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Re-Exploring Agricultural Land Conversion and Expansion Process in The North Central Highlands of Ethiopia Using Gis and Remote Sensing Techniques

KEYWORDS: land use/land cover, expansion of farmland, GIS

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ABSTRACT *Monitoring of agricultural land change and the resultant consequence yields multiple information about the two way relationship between manmade and natural environment. The work was an attempt of assessing the socio economic implications of agricultural land expansion and conversion process over the past half century in part of North Central highlands of Ethiopia. The study area covers 586km2area of land, located in the Eastern part of South Wollo zone of Amhara Region, Ethiopia. The land use/land cover changes were identified by comparing historical Aerial photographs with current time satellite images using appropriate GIS technique. According to the result, as potentially cultivable area was used for production, there was only an imperceptible agricultural land expansion process after 1958 onwards. Farm land expansion process was highly outpaced by the rapidly increasing trend of population, which is in contrary to the general expectation that farm land expansion is the main means of accommodating the food needs of the increasing population in developing countries.*

1. Introduction

Deforestation and land degradation are underlying major environmental issue in sub-Saharan region particularly in Ethiopia. It was recognized that most parts of Northern Ethiopia area are characterized by devoid of significant vegetation cover, shortening of arable lands and population pressure (WB, 2004). Despite this generalization, there is lack of scientific consensus mainly on the recent and ancient of deforestation, land degradation and expansion of farm lands in the Northern part of the country (Crummey, 2009). It was widely believed that t the current environmental state of the area is the result of massive deforestation and land degradation process happened in the area over the last half a century. Some group of scholars however challenge this idea and asserts that deforestation and land degradation in the area was an ancient process than a half century phenomena ,declaring that, the environmental state of the area is on a state of improvement in the last few decade (Crummey, 1998; McCann., 1995; Tewoldeberhen, 1988). Both group of scholars tries to support their argument by extrapolating small area(less than 100km^2) landscape change study findings to the extensive landscapes of Northern Ethiopia. South Wollo area, where this study has been conducted, is part of this debatable geographical region. Similar to the historical trend, landscape change studies of recent centuries are also arguable. Belay (2002) for example documented a subtle expansion of farm lands and a devastating reduction in vegetation areas in Derkolle catchment of South Wollo area. A similar process of reduction in vegetation areas and farm land expansion was evidenced in Kallu district of South Wollo area(Kebrom Tekle et al., 2000). In a nearby district, quite contrary to these two studies, Crummey (1998) documented a simultaneous increment of woody biomass and farm lands. All of the studies were based on land use/land cover change investigation from repeated aerial photographs. Considering this controversies, the present work was conducted to get more convincing ideas about the process of agricultural land expansion at north central highlands of Ethiopia, by making a land use change investigation on relatively large area. The main objective of the study was to assess the socio environmental implications of farm land expansion and conversion process observed in the Eastern parts of South Wollo area between 1958 and 2010

2. Data and Methods

The study was conducted at South Wollo area, massif elevated Ethiopian landmass, ranges from 1746 to 3118 masl located at west of the Great Rift Valley, around 400 km away from North of Addis Ababa. The study region extends between 39^0 29′ to 39^0 45′E and 11^0 16′ to 11^0 2′N covering 586 km^2 area of land (Figure 1). Average annual rainfall was 1000-1115 mm and temperature ranged from 8.2°C in Nov. to 14.4°C in June (Staffan et al., 2007). Total population in the study area has increased from 290,945 to 361,900 (increased by 24.4%) between 1994 and 2007 respectively. The magnified population change observed in the urban centers of Dessie and Kombolcha town has exaggerated this total increase in population. Small scale mixed farming is the major economic activity which substantiates the whole of the rural population (CSA, 2010).

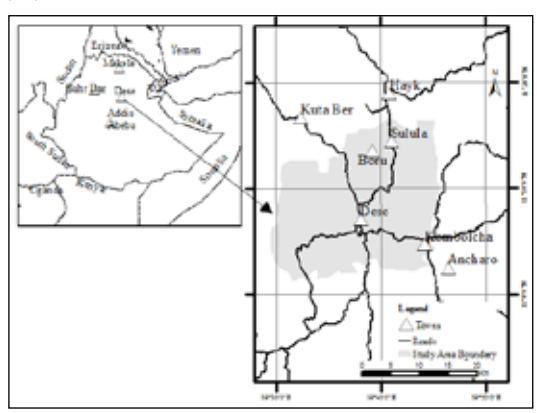

Figure 1 Location map of the Study Area

2.1 Land use/ Land cover data sources and processing

Two sets of 20 aerial photographs were used to analyze the past land use/ land cover trend. The aerial photographs and Topomap were obtained from the Ethiopian Mapping Agency (Table 1). To assess the current state of land use/ land cover, 5 m resolution SPOT image was employed as a source of land use/ land cover data. SPOT image was employed as available land use/land cover data, having a relatively compatible resolution with the historical aerial photographs. The SPOT image was geo-referenced using 20 ground control points. In the geo-referencing process, total root mean square error of 0.8 m was maintained. The aerial photographs were scanned

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and orthorectified. Ground control points for each separate aerial photograph were collected from the Topomap and the geo-referenced SPOT image. The camera model properties of the aerial photographs were employed in the rectification process. In addition, a 30 m resolution ASTER DEM was used as an elevation source to orthorectify the aerial photographs. Then after, the separate orthorectified images were mosaiced. Finally, it is able to generate orthophoto of the study area for the years 1958 and 1986

Table 1.Data types used in the study

Data sources	Time of acquisition	Resolution / Scale	Purpose
Aerial photographs	Jan 1, 1958	1:50,000	Land use/land cover mapping
Aerial photographs	Dec 14,1986	1:50,000	
Spot	2010 2010	3.01 Metter	
Topomap	(Prepared in 1994)	1:50,000	Generation of control points
ASTER DEM	2011	30	Elevation source

2.3 Land use/Land covers digitization and change detection

Visual interpretation of the aerial photographs and the SPOT images in combination with detailed field observation has enabled the generation of ten land cover classes as the major land use/land cover features. Then the land cover features (Table 2) shown on the processed remotely sensed images were extracted using on screen digitization and the data was stored in vector data format. To study the land cover dynamics, land cover change transition matrices were generated by combining 1958 land cover map with its 1986 equivalent and the 1986 with 2010 land cover map.

Table 2. Land use/Land cover classes of the study area

Forest Areas	Areas dominated by trees having a height of 6 meter and above which have a crown cover overlap of 15% and more.
Wood lands:	Scattered and sprinkled trees(equal in height with trees in forest areas) which have not a crown cover overlap between and among different trees; less dense than forests
Shrub lands:	Areas, which have a canopy cover enough to overlay the ground surface, no to be bare; mixed with bushes and small trees (in some cases used as open grazing lands for the local community).
Bare lands	Areas, which are devoid of any vegetation cover or human land uses, including flood plain areas and barren eroded lands.
Farmlands	Land covers used to cultivate perennial or annual crops.
Rural settlements	A collection of scattered hamlets, which are homestead of the local small holder farmers
Water body:	Areas covered with pounds and small lakes.
Grass lands:	Areas with permanent grass cover; located on a plain and water logging areas; used as communal grazing lands throughout the year
Swamps	Areas found in plain landscapes, highly logged water throughout the year.
Urban areas	Land occupied by small and large buildings, roads and factories; spent for urban residential areas and other related functions:

2.2 Interviews with the Local community

To account for the factors causing the observed land use/land cover changes, there was a need to collect information from the local community where land use/land cover change was observed. Accordingly, from the land use/land cover maps, districts over which perceptible and significant land use/land cover changes have been observed. About 12 sites were identified. Four elders, older than 50, were searched from each sites and unstructured interview made to identify the causes for the observed agricultural land conversion and expansion process.

3. Results and Discussion

3.1 General land use /Land cover pattern

The study area is characterized by the domination of farm lands and bare lands, which are the first and the second abundant land cover types irrespective of the change in study times.

Table 3 the area coverage of land use/land cover classes in 1078, 1986 and 2010

Land use/ Land cover classes	1958 Area (km^2)	%	1986 Area (km^2)	%	2010 Area (km^2)	%
Farm lands	261.9	44.6	269.4	45.9	291.2	49.6
Bare lands	192.6	32.8	152.8	26.0	94.3	16.1
Forest	26.2	4.5	27.4	4.7	45.2	7.7
Shrub	44.9	7.6	61.4	10.5	43.1	7.3
Rural settlements	25.9	4.4	28.6	4.9	43.0	7.3
Urban areas	7.4	1.3	16.5	2.8	34.7	5.9
Wood lands	11.4	1.9	16.1	2.8	20.9	3.6
Grass lands	11.7	2.0	9.9	1.7	9.1	1.6
Swamps	3.5	0.6	3.5	0.6	4.0	0.7
Water body	1.0	0.2	1.0	0.2	1.0	0.2
Total	586.6	100	586.6	100	586.6	100

The domination of farm lands, which constitutes about 44.6%, 46% and 49.6% in 1958, 1986 and 2010 respectively (Table 3), is the reflection of the economic activity of the people inhabiting the study area. The unexpected predominance of bare lands in such densely settled areas of land is mainly due to the existence of uncultivable ridge terrains and steep slopes covered by impenetrable rocks. Accordingly, more than 65% of the land areas were dominated by farm lands and bare lands, while the remaining 35% of the land areas were distributed to shrub lands, forest lands, rural settlements, wood lands and urban areas. Water body, swamp areas and grass lands constitute a very little (less than 1%) fraction of the total study area throughout the study periods.

3.2Farm land expansion and conversion process

The most perceivable and consistent land cover changes recorded between 1958 and 2010 includes; reduction of bare lands, regeneration of vegetation areas (forest and wood lands), slight expansion of farm lands, spreading of urban areas and rural settlements.

Table 4 Land cover conversion process between forest areas and other land cover classes

Land use/ Land cover classes	1958 to 1986				1986 to 2010			
	From farm land to others		From others to farm lands		From farm land to others		From others to farm lands	
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Rural settlements	11.76	18.12	10.57	14.59	17.95	29.13	9.87	11.83
Forest land	1.61	2.48	2.93	4.04	4.88	7.92	2.45	2.94
Bare lands	34.61	53.32	47.06	64.96	13.31	21.60	53.05	63.59
Shrub lands	7.46	11.49	6.61	9.12	4.64	7.53	12.62	15.13
Wood lands	1.52	2.34	2.11	2.91	4.39	7.13	1.98	2.37
Grass lands	2.06	3.17	2.97	4.10	3.16	5.13	3.46	4.15
Urban areas	5.89	9.07	0.19	0.26	13.28	21.55		0.00
Total	64.91	100	72.44	100	61.61	100	83.43	100

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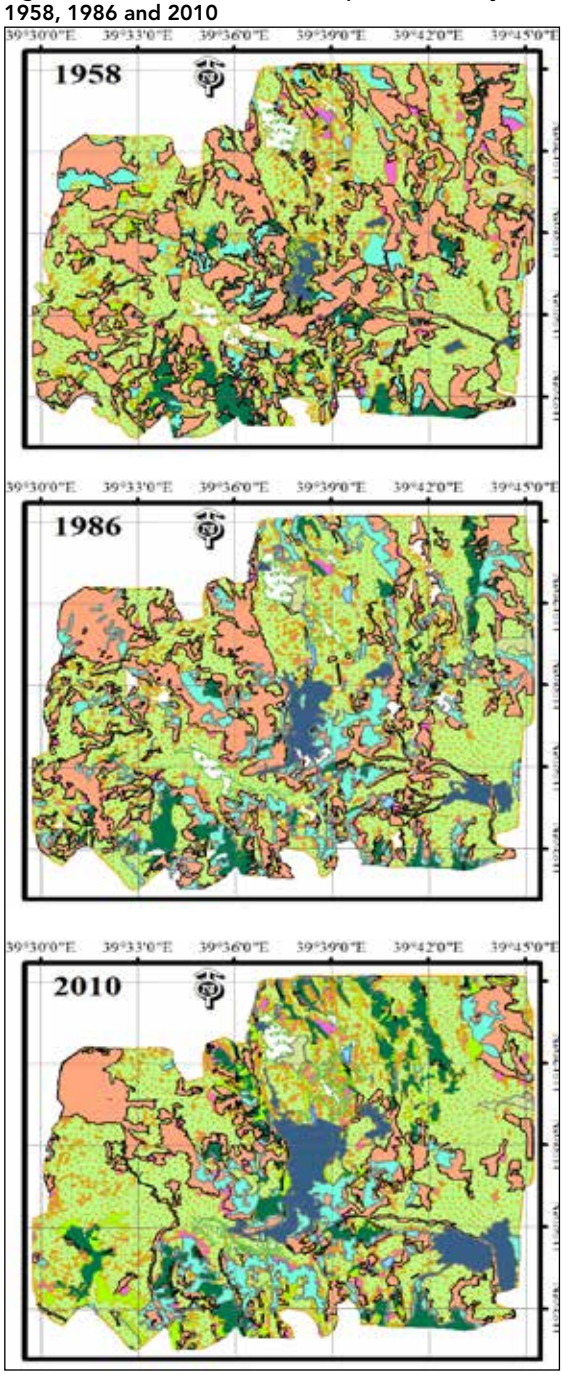
Figure 2 Land use/Land cover Maps of the study area in 1958, 1986 and 2010



Despite the presence of slight farm land expansion, there was a significant trading process between farm lands and the remaining land cover types. Empirically, about 24.7 % (64.9 km^2) of the farm lands of the year1958, were lost to other land cover categories in 1986 (Table 4). This farm land loses has continued in the second study period, where 61.61 km^2 farm lands of the year 1986 were converted to others in 2010. In both of the study periods, a significant portion (53.3% in the first and 21.6% in the second) of these farm lands were converted to bare lands (Table 4).The implication of this conversion of farm land in to bare lands is the existence of noteworthy, but, unexpected farm land abandonment process in such long lasting settled land area. The result of interview with the local community signifies that, abandonment of farm lands is mainly due to reduction in the productivity of farm lands. The farmers of the area gave up cultivating their plots, especially when the amount of return they receive from a plot becomes too low to compensate the expenditure they spent on it. This might be convincing since the area is in the state of exhaustion being cultivated for centuries. In addition to this, expansion of rural settlements and urban areas also contribute their own share for the loss of farmlands. Conversion of farm lands to vegetation was also causing this, especial in the last 24 study years. At the mid of the 1980s, there was hillside afforestation program in the area. In doing so, some farm lands were confiscated from the farmers and were enclosed for rehabilitation. Likewise, the land redistribution program and watershed conservation activity in the undertaken in the area at the early 1990's contributed for the conversation of farm land to vegetation area. Moreover, in recent years, loss of farm land was recorded due to the expansion of urban areas.

The proportion of land areas converted from other in to farm lands exceeded the area lost from farm lands into others, which result in a net increment of farm lands in both of the study periods. Between 1958 and 1986, the total area of farmlands has increased by 7.5 km^2 (2.8%). This number has increased to 8.01% in the second study period (between 1986 and 2010).The most perceivable effect of such expansion of farm lands is reduction in the area coverage of bare lands. One of the reasons for this was the re-cultivation of the previous abandoned farm lands. The farmers re-cultivate their plots after few year of abandonment (when they think that it has rehabilitated after certain years of rest). The other reason was the expansion of new farm lands towards a few ruminant unoccupied marginal steep and very steep slope areas. The latter factor contributed the lion's share for the expansion of farm lands towards bare lands, especially in the last 24 years of the study period. Owing to this, all potentially cultivable lands were occupied before centauries back ago. Due to this reason, farmland expansion process in the study area could be considered as the process of filling the few remnants marginal and semi marginal plots, where the terrain steepness is highly threatening sustainable farming activities.

This is in line with the confirmation of previous land use/land cover change studies in South Wollo area (Belay, 2002; Crummey, 1998; Kebrom Tekle et al., 2000). Unlike the observation of South and South Western parts of Ethiopia (Efrem, 2010; Gessesse Dessie et al., 2007; Resuing, 2000), there was no recent large scale expansion of farm lands in the North central highlands of Ethiopia. This is because, all potentially productive areas were put in to production before half century back ago. Moreover, the existing little farm land expansion has occurred with little, if any, loss of vegetation covers. In contrary, there was a recent expansion of forest and wood lands.

This is mainly because of the absence of significant vegetation covers to be deforested over which farm lands would be expended. This in turn implies the ancientness of deforestation in the area which has been also identified by the studies of (Crummey, 1998). It was also recognized that, the most significant factor causing deforestation is the need of wood and wood resources rather than farm land expansion (Kebrom Tekle et al., 2000)

It is commonly believed that increasing of population in most developing countries drives farm land expansion process and

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deforestation. This general belief however fails to be work in the study area, as the total rate of population growth has outpaced the rate of farm land expansion by far, implying that, expansion of farm lands is not the sole means of acuminating the food demands of the increasing population. This entails that the society is shifting to other methods of accommodating the food needs of the growing population rather than the mere farm land expansion, which needs detail scientific investigation. Rural households found in a similar land shortening and long lasting land areas are being engaged in intensive agriculture and small scale irrigation(Nyssen et al., 2008)

4. Conclusions

The present study drives the implication of land cover changes using GIS and Remote technologies. The study revealed that remotely sensed landscape change studies can provide important information about the socio economic implications of land use/land cover changes beyond to the physical land cover alteration; interpreted directly from the aerial photographs and satellite images. In the study area, farm land expansion and conversion process is a complex phenomenon. There was no a simple forward and direct relationship between population increment, farm land expansion and deforestation. This is implied by the simultaneous increment of both farm lands and vegetation areas with the presence of high population growth rate. The most perceivable effect of farm land expansion was reduction of bare lands. Despite this, it was found that farm lands were converted to rural settlements, urban areas and vegetation lands, which further complicates the phenomena of farm land expansion and conversion process.

Leaving the existing methods of accommodating extra population to be researched in the future, the observed farm land change process implies that it is unlikely to secure the food needs of the increasing population in the existing socio environmental condition via the expansion of farm lands. This is because, nearly all potentially cultivable areas were intensively cultivated for at least more than a century, implying the exhaustion of farm land productivity. More than half of the area is vulnerable for soil erosion as it is dominated by steep and very steep land areas.

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