Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 3, No. 11, p. 31-47, 2013
http://www.innspub.net

INNSPUB

RESEARCH PAPER

OPEN ACCESS

Land use changes induced by irrigation development in the Fincha'a sugar estate, Blue nile basin, Ethiopia

Getahun Kitila[1], Heluf Gebrekidan[2], Tena Alamirew[2], Megersa Oulumana[2], Hans Hurni[3]

[1]*Wollega University, College of Natural and Computational Sciences, P. O. Box 395, Nekemte, Ethiopia.*

[2]*Haramaya University, School of Natural Resource Management and Environmental Science, P. O .Box 138, Dire Dawa, Ethiopia.*

[3]*Centre for Development and Environment, University of Bern, Hallerstrasse 10, CH-3012 Bern, Switzerland.*

Article published on November 5, 2013

Key words: Land use dynamics, irrigation, remote sensing and GIS, Development, sustainability.

Abstract

Land use and land cover changes that occurred from 1984 to 2009 in the Fincha'a Sugar Estate, Blue Nile Basin of western Ethiopia, were monitored using a geographic information system (GIS) and a remote sensing approach with field verification. Fincha'a Sugar Estate is known for its sugar production and export of sugar as a surplus to major areas of the country. However, clearing increasingly flat and steeper land for cultivation and built-up land, land degradation is becoming a serious problem. The study revealed that the Sugar Estate has inundated 2.15% of water body, 8.70 % of natural forest, 4.52% of the built-up land, 12.39 % of the grass land, 38.20 % of the bush land and 34.05 % of the cultivated (sugar and other) farm land respectively. The results show that the natural forest cover declined from 17.25% in 1984 to 10.16% in 2005and 8.70% in 2009. The total natural forest cleared between 1984 and 2009 amounts to 3186 ha. This is 50% of the forest cover that existed in 1984. On the other hand, cultivated land increased from 6.01% in 1984 to 21.96% in 2005 and 34.07% in 2009. The study area had experienced a drastic change in its LUC conditions between 2005 and 2009 because of rapid increases in human settlement, deforestation and irrigation development. Such a dramatic change in 25 years and the increasing proportion of completely degraded lands clearly indicates the prevailing danger of land degradation in the area.

***Corresponding Author:** Getahun Kitila ✉ gkitila@gmail.com

Introduction

Land use is referred to "Man's" activities and the various uses which are carried on land". Land cover is referred to "Natural Vegetation, Water bodies, Rock/Soil, artificial cover and other noticed on the land" (Jitendra, 2011). Thus, changes in land use/cover have occurred at all times in the past, are presently ongoing, and are likely to continue in the future (Fu C, 2003). These changes have beneficial or detrimental impacts, the latter being the principal causes of global concern as they impact on human well-being and safety.

Land use is obviously constrained by environmental factors such as soil characteristics climate, topography and vegetation and take place according to the needs of mankind, misuse and over exploitation of land. Increasing pressure of population and consequent rising demand for food and shelter are putting great pressure on water body areas, fallow land and other vacant lands. Many of the peoples have last substantial portions of their water cover due to conversion of water body areas into Aquaculture land in order to feed the growing population. Land use and land Cover arrangement makes landscape patterns. Today Earth resources satellites data are very applicable and useful for land use /land cover studies. Natural conservation area plays vital role in biodiversity. But it also reflects the importance of land as a key and finite resource for most human activities including Aquaculture, settlement, recreation and water bodies and storage. Land is fundamental factor of production and through much of the course of economic growth. Often improper land use is causing various forms of environmental degradation. For sustainable utilization of the land ecosystem, it is essential to know the natural characteristics, extent and location. Its quality, productivity, suitability and limitations of various land uses.

Ethiopia, situated in the horn of Africa, has a long history of intensive agriculture and human settlement particularly in the highlands due to the presence of favorable climatic and ecological conditions. However, the high population pressure and the concomitant depletion of the scarce resources have made agriculture of the country unsustainable, forcing its expansion into marginal areas such as steep slopes, swampy plains, and traditionally untapped part of the environment and putting tremendous pressure on soil, vegetation and water resources (Hurni, 1985). As a consequence, considerable land use/cover changes have occurred in Ethiopia during the second half of the 20th century (Solomon, 1994; Gete, 2000; Kebrom and Hedlund, 2000). The results of these studies have identified deforestation and encroachment of cultivation into marginal areas as the main agents of land use/cover.

Numbers of research papers were published relating to land use and land cover analysis. Numbers of research papers were published relating to land use and land cover analysis. (e.g., Gete, 2000; Kebrom and Hedlund, 2000; Belay, 2002; El-Swaify, 2002; Woldeamlak, 2002; Woledeamlk, 2003; Kahsay, 2004; Scanol *et al.*2005;Bezuayehu, 2006; Tsegaye, 2009; Behailu, 2010; Efrem, 2010; Eyayu, 2010; Megersa, 2010; Fisseha *et al.*, 2011, Emiru *et al.*, 2012) conducted in different parts of Ethiopia have indicated the existence of considerable change in land use/cover over the past 3 to 4 decades. Kebrom and Hedlund (2000) reported increases in cultivated and settlement land use at the expense of shrub lands and forests between 1958 and 1986 at Kalu area, north-central Ethiopia. Gete (2000) reported a significant increase in cultivated land at the expense of shrub lands and forests between 1957 and 1995 in the Dembecha area, northwestern Ethiopia. Similarly, Birru (2007) indicated that the grassland cover of the Lake Tana Basin declined continuously over the last 40 years. Tsegaye (2009) reported a considerable increase in agricultural land at the expense of dense forest land in Adaba Dodola, southern Ethiopia. A 90.6% increase in cultivated land between 1957 and 2003 at Tara Gedam, northwestern highlands of Ethiopia was reported by Eyayu (2010). Likewise, a study made by Abiy (2010) indicated a 44.53%

increase in cultivated land at the expense of other land uses/land covers in the Antsokia-Gemza District, north-central Ethiopia. In line with this, Belay (2002) reported a serious trend in land degradation resulting from the expansion of cultivated land at the expense of forestlands in the Derekoli Watershed in South Wollo. (Hurni *et al.,* 2004) reported the highland areas of the Horn of Africa have for centuries been favorable places for settlement and agriculture, as the ecological environment is more favorable than in the surrounding lowlands. However, as time goes by, intensive agricultural use and expansion of cropland into marginal areas have led to severe degradation of the natural resource bases in large areas of these zones. Land use changes are a very important aspect of global change (Bezuayehu, 2006). When aggregated globally, they directly affect the biodiversity, soil, environment, etc and contribute to local and regional climate change, altered the ecosystem and affect the ability of biological systems to support human needs (El-Swaify, 2002). Research findings by Gete (2000), Amare (2007), Birru (2007), and Hurni *et al.* (2010), under the NCCR North-South Research framework that is the conflicting use of land resources in the highland-low land problem context and/or upstream-downstream resource use, have indicated that dramatic land degradation has been recorded in the highlands of Ethiopia due to land use/cover changes. Therefore, the need for rational planning of land use/cover development and optimal use of the land resources is evident. That's why precise and credible data on land use/cover change and their trends are necessary for understanding global, regional and local environmental problems (Milanova and Telanova, 2007). Information on land use/land cover in the form of maps and statistical data is very vital for spatial planning, management and utilization of land for agriculture, forestry, pasture, urban, industrial, environmental protection, economic production, etc. Furthermore, documentation of the land use/cover change provides information for the better understanding of historical land use practices, current land use patterns and future land use trajectory. Identifying,delineating and mapping of the types of land use/cover are important activities in support of sustainable natural resource management (Zhang *et al*., 2004). The land use studies in Ethiopia, however, emphases estimation of forest cover and deforestation rates that occur at national level (Mesfin, 1985; EFAP, 1994). So far, analyses of land use dynamics at watershed level are scanty in Ethiopia. Studies of land use dynamics in watersheds where a reservoir and irrigation development were created have been carried out (Buzuayehu, 2006 and Megersa, 2012). However, the knowledge of spatial dynamics of the magnitudes of different land use types, factors driving the changes and the implications of those changes are scarce in FSE.

The development of Fincha'a dam (1975) and Fincha'a Sugar Estae (1995) have caused land use changes and probably aggravated the rate of environmental degradation downstream of Fincha'a watershed in general and Fincha'a sugar estate (FSE) in particular. But there has been no study conducted in the sugar estate that shows the magnitude of land use changes caused by the development of the irrigation and the implication of such changes. Several questions arise with regard to the rapid land use and land cover changes and associated impacts in the area. First, what are the extent and degree of land use and land cover changes in the area in spatial and temporal terms? Second, what are the major consequences of these changes? Third, what will the future trends be in land use and land cover dynamics and associated results? Fourth, are these dynamics well perceived by relevant stakeholders? And finally, what are their implications at the regional, national, and international levels?

The present article mainly addresses the first of these questions, based on spatial and temporal analysis of land use and land cover changes from 1984 to 2009 and investigation of possible implications for degradation of mountain resources in the study area. Land use changes in different types of landscape, trends in expansion of cultivated land and built-up land, and associated results are presented. An additional aim is to create awareness among relevant stakeholders, such as sugar estate planners, community planners and decision- or policy-makers, about the speed and degree of land degradation and its long-term consequences. Eventually, of course, it is not only awareness that is important but improvements of policy, planning, and physical implementation, which are needed to protect potential agricultural soils in this part of the country from further deterioration through loss of soil productivity.

Materials and methods

Geographical environment of the study area

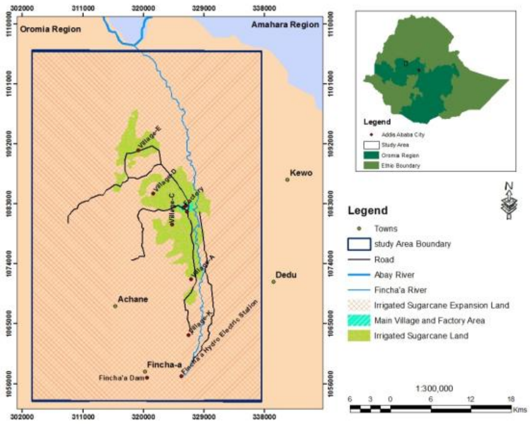

Fig. 1. Location map of the study area.

Geographically Fincha'a Sugar Estate is located in the Oromia Regional State, Western highlands of Ethiopia, Nile basin of western Ethiopia (Fig.1.) lying between of 9°30' to 10°00' of North latitudes, and 37° 15' to 37°30' of East longitude. The study site is situated at a distance of 340 km from Addis Ababa, the capital of Ethiopia and bounded by the Amhara National Regional state in the North, Guduru Woreda in the East, Horro Woreda in the West and Jarte and Amuru Woreda in the South respectively (Fig. 2.).

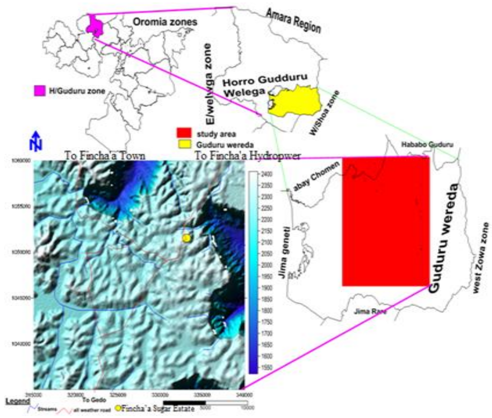

Fig. 2. Accessibility, drainage and location map of study Area.

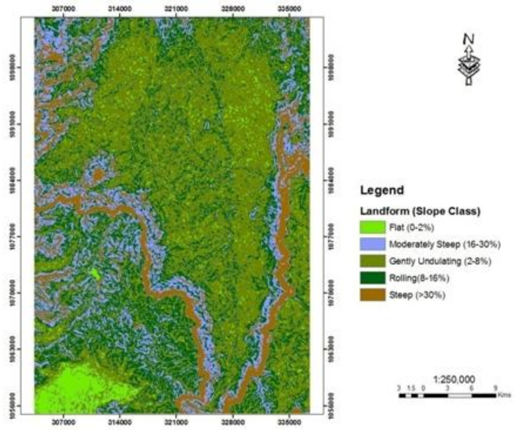

Fig.3. Slope Map of the study area: Source FAO/UNESCO: Soil Map of East Africa (1997).

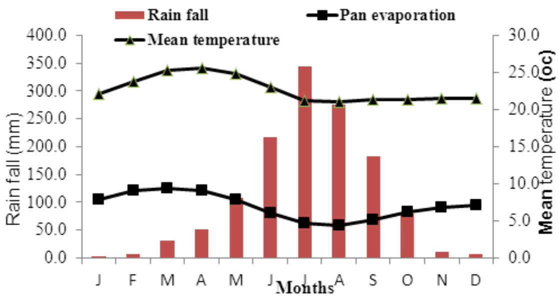

Fig.4. Mean monthly rain fall (RF), mean maximum and minimum temperatures (Temp.) and pan evaporation of the Fincha'a Sugar Estate, Blue Nile Basin, western Ethiopia based on records at the Fincha'a Sugar Estate research station methodological station (1979-2011).

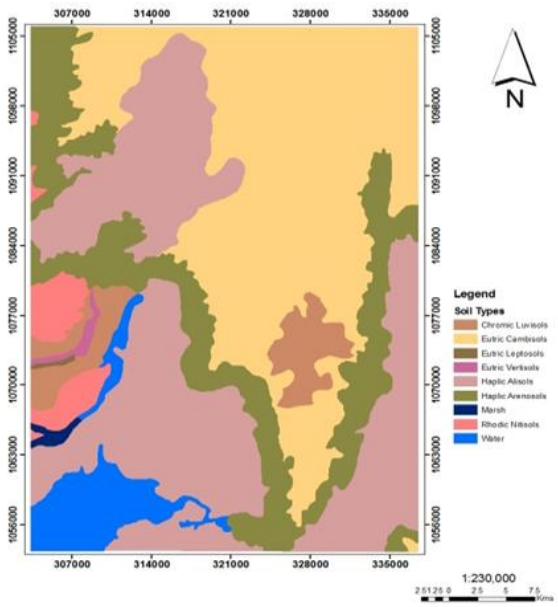

Fig.5. Soil map of Fincha'a watershed based on FAO/UNESCO: Soil Map of East Africa (1997).

The study area is an extension of the typical agro climatic profile of Horo (Shambu), which is situated about 84 km west of the study area and extends from the cold and wet upper zones (Wurch, 4050 m) to the hot and moist/dry lower zones (Kolla, 1000 m) of the Blue Nile River Basin. The drop in altitude of about 3000 m over 75–100 km causes strong gradients in climate and hence in vegetation, land use, and living conditions. The area is located in the middle of these 2 extremes and extends from south to north over elevations of 1350–1600 m. Geologically, the Adigrat sandstone and plateau basalt formations, composed of alternating beds of sandstones and shale's, have been deposited unconformable upon the eroded surfaces of the basement complex dominates the study area. The study area is surrounded by escarpment along its southern, eastern and western sides, which rise approximately 700-850 m above the valley floor. The floor of the Fincha'a valley is dominated by gently undulating surface northwards. The width of the valley, generally, increases from south to north with an average size ranging from 25 to 30 km (Worku, 1995). Fincha'a River divides the valley in to West and East banks. Currently both the West and East bank is are under cultivation, and the extension of the irrigated area to the South-west (Nashe) is planned and on the way to start sugar cane cultivation. Slope varies from, flat (0-2 %), moderately steep (16-30 %), gently undulating (2-8 %), rolling (8-16%) and steep (> 30 %) (Fig.3.).The thirty two years (1979-2011) climatic data from Fincha'a Sugar Estate Meteorological Station recorded the yearly average rainfall 1315.5 mm which is characterized by unimodal rainfall pattern. About 80 % of the annual rain falls between May to September its mean annual maximum and minimum temperatures lies between 30.5 and 14.85^{o} C (Fig.4.) Average pan evaporation was 153.1mm and the average annual reference evapo-transpiration (based on Penman-Monteith) is 1320 mm, with monthly low variation (Girma and Awulachew, 2007). The average annual relative humidity is about 83.8% (Bayissa, 2007). Fincha'a valley has alternate wet (during May to October) and dry (during the rest of the months) seasons Wind speed in Fincha'a Valley is low as the surrounding escarpments hinder wind movement. However, wind speed is high between the months of March to June (Worku, 1995, Ademe, 2001).The soil classes of the Fincha'a watershade are Cambisols, Luvisols, Leptosols, Alisols, Marsh, Vertisols and water associated with the geomorphology and the geology of the area (Fig.5.) Luvisols and Vertisols are the dominant soil types in the irrigated fields of the study area. Dereje, 1995 reported that Luvisols are relatively good in drainage and mineral composition and are largely (75%) distributed and the Vertisols are characterized with poor drainage and high water holding capacity and the distribution is (23%). Most of the Luvisols are situated in the middle of the interfluves and have slopes of 2-5 %. Nineteen percent of the Luvisols are moderately deep. Vertisols are found mostly in the lower areas near The Agul River and at the upper ends of the interfluves (Worku, 1995). Sugarcane mono cropping based on irrigation agriculture is the main agricultural activity taking over. The area is mainly drained by the Fincha'a River.

Data sources and analysis

Monitoring of land use and land cover changes in the study area was done at 3 intervals: (1984, 2005 and 2009). A geo-information modeling approach was used, employing Land sat satellite image analysis (Land sat-TM and ETM, December, 1984, January, 2005, December, 2009). Data interpretation and analysis were conducted using ESRI's UNIX ARC/INFO GIS software. The boundary of the study area was delineated on a 1:50,000 topographic map (EMA, 1984). Before interpreting the satellite images, a reconnaissance survey and a stratified interview were carried out in January 2011 to obtain general understanding of the land use pattern of the study area. Altogether 50 people were interviewed and used as key informants for their past and current knowledge regarding the extent and environmental effects of land use changes in the area. This information was used for complementing the interpretation of the satellite image. Moreover, their traditional knowledge was used for analyses of the onsite and downstream implications of the land use changes in the area. Then, identification and classification of the land use/cover were monitored and seven land use/cover categories were identified (Table 1.).

Table 1. Description of Land use classes identified in Fincha'a Sugar Estate.

Land use class	Description
Water body	Land with water-tables at or near the surface during the time the respective image as taken. It covers low lying and frequently in association with stretches of open water. It also includes water used for treatment, and purification of facilities, extracted/diverted from river water, spring water, water storage and distribution places e.g. reservoirs, water towers and pumping station, sewage disposal and treatment works and bogs.
Built-up Land	This is an area of a permanent residential (village) areas, service centers (as schools and health centers),offices, shops, warehouse, places of worship, barn/store, factory and refinery for processing of sugarcane, places for packing sugarcane, and infrastructures as transportation track ways and foot paths, educational centers, and medical centers.
Natural forest land	This land cover type is characterized by closed canopy vegetation and the reverian forests. It includes mixed deciduous and evergreen forests.
Grass land	An area in which the natural vegetation consists largely of tall perennial grasses associated with crock-ok vegetation, savanna grasses, herbaceous and shrub vegetation with few and very sparse trees.
Sugarcane farmland	An area covered with different status of sugarcane (from seedling generation to the matured sugarcane).
Other farm land	This category involves all cultivated agricultural lands excluding sugarcane farm. It Includes farmsteads, holding areas for livestock, land ploughed and made ready for sowing, fallow land as part of agricultural land, land used for the cultivation of crops.
Bush land	The land that is covered with the natural native species vegetation of bush habitat dominated by the association of trees and shrubs. It consists predominantly of patches of woody species, low woody plants and bushes often cover any kind of habitat from open shrubby with few trees to tall trees. It is an area that has only asperse flora.

The Images used for this study were The multi-spectral land satellite image (Land sat-ETM and TM, with a resolution of 30 m path 169 and row 053) were obtained from International Livestock Research Institute (ILRI) and National Centre of Competence in Research (NCCR) North-South and used to produce the land use/cover classes from the image by visual interpretation and digitized on the basis of false color composites of each land use/cover classes. The accuracy of each of the seven land use/cover classes from the images were validated by comparing ground reference points collected through extensive field visits (2011) guided by handheld Garmin 76 GPS (Global Positioning System) and topographic maps. Then, using line objects on a 50,000 scale topographic sheet, the images were adjusted and clipped to the frame that covers the study area. The Arc GIS 9.3 software made it possible to link the polygon lines to label the specific land use/cover classification and calculate the spatial statistics of each polygon. Environment for Visualizing Images 4.3 software was used for spatial database processing. Finally, three land use/cover maps were produced corresponding to the three periods (1984, 2005 and 2009).

Results and discussion

Types of land use/land cover classes in Fincha'a Sugar Estate.

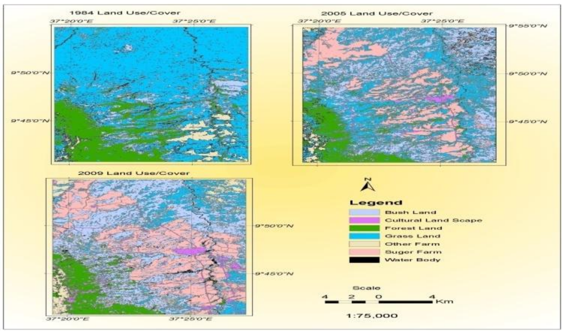

Fig.6. Land use land cover changes (1984, 2005 and 2009) in Fincha'a Sugar Estate, Blue Nile basin, Ethiopia.

The land use trend analysis made for the two consecutive periods; 1984-2005 and 2005-2009 has indicated the Sugar Estate was subject to considerable land use changes, driven exclusively by natural and socio-economic forces (Fig.6.). Analysis of the Landsat images confirmed the existence of seven major land use/cover types (natural forest, Water body, Cultural land scape (Built-up area), bush land, sugarcane farm land, other farm land and grass land) in FSE (Table 2. and Fig.6.).

Table 2. Land use/cover types and areas covered by the respective land use type in the Fincha'a Sugar Estate in three different periods (1984, 2005 & 2009).

Land use type	Area covered by respective land use/cover type					
	1984		2005		2009	
	km²	%	km²	%	km²	%
Water body	6.4	(1.71)	1.5	(0.40)	8	(2.15)
Built-up land	2.10	(0.50)	10.36	(2.75)	16.84	(4.52)
Natural forest	64.29	(17.25)	38.22	(10.16)	32.43	(8.7)
Grass land	237.61	(63.74)	122.78	(32.61)	46.18	(12.38)
Sugar cane farm	-	-	68.7	(18.24)	89.23	(23.94)
Other farm land	22.43	(6.01)	12.2	(3.25)	37.75	(10.13)
Bush land	39.96	(10.70)	121.97	(32.40)	142.39	(38.2)
Total	**372.8**	**100**	**372.8**	**100**	**372.8**	**100**

Between 2005 and 2009 Sugarcane farm land accounted for 16.83 and 23.94% of the total area of the Sugar Estate and there was no land covered by sugarcane farm land in 1984.The other farm, bush and grass land, accounted for 6.01, 3.33, 10.13; 10.71, 32.94, 38.22; and 63.74, 32.93 and 12.39 8 % of the total area of the Sugar Estate in the years 1984, 2005 and 2009, respectively (Table 2.). On the other hand, the Cultural land scape (Built-up area), the water body, overall accounted for 0.57, 1.93, 4.51 and 1.72, 0.40, 2.14 % of the total area of the Sugar Estate in the years 1984, 2005 and 2009, respectively. During the three periods, the natural forest accounted for 17.25, 10.25 and 8.1 % area of the Sugar Estate. Shift of natural forest and grass land to cultivated (sugarcane farm and other farm) land and cultural land scape (Built-up area) ecosystems was identified as a major change class.

Natural forest and grass land

It was found that the natural forest cover declined from 17.25% in 1984 to 10.16% in 2005and 8.70% in 2009. The total natural forest cleared between 1984 and 2009 amounts to 3186 ha. This is 50.35% of the forest cover that existed in 1984. The greatest Reduction of forest occurred between 2005 and 2009 (about 40.65%) as it was a transition period from state farm to sugar estate development. After the irrigation development was started in 1995, all lands under state farm and owned by local community were converted to agricultural (other and sugarcane) farm land and built-up Land. Throughout the period covered by the study, cultivation encroached upon the very flat and moderately steep slopes with gradients (<30%). The shift of natural forest cover into cultural land scape (Built-up area), cultivated (sugarcane and other farm) and bush lands, respectively increased the area coverage of cultivated lands and Built-up area to 74.68 % of the Sugar Estate. In such ecosystems where there is no reported history of immigration into the study area, such a dramatic change in 25 years and the increasing proportion of completely degraded lands clearly indicates the prevailing danger of land degradation in the area.

During the study period, the land under grass declined from 64.74 in 1984 to 32.93% in 2005 to 12.39% in 2009 (Table 2.).This was probably because of two major reasons. There was no sound conservation practice in the area out lined by the estate as indicated by the local communities during interview and group discussions. The fact that the area under grass land declined implies most plots of land were used for cultivation (sugar farm and other farm) lands and built-up lands more repeatedly and fallow periods shortened. This inappropriate land use has come responsible for current deterioration of soil quality and continuous decline in productivity of the land coupled with shortage of soil fertility management technologies that agricultural men can use to sustain agricultural production and environmental degradation in the area. The area of water body had decreased from 1.72 0 in 1984 to 0. 4 %) in 2005 but increased from 0.46% in 2005 to 2.15% in 2009 (Table 2.). This implies that irrigation increased the area cover by water body. The expansion of water body contributed to the waterlogging and other related environmental degradation which are currently a sound problem of most irrigated fields as identified from the groundwater study result.

Table 3. Land use/land cover changes in the in the Fincha'a Sugar Estate for the periods between 1984 to 2009.

Land use type	Change in land use area (Km²) coverage; gain (+) or loss (-)					
	1984-2005		2005-2009		1984-2009	
	km²	%	km²	%	km²	%
Water body	-4.9	76.56	6.5	433.33	+1.60	25.00
Built-up land	+ 10.36	493.3	+ 9.62	57.13	+14.73	701.76
Natural forest	- 26.07	40.55	- 5.79	15.15	-31.86	49.55
Grass land	-114.86	48.34	- 76.6	62.39	-191.43	80.56
Sugarcane farm	-	-	+ 21.50	31.74	+ 89.23	100
Other farm land	-10.23	45.60	+ 25.32	67.07	15.32	68.3
Bush land	+ 82.82	207.25	+ 20.42	16.75	+ 102.43	256.33

Built-up Land

During the entire period of the study, the area under cultural land scape (built-up area) land use increased persistently from 0.57% in 1984 to 1.93 % in 2005 and 4.51% in 2009 (Table 2.). In the first period, 1984-2005, areas under cultural land scape (built-up area) continued to expand receiving additional plots due to the shift of other land use categories; forest land (1.05%), grass land (4.34%), bush land (8.34%), other farm land (12.06%) and water body(0.33%)(Table 3.). However, considerable size (42.85%) of plots which previously were covered by cultural land scape (built-up area) uses were converted to agricultural fields. The increase in this land use advanced rapidly during the second period (2005-2009). Concurrently during this period, about (15.15 and 78.4%) of the study area which was under natural forest land grass land use respectively was abandoned because of the shift from state farm to Sugar Estate and increased the cultural land scape (Built-up area) land use. The major reasons mainly responsible for this change to take place were: the increased demand of built-up materials for settlement, factory construction, built-up of roads, irrigation canals and subsequent regeneration and (2) exhaustive thinning of the natural forest (Selamyihun and Tekalign, 2003). Extractive forest use which converted dense forest areas into sparsely forested areas and forest blanks was a common practice in the area. The ever increasing demands of the population for fuel-wood, timber and fodder were the major driving forces behind this thinning practice. The use of shrubs and bushes as sources of fuel-wood and charcoal production for commercial purposes has also little counterbalanced its expansion. The expansion of sugar estate, population pressure and irrigation development have created job opportunities and attracted people to the study area and accounted for the increase of this land use.

Table 4. Area and percent of land use in the Fincha'a Sugar Estate that was converted from each of the seven categories into the rest between 1984-2005, 2005-2009 and 1984-2009.

Land use type	Changed to:	1984-2005		2005-2009		1984-2009	
		(Km ²)	(%)	(Km ²)	(%)	(Km ²)	(%)
N.F	B.L.	5.16	18.08	0.54	16.25	17.5	51.35
	W. B.	0.04	0.35	0.04	0.8	0.78	2.28
	GL.	10.74	37.63	1.02	8.6	0.99	2.9
	SCF.	9.2	32.23	2.31	36.78	12.28	37.20
	BL.	0.3	1.05	2.33	37.1	0;2	0.58
	O.F.L.	3.04	10.65	0.04	0.8	2.8	8.21
	Ud.	35.75	55.60	31.94	5.08	30.21	46.99
B.L.	GL.	0.32	26.67	0.32	26.67	0.27	17.30
	B.L.	0.28	23.33	0.36	28.75	0.5	32.05
	N.F	0.001	0.83	0.45	23	0.04	2.56
	O.F.L.	0.2	16.67	0.25	15.97	0.65	41.67
	W. B.	0.002	0.16	0.06	3.83	0.06	5.3
	S.C.F.	0.4	33.33	0.01	0.06	0.01	0.88
	Ud.	0.9	42.85	6.09	84.34	0.54	25.72
GL.	B.L.	20.8	75.11	76.51	78.30	97.1	49.70
	O.F.L.	6.6	4.63	11.6	11.87	28.87	14.78
	W. B.	6.6	4.63	0.5	0.51	0.39	0.2
	S.C.F.	107.13	14.58	6.69	6.85	61.8	31.64
	N.F	1.35	0.95	1.97	2.00	0.33	0.17
	B.L.	6.19	4.34	0.42	0.42	6.78	3.47
	Ud.	94.99	39.98	25.09	20.43	42.25	17.78

Bu.L.	O.F.L.	0.37	1.20	13.99	24.5	3.73	19.54
	W.B.	0.56	1.80	6.04	10.57	0.62	3.25
	S.C.F.	14.95	48.16	12.46	21.83	11.80	61.82
	G.L	11.56	37.25	19.12	33.50	0.91	4.77
	B.L.	2.59	8.34	5.41	9.48	3.73	19.54
	N.F	1.01	3.25	0.07	0.12	0.92	4.82
	O.F.L.	0.37	8.34	13.99	24.50	1.63	8.54
	Ud.	8.92	22.32	64.88	53.20	20.87	52.23
O.F.L.	B.L.	2.47	12.06	0.12	19.60		
	N.F	1.01	0.04	-	-	-	-
	GL.	11.56	14.06	0.46	75.40		
	B.L.	0.37	0.58	0.03	4.9		
	WB.	0.56	0.09	-	-	-	
	Bu.L.	14.95	73.14	-	-		-
	Ud.	1.95	8.7	11.82	95.10	3.95	17.61
W.B.	B.L.	0.02	0.33	0.05	25	0.33	80.5
	N.F	0.03	0.50	-	-	0.23	56.09
	G.L.	2.26	38.24	0.04	20	0.05	12.2
	Bu.L.	1.17	19.80	0.03	15	0.3	73.2
	S.C.F	2.39	40.43	0.03	15	0.02	4.88
	O.F.L.	0.04	0.67	0.05	25	0.09	21.95
	Ud.	0.49	7.65	1.3	86.67	5.99	93.60
Total		372.8		372.8			

Bu.L. = bush land, B.L. = built-up land, G.L. = grass land, S.C.F. = sugar cane farm land, O.F.L. = other farm land, N.F. = Natural forest and W.B. = Water body

Cultivated (Sugar cane and other) farm land

There was no land covered by the sugarcane farm land use in the year 1984 as it was the time of transition from state farm to Sugar Estate (irrigation) project and land preparation. Sugarcane farm land sharply increased from 16.83% in 2005 to 23.94% (at an average rate 66300 ha yr^{-1}). During the first period, 36.78 % of the natural forest cover was transformed into sugarcane farm land use, while sugarcane farm land use maintained about 29.88 % of the original size to remain under the same land use (Table 3.). In this period, irrigation development has clearly been the primary agent of change due to the increasing population size, use of heavy tracks, irrigation land size (as stated by the local community during the interview and group discussion)and subsequently increasing demand for food and income. Since the method preferred for increasing production was based on claiming more land for sugarcane farm rather than maximizing production per unit area, it raised the need to put more plots of land under sugarcane farm land mainly for plantation of sugarcane for sugar production. This was clearly due to the increased irrigation development, sugar estate expansion and sugar cane plantation and sugar demand in the country. This an implication of the impact of policy issue on land uses. The increase of sugar cane farm land from 16.83 % in 2005 to 23.94 % in 2009 in addition to water body, bush land and cultural land scape decreased the forest land cover of the sugar estate by 49.56 % during the whole period.

In the first period (1984-2005) the land cover under other farm land declined from 6.01 to 3.33 % for reasons: the transition of the land cover under state farm to sugar estate and the local community to sugarcane farm land much attention was given to converting the but increased 10.13 % in 2009 due population (crop production and irrigation) pressure. This shows the establishment of sugar estate and irrigation development in the valley affected the other land cover types (grass and natural forest) and increased the land cover under this class.

Bush land

It was indicated 10.71, 32.94 and 38.2 % (Table 2.) of the land use was accounted for bush land in 1984, 2005 and 2009 with a net increase of 10243 ha (27.48 %) respectively. It can be clearly seen that the expansion of agricultural (Sugarcane and other) farm land and irrigation development increased the bush land cover. This is an implication of positive impact of irrigation development on bush land.

Extent and type of land use/cover change

In all the periods considered in this study, the cultivated (sugar cane and other farm) land and cultural landscape land was the dominant type of land use/cover in the Fincha'a Sugar Estate. This clearly indicates that the currently cultivated land was increasing while forest land and grass land had a decreasing trend of land use/land cover change in 25 years of establishment of the sugar estate and irrigation development (Fig.7.) which is true for most highlands of Ethiopia (Crummy, 1998 Fisseha *et al.*, 2011).

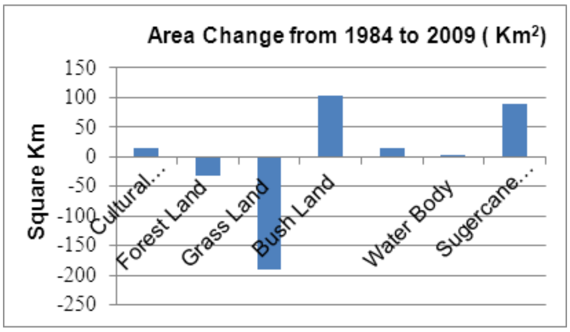

Fig.7. Graph of land use/cover trend across different years in the Fincha'a Sugar Estate.

Irrigation system in the area is increasing in all directions after 2009 due to sugar estate expansion. In the same period, the area of sugar cane farm land increased to 8923 ha mainly at the expense of forest and grass land. Recently the dynamics of the cultivated (sugar cane and other) farm land and cultural land scape (Built-up area) is unusually increasing due to: population (crop production and agro-industry) pressure increased demand of forest products and land for construction, fuel wood and agriculture in the study area. In other words, after the expansion of the new sugar factory and irrigation development to the east bank of Fincha'a River and Nashe River, the land cover of the area was increased by 51.86 %. In this way, a dramatic increase in sugar cane farm land, cultural land scape and bush land and a sharp decrease in forest land become apparent. Following the inundation of the vast forest lands and sugarcane farm land expansion, livestock production activity, which is equally important as sugar cane production, has faced a serious challenge. The two major economic activities have entered a state of competition rather than supplementing each other.

The findings of this study are in consent with the findings of many other studies made in different parts of the country, which reported a significant decline of forest and shrub land cover due to its conversion to other land uses particularly to cultivated and settlement land (Kebrom and Hedlund, 2000; Gete and Hurni, 2001; Belay, 2002; Tsegaye, 2009; Efrem, 2010; Eyayu, 2010; Fisseha *et al.*, 2011; Naga, 2012). In line with the findings of this study, Kahsay (2004) and Amsalu (2006) attributed the decline in grassland cover to expansion of cultivated and settlement area driven by increasing human population. In support of this observation, Hurni (1985) indicated that high population pressure often leads to expansion of agriculture into marginal areas that are prone to degradation.

Soil water conservation practice is still lacking and improved reforestation was not developed in the area either. Hence, the indiscriminate tree cutting for charcoal preparation, cultivation land preparation or forest destruction practices has been major causes of land degradation followed by ecological problem in Fincha'a a sugar estate as well as the western part of the country (Fig.8.).

Fig.8. Natural resources management and its consequence on land degradation in FSE.

But so far, there has been no meaningful policy implementation, which either regulates the livestock numbers, reforestation, afforestation or promotes the production of improved fodder sources. The various effects of drastic land use and land cover changes in these areas will certainly have not only national but also international implications. Since the northwestern highlands of Ethiopia are the potential source of a supply of water and sediment to the Blue Nile, the impacts of change will soon be deeply felt by downs lope users. The problem thus has a multinational dimension and requires an integrated effort before the agricultural potential of the area is lost beyond recovery (El-Swaify and Hurni 1996).

Implications of LUC changes to the environment.

The changes observed did not take place without negative consequences. For instance, as cultivated land was expanded at the expense of other land use and land cover units, grassland declined, resulting in less available fodder and a decrease in the number and quality of livestock. This led to a shortage of animals required for plowing and transport, as well as to a reduction of income and food from animals and their products. There was a significant change in land use/land cover change, due to Sugar Estate establishment, irrigation development and other various reasons, which could lead to differential environmental degradation such as land degradation (deforestation, erosion, sedimentation) and flooding (surface runoff), waterlogging (groundwater rise),etc. Deforested lands are exposed to the impacts of rain drops, which may accelerate the detachment, removal, and transport of soil particles and some other related effects (Megersa, 2012). Conversion of native forest to other land cover types may produce permanent changes in annual stream flow (Bruijnzeel, 2004). Based on the susceptibility to erosive rainfall, the land use of FSE could be categorized into four groups: (i) areas that are bare when erosive rain occurs and exposed to accelerated erosion (i.e. cultivated land), (ii) areas that have a relatively better vegetation cover but exposed to indiscriminate tree cutting (iii) areas with better vegetation cover all year round but subjected to limited encroachment (i.e., forest), and (iv) the water body, saturation of soil(waterlogging), environmental degradation. Thus, the irrigated fields in the Sugar Estate are exposed to the possible maximum deforestation and water erosion. This shows that land degradation is increasing from time to time. Consequently rill and gully erosion are the abundant forms of erosion in cultivated land. Field observation showed a high sediment influx into the water body, high land degradation followed by soil physical degradation (Fig. 8.), which caused reduced forest land and accelerated rate of environmental degradation. In spite of this, environmental impact studies, reforestation and soil and water conservation activities are lacking in the study area. The sugar estate plays a significant role in supporting the national economy through sugar and ethanol production. But the community service that the community in and around FSE incurs from the estate is very limited as usual. According to the key informants the sugar estate development had negatively affected ecology, livestock condition, vegetation cover and environmental aspects in the study area. Streams often burst and cause habitat destruction. When the valley was with good vegetation cover, clean water was obtained from streams and springs the whole year round, but today pure water supply from these sources is short-lived.

Conclusions

Analysis of land use land cover change has clearly shown that the Fincha'a Sugar Estate was subject to continuous successions during the study periods (1984-2005 and 2005-2009), whilst the changes vary in magnitude and direction. The spatial and temporal analysis of land use and land cover change presented here, though not an end in itself, clearly indicates the prevalence of serious land degradation and the related problems the area will face in the near. The changes have been dramatic for the traditional agricultural system, and the impacts are now highly visible. Vegetation cover has completely declined; the proportion of degraded lands has increased. However, these processes have not yet been fully recognized by planners and decision-makers, who still believe that agricultural potential, can be tapped as before. If this perception is not corrected and current trends averted, the great agricultural potential of this part of the country will soon be severely degraded, perhaps beyond recovery in some places.

In general, it can be concluded that the processes and associated problems observed have regional, national, and international implications Hence, further research and development interventions into ecosystem dynamics at various spatial scales are required if conservation and agricultural development goals for this watershed in particular and the country at large are to be met on a sustainable basis. Last not least, the use of GIS as a vital supporting tool in management of natural resources, which is currently either overlooked or underestimated in the country, must be enhanced to speed up and improve understanding and efficiency of decision-making processes at various levels. A multilevel stakeholder approach to sustainable land management is needed. To this end, existing biophysical, socioeconomic, land policy, and institutional conditions need further careful investigation. Moreover, introduction of proper land management and tenure systems, population growth control mechanisms, and integrated environmental rehabilitation strategies must be given high priority, at the least to prevent existing potential from further deteriorating. The authors also believe that detailed investigations of household mechanisms for adaptation to the changes observed are essential for future action.

Acknowledgements

The authors are grateful for the financial support of the NCCR (National Centre for Competence in Research) North-South and associating the main author as a PhD student to the Institution. We also acknowledge the Ethiopian sugar corporation in general, and in particular Mr. Ambachew Damte, the former directorate for research, Mr. Dereje Gutama, directorate for factory operation and expansion, for their limitless support during the data collection, analysis, and all the people at the Fincha'a Sugar Estate who contributed knowledge and skill, provided, advice and material assistance during the entire study time. The assistance of the staff and GIS expertise of the Earth Science Department of the Wollega University especially (Mr.Gizachew Kabite and Mr. Muleta Ebsa) for their unreserved assistance and preparing suitable graphics for this research paper are gratefully acknowledged.

References

Abiy D. 2010. Land use/land cover dynamics and soil erosion risk analysis, for sustainable land management in north central Ethiopia: The Case of Antsokia-Gemza Woreda. MSc Thesis. Addis Ababa University, Ethiopia.

Addisalem A. 2009. Agricultural land suitability evaluation for rained crops using GIS and RS techniques: A Case Study of Debre-Mewi Watershed. Thesis, Bahir Dar University, Ethiopia.

Ademe A. 2001. Summary of Metrological Data (1979-2000), Fincha'a Research Station, Fincha'a, Ethiopia.

Amare B. 2007. Landscape transformations and opportunities for sustainable land management along the Eastern Escarpment ofWollo,Ethiopia.PhDDissertation. Switzerland.

Asefa K.1994. Valuing Environmental Quality Changes in Horro-Guduru. Field Survey Report.

Neqamte, Ethiopia: The Finnish Forest Research Institute.

Asefa T. 2003. Hydropower development in Ethiopia. Fact-sheet. EEPCo, Addis Ababa, Ethiopia.

Bayissa C. 2007. Assessment of Malaria as a Public Health Problem in Fincha'a Sugar Factory based on Clinical Records and Parasitological Surveys. MSc Thesis. Addis Ababa University, Ethiopia.

Bassett T, Bi Zueli K. 2000. Environmental discourses and the Ivorian savanna. Ann. Assoc. Am. Georg. **90(1),** 67–95.

Behailu A. 2010. Land use and land cover analysis and modeling in south western Ethiopia: The Case of Selected Resettlement Kebeles in Gimbo Woreda. MSc Thesis, Addis Ababa University, Ethiopia.

Belay T. 2002. Land-cover/land-use changes in the Derekolli Catchment of South Wello, Ethiopia. Eastern Africa Social Science Research Review 17.

Bezuayehu T. 2006a. "People and dams: environmental and socio-economic changes induced by a reservoir in Fincha'a watershed, western Ethiopia."Tropical" Resource ManagementPapers75.Wageningen University, Wageningen, the Netherlands.

Bezuayehu T. 2006b. Environmental Impact of a Hydropower Dam in Fincha'a Watershed, Ethiopia: Land Use Changes, Erosion Problems, and Soil and Water Conservation Adoption. Sustainable Sloping Lands and Watershed Management Conference. Wageningen University, Wageningen, the Netherlands.

Birru Y. 2007. Land degradation and options for sustainable land management in Lake Tana Basin (LTB), Amhara Region, Ethiopia. PhD dissertation. Switzerland.

Bruijnzeel L. 2004. Hydrological functions of tropical forests; not seeing the soil for trees? Agriculture, Ecosystems and Environment 104: 185228.

Dechassa L. 2003.Surplus producing eastern highland parts of eastern Wollega zone badly hit by current crisis. Assessment report submitted to the Office for the Coordination of Human Affairs, UN, Addis Ababa, Ethiopia.

Dereje G. 1993**.** Phosphorus status and availability to Sugarcane (*Saccharum officinarum* L.) Grown on two major soil types in Fincha'a valley: MSc Thesis. Alemaya University, Ethiopia.

EFAP (Ethiopian Forestry Action Program). 1994. The Challenge for Development. Volume II: Final Report. Addis Abeba, Ethiopia: Transitional Government of Ethiopia, Ministry of Natural Resources Development and Environmental Protection.

Efrem G. 2010. Land-use and land-cover dynamics and rural livelihood perspectives, in the semi-arid areas of central Rift Valley of Ethiopia, Faculty of Forest Sciences, Department of Forest Resource Management, Umeå, Swedish University of Agricultural Sciences.

El-Swaify SA, Hurni, H. 1996**.** Trans boundary effects of soil erosion and conservation in the Nile Basin. International Journal of Soil and Water Conservation **1**:7–21.

El-Swaify, SA. 2002**.** Impacts of land use change on soil erosion and water quality: A case study from Hawaii. In: Jiao Juren, editor. Technology and Method of Soil and Water Conservation.Proceedings of 12th International Soil Conservation Organization Conference, Beijing, China. Volume III. Beijing, China: Tsinghua University Press, pp 267–270.

Etter A, McAlpine C, Pullar D, Possingham H.2006a. Modelling the conversion of Colombian lowland ecosystems since 1940: drivers, patterns and rates. Journal of Environmental Management. **79**, 74–87.

Eyayu M. 2010. Land use change, topographic aspect and vegetation effects on the dynamics of soil properties in the northwest highland Ethiopia and options for sustainable land management. PhD Dissertation. Haramaya University, Ethiopia.

Fu C, 2003**.** Potential impacts of human-induced land cover change on East Asian Monsoon. Global Planet. Change **37**, 219–29.

Getachew F, Heluf G, Kibebew K, Birru Y, and 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. Biodiversity and Environmental Sciences **1,** 184-198.

Gete Z, Hurni H. 2001. Implications of land use and land cover dynamics for mountain resources degradation in the Northwestern Ethiopian highlands. Mountain Research and Development **21,** 184-191.

Gete Z. 2000. Landscape dynamics and soil erosion process modeling in the Northwestern Ethiopian highlands. PhD dissertation. Switzerland.

HEC (HARZA Engineering Company).1965. . Appraisal of Potential Agricultural Development. Fincha'a Project, Ethiopia. Report prepared for Ministry of Public Works and Communications. Volume III, Appendices. Addis Abeba, Ethiopia: Imperial Government of Ethiopia, Ministry of Public Works and Communications.

Herweg K, Stillhardt B. 1999**.** The Variability of Soil Erosion in the Highlands of Ethiopia and Eritrea. Average and Extreme Erosion Patterns. Soil Conservation Research Report 33. Berne, Switzerland: University of Berne.

Hurni H. 1993. Land degradation, famine, and land resources scenarios in Ethiopia. In*:* Pimentel D, editor. World Soil Erosion and Conservation. Cambridge Studies in Applied Ecology and Resource Management. Cambridge, UK: Cambridge University Press, pp 27–61.

Hurni H. with the assistance of an international group of contributors. 1996. Precious Earth: From Soil and Water Conservation to Sustainable Land Management. Berne, Switzer land: International Soil Conservation Organization (ISCO) and Centre for Development and Environment (CDE).

Hurni, H. 1998**.** A multi-level stakeholder approach to sustainable land management. *In*: Blume HP, Eger H, Fleischhauer E, Hebel A, Reij C, Steiner KG, editors. Towards Sustainable Land Use. Furthering Cooperation between People and Institutions.AdvancesinGeo-Ecology. Reiskirchen: Catena Verlag, **31:** pp 827–836.

Hurni H, Solomon A, Amare B, Berehanu D, Ludi E, Portner B, Birru Y, Gete Z. 2010. Land Degradation and Sustainable Land Management in the Highlands of Ethiopia. p. 187-207. In: Hans Hurni and Urs Wiesmann (eds.) Global Change and Sustainable Development: A synthesis of Regional experiences from research partnerships.Perspectives,5. NCCR North-South, Swiss National Center of Competence in Research North-South, University of Berne, Switzerland.

Jitendra K. 2011. Mapping and Analysis of Land Use and Land Cover of Kanpur city using Remote Sensing Technique, 2006, Journal of the Institute of Indian Geographers, **33** (**1**), Pp.43-54.

Kahsay B. 2004**.** Land use and land cover changes in the central highlands of Ethiopia: The case of Yerer

Mountain and its surroundings.M.AThesis.AddisAbaba University, Ethiopia.

Kebrom T. Hedlund L. 2000. Land use and land cover change between 1958 and 1986 in Kalu district, southern Wollo, Ethiopia. Mountain Research and Development **20,** 42-51.

Manandhar R, Odeh I, Ancev T. 2009. Improving the Accuracy of Land Use and Land Cover Classification of Landsat Data Using Post-Classification Enhancement. Rem. Sens. **1**: 330–44.

Mapedza E, Wright J, Fawcett R. 2003. An investigation of land cover change in Mafungautsi Forest, Zimbabwe, using GIS & participatory mapping. Appl. Georg. **23**, 1–21.

Megersa O. 2012. Analyzing decadal land use⁄cover dynamics of the Lake Basaka catchment (Main Ethiopian Rift) using LANDSAT imagery and GIS. Institute of Technology, School of Natural Resources and Environmental Engineering, Haramaya University, Dire Dawa, Ethiopia. Journal of Lakes and Reservoirs: Research and Management. **17**: 11–24.

Mesfin W. 1985. Northern Shewa and Wello. Background paper on development strategy for the problem of vulnerability to famine. Addis Abeba, Ethiopia: FAO (Food and Agriculture Organization).

Nega E. Heluf G. Degefe T. 2012. Analysis of land use/land cover changes in western Ethiopian mixed crop-livestock systems: the case of Senbat watershed**.** Biodiversity and Environmental Sciences **2**, 8-17.

Nobre A, Sellers PJ, Shukla J. 1991. Amazon deforestation and regional climate change. J. Climate **4**, 957–88.

OADB(OromiaAgricultureand Development Bureau). 1996**.** Land Resource and Socio-economic Survey Report of Cooman Watershed, Ethiopia. Addis Abeba, Ethiopia: Oromia Agriculture Development Bureau.

Pielke RA. 2001**.** Influence of the spatial distribution of vegetation and soils on the prediction of cumulus convective rainfall. Rev. Geophys. **39**, 151–77.

Soil Conservation Research Programme (SCRP). 2000**.** Soil Erosion and Conservation Database. Area of Anjeni, Gojam, Ethiopia: Long-Term Monitoring of the Agricultural Environment, 1984–1994. Berne, Switzerland: Centre for Development and Environment in association with the Ministry of Agriculture, Ethiopia.

Solomon A. 2005. Land use dynamics, soil degradation and potential for sustainable use in Mettu area, Iluabor region, Ethiopia. PhD dissertation, African Studies Series A13, Geographica Bernensia, Berne, Switzerland.

Todkari GU. 2012. Role of Co-operative Sugar Factories in Rural Development: A case study of Damaji Sugar Factory, Man-galweda. International Journal of Agriculture Sciences, ISSN: 0975-3710 & E-ISSN: 0975–9107, **4,** (1), pp-168-171.

Tsegaye S. 2009. Study of forest dynamics of Adaba Dodola, southern Ethiopia. M.Sc. Thesis, Bahir Dar University, Ethiopia.

Wei KL. Fu CB. 1999. Study of the sensitivity of a regional model in response to land covers change over Northern China. Hydrological. Process. **12**, 2249–65.

Woldeamlak B. 2002. Land cover dynamics since the 1950s in Chemoga watershed, Blue Nile Basin, Ethiopia. Mountain Research and Development **22(3),** 263–269.

Woldeamlak B. 2003. Towards Integrated Watershed Management in High land of Ethiopia: The Chemoga Watershed Case Study [PhD dissertation]. Tropical Resources Management Papers 44. Wageningen, the Netherlands: Wageningen University**.**

Worku B. 1995. Agro ecological Conditions andbackgroundInformationonFincha'aSugarFactory, Fincha'aresearchstation, Ethiopia.MSC thesis .Alemaya University, Ethiopia.

Zhang Z, Peterson J, Zhu X, Wright W. 2004. Modelling land use and land cover change in the Strzelecki Ranges. An overview. Monash University, Australia.