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Impact assessment of Land Use and Land Cover Change on Soil Erosion in Ethiopia using Geospatial techniques

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Abstract: - The impact of land-use land-cover (LULC) change on soil resources is getting global attention. Soil erosion is one of the critical environmental problems worldwide with high severity in developing countries. Land use and land cover (LULC) dynamics, in general, and the conversion of the natural vegetation cover into cultivated land, in particular, are major human-induced problems in Ethiopia, which have played a significant role in increasing the rate of soil erosion and altering the hydrological balance in the country. The main aim of this review was to view previous studies in Ethiopia that quantify the change in the rate of soil erosion and the change in land use and land cover in the country. From the past researches reviewed in this paper, the expansion of cultivated land at the expense of forest land, shrub land, and grassland in Ethiopia has increased the mean rate of soil erosion, sediment yield, and surface runoff, mean wet monthly flow, and mean annual stream flow in the last four decades. On the other hand, the change has reduced the dry average monthly flow, groundwater recharge and groundwater flow, and evapotranspiration (ET) in the country. Future research works should pay more attention to the investigation of the impacts of land use and land cover change on soil erosion and the prediction of future soil loss and the changing land use and land cover in the country since little information is available from past researches on these issues. Research works are also required in lowland arid and semiarid areas in Ethiopia to effectively manage soil and landuse planning in all parts of the country.

1. Introduction

1.1 Bacground of the Review

Land use and land cover (LULC) change triggered by the interaction between demographic and socioeconomic changes as well as biophysical conditions [1, 2] is one of the main driving forces on global and local environmental changes [3, 4]. It exerts multidimensional consequences on essential Earth's ecosystem functions and services at local, regional, and global scales [2]. In sub-Saharan African countries, land use and land cover change, in general, and conversion of the natural land cover into agricultural land, in particular, are major continuous phenomena mainly caused by anthropogenic activities [5]. Like other sub-Saharan African countries, human-induced conversion of the natural land cover into cultivated land is the major problem in different areas of Ethiopia where agricultural activity serves as the backbone of the economy [6, 7].

Land use and land cover (LULC) change in Ethiopia is triggered by the interaction of various demographic, socioeconomic, institutional, and biophysical factors [1]. Studies have shown that population pressure [6, 8–11], widespread agricultural expansion [6, 10–12], expansion of settlement [10, 12], rural poverty [9], inadequate management of common property resources, and land tenure insecurity due to institutional and policy reforms [3, 8, 9, 11, 13] and demand for fuel wood and construction materials [10–12] were recognized as the major drivers of land use and land cover change in the country.)e level of land cover conversion is particularly higher in the highland areas of the country mainly due to demographic pressures and consequent expansion of croplands and household energy demands [6, 14].Different studies indicated that land use and land cover change triggered by the aforementioned factors in the country have led to severe soil erosion [6, 11, 15], loss of Biological diversity [8, 11, 15, 16], decline of agricultural production and productivity [8, 15–17], and decline of Ecosystem service values (ESV) due to changes in individual ecosystem service functions such as erosion control, provision of raw material, nutrient cycling and climate regulation [18–21] and change of livelihood [11].

The problem of soil erosion is one of the major environmental constraints to agricultural sustainability and food Security in Ethiopia particularly in the highlands [22, 23]. The overall soil loss of the country is estimated at about 1.5 billion tons per year with a mean erosion rate of 42 $t \cdot ha^{-1} year^{-1}$ [9, 24, 25]. The rate of soil erosion has been accelerating in the country due to land use and land cover (LULC) change and inappropriate land use and management practices [22, 26].

Ethiopia is historically passed significant dynamics in LULC for many decades. However, nowadays, LULCs and degradation are increasing at an alarming rate, playing a significant role in the increasing rate of soil erosion. The need for more cultivated lands has negatively affected the presence of forest and grasslands, eventually fostering soil erosion [23]. Environmental conversions and changes can be mainly attributed to various adverse human actions such as the expansion of farm plots at the expense of agricultural lands, massive fuelwood and charcoal production, overgrazing, and encroachment of farmsteads into vegetated lands.

The quantification of land-use/land-cover (LULC) changes and monitoring of their impacts on soils, biodiversity, water, air and climate stipulates at least two sets of data: the reference and target data. The reference soil data is a baseline data, which offers benchmark information prior to the LULC change. Target data, on the other hand, represents the changed parameter after LULC change took effect on the soils. While LULC change studies have significantly benefited from the advancement of remote-sensing technologies for over four decades now, soils under those land covers have barely benefited from those technologies. This is because of the challenges involved in the acquisition of soil biophysical data directly from remotely sensed imageries – dueto shallow penetration and the spectral mixing from plant canopies and dry litters [27]. The absence or limitation of periodic soil data significantly limits the detection of soil property changes due to LULC changes.

The main objective of this article is to review the actual literatures on impact assessment of LULC change that can erode soil in Ethiopia, to point out what are the existing situations and the research gap that should be addressed in the future.

2 Materials and methods

2.1 Description study area

Ethiopia is located in the north-eastern part of the African continent, in the so-called Horn of Africa, which lies between 3 ^{0} and 18 ^{0} north latitude and 33 ^{0} and 48 ^{0} east longitude, within the tropics. The East African Rift Valley runs from northeast to southwest, creating three major relief regions: the Eastern Highlands, the Western Highlands, and the low- lying Rift Valley. Ethiopia comprises a complex blend of lowlands and highlands; elevation ranges from 125 m below sea level at the Danakil Depression to 4620 m above sea level at Ras Dejen (Dashen). Because of the marked contrast in elevation and its proximity to the equator and the Indian Ocean, Ethiopia has large spatial variations in temperature and rainfall [28]..Ethiopia is a country where about more than 110 million people, containing 50.46% male; the country is grappling with all sorts of natural and manmade problems such as famine, environmental degradation, erratic rainfalls, the prevalence of malaria and HIV/AIDS, poor but improving governance, and widespread poverty. About 84% of the people live in rural areas, assuring their livelihoods with subsistence agriculture, which is a sector nowadays suffering from the lack of essential inputs and a very variable rainfall pattern. Poverty is more than common in Ethiopia, though slightly declining over time.

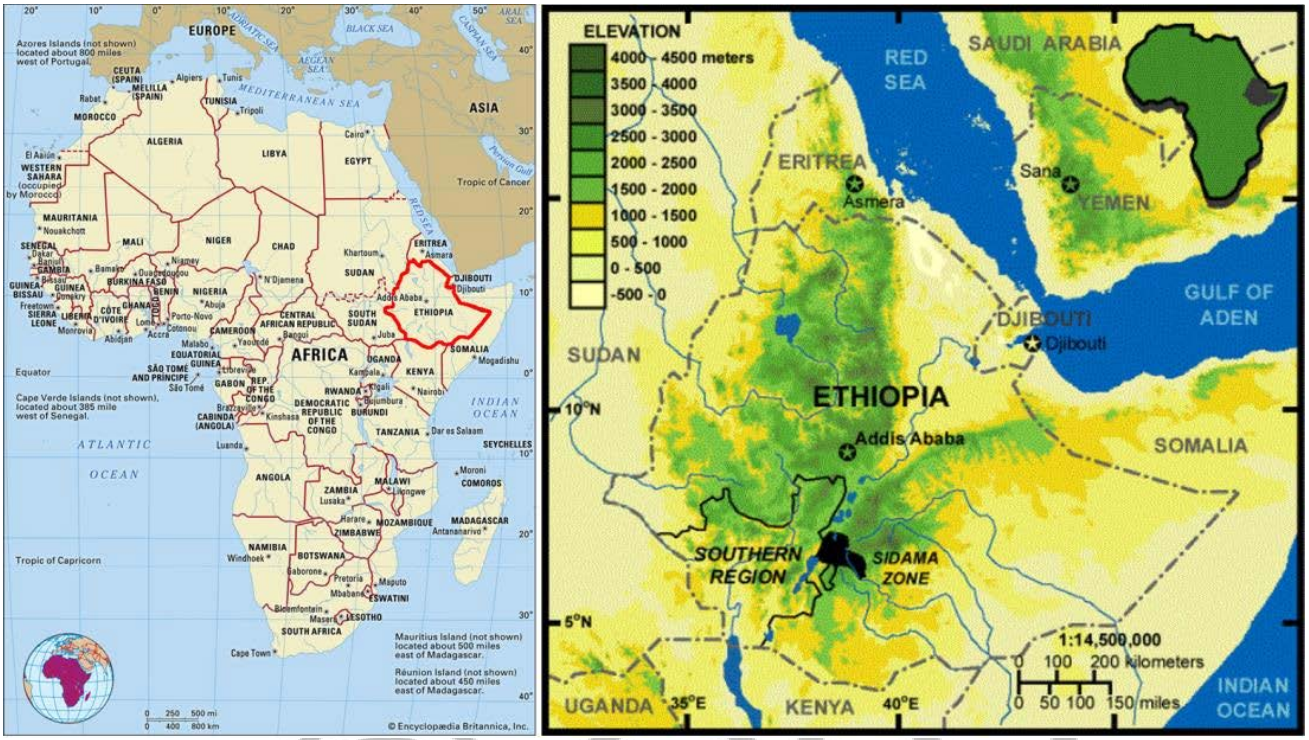

Figure 1. Maps of Africa (on the left) and Ethiopia (on the right)

Land Use and Land Cover in Ethiopia

Land use and land cover (LULC) change is the human modification of Earth's terrestrial surface from existing management of the land or land cover to new management of land or new land cover type [28]. The nature of LULC dynamics significantly differs from country to country as the drivers of LULC change and land management activities vary from place to place. In Ethiopia, land use and land cover (LULC) change is mainly dominated by the conversion of natural vegetation cover to use for agriculture activities [9, 29].

The cultivated land of Ethiopia was distinguished and delineated by usng various data sources. These include: the topomap of the area, satellite image and Google Earth. A landsat image with 1: 50000 scale was acquired (downloaded) from the website (http://glcf.umd.edu; http:// soto. arcgisonline. com/maps; World Imagery.

According to FAO [30], the forest cover in Ethiopia has decreased from 13.3% of the total area of the country (14.69 million ha) in 1993 to 11.4% of the total area (12.54 million ha) in 2016 with an estimated annual rate of change 0.8% (104,600 ha·year^{-1})

The researches that have been conducted in different parts of Ethiopia have shown that there were considerable land use and land cover changes in the country. Most of these studies indicated that croplands have expanded at the expanse of natural vegetation including forests and shrublands; for example [31] in northern part of Ethiopia, [32] in north western part of Ethiopia, [33] in north eastern part of Ethiopia; and [34] in south western part of Ethiopia

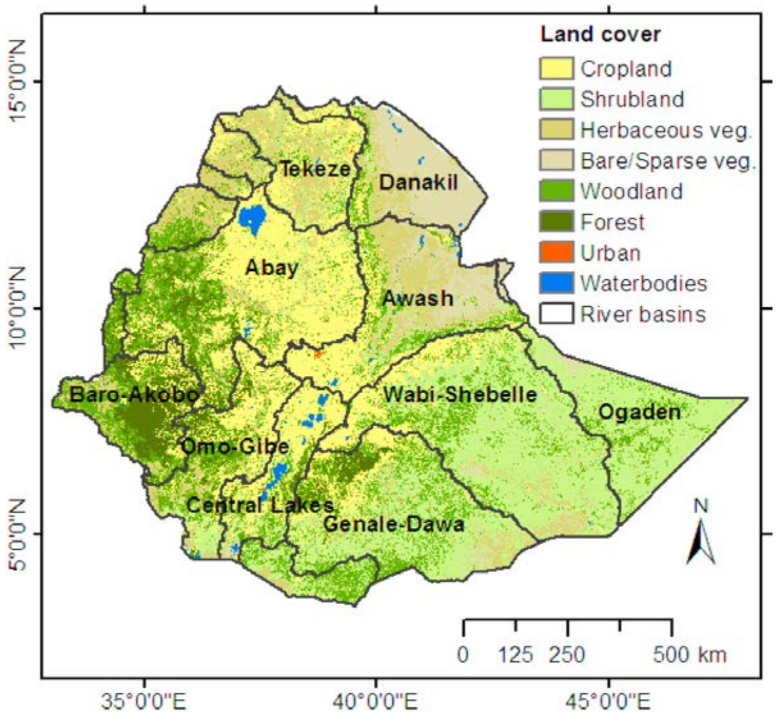

Figure 2 Major land cover types of Ethiopia according to the 2015 land cover map provided by the Copernicus Global Land Service (https://land.copernicus.eu/global/)

Land use and land cover is changing rapidly in most parts of the world. In this situation, accurate, meaningful and availability of data is highly essential for planning and decision making. Remote sensing is particularly attractive for the land cover data among the different sources. [35] ,reported that in 1970's satellite remote sensing techniques have started to be used as a modern tool to detect and monitor land cover change at various scales with useful results.

Climate condition of Ethiopia

The climate of Ethiopia can be classified in different ways including the Traditional, Koppen's, Throthwaite's, Rainfall regimes, and Agro-climatic zone classification systems. The most common used classification systems are the traditional and the agro-ecological zones. According to the traditional classification system, this mainly relies on altitude and temperature; there are five climatic zones namely: Wurch (cold climate at more than 3000 Mts. altitude), Dega (temperate like climate-highlands with 2500-3000 Mts.altitude), Woina Dega (warm at 1500-2500 Mts. altitude), Kola (hot and arid type, less than 1500m in altitude), and Berha (hot and hyper-arid type) climate [36]

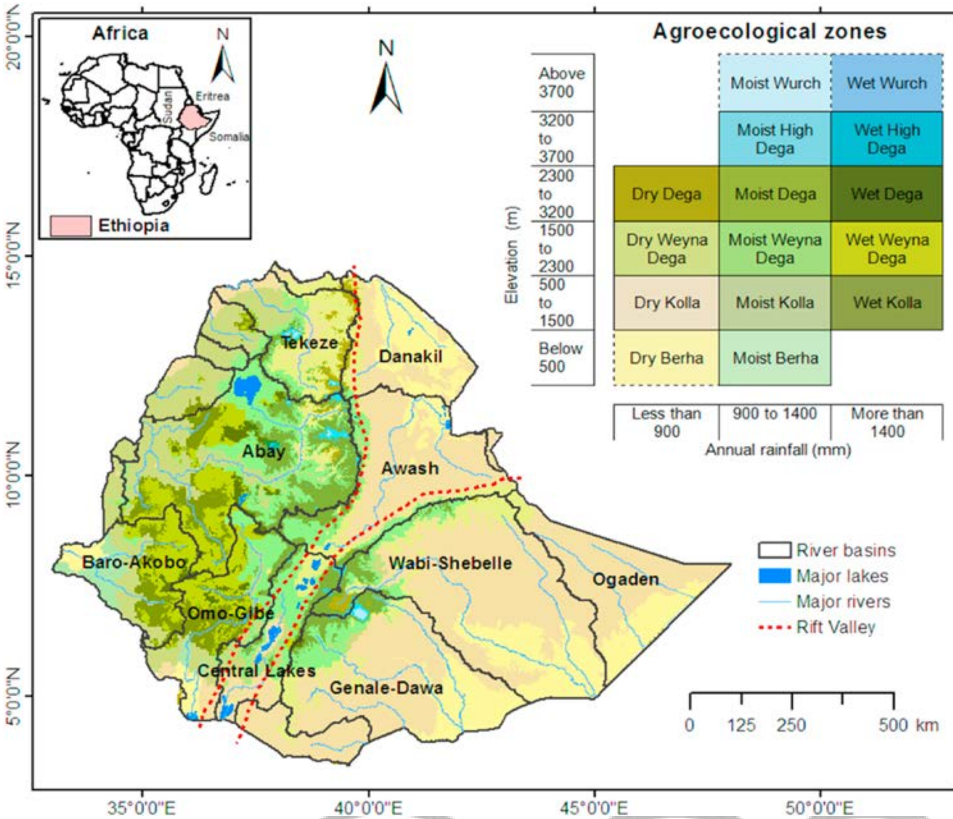

Figure 3 agroecological zones of Ethiopia; the scheme was produced bycombining a scheme in Hurni et al. (1998), elevation data (Shuttle Radar Topographic Mission: http://srtm.csi.cgiar.org/), and long-term data (1981–2016) on mean annual rainfall (Climate Hazard Infrared Precipitation with Stations: https://www.chc.ucsb.edu/data/chirps). Berha ≈ warm, arid lowlands; Kolla ≈ warm, semiarid lowlands, Weyna Dega Dega ≈ cool, humid highlands; Dega ≈ temperate cool sub-humid highlands

Soil types and Geology of Ethiopia

Soil survey in Ethiopia is a recent phenomena. The first soil map of the county, as a part of the soil map of Africa was prepared in 1923 [37]**.** The other major works of the soil mapping (soil and geomorphology of Ethiopia) in Ethiopia was conducted by Land Use Planning and Regulatory Department of Ethiopia with the assistance of UNDP in 1984 which produced a 1: 1 mln soil map [38]. After augur surveying, the site of the soil profile located fixed using the combination of top sequences techniques. Soil pits opened to a depth of 2 m with 1m width and 1m length. Morphological and some physical characteristics of the horizons of soil profiles were described. Soil samples were also taken according to the Guidelines for Soil Description. Soil color was described using soil color charts [39].

Soil erosion is a serious problem in Ethiopia. Particularly in the Northern provinces, which have been settled with sedentary agriculture for millennia, population density has caused major damage to the soil's physical base, to its organic and chemical nutrients, and to the natural vegetation cover. Even on the cool plateaus, where good volcanic soils are found in abundance, crude means of cultivation have exposed the soils to heavy seasonal.

The geology of Ethiopia includes rocks of the Neoproterozoic East African Orogeny, Jurassic marine sediments and Quaternary rift-related volcanism. Events that greatly shaped Ethiopian geology is the assembly and break-up of Gondwana and the present-day rifting of Africa.

Materials and Methods

The available soil erosion models range from simple empirical [40] to complex process-based models.To facilitate soil loss estimation in data-sparse regions and the use of these estimates by local stakeholders, it was vital to select a modeling approach that is flexible in terms of data input, adjustment of erosion factors, and simulation of the potential of different management interventions in reducing soil loss.Several studies used RUSLE model ,which is the modest data demand and low computational cost ,used different parametrs as input.LULC change leads soil erosion in the country even in world wide,the same thing in Ethiopia.So,RUSLE is compatible with remote sensing data like satellite imagery,and GIS tools,and can estimate and/or assess the impact of long years of land use landcover change on soil loss in large spatial domain.

$$A = R \times K \times LS \times C \times P$$

Where A- Annual soil loss

R-Rainfall erosivity

K-soil erodibility

LS-topography generated from DEM-slope lengh & steepness

C- Cover management

P-conservation practices

Most researchers, almost all erosion factor layers were resampled to a 100-m grid size to conform to the land cover data used in the soil erosion modeling erosion used the Spatial Analyst tool in ArcGIS software to compute soil loss rates, to produce soil loss severity classes, to explore the link between soil loss severity and population density, and to extract land-cover-, agroecology-, and basin-specific summary statistic.

Results and Discusion

The central and northern high lands and the mountainous regions along the eastern and western branches of the riftvalley had highly eroded areas: the erosion was attributed mainly to the high R-factor and high LS-factor .Southeast Ethiopia was less susceptible to soil less because of landuse landcover change likely because of the low C &LS –factor .The southwest had the lowest soil loss because of the low C and LS factors.

The results of the reviewed articles indicated that LULCCs for the past decades, as derived from the analysis of satellite imagery, were in accordance with field evidence (e.g., ground truth data and focus group discussion). In fact, most of the authors used techniques such as key informant interviews, focal group discussions, and field data collection to study the socio-economy and to validate the results obtained from Landsat data. The outcomes presented in this review article agree with the analysis performed, who reviewed different studies covering a wider spatial scale.

Conclusion

The reviewed articles addresse, LULC changes with high detail brngs a significant on soil erosion.Infact, all the studied LULC change impact on soil erosion experienced a general trend towards the more intensive lan-duse, the more soil erosion and the more people, the more erosion with implications interms of soil erosion and landuse landuse cover change response. However, there is a lack of (i) detailed investigations of the im-plications of LULCC s on land erosion.(i) studies focused on forecasting future trends of LULCCs .

Therefore, there is the need to tackle both these aspects in detail to develop adequate strategies for landuse management and soil monitoring systems needed for assuring in sustainable Ethiopia for the next decades.

The review of several recent articles on LULCCs in Ethiopia pointed out that the predominant methods to classify LULC are unsupervised and maximum likelihood supervised classification, generally performed via GIS and ERDAS imagine software (Geospatial technology).

A comparison among between articles pointed out that the different driving factors for intensve landuse brought soil erosion in world wide ,as well as in Ethiopia,eg a large number of population brings agricultural land when settle in certain country.By same ,in Ethiopia ,population over growing and challenging.Thus ,in next research appropriate land use management and agriculture is strongly needed and farmer awareness.

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