Drivers and Implications of Land Use and Land Cover Change in the Central Highlands of Ethiopia: Evidence from Remote Sensing and Socio-demographic Data Integration

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Abstract

This study explores the major drivers of Land-use/Land-cover (LULC) dynamics and the observed environmental degradation as a response to these changes in the Modjo watershed, central Ethiopia. Data for this study were generated through household survey and supplemented with remotely sensed image interpretation. The data were analyzed using descriptive statistics and remote sensing-based image processing. The findings of the study revealed that LULC dynamics together with a range of ecological changes are serious environmental problems in the study site. LULC changes are driven by a combination of proximate and underlying drivers such as economic, demographic, biophysical and institutional factors. Bareland expansion, increased surface runoff production and soil erosion are major environmental damages partly attributed to LULC dynamics in the study site. These environmental degradation processes have adverse impacts on local agricultural productivity, water resource availability and food security of communities. Thus, policy responses are needed for integrated natural resource management and livelihood sustainability in the study area.

Key words: *Ethiopia, Land Use and Land Cover Change, Modjo Watershed, Remote Sensing*

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Introduction

Watersheds provide essential goods and services on which living organisms depend, such as provisioning, regulating and supporting functions and services (Millennium Ecosystem Assessment 2005). However, LULC has been intensely subjected to change globally in the forms of conversion or modification and their environmental functions and services have been weakened from time to time (Turner and Meyer 1994; Geist et al. 2006).

Like many other developing countries, Ethiopia has been experiencing environmental degradation problems including LULC conversion, soil erosion, loss of forest and other vegetation covers and water resource degradation (MoA and WB 2007). National level detailed investigation regarding the magnitude of LULC change and its environmental implication is inadequate, however, micro-watershed level land use change studies using remotely sensed images were carried out in different parts of Ethiopia (Solomon 1994; Gete and Hurni 2001; Kebrom and Hedlund 2000; Woldeamlak 2002; Aklilu et al. 2007; Bezuayehu and Sterk 2008; Mohammed and Tassew 2009).

Almost all of these studies found that LULC conversion process is very intense in the highlands of Ethiopia. For example, one of the land cover components, forest has declined from 40% about a century ago to an estimated less than 15% currently with an approximate deforestation rate of 160,000 to 200,000 ha yr^{-1}. Nonetheless, the estimated figure lacks consistency from literature to literature. The expansion of cultivated, grazing and both urban and rural settlement were the typical reasons for this (Shiberu and Kifle 1998; Badege 2001; MoARD and SLM Secretariat 2008). Besides, too much reliance on woody biomass for fuel, the expansion of agricultural activities at the expense of vegetation cover and demand for wood for construction materials contributed to uncontrolled land cover change and deforestation in Ethiopia (Alemu and Damte 2011).

Theorists in the field of social and earth system sciences hypothesized that LULC dynamics are triggered by the interaction of anthropogenic and biophysical driving forces. These drivers are a complex mixture of political, social, economic and biophysical factors that add force to environmental changes (Geist et al. 2006) and intensified through high population growth rates (UNEP 2000). The expansion of diversified agricultural activities, wood extraction and infrastructure extension are clusters of proximate (direct) causes of LULC changes. As opposed to proximate causes, complexes of technological, economic, demographic, political, institutional and socio-cultural factors are grouped under underlying (root) causes of LULC changes. Thirdly, biophysical triggers such as topography, landslides, droughts, and natural fires are referred to as biophysical factors that underpin LULC changes (Ojima et al. 1994, Lambin et al. 2003, 2006, Geist et al. 2006).

Extensive conversion of vegetation cover and expansion of farmlands along with the dissected terrain and ecological vulnerability lands have implications for large-scale geo-ecological fragmentation and land degradation in Ethiopia (Lakew et al. 2000, Bezuayehu et al. 2002, Dessalegn 2001, Vivero et al. 2005, MoARD and WB 2007). The whole process leads to deterioration of soil quality and productivity. Increasingly focused studies were carried out in Ethiopia to examine the major challenges for the adoption of land management technologies (Shiferaw and Holden 1998, Woldeamlak and Sterk 2002, Berhanu and Swinton 2003, Wegeayehu and Drake 2003, Fitsum and Holden 2006, Woldeamlak 2007, Aklilu and de Graaff 2007). However, integrated discourse regarding the driving forces, implications of LULC changes and major determinants of land management investment decisions have been limited indicating the need for further studies.

This study attempts to contribute to the limited literature in line with the major drivers of LULC change, and on-site and off-site implications these changes have on the rain-fed farming landscapes of the Modjo watershed (central highlands of Ethiopia). The specific objectives of the study were to: (i) investigate the major driving forces of LULC change processes, and (ii) assess the effects of long-term LULC changes on local environmental condition, and (iii) draw lessons for land resource management interventions.

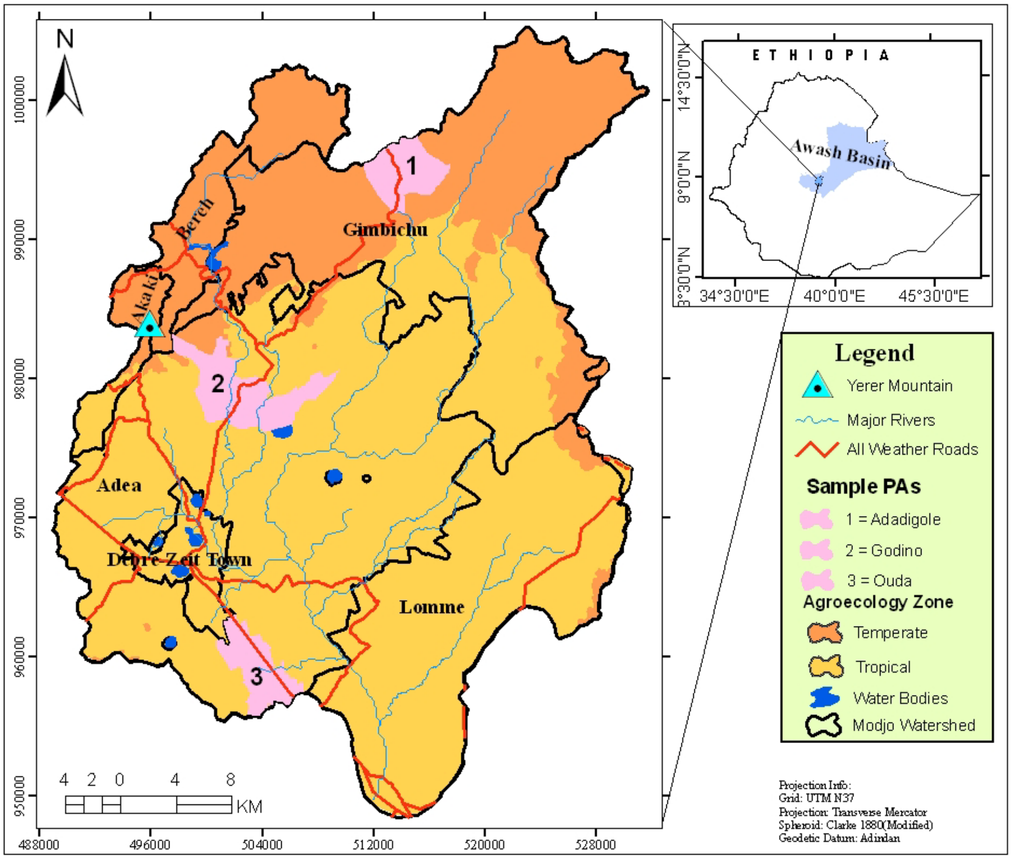

Figure1: Location of sample peasant associations (PAs) within the Modjo watershed.

Materials and Methods

Site Description

The study watershed, Modjo (ca. 1,478 km^2 area), is found in East Shewa Zone of Oromia National Regional State. It is located in the upper Awash River basin in central Ethiopia, stretching over 8^{0}35'00" to 9^{0}05'11" N and

$38^0$54'35" to $39^0$15' 30" E (Figure 1). It is characterized by undulating topography with hills, mountains, plains and river valleys. Elevation in the watershed ranges from 1740 m (south of Modjo town) to 3060 m asl (at *Yerer* volcanic mountains) with a mean value 2142 m. According to Alemneh (2003) and Hurni (1998) traditional agro-ecological zonation of Ethiopia, the Modjo watershed falls under the Weyna-Dega (Tropical) (1740m to 2300 m) and Dega (Temperate) (2300m to 3060m) agro-ecological zone.

Considering FAO's (2006) slope classification scheme, the gradient of Modjo watershed is categorized into flat to very gently sloping (<2%) (9.5% of the total watershed), gently sloping to sloping (2 - 10%) (61.2%), strongly sloping to moderately steep (10 - 30%) (18.4%) and steep to very steep (>30%) (2.9%). The annual total rainfall and mean annual temperature of the area are 881 mm and 19.5^0C, respectively. Nine generalized LULC classes including bare land, cultivated land (comprises cropland plots with scattered rural settlements), forest, grass land, marsh land, plantation areas, shrubs, urban settlements and water bodies were identified in the study watershed based on the year 2007 SPOT image interpretation and classification.

Based on the year 2010 Central Statistical Authority (CSA) population projection, about 625,131 people with an average population density of 172 persons per km^2 live in and around the Modjo watershed. The majority of this population depends on mixed crop-livestock production. In addition, some part of the Modjo watershed is inhabited by urban dwellers and densely populated areas are observed particularly in and around *Chefe-Donsa, Godino, Bishoftu, Ejeri* and *Modjo* towns.

Data Sources and Analysis

The study was mainly based on a survey of farm households supplemented with interpretation of satellite remote sensing images. Specifically, the data required for the study were generated through both primary and secondary sources including household survey, field observation, informal discussion with local land users and experts as well as remotely sensed data interpretation. The geographical distribution of the sample Rural Kebele

Associations (RKAs) in the upstream, midstream and downstream parts of the watershed as well as agro-ecological zones, spatial patterns of the LULC, land degradation hotspot sites and land management practices were used as criteria for selecting the sampling sites for the household survey. Multistage sampling design was used to select the sample households (Table 1). First, the watershed was purposively clustered into upstream, midstream and downstream parts together with the two agro-ecological zones namely Dega (temperate) and Woyna-Dega (tropical). Then, based on the set criteria mentioned above, three RKAs namely Adadigole, Godino and Ouda were selected (Figure 1). In the third stage, 10% of sample households were selected from a list of registered households obtained from the respective RKA offices.

Table 1: Distribution of sample respondents in the Modjo watershed

Position	Elevation(m)	Climate zone	District	RKA	Sample size	%
Upstream	2300-3060	Temperate	Gimbichu	Adadigole	32	26.45
Midstream	1740-2300	Tropical	Addaa	Godino	47	38.84
Downstream	1740-2300	Tropical	Addaa	Ouda	42	34.71
		Grand Total			121	100

A survey instrument was developed and used to collect information on household characteristics, long-term spatio-temporal LULC changes, driving forces to LULC changes, and implications of LULC changes as well as constraints that influence farmers' decisions to plant trees. One hundred twenty one respondents (of which 14.9% were female household heads) were selected using a random sampling technique. Two extension workers in each RKA were trained as enumerators to carry out the household survey under close supervision by the researcher. Respondents were interviewed at the end of 2011. A structured questionnaire was used to explore the background information of the respondents, major driving forces of the LULC process, its environmental implications and factors that are likely to influence farmers' decisions on tree planting for land management. Besides, formal and informal discussions with key informants including elders, extension workers and district (*Woreda*) level natural resource conservation experts as well as field observations were carried out. Finally, the survey data were analyzed using the Statistical Package for Social Scientists (SPSS) version SPSS 20.

Results and Discussion

Socio-demographic Characteristics of Sample Households

Table 2 shows key demographic and socioeconomic characteristics of the surveyed households. A large percentage of household heads (85.1%) was males whereas females constituted the remaining proportion (14.9%). Large proportions (85.1%) of respondents were between the ages of 31 and 64 years, while 9.1% and 5.8% of them were between 21 and 30 years, and 65 or older, respectively. Family seizes ranged from one to 11 persons, with an average family size of 5.9 persons. About 37.2% of respondents had between one and five household members, while a majority (62.8%) of them had six or more members in the family. Households with productive labor force of 1-3, 4-6 and 7-10 categories accounted for 45.5%, 33.9% and 20.7% of the sample households, respectively. Economically dependent age groups (0-14) and elderly (65 and above) varied from family to family. In this regard, 66.1% of respondents had household dependency ratios of between 0.0 and 0.5, while 33.9% of households had dependency ratios of between 0.5 and 3. Twenty-three percent of the respondents were illiterate.

Relatively a greater proportion (38.8%) of the respondents could read and write whereas the educational achievements of 28.1% of respondents ranged from grade 1 to grade 8. A small proportion of the household heads (9.9%) had attended grade 9 and above level of formal education. Most of the surveyed households were engaged in mixed farming activities (70.3%), and some of them (2.5%) were engaged in some form of off-farm activities like petty trading, informal labor and selling charcoal and wood. The landholdings of households in the study area varied from 0.5 ha to 4.8 ha with an average holding size of 1.8 ha per household. A large majority of the surveyed households (63% from the three sample sites) had planted trees for reversing land degradation and ecological reasons of sustainable land management. A large number of households were aware of land degradation particularly soil erosion, soil nutrient depletion and development of gullies as major problems in their localities.

Table 2: Households demographic, socio-economic, asset and livelihood characteristics

Demographic and socioeconomic characteristics	Peasant Associations (PAs)							
	Adadi-Gole		Gudino		Ouda		Total	
	(# 32)	%	(# 47)	%	(# 42)	%	(# 121)	%
Gender: Male	23	22.3	43	41.8	37	35.9	103	85.1
Female	9	50.0	4	22.2	5	27.8	18	14.9
Age: 21-30	3	9.4	2	4.3	6	14.3	11	9.1
31-40	16	50.0	12	25.5	14	33.3	42	34.7
41-64	13	40.6	26	55.3	22	52.4	61	50.4
≥ 65	--	--	7	14.9	--	--	7	5.8
Household size (N): 1 – 5	24	75.0	4	8.5	17	40.5	45	37.2
6 and above	8	25.0	43	91.5	25	59.5	76	62.8
Productive labour force :1 – 3	21	65.6	12	25.5	22	52.4	55	45.5
4 – 6	11	34.4	18	38.3	12	28.6	41	33.9
7 – 10	-	-	17	36.2	8	19.1	25	20.7
Education : Illiterate	11	34.4	17	36.2	-	-	28	33.1
Read and write	17	53.1	17	36.2	13	31.0	47	38.8
Primary school(1-8)	3	9.4	10	21.3	21	50.0	34	28.1
High school &above (≥ 9)	1	3.1	3	6.4	8	19.1	12	9.9
Farming experience:21-30 yrs	3	9.4	2	4.3	6	14.3	11	9.1
>30 yrs	29	90.6	45	95.8	36	85.7	110	90.9
Landholding size:0.50-1.75	11	34.4	29	62.0	26	61.9	66	54.5
1.76-2.75	8	25.0	14	30.0	15	35.7	37	30.6

2.75-4.75	13	40.6	4	9.0	1	2.4	18	14.9
Livelihoods: Only crop cultivation	0	0	15	31.91	18	42.9	33	27.3
Mixed framing	31	96.9	30	63.8	24	57.1	85	70.3
Off-farm activities	1	3.1	2	4.3	0	0	3	2.5
Involving in tree planting: Yes	16	50	45	95.7	14	33.3	75	62
No	16	50	2	4.3	28	65.7	46	38

LULC Change: Reality and Perceptions

The dynamics of LULC were analyzed using household heads' perceptions supplemented with interpretation of remote sensing images. The key findings of change detection results are presented in Table 3, and this can be compared with the perceived LULC changes.

Table 3: LULC changes in the Modjo watershed between the years 1973 and 2007

	1973		2007		Change b/n 1973 & 2007	
	Area(km2)	%	Area(km2)	%	Area(km2)	%
Bare	41.5	2.8	53.3	3.6	11.9	28.6
Cultivated	812.8	55.0	1107.2	74.9	294.4	36.2
Forest	16.9	1.1	4.3	0.3	-12.5	-74.3
Grassland	319.1	21.6	80.5	5.5	-238.6	-74.8
Marsh	6.3	0.4	4.5	0.3	-1.8	-28.6
Plantation	7.9	0.5	18.1	1.2	10.2	129.9
Shrubland	212.7	14.4	125.6	8.5	-87.1	-40.9
Urban	53.9	3.7	74.4	5.0	20.4	37.9
Water bodies	6.8	0.5	9.9	0.7	3.1	46.1
Total	1477.8	100	1477.8	100		

Source: Derived from the 1973 Landsat & 2007 SPOT images interpretation (Berhan et al. 2014).

The LULC statistical data of this study are extracted from Berhan et al. (2014). Remotely sensed satellite images interpretation results revealed that the study watershed was dominantly covered with cultivated lands (55%) and a range of land cover components (forest, grass, shrub and plantations)

(37.7%) in 1973. The remaining 7.3% of the study area was covered by bare land, urban settlement, water bodies and marsh land. In 2007, about 74.9% of the watershed area was covered by cultivated land. About 25% of the watershed was covered with the remaining eight LULC types in the same year. Specifically, areas in bare land, cultivated, plantations, urban and water bodies expanded by 28.6%, 36.2%, 129.9%, 37.9% and 46.1%, respectively, at the expense of other land cover types whereas forest, grassland, shrub land and marshland declined by 74.3%, 74.8%, 28.6% and 40.9% since 1973, respectively, primarily due to conversion into cultivated, built-up and bare land categories (Table 3).

The LULC change was also recognized by farmers and their response is presented in Table 4. The findings from survey analysis (Tables 4, 5 and 6) highlighted that a large number of farmers in the study area were aware of the long term dynamic processes, driving forces and implications of LULC changes.

Table 4: Perceived LULC changes over the past two or more decades in the Modjo watershed

LULC	Patterns of LULC conversion process (N=121*)			
	Increased (%)	Unchanged (%)	Decreased (%)	Total (%)
Bare land	52.1	1.7	46.3	100
Cultivated land	69.6	3.1	27.3	100
Forest	5.8	9.1	85.5	100
Floriculture	57.9	21.5	20.7	100
Grass land	0.8	9.9	89.3	100
Irrigated land	64.5	12.4	23.1	100
Marshy area	1.7	33.1	65.2	100
Native trees	16.5	11.6	71.9	100
Plantations	33.9	22.3	43.8	100
Shrub lands	1.7	12.4	86	100
Urban lands	78.5	8.3	13.2	100
Water bodies	-	35.5	64.5	100

* Total number of cases is 121 and due to a multiple response questions, multiple counts are possible

The data presented in Table 4 from 121 cases confirmed that the size of cultivated and irrigated lands increased since the 1970s. Besides, the development of the floriculture land use is a newly emerged land use system and its areal extent has increased recently as argued by 57% of the respondents. Conversely, a large number of respondents argued that the size of forest (85.5% of respondents), grass (89.3%), native vegetations (71.9%), shrub land (86%) and marshy areas (62.2%) declined in the Modjo watershed. On top of that, a large number of farmers (52.1%) were aware of land degradation in the forms of bare land expansion and development of gullies in their farms in particular and in the study watershed at large. Therefore, data extracted from local farmers reflects the LULC change information derived from interpretation of remotely sensed datasets.

Farmers' Perceptions of LULC Change Drivers

Responses from the surveyed farmers in Table 5 indicate that LULC conversion is triggered by a combination of factors, proximate, underlying and biophysical driving forces. Although LULC changes are the result of human influences, biophysical drivers and natural processes (Geist et al. 2006), the human influences are the dominant factors highly affecting LULC change in the Modjo watershed.

Table 5: The frequency of the major driving forces of LULC changes in the Modjo watershed according to the perception of local land-users' (N= 121*)

Drivers of LULC changes	Perception about LULC drivers					
	Agree		Undecided		Disagree	
	No.	%	No.	%	No.	%
Agricultural activities	114	94.2	6	5.0	1	0.8
Livestock pressure and overgrazing	90	74.4	8	6.6	23	19.0
Wood extraction	114	94.2	5	4.1	2	1.7
Urban expansion and infrastructure extension	100	82.6	8	6.6	13	10.7
Population pressure	100	82.6	10	8.3	11	9.1

Uses of trees for income generation	106	87.6	4	3.3	25	20.7
Better market and road accessibility	85	70.3	23	19.0	13	10.7
Land tenure system and limited transfer rights	57	47.1	19	15.7	48	39.7
Physiography of the watershed (slope nature, accessibility)	109	90.1	6	5.0	6	5.0
Rainfall variability and drought occurrences	107	88.4	4	3.3	10	8.3

* Total number of cases is 121 and due to a multiple response questions, multiple counts are possible.

Proximate Driving Forces

Agricultural Activities: Subsistence rain-fed farming and livestock husbandry are the major livelihoods of the rural community in the Modjo watershed. As the study area is a typical rain-fed farming system, smallholder agricultural land expansion at the expense of other land covers is by far the most widespread proximate driver of land use dynamics and related land cover and ecosystem changes. The change detection analysis based on remotely sensed data showed that 294 km^2 areas of grass, forest, plantations, shrub and marsh land covers were changed into cultivated land between 1973 and 2007 (Table 3). Moreover, extensive areas of private woodlots, grazing lands, communal shrub and woodlands, state forests and plantation were changed to cultivated land as reported by 94.2% of respondents (Table 4). Free grazing in vulnerable steep slope sites is also one of the major drivers of land cover change. As shown in Table 5, 74.4% of respondents reported that increasing livestock population and livestock density along with prevalence of free grazing system are major causes of land cover change and land degradation. Shiberu and Kifle (1998), Badege (2001), MoARD and WB (2007), and MoARD and SLM Secretariat (2008) also concluded that the dominant mixed farming practices in the highlands of Ethiopia without appropriate and integrated land management practices were major driving forces of vegetation cover loss and land degradation.

Wood Extraction: Wood extraction to fulfill the demand of fuel and pole woods is one of the major drivers for clearing extensive area of vegetation cover and trees in Ethiopia in general. Felling of trees for firewood, charcoal and constructional materials without replacement is a critical problem contributing to the loss of various forms of vegetation in general and native tree species in particular. In this regard, a study conducted by Geist and Lambin (2001) indicated that harvesting of fuel and pole woods for commercial purposes and domestic uses were the leading causes of deforestation in Africa, Latin America and Asia. As Table 3 shows, between 1973 and 2007, forest, shrub and grasslands declined by 74.7%, 74.8% and 40.9%, respectively. About 340 km^2 of vegetation cover was converted into other land-use systems like cultivated land and built up areas. A large number of respondents (90.2%) suggested that wood cutting for the fulfillment of domestic uses was the most prevalent driving force of vegetation destruction. The majority of the surveyed farmers (87.6%) also noted that some households that are very poor were engaged in cutting and selling of trees for income generation. Discussion with elders and local natural resource conservation experts also confirmed that the increasing demand of tree products such as fuel wood, construction materials and charcoal for domestic uses in and around the Modjo watershed was one of the major driving forces of land cover change. Therefore, the findings of this study support the assumption that poverty is a cause for land resource degradation, as argued by the political ecology school of thought advocates such as Jolly (1994), De Sherbinin et al. (2007) and Andersson et al. (2011) just to mention a few.

Infrastructure and Settlement Expansion**:** Information derived from change detection analysis using remotely sensed data confirmed that the expansion of infrastructure such as urban and rural settlements, road network and reservoir construction (e.g. Wedecha and Belbela reservoirs) increased by 38% at the expense of other LULC units in the Modjo watershed since the 1970s (Table 3). Some 82% of the respondents also argued that the expansion of built-up areas was a cause of LULC change in the Modjo watershed. Previous studies also highlighted that better market and road infrastructure availability were driving forces of LULC changes (Lambin et al. 2003, Geist and Lambin 2004, Geist et al. 2006). In this respect, 85% of respondents argued that road accessibility and better market opportunities for pole wood, fuel wood and charcoal as well as various forms of agricultural outputs are also the conditioning factors for land cover change in the study site. Based on reconnaissance field survey almost all parts of the watershed have become accessible by all-weather roads and there are big markets nearby like Addis Ababa, Bishoftu and Adama. This market accessibility stimulates the expansion of crop and grazing lands into vegetation covers like natural forest, plantations as well as shrub lands, and consequently leads to the LULC change processes.

Underlying Drivers

Demographic Factors: The demographic characteristics mainly population growth and density are indirect factors for LULC conversion through the growing needs for additional lands for farming and grazing as well as demands for tree products (fuel and construction wood). In this regard, recent studies concluded that land cover conversion due to demographic pressure are more serious largely in tropical regions such as Latin America, Africa and Southeast Asia (Lambine et al. 2003, Geist and Lambin 2004, Geist et al. 2006). The land cover conditions of the Ethiopian highlands have also been modified or significantly transformed by the rapidly increasing population pressure and growing livestock population. Human population in the highlands has grown fast on the limited land area and almost every piece of land is converted into cultivated land to produce food (Solmon 1994, Badege 2001, Woldeamlak 2002, Alemneh 2003, Hurni et al. 2005). Like elsewhere in the country, the study area watershed has experienced fast population growth (Table 6, CSA, 2010).

Table 6: Population growth in 5 districts in and around Modjo watershed between 1994 & 2010

Districts	Area(km2)a	Populationb		Growth b/n 1994 &2007	Densityd	Portion of the watershed in each district (%)
		1994b	2010c			
Ada'a	934.4	234,614	263,358	28,744	281.9	25.7
Akaki	582.6	53,886	85,219	31,333	146.3	16.0

Berhe	736.5	77,967	88,916	10,949	120.7	20.3
Gimbich u	705.2	62,561	94,427	31,866	133.9	19.4
Lomme	675.2	93,007	12,7564	34,557	188.9	18.6
Total	3633.9	522,035	625,131	103,096	172.03	100

Data source: a) CSA 2007 Ethiopian administrative digital datasets, b) the 1994 Hosing and Population Census of Ethiopia, c) 2010 CSA Report, d) the density is calculated based on 2010 population data.

The high population growth increases the demand for land for agricultural activities and biomass as the source of fuel and construction materials. Due to the increase in food and fuel wood demands resulting from population pressure, local farmers are forced to push farm lands at the expense of vegetation cover (forest, shrub lands and grasslands) in the more marginal and fragile landscapes, for instance, along the buffer zones of highly degraded lake, Lake *Chelekleka* and even above the timberline of the *Yerer* mountain. Over 82% of the surveyed farmers indicated that rapidly growing population pressure is one of the major driving forces of LULC change and related land degradation in the study area (Table 5). Key informants also asserted that land holding per capita had declined due to the increasing population pressure. This situation has created pressure on the limited land for agricultural production. This is a clear evidence in favor of the Malthusian and Neo-Malthusian theoretical premise and the stand of political ecologist school of thought regarding population dynamics, land system change and resource degradation (Malthus 1798, Jolly 1994, Panayotou 2000, Geist et al. 2006, De Sherbinin et al. 2007, Andersson et al. 2011).

Property Rights Issues: Land tenure arrangement affects the utilization of land resources and land management investment decisions. In this regard, Fitsum et al.(1999), Lakew et al. (2000), Bezuayehu et al. (2002), MoARD and WB (2007) and MoARD and SLM Secretariat (2008) argued that easily transferable and secure property rights have long been identified as key elements to bring about natural resources conservation, sustained use of resources and investments on land resources management. Under the current land tenure policy of Ethiopia, land is public property and land users have only use rights. Short-term leasing or sharecropping is allowed, however, land cannot be sold, exchanged, or mortgaged (MoARD and WB 2007). Since the utilization of land resources and application of land resource management practices involve long-term investments, land tenure security is an important consideration for sustained use of land resources. Results from discussions with key informants and interviews with household heads showed mixed arguments. About 47% of respondents suggested that the existing tenure system had negative effects on LULC change and contributed to land degradation, whereas 15.7% of respondents did not agree with this view and 39.7% of respondents were unable to judge on this. Some key informants highlighted that the existing land tenure system had undermined farmers' motivation for sustainable land management and tree planting.

Biophysical Factors

Low lying zones and flat topography, natural fires, climate variability and droughts are some of the possible biophysical triggers for LULC change mainly in Africa, Latin America and Asia (Lambin et al. 2003, Geist et al. 2006). In this context, elders, local natural resource conservation experts and interviewed household heads argued that the general topography of the Modjo watershed was one of the biophysical factors conditioning LULC changes. Landscape restrictions such as steep slopes and inaccessibly high elevation zones played a key role in protecting and preserving forests, shrub and grass vegetation covers. However, about 81.3% and 92.4% of the Modjo watershed lies between 1760 m and 2300 m elevation and less than 15^0 slope inclination, respectively (Berhan et al. 2014). From a topographic point of view, most parts of the watershed are easily accessible by local land-users. This condition has contributed to the expansion of various forms of agricultural activities at the expense of vegetation cover. In this regard, 90.1% of respondents argued that the remnants of natural and plantation vegetation covers found in the flat and gently sloping areas are highly vulnerable to deforestation and conversion into other land use systems

(Table 5). Increased rainfall variability and recurrent droughts are other factors contributing to the land-use changes and various forms of land degradation as argued by 88.4% of respondents.

Environmental Implications of the Observed LULC Changes

LULC change is one of the crucial environmental phenomena that affect many parts of the earth's systems including climate, hydrology, biodiversity and fundamental sustainability of land resources on the earth (Gete and Hurni 2001, Mustard et al. 2004). Remotely sensed data coupled with interviews with household heads and field observation confirmed that bare land expansion, runoff production, soil erosion, expansion of flood affected areas and sedimentation problem were some of the observed environmental problems directly linked to LULC change in the study watershed.

Table 7: Perceived environmental degradation in response to LULC change in the Modjo watershed

	Magnitude of severity level (%) (N= 121*)			
Observed environmental problems	Severe	Slight	Not visible	Total
Deforestation	88.4	8.3	3.3	100
Reduction of biodiversity	45.5	43.0	11.6	100
Bare (degraded) land expansion	49.6	48.8	1.7	100
Increasing of soil erosion	81.0	18.2	0.8	100
Increasing of soil fertility loss	75.2	24.0	0.8	100
Siltation and sedimentation	45.5	40.5	14.1	100
Reduction of grazing land	80.2	15.7	4.1	100

* Total number of cases is 121 and due to a multiple response questions, multiple counts are possible

Change in LULC has a significant effect on runoff generation, soil erosion and soil fertility loss. The presence of rugged terrain, deforestation, inappropriate land use system and relatively high amount of summer rainfall are major factors which contribute to the high runoff production, soil erosion, soil fertility loss, and bare land expansion and gully formation in the study watershed. As Table 3 shows, the size of bare land had expanded by 28.6% since the 1970s. Furthermore, the impact of LULC change on surface runoff generation and soil erosion in the watershed was simulated using the ArcSWAT (Soil and Water Assessment Tool) model (Berhan et al. 2014). Results showed that vegetation cover loss and increasing of bare and farming lands led to increases in surface runoff generation (by 14.1%) and soil losses (by 37%) since 1970s. This high surface runoff and soil erosion leads to the occurrence of significant soil nutrient losses in the upstream part and siltation and sedimentation problems in the downstream part. Similarly, about 81%, 75% and 50% of the respondents argued that increasing soil erosion, soil fertility loss and bare land expansion, respectively, were some of the observed environmental consequences that resulted from LULC changes (Table 7).

Concluding Remarks

The objective of this study was to explore the major driving forces of LULC change and their environmental implications in the Modjo watershed. Long term watershed level LULC change detection analysis is mostly done using remotely sensed images, however, this study verified that household level survey data provide an equally important source of information and even additional details can be extracted regarding the magnitude, driving forces and environmental and socioeconomic impacts of LULC changes. The study found that significant LULC change has occurred in the study area, with associated land resource degradation. The major changes observed include expansion of cultivated land, bare land expansion, and loss of wetlands.

Proximate factors (the traditional practices of farming and overgrazing, wood extraction and infrastructure extension), underlying pressures (demographic pressure coupled with poverty, the land tenure system) and biophysical factors (the topography of the watershed) are the key drivers of LULC change in the study site. Hence, addressing the underlying drivers such as balancing human population pressure with available land resources, devising policies and programs for sustainable utilization of natural resources, and community-based watershed management will be required to ensure sustainable local development in the study area.

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