Land Use/Land Cover Patterns and Their Driving Factors in The Hirmi Watershed and Its Surrounding Agro-Ecosystem, Ethiopian Highlands

[1]Anvesha Sinha, [2]Dr. Sudheesh Shukla, [3]Priyank Bharti, [4]Dr. Manisha Rastogi,
[1,2,3,4]Shobhit Institute of Engineering and Technology (Deemed to be University), Meerut
EmailId- [1]msanvesha@gmail.com, [2]shukla@post.bgu.ac.il
[3]priyank.bharati@shobhituniversity.ac.in, [4]Manisha.rastogi@shobhituniversity.ac.in

ABSTRACT: Long-term land use/land cover (LULC) dynamics, as well as their underlying causes and consequences for land resource management, were investigated in a dryland watershed of Hirmi and its neighboring agro-ecosystem in Ethiopia's northern highlands. The research included two sets of aerial photos (1964 and 1994) as well as Spot 5 satellite images from 2006. Focus group talks and personal interview techniques were used to supplement the generated data. Cultivated and rural settlements, woodland, grassland, town, and a small artificial pond were all recognized as LULC categories in the research. Throughout the study period, there was an increase in agricultural and rural settlement, forestland use/land cover, and a decrease in grassland and shrubland use/cover types Cultivated and rural settlement land grew by 24.6 percent during a 42-year period. Grassland has decreased dramatically from 20% in 1964 to 11.3 percent in 2006. Forest coverage increased from 0.9 percent in 1964 to 1.8 percent in 2006. Indaselassie's population grew at an annual rate of 8.95 hectares (8.1 percent). Between 1994 and 2006, a 6-hectare artificial pond was built. LULC patterns in the Hirmi watershed and the surrounding agro-ecosystem have been affected by a combination of proximal and underlying reasons such as poverty, demographic pressure, institutional, and policy issues. Land resources were degraded as a consequence of the LULC dynamics. The immediate causes of LULC dynamics must be controlled by restricting farmland growth via increased land productivity and developing methods to manage urban land development. Long-term solutions, such as measures to slow population increase and alleviate rural poverty, must be developed in order to achieve sustainable land resource management practices in the study area.

KEYWORDS: Land Use/Land Cover Dynamics, Remote Sensing, Degradation, Hirmi, Northern Ethiopia.

1. INTRODUCTION

For decades, human-induced land use/land cover (LULC) changes have radically altered regional and local landscapes. Changes in hydrological cycles, microclimates, and groundwater sources, as well as land degradation, biodiversity, and land management techniques, are all affected by these changes Recent research has shown that LULC dynamics exist across time and place. In this respect, LULC dynamics are significant in Sub-Saharan Africa, where rapid population expansion is often coupled with overexploitation of natural resources and poor land productivity (Bassett & Bi Zueli, 2000). These LULC dynamics have mostly impacted forestlands, which has resulted in an increase in cultivable land. Globally, the amount of agricultural fields has doubled in the last century (Etter, McAlpine, Wilson, Phinn, & Possingham, 2006). Many areas of Ethiopia's highlands have experienced this situation (Fikir et al., 2009; Gete, 2000; Gete & Hurni, 2001; Kebrom & Hedlud, 2000; Mohammed, 2011).Although a recent forest resource assessment put Ethiopia's forest cover at just 11 percent (FAO, 2010), historical sources suggest that natural forest formerly comprised 35–40 percent of the country's total land area (Breitenbach, 1961; [1] Ethiopian Forestry Action Program [EFAP], 1994). According to Zerihun and Feoli (2001), the dry evergreen montane forest that formerly blanketed Ethiopia's northern plateau is vanished. At the turn of the twentieth century, major deforestation events occurred all across Ethiopia (Bekele, 2003; EFAP, 1994). Despite the fact that the amount, pace, and effects of forest loss in Ethiopia have been recorded at a macro level (EFAP, 1994; FAO, 2010), research on the connections between demographic, economic, and institutional variables that influence LULC dynamics at the local level is limited. Understanding the causes of change and seeking feasible land management solutions necessitates a study of LULC dynamics at local scales [2].

The majority of Ethiopian research found that LULC dynamics have had negative biophysical and social consequences. Between 1958 and 1986, for example, a significant reduction in shrublands, woodlands, and riverine vegetation was observed in the Kalu region of south Wello (Ethiopia) (Kebrom & Hedlud, 2000). In the Dembecha region of northern Ethiopia, there was a significant increase in cultivated land between 1957 and 1995. (Gete, 2000). Between 1957 and 2000, the Beressa watershed in Ethiopia's central highlands saw a remarkable growth in grassland at the expense of agriculture and barren ground (Aklilu, 2006). Between 1965 and 2007, Mohammed (2011) observed a significant loss of marsh, woodland, grassland, and shrubland in the Alemaya region of eastern Ethiopia. Forestland increased in the Chemoga watershed in Ethiopia's northern highlands between 1957 and 1998 (Woldeamlak, 2003) and the Gerado catchment in northeastern Ethiopia between 1958 and 2006 (Woldeamlak, 2003). (Asmamaw, Mohamed, & Lulseged, 2011). According to these research, natural vegetation cover is vanishing, cultivated land is expanding, and land degradation is increasing. As a result, local populations' livelihoods may be impacted. Empirical knowledge of the origin, pace, patterns, and consequences of LULC dynamics at the watershed level may help designers create more effective land management choices in local situations. However, in the dryland regions of Ethiopia's northern highlands, such as the current research area, investigations of LULC dynamics at this scale are uncommon. The goal of this research was to examine LULC dynamics in the dryland region of the Hirmi watershed and surrounding agro-ecosystem in Ethiopia's northern highlands, as well as to determine their driving factors and consequences for land resource management.

Understanding the nature of LULC and their patterns at different geographical and temporal dimensions is essential for effective land management. The Hirmi watershed and its associated agro-ecosystem are located in Ethiopia's northern highlands (Figure 1). It spans 240 km2 and is situated at 14 0–14 9 N and 38 14–38 25 E. The local population is made up of 11,617 homes with 69,705 people (CSA, 2007; Tahtay Koraro Wereda Office of Agriculture, 2011), resulting in a population density of 290 people per square kilometer (CSA, 2007). The research area's terrain varies from an undulating, hilly plateau to small valleys between high mountains. On the hill slopes, the slope gradient ranges from low (0.5–5%) to extremely steep terrain (>60 percent). The watershed is part of the typical Ethiopian highlands geologically. During the Tertiary era, volcanic activity resulted in the ejection of massive amounts of flood lavas, which formed a sequence of strata known as the Trap series. The Trap series is made up of a variety of rock types, including rhyolites, trachytes, tuffs, and ignimbrites, although basalts are the most common and make up the majority of the rock types in the studied region (Mohr, 1971). The relief is mostly the consequence of a basaltic lava outpouring that occurred during the Tertiary epoch of the Caenozoic era (Mohr, 1971). The research region is defined by its broad variety of elevation, which controls its climatic features. 38° 16′ 0″ E 38° 18′ 0″ E 38° 20′ 0″ E 38° 24′ 0″ E Legend Stream Road Indasilassie Town Study area border according to Ethiopian traditional agro-climatic categorization system1st Figure (online color) The Hirmi watershed and its associated agro-ecosystem are located in Ethiopia's northern highlands [3].

The mean total annual rainfall in the watershed is 987 mm, with a maximum of 1380.2 mm in 1975 and a low of 679.7 mm in 1984, according to meteorological data from a station inside the watershed (1971–2007). The average yearly temperature is 20.3°C, with little fluctuation month to month. Rainfall has a monomodal trend, with over 80% falling between June and September. The Tekeze River basin, which is a tributary of the Blue Nile River and flows into the Mediterranean Sea, includes the watershed. The soils in the study region are mostly Vertisols (locally known as Walka), Cambisols (Baekel), Leptosols (Chincha), and Luvisols, which have formed from the parent rock material (Keyh). The major economic activity in the region is rainfed agricultural cultivation. Small-scale family farms are the only kind of agriculture in the Hirmi watershed. Eragrostis tef (teff), Sorghum bicolor (sorghum), Zea mays L. (maize), Pennisetum glaucum (millet), Cicer arietinum (chick pea), and Vicia faba (faba bean) are the most significant crop production systems in the region (horse bean). The farming community's average agricultural landholding size is 0.7 ha, indicating that the research region is densely inhabited [4].

2. DISCUSSION:

Two sets of aerial photos and satellite images were used to track the spatial-temporal changes in LULC in the research region. As main data sources, aerial photos from 1964 and 1994, as well as Spot 5 satellite imagery from 2006 with a matching topographic map at 1:50000 scale, were used. A 1:50,000 topographic map acquired from the Ethiopian Mapping Agency was used to define the research area's boundaries. The aerial photos were scanned using a 1200 dots per inch scanner and stored in a tagged image file (TIF) format for the research. The aerial photos and SPOT 5 satellite data were manually digitized and registered to a common UTM projection based on a topographic map at a scale of 1:50,000. Roads and hill tops, which were plainly visible on the aerial photos, were utilized as control points. The pictures were then modified and clipped to the frame that covers the research region using line objects on a 1:50,000 scale topographic sheet. To create the particular LULC classification and compute the spatial statistics of each polygon, the ArcGIS program (ESRI, 2009) was used to connect the polygon lines. Visual interpretation and extensive use of a mirror stereoscope were used to identify and classify LULC classes on aerial images. For the years 1964, 1994, and 2006, three LULC maps were ultimately created. For the relevant times, gully measurements were also taken. Focus group discussions (n = 3) with 4 to 6 participants from the local elderly, local community leaders, and agricultural extension workers were organized to identify the major driving forces of LULC changes and other nonvisual information that could not be extracted from aerial photographs or satellite images.

In addition, key informants (n = 24) from the local community were interviewed to get further perspectives on LULC-related [5] problems. The research location included six LULC classes: forest, grassland, cultivated and rural settlement, town, shrubland, and an artificial pond (Table 1). Plantation and natural forest were included together in the forestland cover category because the images had the same tone, making it impossible to distinguish between them. The same category was used to classify rural settlements and agricultural land cover units. Visual interpretation and on-screen digitization of the SPOT 5 satellite picture generated the LULC classes.1st Table The Hirmi watershed and its surrounding regions in Ethiopia's northern highlands have been recognized as having LULC classifications. Cultivated land and rural habitation Crop-growing regions and dispersed rural communities are included. Forests are areas that are covered with both natural and cultivated trees. Shrubland Shrubs, bushes, and tiny trees cover the ground. Grassland Grassy region where collective grazing takes place. Town Land is a portion of the land that has been set aside for urban development. Pond Rainfall and run-off feed an artificial lakeChanges in LULC trends Grassland Town +150 +136.4 +226 +86.9 +376 +341.8 basis on reflectance characteristics of the different LULCtypes For each research period, the magnitude and trends of each LULC type change were determined (Table 2). Finally, using an ArcGIS overlay analysis method, transformation matrices from the three LULC maps of the watershed were analyzed for the two eras (1964–1994 and 1994–2006). (Table 3). Discussions and outcomesThe LULC map of the watershed and its surrounding agro-ecosystem for three periods is shown in Figures 2–4. LULC dynamics (section 3.1.1. Land that has been cultivated and that has been used for rural settlement Cultivated and rural settlement land constituted the biggest LULC type in the research site throughout the study period. In the years 1964, 1994, and 2006, the proportions of agricultural and rural settlement land in the watershed were 42.8 percent, 45.7 percent, and 53.3 percent, respectively (Table 4). This indicates a steady rise in the amount of land used for agriculture and rural habitation. Furthermore, the area under agriculture and rural settlement grew by approximately 6.9%, or 23.7 hectares per year, between 1964 and 1994.

Between 1994 and 2006, the pace of agricultural and rural settlement land growth was 151.2 ha Changed to a percentage of a percentage of a percentage of a percentage of a percentage of a percentage of Settlements that are both cultivated and rusticForest Cultivated land and rural habitation 145.1 47.7 55 25.7Town 0 0 Grassy terrain [6]Shrubland 29 13.55 35 11.5 Shrubland 21 9.8 8 2.6Grassland Cultivated land and rural habitation 2889 59.69 1500 32.3 Town 38.6 0.79 103.5 2.2 Forest 82 1.69 128 2.8Grassland 1149 23.73 2309.3 49.7 Shrubland 681 14 602.2 13 Grassland 1149 23.73 2309.3 49.7 Grassland 1149 23.73 2309.3 49.7 Grassland 1149 23.73 2309.3 49.7 Grassland 11Town 31.7 0.37 94 1.2 Forest 160 1.86 45.5 0.6 Grassland 951 11.1 1039 13.3 Shrubland 6035 70.45 5156 66 Grassland GrasslTown Cultivated land and rural habitation Town 109 99 240.5 92.3 0.4 0.36 7.7 2.96Forest 6.9 2.65 0.4 0.36Grassland 4.5 1.73 0.41 0.37Shrubland The transition of 1500 ha (32.3%) of grassland, 1476 ha (17.7%) of shrubland, and 145.1 ha (47.7%) of forestland into cultivated land and rural habitation occurred in the second period (1994–2006). The growth of agricultural and rural settlement land at the expense of other LULC kinds, according to key informants, was owing to a scarcity of agricultural land induced by strong population pressure. More arable land where small-holder traditional subsistence farming is conducted is needed due to population pressure. The decreasing productivity of the land owing to inadequate external inputs and usually poor resource management methods has led to the extension of farmland to compensate for the lost yield, according to the findings of the interviews. Over the research period, the area under forest cover increased slowly but steadily. It accounted for 0.9, 1.3, and 1.8 percent of the total area of the watershed in 1964, 1994, and 2006, respectively. The annual rate of forest growth was between 3 and 10.6 hectares.

Cultivated landsand rural communities Grassland in a GullyForestContourFigure No. 2 (online color) Between the first era (1964–1994) and the second period (1994–2006), LULC map of the Hirmiwatershed and its surrounding regions, Northern highland of Ethiopia, in 1964.of 217 hectares (5.2 ha/year) throughout the course of the study. Between 1964 and 1994, about 26% (55 ha) and 16% (29 ha) of this land cover type was changed into cultivated and rural settlement and shrubland, respectively, while almost 48% of the forest cover was turned into cultivated and rural settlement land in the second period. However, it benefited significantly from other land use and cover types, resulting in an increase during the 42-year period. The main cause for the rise in forest cover, according to local elders, was the planting of eucalyptus trees. The shrubland and grassland cover types produced the most modifications to this land cover throughout the course of the study period It then dropped to 11.3 percent in 2006, after rising to 19.4 percent (Table 4). The conversion of grassland to other LULC was blamed for the decrease in grassland coverage. In the first and second study periods, about 2889 ha (59.69%) and 1500 ha (32.3%) of grassland use/cover category were transformed into cultivated and rural settlement LULC, respectively. Changes in the area covered by grass land cover were partially caused by increasing demand for croplands, which may be anticipated as the human population grows. Furthermore, between 1964 and 1994, 681 ha (14%), 82 ha (1.69%), and 38.6 ha (0.79%) of grassland were converted to shrubland, forestland, and urban settlement land, respectively. A total net loss of grass of 2138 hectares (44.2%) was recorded. Population pressure [7] (3.2.1.2).

In many areas of Ethiopia's highlands, population pressure has been the most significant human factor driving LULC alterations (Aklilu, 2006; Fikir et al., 2009; Gete & Hurni, 2001). With an average yearly growth rate of 4.8 percent, the total population of the current study area grew from 39,299 in 1994 to 69,705 in 2006. If the current growth rate (4.8 percent) continues, the population may double in less than 15 years. This indicates that population pressure on land resources is strong in the region, which may have resulted in more agricultural and settlement land being claimed, as well as increased fuel wood use. This has resulted in greater clearance of shrublands and the development of cultivated and settlement lands, implying that population growth is a significant driving factor in LULC dynamics in the Hirmi watershed and its surrounding agro-ecosystem. Institutional and policy considerations (3.2.1.3). In terms of land resource management, Ethiopia has made many institutional and policy reforms. Reforestation efforts, backed by increasing government backing and international assistance, were partially responsible for the modest growth of plantation forest in the watershed during the 1990s, according to accounts from focus group talks. The Relief Society of Tigray (ReST), a non-governmental local organization that collaborated with the regional administration, began large-scale reforestation operations and created extensive area closures, according to the findings of the interviews. This implies that suitable institutional settings should be consolidated. As a result, institutional and policy variables had a significant role in explaining changes in land use and cover in the watershed and adjacent agro-ecosystem.

The removal or limited cover of vegetation is the first step in land degradation. One of the soil erosion causes is land cover and management (Morgan, 1995). When vegetation is removed, the ground is exposed to soil erosion. As a result, the grass and cultivated LULC groups are more vulnerable to soil erosion. As a result, soil erosion affected 63, 65.1, and 64.5 percent of the total area of the watershed and its surrounding agro-ecosystem in 1964, 1994, and 2006, respectively. As a result, the amount of land in the watershed that is devoid of vegetation and therefore susceptible to soil erosion has grown over time. In the absence of effective soil and water conservation strategies, the loss of natural vegetation cover, such as shrublands and minimal forest cover, in the watershed and its adjacent agro-ecosystem, and their subsequent conversion to cultivated and settlement areas indicated the prevalence of soil erosion. Because most of the planted tree species were eucalyptus with little or no undergrowth, which barely decreases soil erosion, the modest increase in forest cover in the watershed and its surrounding agro-ecosystem does not imply minimum erosion. Moreover, Furthermore, gully development is noted as a significant indication of land degradation in the research site, which is an indicative of the worst type of soil erosion (Morgan, 1995). Aerial picture interpretation revealed that gullies had grown in length and exhibited spatial diversity throughout the research period. As a result, the length of gullies in 1964 was about 131 kilometers. It grew to 157 kilometers in 1994 and 192 kilometers in 2006. This is a 19 percent increase between 1964 and 1994, a 22 percent increase between 1994 and 2006, and a 47 percent increase throughout the whole research period.

The majority of gullies were found on cultivated areas, indicating that agriculture is the primary source of land [8] degradation in Ethiopia. This graphic depicts the prevalence of soil erosion's geographic variations. This demonstrates the need of prioritizing and developing various conservation strategies and plans at the micro-watershed level, such as the Hirmi watershed. Local informants verified that many indigenous plant species that formerly blanketed the region had vanished, despite the fact that this research did not involve empirical data analysis. During the research period, for example, substantial reductions in Hanse (Anogeissus leiocarpus), Akui (The afforestation of alien species, mostly eucalyptus, resulted in a modest increase in forest area. The decrease of natural vegetative cover has ramifications for wild animal populations. According to important sources, lions, leopards, snakes, apes, and monkeys, which previously protected the wyvern, are now on the move.

3. CONCLUSION

Over a 42-year period, this research looked at LULC dynamics, their driving factors, and the consequences for land resources. The findings revealed significant increases in LULC in the Hirmi watershed and its surrounding agro-ecosystem in Ethiopia's northern highlands. Urban settlement increases and woodland expansions were the most significant changes. decrease in grassland and shrubland cover, cultivated and rural settlement land, and reduction in grassland and shrublandcategories to use/cover The findings revealed that grassland cover was one of the most important factors. With approximately 76 and 50 percent of its entire area transformed into other LULC, the land cover has been impacted. during the years 1964–1994 and 1994–2006, respectively. Settlement in a cityWith a roughly 342 percent increase throughout the whole study period, there was a significant shift. The LULC dynamics were influenced by a mix of proximal and underlying factors. causes. The need to expand agricultural and settlement areas, as well as the rising cost of rural fuel One of the immediate reasons was the need for wood. Population pressure, poverty, and institutional and policy issues are among the root reasons. The modifications have ramifications [9].

for the prevention of soil erosion and the conservation of biodiversity The picture interpretation also revealed that soil erosion had affected a large part of the research region. These have the potential to be beneficial. have an impact on the local community's livelihood Furthermore, since the soils underneath the farmed fields are barren, and because intercropping is not an option, because it is not extensively used in the region, soil erosion by water is common. Thus, Land deterioration will occur if nothing is done to improve the situation and restore the region would have a negative impact on the watershed's exploitation in fulfilling local demandThe Journal of Land Use Science (JLUS) is a peer-reviewed journal that publish People are employed in the production of food, firewood, and timber. This indicates that in order to keep farming going in the region, certain land management techniques are required. To provide food for its people In this case, agricultural extension workers would play an important role. have the highest priority. The causes of the observed alterations must be controlled. in order to achieve long-term land management There is a need to maintain instant control. by restricting agricultural growth and increasing land productivity via the use of terracing, check damming, and use of better land management methods the number of external inputs These should be combined with shrub improvement and expansion. increasing forest cover and reducing human strain on the land, as well as providing the community with alternate energy sources The Tigrinya government has developed a land use strategy. Redistribution of hill slopes for tree and grass plantings among regional governmentsAs quickly as possible, the young must be implemented. This guarantees the safety of its usage the resources in the shared pool Urban area growth that is planned and controlled is also required [10]

REFERENCES

[1] P. Jouquet, E. Chaudhary, and A. R. V. Kumar, “Sustainable use of termite activity in agro-ecosystems with reference to earthworms. A review,” *Agronomy for Sustainable Development*. 2018.

[2] C. Andres and G. S. Bhullar, “Sustainable intensification of tropical agro-ecosystems: Need and potentials,” *Front. Environ. Sci.*, 2016.

[3] F. Lescourret *et al.*, “A social-ecological approach to managing multiple agro-ecosystem services,” *Current Opinion in Environmental Sustainability*. 2015.

[4] J. Wickama, A. Kessler, and G. Sterk, “Modelling and mapping erosion in smallholder agro-ecosystems, Tanzania,” *L. Degrad. Dev.*, 2018.

[5] S. T. Williams, N. Maree, P. Taylor, S. R. Belmain, M. Keith, and L. H. Swanepoel, “Predation by small mammalian carnivores in rural

agro-ecosystems: An undervalued ecosystem service?," *Ecosyst. Serv.*, 2018.

[6] F. Langerwisch, T. Vaclavik, W. Von Bloh, T. Vetter, and K. Thonicke, "Combined effects of climate and land-use change on the provision of ecosystem services in rice agro-ecosystems," *Environ. Res. Lett.*, 2018.

[7] P. H. Thrall *et al.*, "Evolution in agriculture: The application of evolutionary approaches to the management of biotic interactions in agro-ecosystems," *Evol. Appl.*, 2011.

[8] D. D. Cameron, "Arbuscular mycorrhizal fungi as (agro)ecosystem engineers," *Plant Soil,* 2010.

[9] E. H. Stukenbrock and B. A. McDonald, "The origins of plant pathogens in agro-ecosystems," *Annual Review of Phytopathology*. 2008.

[10] G. R. Maharjan *et al.*, "Approaches to model the impact of tillage implements on soil physical and nutrient properties in different agro-ecosystem models," *Soil and Tillage Research*. 2018.