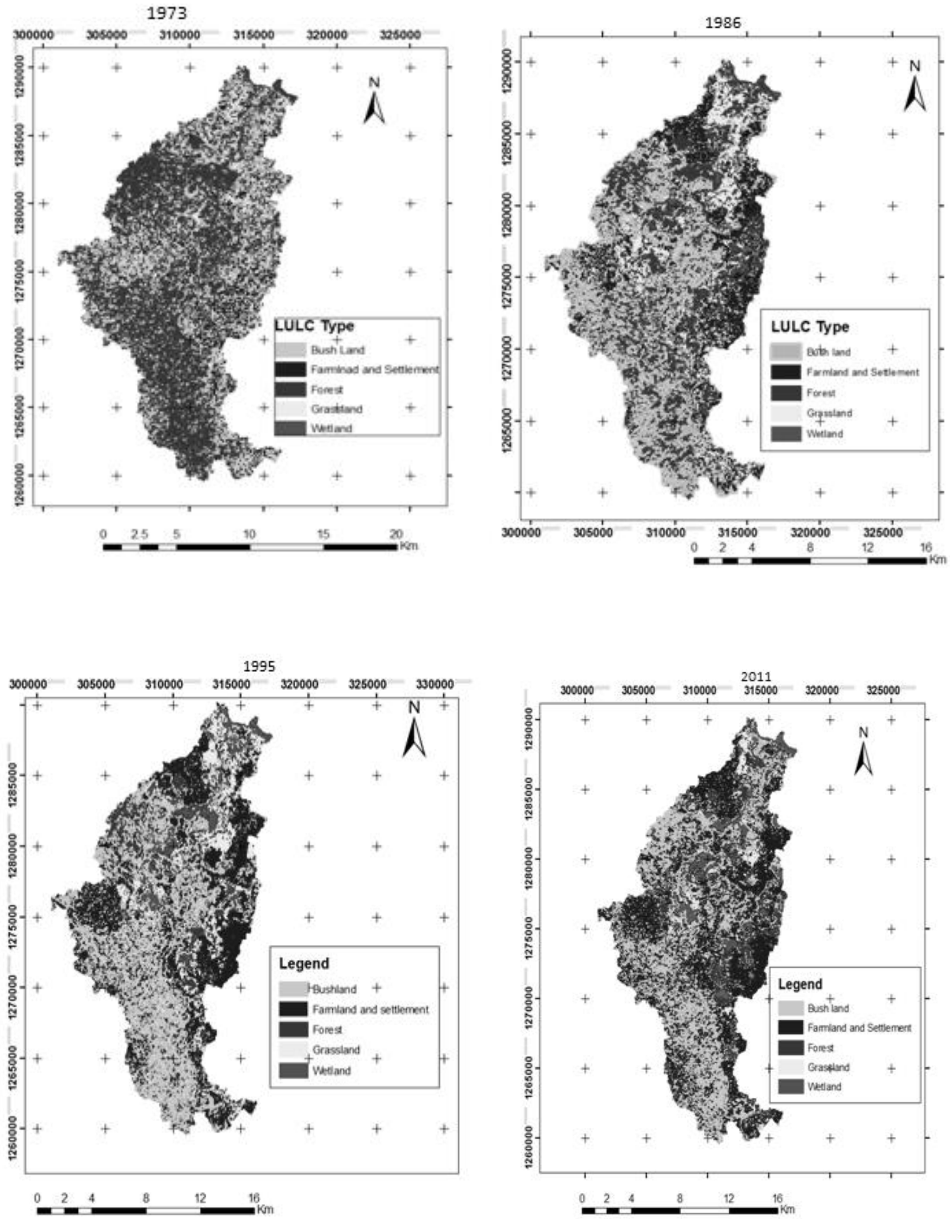


Table 3: Land cover/use of Infraz watershed from 1973-2011

Land cover classes	1973		1986		1995		2011		1973-2011
	Area (ha).	%	Area (ha).	%	Area (ha).	%	Area (ha).	%	Total loss or gain
Grass	595.8	2.3	2655.6	10.0	2485.8	9.7	934.1	3.7	+338.3
Farm and settlement	4491.8	17.6	6279.9	24.2	8876.9	34.8	11177.1	43.8	+6685.3
Bushland	17362.2	68.0	12772.4	49.6	12086.6	47.4	11023.5	43.2	-6338.7
Forest	1492.4	5.9	3105.6	12.2	1301.6	5.1	1850.1	7.3	+357.7
Wetlands	1580.1	6.2	1015.8	4.0	769.1	3.0	535.2	2.1	-1044.
Total Area	25522.3	100.0	25522.3	100.0	25520.0	100.0	25520.0	100.0	

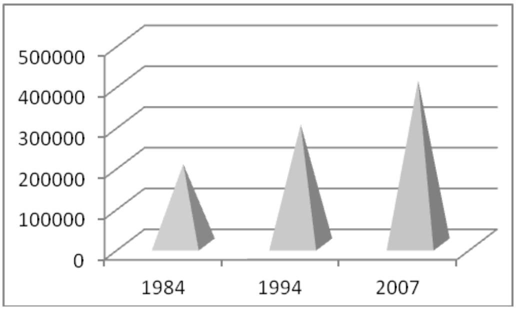
Accuracy Assessment

The assessment of the accuracy of classification was performed through the examination of the identity of certain selected evaluation pixels representative of respective land covers. A common approach to reporting image classification accuracy is to calculate the proportion or ratio of the mapped area that has been correctly classified in comparison to reference data or ground data to the total area mapped. The accuracy report of Kappa Statistics shows about 86% of the 2011 image was classified correctly.

Population and Socio-Economic Aspects

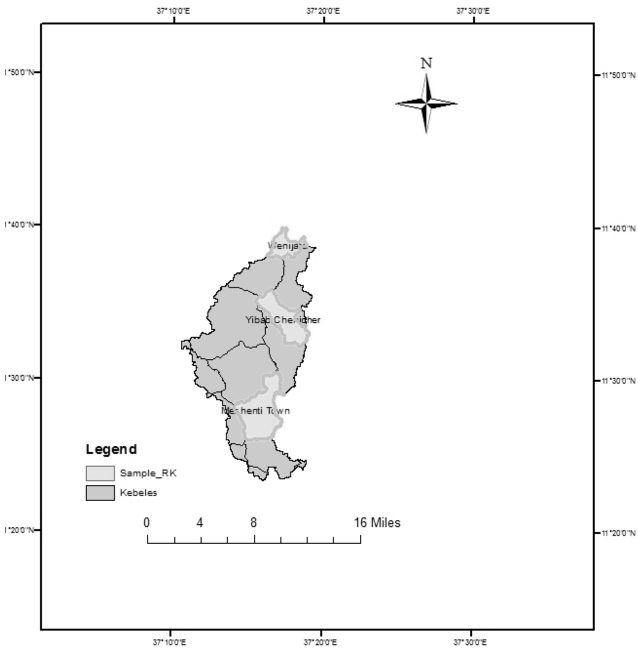
The demographic dynamics and environmental changes have direct and immediate implications for local livelihoods by changing the land cover into different land use units (Amare, 2013). Since the Infraz watershed is entirely located in Bahir Dar Zuria District (BDZD), the change in population in the district has a greater role on the land cover/use changes within the watershed. The changes in population for the BDZD were made in the periods between 1984 and 2007 only because there was no census activity in the country and in the study areas prior to this period. In BDZD total population in 1984 was 197,581 and in 1994 population of the same district became 294,424 and in 2007 population of district was 403,020 (CSA, 1984, 1994, 2007) (Fig. 3). The population has doubled in numbers with in less than 20 years. This is a good example of what is happening with the population for the last 25 years. The growth of population per year in the district from 1984 to 1994 was 3.9% and from 1994-2007, it was 2.4 % per year. Although it is declining, it is still one of the highest in its size and growth.

Fig. 3: Population change from 1984-2007 per year/1000 in BDZD

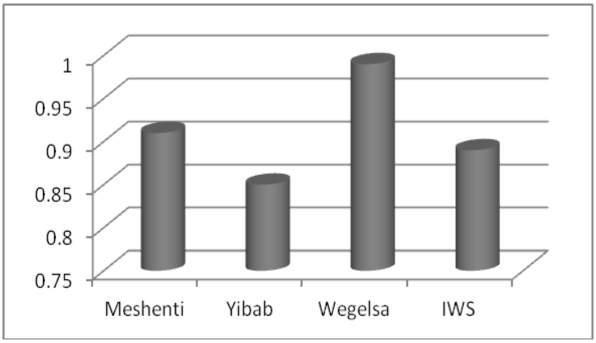


Land is the only resource for the livelihood support to the Infraz Watershed inhabitants because of their low literacy, educational and awareness levels (Amare, 2013). The total land owned by all the sample households' accounts for 105 ha with a mean of 0.89. However, over the three village of watershed; outlet village (Wegelsa) had relatively greater holding size, with a mean of 0.99 ha (Fig. 4 a and b). The other villages included in the study cover 0.91 and 0.85ha respectively (Fig. 4). The land holding is the most fragmented and a household may own one to four plots, which is a result of frequent land distribution system based on a household size/ during the Derg regime. The land plot owned by the respondent is one indicator of dependency of community on natural resources.

Fig. 4: Sample kebele (a) and average land holding (ha) (b) in Infraz watershed
(a)



(b)

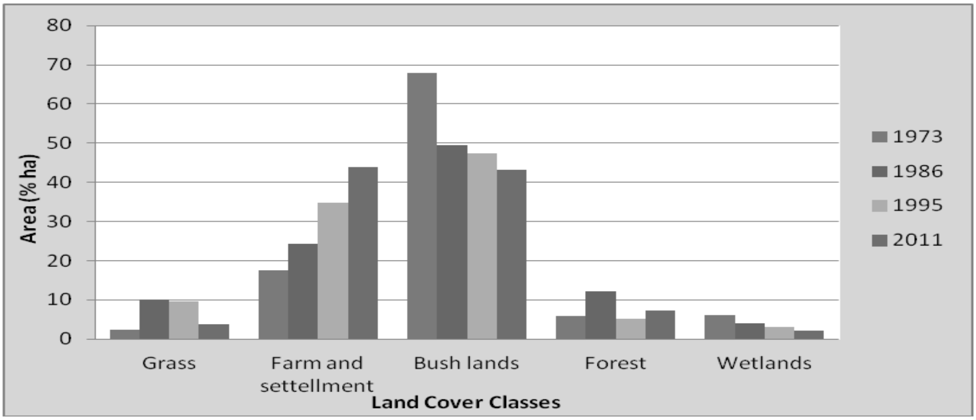


DISCUSSION

The major LULC categories identified are given in (Table 1). Over the three decades and from other studies stated above, similar trends of LULC changed at different rates of conversion were shown in all cover types except for the scattered grassland. The grass and forestland were dynamic in their changes (Fig. 5). Also, in most East African countries, areas under canopy cover was converted into grazing land, farmland or for charcoal production (Amare, 2013). The change was related to mainly to anthropogenic factors. Similarly, according to Nurlign and Amare (2014) in the Ribb River watershed there was a continued expansion of cultivated land and settlement over years which has brought significant decrease in water bodies, forest and bush LULC classes. This threatens both the local highland users through a reduction in soil productivity, and lowlands through sedimentation. The study by Birru (2007) from the analysis of satellite images (between 1985 and 2001 has also found that in Lake Tana Basin croplands have increased to about 4.2% in 15 years (between 1985/86 and 2001/03), which largely occurred at the expense of grassland and shrubland. As Birru (2010) indicated land use/cover in the upstream of Ribb and adjoining watersheds are being degraded contributing to the flood hazard prevailing in the area. Since the Ribb Watershed has been subjected to prolonged use for agriculture without conserving natural resources, forest degradation, loss of biodiversity, shortage of fuel wood and forage trees are vegetation related problems existing in the area (Nurlign & Amare, 2014).

Infraz Watershed is one of the most known cereals producion area in the country. However, the increase in population imposes greater pressure on the land and other natural resources in the watershed, which results in the degradation of the resources in quality and quantity. Population growth tends to cause conversion of natural landscapes into use for the needs of the community resulting in changes in the land use pattern (Amare, 2013; 2013). The population growth was very rapid and within this time in the watershed there was very rapid land cover and use change. There was demand for agriculture and settlement lands for increasing population and obtaining fuel wood from open access wood lands. This has led to expansion of agriculture and settlement lands by clearing bush lands and wetlands (Fig. 5). Similar studies by Luca (2013) in West Bengal revealed that area under dense forests decreased from 58% in 1990 to 33% in 2000 but increased to 39% in 2005, whereas open forest has increased from 10% in 1990 to 22% in 2000 but again decreased to 7% in 2005. This shows the dynamic conditions of land cover change in the study area. This implies that population growth in Infraz watershed was one of the causes of conversion of bushland and wetland into farm and settlement lands within the stated periods and its final consequence is disturbance of the ecosystems of the watershed. Unlike other studies, the case of forest resource change trend is different. This is because during classification of land planted eucalyptus tree is included under forest category and the area is known in its commercial eucalyptus production. The other issue is the late introduction of *chat* in the watershed. This has made the forest land use difficult to see the trends of its change.

Fig. 5: Trends of land cover change in Infraz Watershed between 1973-2011



Land is very much intertwined with human culture and identity in the watershed. It is also the main asset that farmers have to accumulate wealth. Accordingly, the size of the land that they own and the level of security they have in their holdings affect a household's income, and their incentive to work and to invest on it (Berhanu *et al*., 2002). From the researcher personal experience and observation and discussion with community in the area, farmers did not have enough land and they have not practiced use of chemical fertilizers because of high cost. Instead they try to expand their plot by clearing bushland and wetlands near their plot of farm lands (Amare, 2013; 2013). The farmers, because of lack of land, they plough steep slopes with no more products. Their farming system has been the most ancient type and has no any attached technique of managing soil loss. Thus, for the land to be secured and use for long and sustainable manner the land holding system should be private. However, the land holding system in the study area in particular and in the country in general has been in the hands of the government for a long time. Hence, one of the reasons for the land cover and use change in Infraz watershed was the land security problem.

As a result, many people in the watershed have to get living income from other sources such as selling fire wood, cow dung and others that are obtained from exploitation of environmental resources. These activities in turn degrade the land and expand the land cover and use change in the Infraz Watershed. In addition, farmers started to cultivate chat by clearing bush and wetlands. The plant requires more water to grow so that farmers plant it near the springs and add chemical to protect it from insects. This process is linked to improper agricultural practices, population pressure and poverty in a complex web of cause and effect (Amare, 2013; Sonneveld, 2003). This has led to cultivation without sufficient amendments, which often accentuates the processes of degradation (Shiferaw & Holden, 2001). This implies bush and wetlands near the springs were converted to chat cultivation (Fig. 6). Thus, improper agricultural activities are the other causes of land degradation in Infraz watershed.

Fig. 6: Chat cultivation in Infranz watershed

CONCLUSION

The demand for agriculture and settlement for increasing population and expansion of agriculture led to clearing of bush and wetlands in Infraz watershed. A large extent of land was converted to farms and settlements, but the individual farm size has been declining. This implies that despite more area is converted to cultivation, the household land size have been reduced. The access to the family planning practices to the rural area was very insignificant in the Infraz Watershed. There is an urgent need to limit population growth in the Infraz Watershed through the implementation of family planning. There should be land use planning by identifying the proper land for specific purpose so that the marginal lands will not be put into use. Therefore, the current trends in land use/cover must be improved, towards the resources management and conserving of the existing vegetation and other natural resources in the study area. There should be well organized, strong and effective policy intervention to protect the remaining vegetation and avoid further conversions.

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