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RESEARCH ARTICLE

Land use and land cover change and implication to watershed degradation by using GIS and remote sensing in the Koga watershed, North Western Ethiopia

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Abstract Information on use/land cover change is important for planners and decision makers to implement sustainable use and management of resources. This study was intended to assess the land use land cover (LULC) change in the Koga watershed. The MSS of 1973, TM images of 1986, 1995 and 2011 were used together with survey and demographic data to detect the drivers of land cover changes. The result revealed that a remarkable LULC change occurred in the study area for the past thirty eight years. The area of cultivated and settlement has increased by 7054.6 ha, while, grass and bush lands decreased by 4846.5 and 3376 ha respectively. Wetland also declined from 580.2 ha to 68.3 ha. The growing demand for cultivable land and fuel wood were the major causes to the deterioration of grass and bush lands. Hence, the appropriate land use policy should be employed to sustain available resource in the watershed.

Keywords Demographic factors · Land conversion · Land cover/use · Images · Watershed

Introduction

Land use is describe as human uses of the land, or immediate actions modifying or converting land cover (Lambin et al. 2003). Whereas, land cover refers to the natural vegetative

cover types that characterize a particular area. But these terms sometimes are too difficult to differentiate (De Sherbinin 2002). Similarly, Gomarasca (2009) stated land cover as the physical surface of the earth, including various combinations of natural and cultivated vegetation and manmade infrastructures. Land use, instead, includes both the way in which the Earth's biophysical attributes are modified and the reasons for which they are altered (Messay 2011). The land use is affected by human activities, especially with reference to those who decide about land management, institutions included.

The process of land cover and use has been a continuously occurred at all times in the past, are presently ongoing, and are likely to continue in the future (Gomarasca 2009). However, over two decades, the issue of LULC change has gained considerable attention in a number of fields, for example remote sensing, political ecology and biogeography (Getachew et al. 2011). This is partly because it is the most important component of global change (Chamaporn and Tonny 2011). There are many driving forces contributing to LULC change which could be social, economic, institutional or geographic in nature. The global LULC change is a result of two main factors such as natural, and human forced, such as population growth, economic policies and domestic behaviour (Bezuayehu and Sterk 2008). Nevertheless, global population growth and increased economic development over the last century have been major causes of land use changes. Natural land covers have been transformed to agricultural lands and urban areas to meet the increasing demands for food, water, consumption of goods and other public utilities for over six billion people worldwide (Amare and Kameswara 2011).

Land use and land cover changes have many ecological, social and economic impacts on biotic diversity, soil degradation, and the ability of biological systems to support human needs (Hussein 2009). Land use and land cover changes also determine, in part, the vulnerability of places and people to

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climatic, economic, or sociopolitical perturbations. When aggregated globally, LULC changes significantly affect central aspects of earth system functioning (Lambin et al. 2003). LULC change plays an important role in global environmental change and sustainability, including response to climate change, effects on ecosystem structure and function, species and genetic diversity, water and energy balance, and agroecological potential (Hussein 2009).

There are many driving forces contributing to LULC change which could be social, economic, institutional or geographic in nature (Lepers et al. 2005). Natural land covers have been transformed to agricultural lands and urban areas to meet the increasing demands for food, water, consumption of goods and other public utilities for over seven billion people worldwide (Chamaporn and Tonny 2011). For example, Europe and eastern China experienced first the most rapid cropland expansion during the eighteenth century. A very gradual cropland expansion occurred in Africa, South and Southeast Asia, Latin America, and Australia until 1850, but since then, these regions have experienced dramatic increases in cropland, especially during the second half of the twentieth century. The greatest cropland expansion in the twentieth century occurred in South and Southeast Asia (Lambin et al. 2003).

Like in many other developing countries, most of the population of Ethiopia live in rural areas and depend directly on the land for its livelihood (Woldeamlak and Sterk 2005). In this regard, Kiros (2008) indicated that in response to the increasing demands for food production, agricultural lands are expanding at the expense of natural vegetation and grass lands. According to Hussein (2009) and Amare (2013a, b) in their study in the Ethiopian highlands concluded that LULC changes were mainly driven by human actions. Consequently, LULC changes could lead to a decreased availability of different products and services for human, livestock, agricultural production and damage to the environment as well.

Thus, comprehensive knowledge of these dynamics is useful to reconstruct past LULC changes and also predict future changes, and to elaborate sustainable land resource management practices aimed at preserving essential landscape functions (Hietel et al. 2004). As a result, there is the need to understand LULC change: its dynamics, the possible causes, its effect on the environment, the economic and social impacts as well their role on watershed degradation. There is also a continuing demand for accurate and up-to-date LULC change information for any kind of sustainable development programs where LULC serves as one of the major input criteria (Das 2009). However, to study LULC change, it is necessary to employ advanced technologies which have the potential to provide timely, accurate and reliable information. GIS and remote sensing in this perspective have been proved to be important tools in LULC change studies. These days GIS

and remote sensing capabilities are utilized in various fields. LULC change detection is one of the GIS and remote sensing applications in environmental change studies.

Investigating LULC change has become an important tool to generate evidence for decision-makers, spatial planners, local communities, or actors who are operating within a given landscape to formulate appropriate policies and strategies. Hence, LULC change analysis helps decision-makers ensure sustainable development and understand the dynamics of the changing environment (Carmel and Kadmon 1998). Identifying the driving forces behind LULC changes, and developing appropriate measures to minimize their ecological effects have great deal of importance for land use planning. Specifically, this study determines the land cover and use status with special reference to its causative factors through time in Koga watershed, one of the most densely populated areas of Ethiopia. Thus, this study was intended to assess the LULC change and causative factors in Koga watershed by using GIS and remote sensing techniques for the past thirty eight years (1973–2011). Specifically the study was, amid to investigate LULC change drivers between 1973 and 2011 at the watershed level.

Research methods

Description of study area

Koga watershed, is situated in Northwestern part of Ethiopia, southern part of Lake Tana catchment, between 11^0 10′ and 11^0 25′ North latitude and 37^0 2′ and 37^0 17′ East longitude (Fig. 1). The watershed consists of land drained by the Koga River above its confluence with the Gilgel Abay. The Koga River flows south to Northwest with a total length of 49 km (Fikru 2009). Amare and Kameswara (2011) also states that, the Koga River is a tributary of the Gilgel Abbay and it joins to the Gilgel Abbay River downstream of the town of Wetet Abbay, at an altitude of 1985 m a.s.l. The watershed is characterized by tapered, strongly dissected highlands to the south, and a relatively flat plateau in the north. The elevation ranges from 1800 to 3200 m above sea level (masl).

The rainfall in the Koga watershed area has a unimodal characteristic with one rainy and one dry season. The dry season occurs between November and April, while the wet season is observed between the months of May and October. Some rain is also received during the months of April and May. Mean annual rainfall is approximately 1560 mm, and a mean daily temperature is between 16 and 20^0c (Tilashwork 2009). The annual mean temperature in Koga watershed is about 22^0c. The typical economic activity in the study area is a mixed crop-livestock small holder farming system.
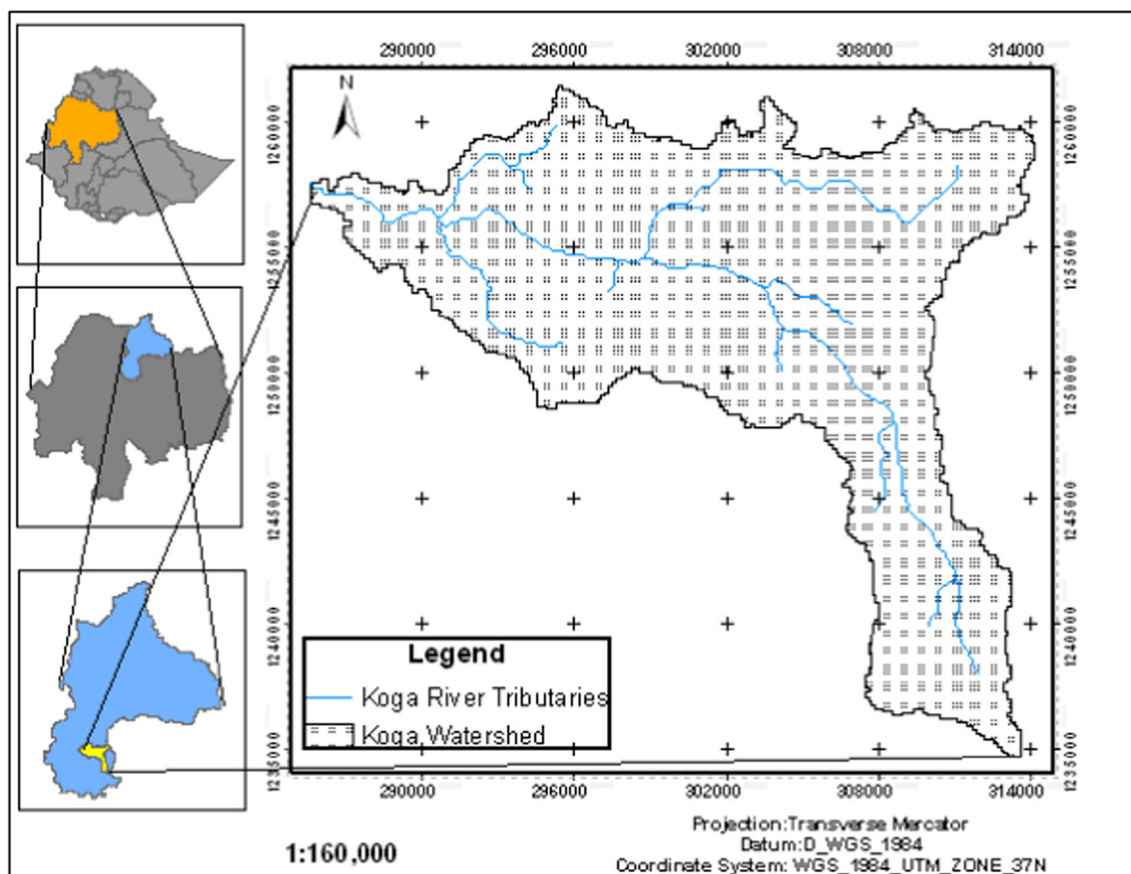
Fig. 1 Map of Koga River watershed

Research methods

Primary data were acquired from field survey using the Garmin GPS and structured household questionnaire, focus group discussions and interview with key informants. Landsat imageries used for this study were selected based on availability, percentage of cloud cover and correspondence with years of major events in the study area. All Landsat imageries were accessed free of charge from the US Geological Survey (USGS) Center for Earth Resources Observation and Science (EROS) via http://glovis.usgs.gov/. The nonaligned scenes were geocoded to the underlying base layers by using control points. Re-projection to the local projection system was made (UTM, map projection; Clarke 1880, Spheroid; and Adindan Datum). A freely available IDL and ERDAS software used for the correction. Atmospheric and radiometric correction of all Landsat images acquired for the different times were also made using a fully image-based technique developed by Chavez (1996) known as the COST model; this model derives its input parameters from the image itself. In a next step, temporal normalization of all the images was achieved by applying regression equations to the 1973, 1986, 1995, and 2011 imageries which predict what a given Brightness Value (BV) would be if it had been acquired. This pre-processing step reduces pixel brightness value variations caused by non-surface factors and enhances variations in pixel BV between dates related to actual changes in surface conditions. The 2011 TM image was selected as the reference scene to which the other images were normalized, because it was the only year for which quality in situ ground reference data were available.

A hierarchical land use classification was derived from the authors' prior knowledge of the study area and based on the most popular scheme of the U.S. Geological Survey Land Use/Cover System devised by Anderson et al. (1976). A hybrid unsupervised/supervised classification approach was integrated with successive Geographic Information System (GIS) operations (spatial analysis) to classify the imageries of 1973 (MSS), 1986 (TM), 1995 (TM) and 2011 (TM) to land classes (Table 1).. First, to determine the spectral classes Iterative Self-Organizing Data Analysis (ISODATA) clustering was performed. Ground truth (reference data) was collected to associate the spectral classes with the cover types of the already defined classification scheme for the 2011 (TM) imagery from field observations.

The ground truth data collection was carried out for training and ground verification for image classification and accuracy assessment respectively. To assess the accuracy of

Table 1   Description of LULC types in the Koga watershed

LULC type	Brief description
Cultivated and Settlement	Areas allotted to crop cultivation and scattered rural settlements
Forest Cover	Areas with a high density of trees which include patches of natural forest and eucalyptus plantation.
Bush and wood lands	This refers to sparse, low vegetation- bushes and small trees with little wood mixed with some grasses.
Grass Land	Area covered with grass that is used for communal grazing and covered by grass for a considerable time of the year.
Wetland	Area which remains water logged and swampy throughout the year.

thematic information derived from 1973 (MSS), 1986 (TM), 1995 (TM) and 2011 (TM) imageries, the design-based statistical inference method was employed which provides unbiased map accuracy statistics (Jensen 2005). Among other sources of information, reference data was collected from previous maps for the 1995 image (Zeleke and Hurni 2001). A total of 2277 reference data points for each year were obtained, of which 759 points were used for accuracy assessment and 1518 points were used for classification. Training sites were developed from the ground truth data collected to generate a signature for each land cover type. The number of samples required for each class was adjusted based on the proportion of the class and inherent variability within each category. Discrete multivariate analytical techniques were

used to statistically evaluate the accuracy of the classified maps (Foody 2002). As there is no single universally accepted measure of accuracy for this study a kappa index was accepted (Stehman 1997).

The Post classification comparison was employed using separately classified landsat images and then a comparison was made for the LULC maps of 1973–1986, 1986–1995 and 1995–2011. Hence, change matrix was applied in ERDAS Imagine 10 to determine type of LULC changed and the direction of LULC change in the study area. In this study the farm and settlement areas were included in the same land cover, because settlements in the rural areas are near their farmlands and difficult to separate from low resolution imageries.
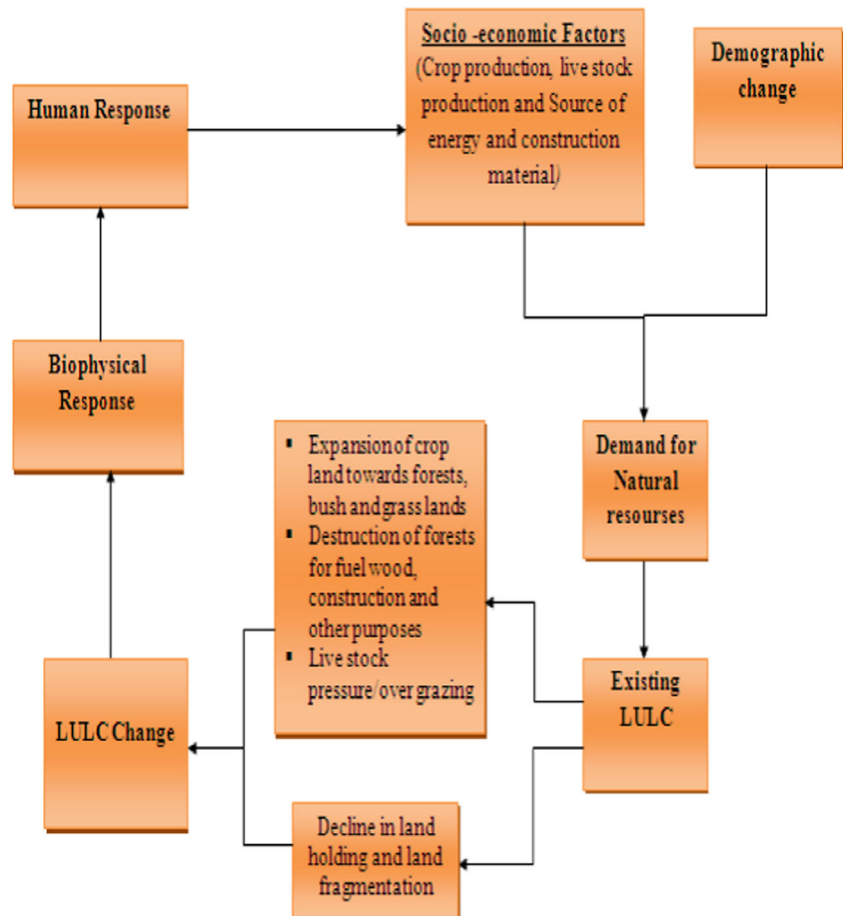
Fig. 2 Methodological flow of the study variables

Table 2 Land use/cover change from 1973 to 2011 in the Koga Watershed

LULC type	1973		1986		1995		2011	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Cultivated & Settlement	16131.6	55	20383.9	69.4	22979.5	78.3	23186.2	79
Forest Cover	966.6	3.2	230.8	0.8	207.4	0.7	1058.8	3.6
Bush Land	5272.6	17.9	2927.9	10	2665.2	9.1	1896.6	6.5
Grass Land	6397.8	22	5732.4	19.5	3398.1	11.6	1551.3	5.3
Wetland	580.2	1.9	73.8	0.3	98.6	0.3	68.3	0.2
Water Body	–	–	–	–	–	–	1587.6	5.4
Total	29348.8	100	29348.8	100	29348.8	100	29348.8	100

In order to acquire supplementary data related to LULC change in the study area, the structured questionnaire was used and data related to demographic features of households, land holding size, crop production, livestock production, sources of energy etc. The intensive interviews and focus group discussion were held with individuals who have lived at least 20 and above years in the study area. The focus group discussion was organized to obtain additional information on historical and current LULC changes in the study watershed. Two sample kebeles were taken from 14 kebeles by using randomly sampling technique. Subsequently, sample households were selected from each cluster using simple random
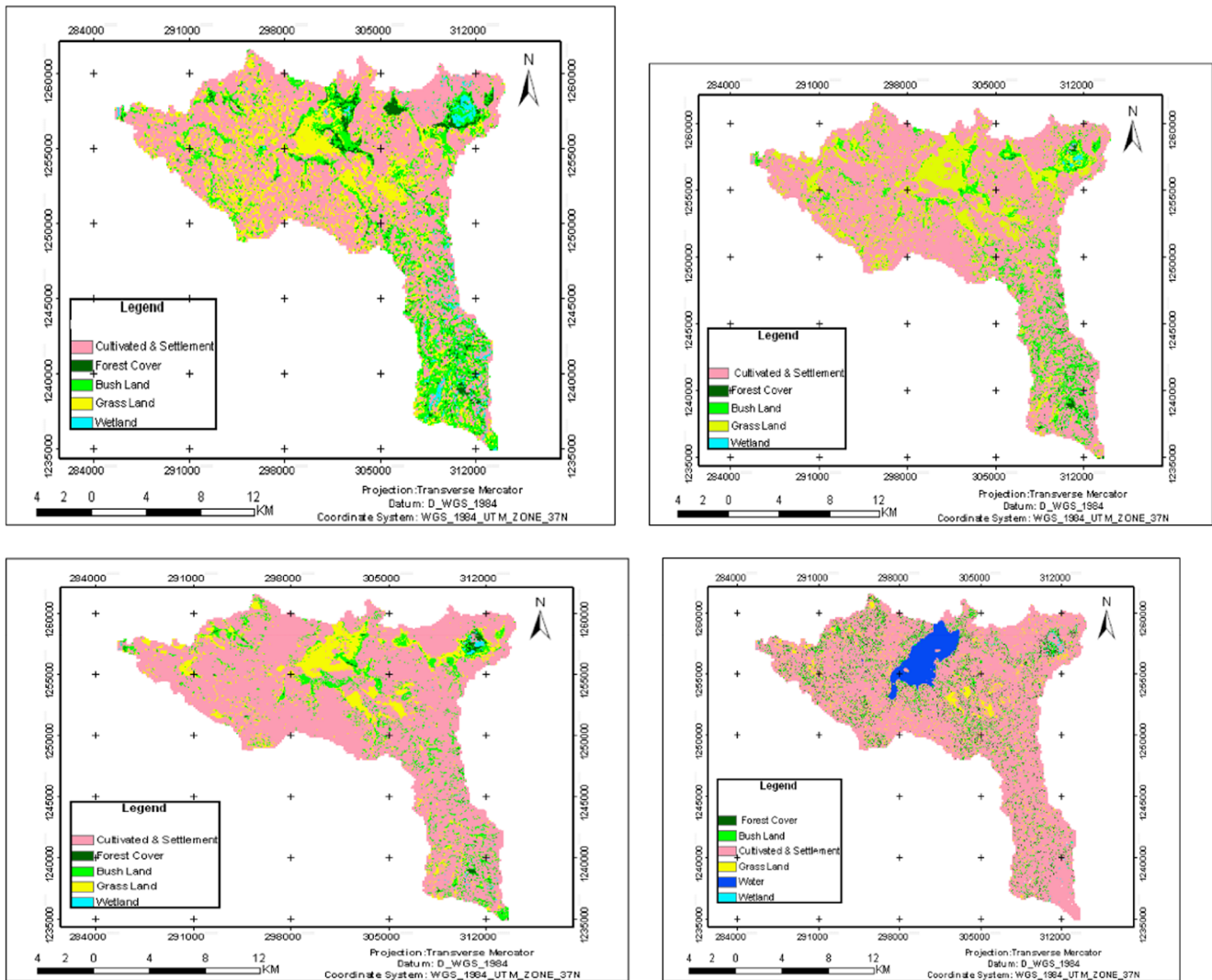

Fig. 3 Land cover change from 1973 to 2011

Table 3 Trend of LULC change from 1973 to 2011 and expected in 2021

LULC	Area (1973)	Area (2011)	Change between 1973 and 2011		Average rate of change		Change in ha after 10 years(20121)
	ha	ha	ha	%	Ha/yr	%	ha
Cultivated& Settlement	16131.6	23186.2	+7054.6	+44	+185.6	+1.2	+222.72
Forest Cover	966.6	1058.8	+92.2	+10	+2.4	+0.3	+0.72
Bush Land	5272.6	1896.6	−3376	−64	−88.8	1.7	−150.96
Grass Land	6397.8	1551.3	−4846.5	−76	−127.5	2	−255
Wetland	580.2	68.3	−511.9	−88	−2.3	2.3	−202.4
Water	–	1587.6	+1587.6	–	–	–	–
Total	29348.8	29348.8	–	–			−384.92

sampling technique. Accordingly, a total sample size of 138 household heads were taken from the whole clusters in which 23 households were selected on average from each cluster. Finally, a structured household survey questionnaire was administered to sample households. Interviews were conducted to the household heads to gather data on demographic characteristics, household assets (land holding, livestock, etc.), crop production, household supply (fuel, fodder).

The socio economic data that was obtained from the household survey was entered and analyzed using Statistical Package for the Social Sciences (SPSS, version 16). Hence, to attain the objectives of the study, descriptive analysis methods were done by using the above statistical package software. Moreover, relevant issues collected through focus group discussion, interviews and observation methods were summarized and presented to supplement household survey data analysis (Fig. 2).

Result and discussion

Land use and land cover change in the Koga watershed

During the study periods cultivated and settlement areas has been increased by 26.4% between 1973 and 1986. While, forest cover and bush lands, have shown a reverse trend and reduced by 76.1% and 44.5% respectively at the same period. Similarly, the area under wetland and grass land has declined by 87.3% and 10.4%, respectively in the same time (Table 2). This indicates that cultivated and settlement areas were expanded at the expense of other LULC types between 1973 and 1986. At the same time, cultivated and settlement area have increased by 12.7% between 1986 and 1995. While, forest cover and bush land have been declined by 10.1% and 8.9% respectively during the same time. Likewise, grass land has declined by 40.7% in this period. On the other hand,
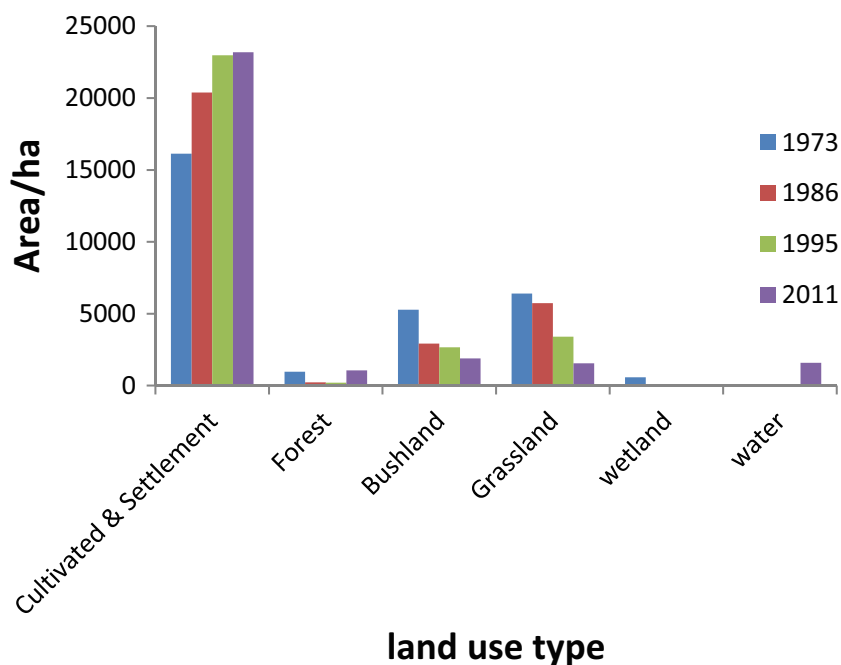
Fig. 4 LULC changes from 1973 to 2011

Table 4 Accuracy assessment of LULC classification, 2011

LULC	Cultivated & settlement	Forest	Bush land	Grass land	Wetland	Water	Total
Cultivated & Settlement	41	2	3	0	2	0	48
Forest	0	4	0	0	0	0	4
Bush Land	0	2	3	0	0	0	5
Grass Land	1	0	0	4	0	0	5
Wetland	0	0	0	0	4	0	4
Water	0	0	0	0	0	4	4
Total	42	8	6	4	6	4	70

Overall classification accuracy = 89.55%

Overall kappa statistics = 0.635

wetland has increased by 33.6% (Table 2). Similar to the previous period, cultivated and settlement has shown a remarkable increment. Thus, it is possible to say that cultivated and settlement land has expanded at the cost of other LULC types, mainly grass and bush lands.

Between 1995 and 2011, the area of cultivated and settlement area has increased slightly to 206.7 ha as compared to 2595.6 in the previous period. However, forest cover has shown a slight increment (Table 2). This was due to the plantation of eucalyptus tree in the watershed, as response to scarcity of wood for fuel and other demands. In the same way, study by Woldeamlak (2002) confirmed that as there was persistent increase of forest cover which includes trees planted around homesteads (Most of the tree species planted were varieties of Juniper and Eucalyptus) in the Chemoga Watershed led to increment of forest cover. Getachew et al. (2011) also reported a slight increase in eucalyptus tree between 1982 and 2008 in the Debre

Mewi watershed near to the study watershed. On the other hand, grass land has diminished drastically (reduced by 54%) being pushed by the expanding cultivated land and the construction of the Koga dam that was observed on 2011 imagery. Similarly, bush and wetland lands have declined by 29% and 31% respectively in this period. Water body has shown a considerable expansion over the same period (Table 2 and Fig. 3). This was due to the construction of the Koga dam in the watershed.

Generally, the result indicated that there was a series of LULC change for the last thirty eight years (1973–2011). In this regard, the trend has shown a tendency towards more land being brought under cultivated and settlement area. At the same time, forest (i.e. eucalyptus plantations) became more important in the study watershed and has shown a slight expansion for the past sixteen years. This finding has similar results to Amare (2013a, b) that confirmed the expansion of agriculture and settlement land at the expense of other land

Table 5 Population distribution in the Koga watershed by kebele and sex, 2007

S.No	Kebele	Population Male	Population Female	Total	Number of households
1	Yinesa Lemirt	3571	3490	7061	1452
2	Abro Menor	3725	3873	7598	1528
3	Abyot Fana	5393	5296	10689	2384
4	Rim	2847	2917	5764	1384
5	Felege Hiwot	2450	2420	4870	1017
6	Midre Genet	2678	2618	5296	1118
7	Sira Betegbar	1647	1476	3123	640
8	Kurt Bahir	3525	3413	6938	1510
9	Enashenfalen	4565	4297	8862	1908
10	Inamirt	3356	3333	6689	1511
11	Tatek Gebere	2627	2552	5179	1165
12	Ambo Mesk	3687	3364	7051	1565
13	Mekni Warka	3149	3035	6184	1329
14	Kudmi	4621	4166	8787	1856
Grand Total		47841	46250	94091	20367

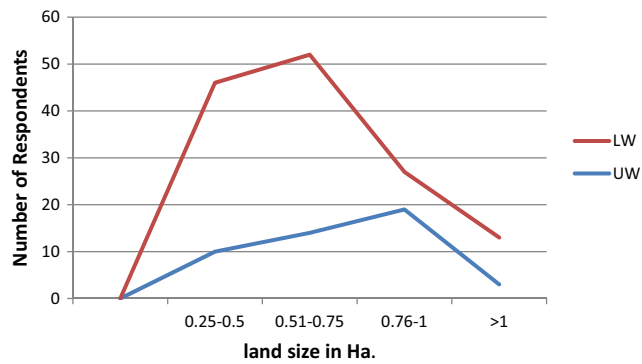CSA, (2008:350), the 2007 population and housing census of Ethiopia

Fig. 5 Land size of respondents in Ha,Upper Watershed (UW) and Lower Watershed (LW)

uses. The finding was also consistent with the findings of Getachew et al. (2011) and Abate (2011) who reported a significant increase of agricultural land at the expense of shrub and grass land.

Trends of change in land use and land cover

Taking into consideration the overall study period, cultivated and settlement land has shown a remarkable areal increment; by 44%. Forest cover has shown relative increment in coverage, by 10% in the same period. Contrary to this, wetland and grass lands have diminished by 88% and 76% respectively in this period. Similarly, bush land has declined by 64% (Table 3 and Fig. 4).

Generally, the result has indicated a series of LULC change for the last thirty eight years (1973–2011). In this regard, the trend has shown a tendency towards more land being brought under cultivated and settlement area. At the same time, forest (i.e. eucalyptus plantations) became more important in the study watershed and has shown a slight expansion for the past sixteen years. To the contrary, more and more land covered by bush, grass and wetlands had transformed to cultivated and settlement areas and declined severely. This is consistent with the findings of Getachew et al. (2011) and

Abate (2011) who reported a significant increase of agricultural land at the expense of shrub and grass land.

The overall accuracy assessment (Table 4) indicated that the nature of the classification error used in many other research works not far from this result (Abate 2011). The overall accuracy and kappa coefficient is 89.55% and 0.635 respectively (Table 4). According to Ismail and Jusoff (2008) the agreement criteria for Kappa statistics (K) was defined as: poor when K < 0.4, good when 0.4 < K < 0.7 and excellent when K > 0.75. Thus, according to these agreement scales, the LULC change classification for 2011 in this study denotes as better represented. The finding was also similar to Diallo et al. (2009) and Reis (2008) who reported a satisfactory overall accuracy of 85.1% and 87.1% respectively. Hence, the overall accuracy is considered acceptable for this study.

Causes of land use and land cover change in the Koga watershed

In the study area there was continuous LULC changes. The changes have been due to different factors which may lead to an irreversible environmental problems and natural resource degradation (Lepers et al. 2005). These include the institutional, socioeconomic and demographic conditions of the surrounding community. The human activities are to be responsible for the major LULC changes in the study area. As in other areas of the country, the number of people in the Koga watershed is growing rapidly from time to time. The population of the Koga watershed was growing at a rate of 2.4% per annum between 1994 and 2007 (Table 5). Moreover, the population of the watershed doubles its size within 29 years. Hence, the population of the Koga watershed will increase twofold within a span of 29 years. As a result of such unparalleled increases in population size, the pressure on existing natural resources is expected to intensify in the study area (Amare 2013a, b). The crude density in the study area was about 235 persons per km^2 in 1994 and about 321 persons per km^2 in 2007 (Table 5).

Fig. 6 Live stocks consuming maize stack (**a**) and women collecting fire wood (**b**)

This finding is in line with that of Braimoh and Vlek (2005) who indicated that population density is important determinant where the dominant change process is extensification. An increase in population density between 1984 and 2007 significantly decreased the probability of observing the grassland-to-cultivated land conversion. This result suggests that an increasing population pressure could rather lead to intensified cultivation of land as a land use change process than an agricultural extensification. This indicates that the study watershed is a densely populated area, which implies that there is very high pressure on the natural resources in the study area.

Land is the most important natural resource for rural households. However like most highland areas of Ethiopia, the farm size of the sample households is on average is less than 1 ha. Based on the household survey, the average land ownership for a household was 0.69 ha which ranged from. 0.5 to around 1. ha (Fig. 5). This shows that there is acute shortage of farm lands in the study area. In this regard, Fikru (2009) and Amare (2013a, b) states that because of shortage of farm size, fallow lands are not common and there is also a shortage of grazing land in the koga watershed. Thus, it is possible to say that land holding size has probably adversely influenced LULC changes in the study area. The major LULC change observed in the study area was the remarkable expansion of crop land at the expense of forest cover, bush land, grassland and wetland. The farmers in the study area depend on rainfed crop production, where production is carried out on a subsistence basis using the traditional farming system. Thus to feed the growing population, the farmers increased crop production through aerial expansion of cultivated land towards forest cover, bush and grass lands. The field observation confirmed that, these days almost all the lands which are suitable for crop production are already cultivated. Overuse of the agricultural land without appropriate conservation measures is facilitating erosion, which is reflected in the sediment laden runoff from the ploughed agricultural fields in the catchment. So, the only chance to increase crop production is to increase productivity on every plot of crop land.

As in all other parts of the Ethiopian highlands, oxen are the major source of draught power in the study watershed (Fig. 6a). However, 78 (56.5%) have only one ox per household and 23 (16.7%) have only two oxen per household. The rest 37 (26.8%) of the households do not have any oxen. In the Koga watershed livestock population is exerting much pressure on the environment resulting in degradation of the land that in turn is reflected by the increasing tendency of the farmers to shift to plantation of eucalyptus trees on their crop farms, and deforestation and degradation of the natural woody vegetation cover as confirmed by the key informants. The wood demand as source of energy is also another important factor that causes LULC change in the study area (Fig. 6b). In the study area, the major source of domestic energy for cooking and heating comes from fuel wood. Moreover, the demand of wood products for the construction of house has provoked the destruction of forest in the study area. According to the information acquired through focus group discussion, cutting down trees for house construction is, to some extent, considered to be the causes of LULC change in the study area.

Conclusion

The has identified that the main change observed for the stated time was a substantial areal expansion of cultivated and settlement; increased approximately by 7054.6 ha at the expense of grass land, bush land and natural forests. The major responsible for this change were change in population dynamics and socioeconomic conditions (i.e. land holding size, crop and livestock production and wood demand for source of energy and construction material). Hence, there should be family planning programs to balance the existing natural resources with population, develop and expand appropriate agricultural technologies and rural infrastructure so as to improve agricultural productivity. Since, the major source of domestic energy for cooking and heating in the study area comes from fuel wood, cutting trees for fuel wood partly causes LULC changes in the study area. Therefore, concerned authorities should provide alternative energy sources and energy saving technologies for households in the study area. The appropriate land use plan should be also put in place.

References

Abate S (2011) Evaluating the land use and land cover dynamics in Borena woreda of South Wollo highlands, Ethiopia. J Sustain Dev Afr 13(1):87–107

Amare S (2013a) Population and environment interaction: the case of Gilgel Abbay catchment, Northwestern Ethiopia. E3 J Environ Res Manag 4(1):0153–0162

Amare S (2013b) Retrospective analysis of land cover and use dynamics in Gilgel Abbay watershed by using GIS and remote sensing techniques, Northwestern Ethiopia. Int J Geosci 4(7):1003–1008

Amare S, Kameswara R (2011) Hydrological dynamics and human impact on ecosystems of Lake Tana, Norhwestern Ethiopia. Ethiopian J Environ Stud Manag 4:56–74

Anderson BJR, Hardy EE, Roach JT, Witmer RE (1976) A land use and land cover classification system for use with remote sensor data. Dev 2005:28–28

Bezuayehu, T., & Sterk, G. (2008). Hydropower-induced land use change in Fincha'a watershed, Western Ethiopia: analysis and impacts. Mt Res Dev 28(1), 72–80.tershed

Braimoh A, Vlek P (2005) Land-cover change trajectories in Northern Ghana. Environ Manag 36:356–373

Carmel Y, Kadmon R (1998) Computerized classification of Mediterranean vegetation using panchromatic aerial photographs. J Veg Sci 9:445–454

Chamaporn P, Tonny JO (2011) Land-cover changes and potential impacts on soil erosion in the nan watershed, Thailand. Int J Remote Sens 32(21):6587–6609

Clarke AR (1880) Geodesy. Clarendon Press, Oxford

Chavez PS (1996) Image based atmospheric corrections – revisited and revised. Photogramm Eng Remote Sens 62:1025–1036

CSA (2008). The 2007 population and housing census of Ethiopia: statistical report for Amhara region; part I: population size and characteristics". Addis Ababa, Ethiopia

Das T (2009) Land use / Land cover change detection: An object oriented approach, Münster, Germany. Unpublished M.sc. thesis, Institute for Geoinformatics, University of Münster

De Sherbinin A (2002) Land-use and land-cover change (LUCC). A CIESIN Thematic Guide. Center for International Earth Science Information Network of Columbia University, Palisades

Diallo Y, Hu G, Wen X (2009) Applications of remote sensing in land use/land cover change detection in Puer and Simao counties, Yunnan Province. J Am Sci 5(4):157–166

Fikru A (2009) Assessment of adoption behavior of soil and water conservation practices in the Koga watershed, highlands of Ethiopia. Unpublished M.Sc. thesis, Faculty of the Graduate School, Cornell University

Foody GM (2002) Status of land cover classification accuracy assessment. Remote Sens Environ 80:185–201

Getachew F, Heluf G, Kibebew K, Birru Y, Bobe B (2011) Analysis of land use/land cover changes in the Debre-Mewi watershed at the upper catchment of the Blue Nile basin, Northwest Ethiopia. J Biodivers Environ Sci (JBES) 1(6):184–198

Gomarasca MA (2009) Basics of geometrics. Springer Science Business Media B.V, Dordrecht

Hietel E, Waldhardt R, Otte A (2004) Analysing land-cover changes in relation to environmental variables in Hesse, Germany. Landsc Ecol 19:473–489

Hussein AO (2009) Land use and land cover change, drivers and its impact: a comparative study from Kuhar Michael and Lenche Dima of Blue Nile and awash basins of Ethiopia. Unpublished M.Sc. thesis, Faculty of the Graduate School, Cornell University

Ismail MH, Jusoff K (2008) Satellite data classification accuracy assessment based on reference data set. International Journal of Computer and Information Engineering 2(6):386–392

Jensen JR (2005) Introductory digital image processing: a remote sensing perspective. Prentice Hall, Upper Saddle River

Kiros MH (2008) Temporal and spatial changes in land use patterns and biodiversity in relation to farm productivity at multiple scales in Tigray, Ethiopia. Unpublished PhD thesis, Wageningen University

Lambin EF, Geist HJ, Lepers E (2003) Dynamics of land-use and land-cover change in tropical regions. Annu Rev Environ Resour 28: 205–241

Lepers E, Lambin EF, Janetos AC, Defries R, Achard F, Ramankutty N, Scholes RJ (2005) A synthesis of information on rapid land-cover change for the period 1981–2000. Bioscience 55(2):115–124

Messay M (2011) Land-use/land-cover dynamics in Nonno district, Central Ethiopia. J Sustain Dev Afr 13(1):123–141

Reis HT (2008) Reinvigorating the concept of in social Psychology. Personal Soc Psychol Rev 12:311–329

Stehman SV (1997) Selecting and interpreting measures of thematic classification accuracy. Remote Sens Environ 62:77–89

Tilashwork C (2009) The effect of eucalyptus on crop productivity, and soil properties in the Koga watershed, Western Amhara Region, Ethiopia. Unpublished M.Sc. thesis, Faculty of the Graduate School, Cornell University

Woldeamlak B (2002) Land cover dynamics since the 1950s in Chemoga watershed, Blue Nile basin, Ethiopia. Mt Res Dev 22(3):263–269

Woldeamlak B, Sterk G (2005) Dynamics in land cover and its effect on stream flow in the Chemoga watershed, Blue Nile basin, Ethiopia. Hydrol Process 19:445–458

Zeleke G, Hurni H (2001) Implications of land use and land cover dynamics for mountain resource degradation in the Northwestern Ethiopian highlands. Mount Res Dev 21:184–191