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Use of Geospatial Technologies to Identify the Impact of Deforestation and its Associate Event (Soil Erosion) in the North-Bilate Watershed, Southern Ethiopia

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The rapid population growth in Southern Ethiopia's North-Bilate watershed, specifically in the Boyo Lake area, has resulted in widespread deforestation and soil erosion, affecting the livelihood of farmers. Thus, the current study aimed at assessing the effects of land cover change on soil

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erosion and agricultural land. For this purpose, 2 lands sat ETM images for the years 2000 and 2020 which have 30*30m resolution were used. The main trajectories of land use change are based on five land use classes which are farmland, built-up area, forest, bare land, water, and open area derived from the remotely sensed images. The analysis showed that Bushland and built-up areas increased with a rate of 1.2 and 2.6 ha/year between 2000 and 2020, respectively. On the contrary, woodland, farmland, and bare land had decreased by 0.2, 0.4, and 3.2 ha/year in the same study period. The NDVI value response of the study period clearly shows the highest value for vegetation cover change, as the maximum value was +0.91 in 2000 and the minimum value was -0.38 in 2020. The dramatic expansion of settlements was due to the runoff of farmland, woodland, and bare land within the allotted period due to rapid population growth and migration from the surrounding rural areas, poor land management, and illegal housing. In summary, signs of deforestation and consequent soil erosion due to population growth, agricultural expansion, forest depletion, and mismanagement are leading to reductions in vegetation cover and agricultural productivity. To minimize soil erosion, physical measures such as terracing and dams should be implemented. In addition, to preserve and increase the biodiversity of the study area, the planting of various types of native vegetation and plantation tree species should be carried out with a viable afforestation and reforestation program.

Keywords: Deforestation; erosion; GIS; LU/LC change; modelling; remote sensing.

1. INTRODUCTION

1.1 Background of the Study

The land use of the land cover of an area reflects the quality of an environment, and changing it has visible effects on forest resources and soil quality. Forests have irreplaceable benefits for mankind, contributing to the economy, environmental protection, climate regulation, ecological function, and the tourism sector. Additionally, forests play an important role in reducing soil erosion to preserve the environment [1,2]. The current bold environmental challenge facing the world is depleting forest resources at a rapid pace due to alarming population growth and irresponsible deforestation. The world's population has boomed over the past 100 years, leading to extensive deforestation for farmland, timber, fuel wood, fodder, energy, housing, and building materials. Sub-Saharan Africa, including Ethiopia, relies on their forests, and they argue that they should be able to use their land. In response, they would not implement forest restoration programs to restore declining forest resources. Ethiopia has a favorable climate, abundant plant species, and other natural resources in Africa, mainly located in the southern and southwestern parts [3].

Deforestation not only affects the climate by increasing the atmospheric level of carbon dioxide but also affects the environment by inhibiting water recycling, triggering severe flooding, aquifer depletion, soil degradation, and the extinction of plant and animal species [4,5]. Animal life thrives mainly on vegetation. By cutting down trees, we deprive animals of their sources of food and destroy animal life. It can lead to the extinction of a variety of animal species. Global warming which is largely caused by deforestation further endangers plant and animal life, thereby disturbing the balance in nature. Animals may also encounter dangerous situations when they attempt to migrate between habitat fragments, such as increased human-wildlife conflicts [6]. With increased habitat edge, wildlife may experience an increased vulnerability to predation, poaching, wind, sunlight, invasion of exotic plant and animal species into remaining forest habitat, and other factors such as natural disasters that were not as much of a threat before the deforestation event [7].

In many areas of the country, excessive population pressure has resulted in steep slopes or flat soils being cultivated, despite the inability of these lands to support sustainable agriculture. Heavy and huge deforestation causes a rapid rate of deforestation. Ethiopia's current rate of deforestation is estimated at 160,000 to 200,000 hectares (ha) per year and fertile topsoil is being lost at an estimated rate of 1 billion cubic meters per year [8], as a result of the country's forest resources being lost from 16% to 2% 7% in 1980-1989 [9], leading to massive environmental degradation and posing a serious threat to sustainable agriculture and forestry. The Bilate Basin, one of the Twelve Basins of Ethiopia, is located in the southwestern highlands and is home to various sub-climates and diversified forest types. The areas largely consist of natural but deforested forests due to their high population density. As a result, in the past four to fifteen years, the forest cover of the Bilate Basin has been switched to other land cover types and the country has been subject to land degradation and productivity loss. Although the government carries out huge afforestation activities on bare land, farmland, and mountainous areas annually, the rate of deforestation still exceeds the rate of planting.

Geospatial technologies have emerged as valuable techniques for assessing LU/LC changes [10], and susceptibility to soil erosion at larger scales due to the amount of data required and larger area coverage [11]. These technologies provided the necessary information about degraded areas, such as B. erosion-prone areas, and vegetation cover from various sources. Therefore, for this study, Landsat imagery and GPS data, as well as GIS and remote sensing techniques, were applied to study land cover change, the rate of deforestation, and the impact of deforestation on soil erosion.

1.2 Statement of the Problem

Ethiopia is one of the sub-Saharan African countries endowed with rich biodiversity, good water resource potential, and natural resources [12]. The rate of destruction of forests in the country is high [13]. Deforestation leading to deforestation is one of the most important factors for soil degradation in the Bilate river basin. The Bilate river basin is one of the most densely populated districts in Ethiopia, which is the Silti, Hadya, Kembata, and Halaba zones district Field observations and experiences in the area show that there has been a high rate of deforestation and the associated impacts (socioeconomic and ecological impacts) have become a threatening problem in the study district, the lack of vegetation cover resulting to faster topsoil erosion, environmental degradation, biodiversity loss and productivity loss of productivity soil erosion and various other degradation processes reduce land productivity and the loss of yield and production by humans. This serious problem requires proper management and conservation.

Accordingly, the SNNPR Regional Office of Agriculture and Rural Development, in collaboration with other stakeholders, has undertaken various soil and water conservation activities and applied various household and community-level packages to cause the problems. However, a significant change has not yet been overcome and the problem persists. The integrated and participatory approach to watershed development is an important tool to ensure sustainable environmental development. However, detailed studies on deforestation and modeled soil loss prediction using RS and GIS at the watershed level are very limited in the study area. In addition, understanding up-to-date information on the extent and rate of deforestation and the impact of soil erosion on productivity and yield losses is essential to designing an effective strategic plan to protect, conserve and utilize forest and soil resources. However, there is no study conducted using geospatial technologies on a similar topic in the study area. Therefore, the main purpose of this study was to assess the extent and rate of deforestation and study its impact on soil erosion in North Bilate (Lake Boyo area) watershed. Remote sensing and GIS technologies, as well as the RUSLE model, are important in providing updated, reliable, and workable land use, land cover, and soil information for environmental and resource management and administrative actors and decision-makers.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The Bilate basin is one of the 12 basins in Ethiopia. Boyo lake area is found in Northern Bilate which is the largest of the 6 watersheds of the Bilate basin. It is located north of lake Abajata (the second largest lake in Ethiopia); touches a part of Silti, Hadya, Kembata, and Halaba zones, SNNPR, southern Ethiopia from 6°34'30"N -- 8°05'45"N latitude and 37°47'50" -- 38°20'25"E longitude. The selected watershed occupies an area of 5625 km-2, and it is a highland area its elevation ranges from 1199 to 3285 m above sea level.

The digital soil map of the watershed collected from FAO indicated that Haplic alisols are the dominant soil type in the watershed, covering an area of 90.67 km2 (43.76%). The study watershed received mean annual rainfall and temperature ranging from 910mm to 1800mm and from 17.6°c to 25°c respectively [14]. The study area experiences a highland tropical climate. ecology/climate zone due to its topography and closeness to the equator.

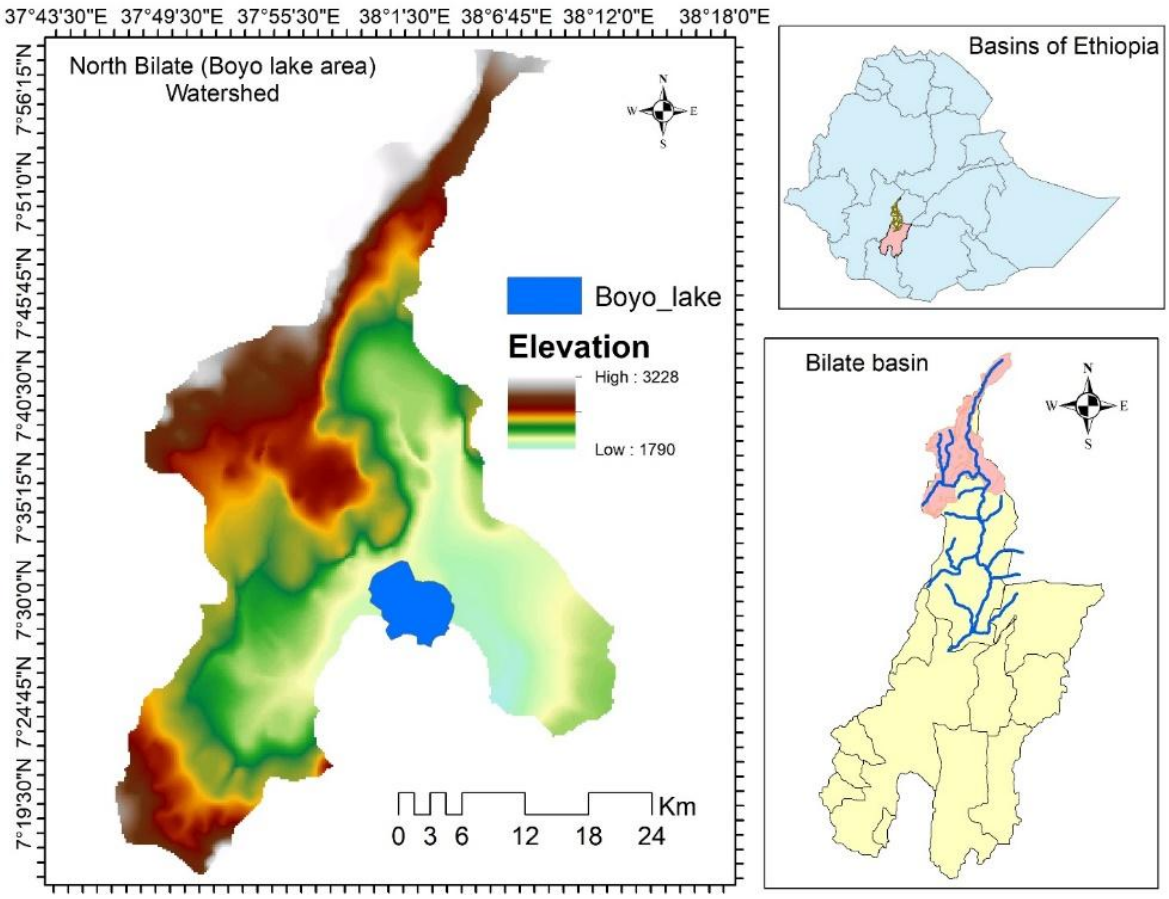

Fig. 1. Map of the Study Area

The study area is largely covered by exotic plants such as Eculapthus, which are protected by a reforestation program. Currently, LULC in the watershed is dominated by cropland (58.09%) (Table 1; Fig. 1), and people used traditional farming techniques. Subsistence farming in the form of mixed cultures and animal husbandry is the main source of income for almost 90% of the households in the study area. And its population density was high, at 158 [15]. As a result, the annual production cannot meet the needs of household consumption.

2.2 Materials of the Study

The main concern of this study was the data needed to be used to study the effects of deforestation on soil erosion. Different types of data are available from different sources depending on access, quality, and cost of the data. Land Sat ETM+ from 2000 and 2020, which have 30m resolution from USGS, were used for land use land cover classification to analyze LULC change and understand the quality of the natural environment over the study period. ERDAS IMAGIN 10.5 was applied for band combining, atmospheric correction, and classification of the Landsat images. Arc GIS 10.8 was used for accuracy assessment, comparison matrix, land use analysis, land cover change, generation, and mapping of the final output. The non-spatial (socio-economic) data on causes of deforestation, forest management activities, and the impact of deforestation on soil erosion were obtained from primary and secondary data sources. To collect reliable and appropriate data, researchers used questionnaires, semi-structured interviews, and field observations. They prepared both closed and open-ended questionnaires and semi-structured interviews to obtain the necessary data from HH, experts, and DA staff. SPSS 20 was used to analyze and interpret non-spatial data.

2.3 Methods of Data Analysis

2.3.1 Image pre processing

Landsat imagery from (ETM+ from 2000 and 2020) of the same season with a resolution of 30 m was used for the calculation of the extent and rate of deforestation, for the LU/LC change comparison, and for the NDVI calculation. While the USGS images are geometrically corrected; radiometric and atmospheric corrections were processed to reduce data uncertainty due to radiometric and atmospheric disturbances. In addition to the true color band RGB (3 2 1), the images were enhanced with different false color composites with band combinations for better visualization and interpretation during classification. Finally, each year's images were cropped by the extent of the watershed and each band of images was stacked using the stacking tool in ERDAS 10.5. USGS ASTER DEM with a resolution of 30 m was used to analyze the topographical features of the study area such as elevation and dip. The Google Earth imagery of the study area was imported from Google Earth Pro software in KML format into Elshayal Smart GIS software for correction and then converted to Arc GIS software.

2.3.2 Image classification and accuracy assessment

Arc GIS 10.8, Elshyal Smart GIS, and ERDAS Imagine 10.5 software were used for all image processing procedures. Image classification refers to the task of extracting information about classes from a multiband raster image. For this study, approximately 461 training sample points for each land cover type, typically representative of land cover classes, were collected in the primary phase. Next, the images were classified into seven dominance classes (arable land, built-up land, bare land, woodland, forest grassland, and water) using a supervised maximum likelihood classification tool based on visual interpretation and field observation until the correct classification was performed.

After classification, an accuracy assessment was required to validate the classification results. To perform an accuracy assessment analysis, randomly selected points should be used as references for the land cover maps of the three survey periods; accordingly approximately 100 points from each survey year were selected for this study. To validate the result of the classification with known ground truth, the accuracy assessment of the signature values of classified images for calculating the error matrix in ERDAS Imagine was checked. To assess the accuracy of the classification, a confusion matrix, sometimes referred to as the error matrix, was created. This is a table with columns and rows representing the reference (observed) classes and the classified (mapped) classes, [16]. For this study, the most common (user accuracy) error matrices were calculated to assess classification accuracy.

2.3.3 Land use/land covers change detection

After the 2000 and 2020 LU/LC maps were produced, the rate of LU/LC change was calculated and plotted. The rate of change from 2000 to 2020 and the change conversion matrix were calculated and analyzed to know the area coverage and to get information about the conversation trend and the LULC dynamics from which the class drives concerning time, [17].

2.3.4 NDVI computation for vegetation change detection

NDVI is used as a tool to define vegetation, and for its value ranges between 1 and -1, very low NDVI values (0.1 and below) correspond to barren areas with rocks, sand, or snow, medium values represent scrub and grassland (0.2 to 0.3), while high values indicate dense temperate and tropical rainforests (0.6 to 0.8), [18]. The negative threshold indicates a loss of NDVI and a positive threshold indicates an area of increased NDVI. Although NDVI image differencing cannot provide very detailed change information, it can provide information about an increase or decrease in the NDVI value. The negative NDVI values indicate less or no vegetation cover, while the positive values indicate healthier vegetation (forests, shrubs, and bushes). The greater the amount of photosynthesizing vegetation present, the higher the NDVI value [7]. In this study, the NDVI was used to provide an overview of the location and presence of vegetation biomass over the area for the three periods. It was also used for visual comparison and to aid in classification.

2.3.5 Sample size and sampling techniques

For this study, samples were selected from all households in the study area using simple random sampling. The watershed of the Boyo study area is divided into four districts according to political administration. Namely; Silti, Hadiya, Kembata and Halaba Zones. This sampling technique was used to give equal opportunities and obtain adequate information from respondents based on the district's homogeneity in terms of people's economic engagement.

Sample households were selected from these zones by applying systematic random sampling techniques to select informants to distribute questionnaires and conduct interviews. The interview with key informants was prepared to analyze, assess and assess the factor that determines the physical environmental conditions of the study area as mentioned. All have been purposefully selected from different positions and fields who have gained experience or knowledge in Agriculture and Rural Development, Natural Resource Management, and Environmental Protection sectors. The total sample size was 98 respondents. Therefore, 80 sample households were selected proportionally from the woredas of each zone, and the investigator used the simplified formula (Israel, 1992) to calculate the sample household size. The sample size was determined using a formula (Yamane Leuelsegeds, 2006).

Accordingly, 6 people from agriculture and rural development, 5 officials from natural resource management, 4 environmental protection agencies, and 3 land resource experts were selected. To generate relevant information collected from the selected sample households, there could be a 5.5% of marginal error and a 95% of confidence level. The data collected will be interpreted using both descriptive statistics to calculate frequency and percentage, and qualitative methods with narrative description.

2.3.6 Integrated methodology

Generally, the total research activities concerning the stated objectives are stated below.

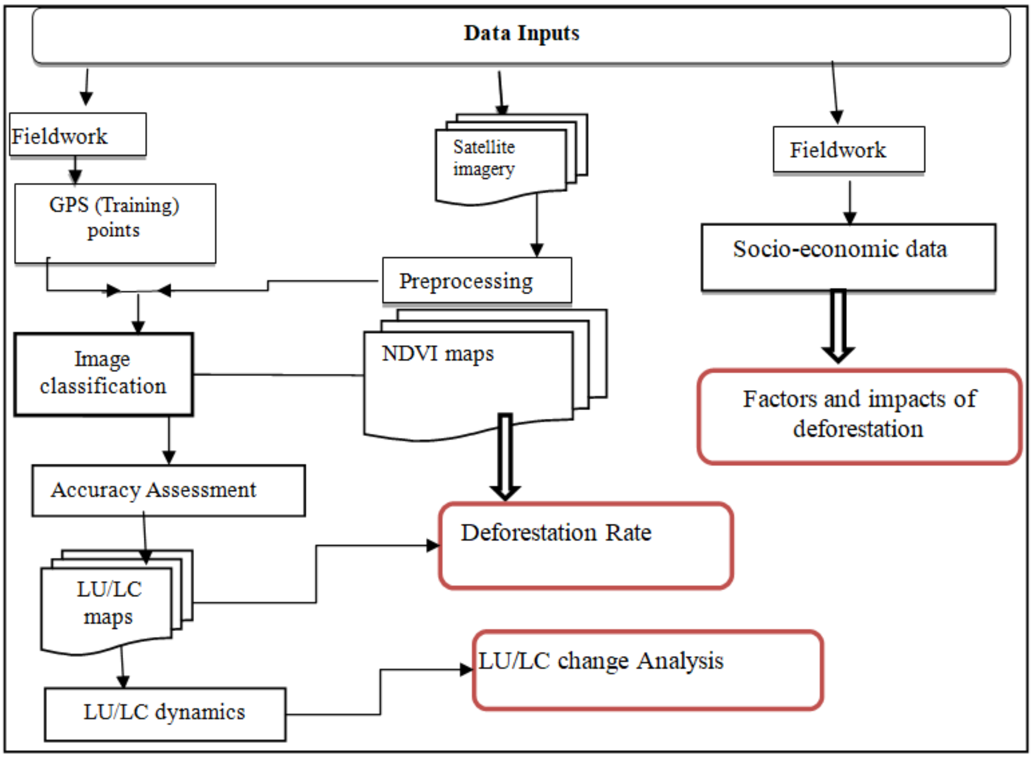

Fig. 2. Method of data analysis and study design

3. RESULTS AND DISCUSSION

3.1 Land Use /Land Cover Classification for 2000 and 2020

The land use classes and their areas derived from the classification of 2000 and 2020 Sat images are given in the following (Table 1). The area statistics of the LULCs could better be quantified if interpreted with visual support than numerical. Visual image interpretation and frequent field observation have been done to classify correctly and to distinguish the dominant land use types of the study area. Accordingly, a Land use/land cover unit was categorized into seven classes; bare land, farmland, built-up, woodland, forest land, wetland, and water.

The land use land cover classification for the 2000 TM satellite image was used. According to the classification, the highest proportion of land cover of the study area was farmland with 3719 km^2 (66.6%), followed by woodland with 619.83km2 (11%), and the lowest proportion was grassland with 5.6 km2 (0.1%) its majority located around Boyo and Abaya natural lakes (Table 1).

In 2020 from the land use/land cover units 4466 (79.4%) of the total area is covered with farmland, and residential area accounts for about 346km2 (7.37%). The LULC in the year 2010 shows that the maximum and minimum aerial coverage for farmland and water class was 3719 km2 (66.56%) and 6.5 km^2 (1.11%), respectively (Table 1). The results of land use land cover from the classified Land sat image of the area under farmland and Bushland and woodland patterns increased in 2020 from 2000 (Table 1).

3.2 Rate of LU/LC Change Detection between 2000 to 2020

The result of sat imageries classification showed undergoing huge LU/LC change in the study area. Rapid population growth and related socio-economic developments aggravated the change in the last couple of decades which speeded up environmental degradation and swayed negatively on the forest resources and the soil. The result is similar to [19]. Land use and cover dynamics since 1964 in the afro-alpine vegetation belt: Lib Amba Mountain in north Ethiopia. Land Degradation & Development. The population has been clearing the forest resources for various purposes, bringing deforestation and exposing the soil to erosion which finally results in a reduction of soil productivity and yield production loss.

As a result, the rate of decrease was greater for forest and water, while the reaming land uses showed a general trend of increase in the study period. This implies that with the expansion of farmland and settlement, there is high exploitation of land and reforestation activities. This is just the general impression of land cover based on a comparison of the land cover change map.

Table 1. Summary Statistics of Land Use and Land Cover in the Study Period

ID	Land Use	LU/LC area			
		2000		2020	
		In km^2	In Percent	In km2	In Percent
1	Built up	132.46	2.3	346.4	6.2
2	Forest land	366.41	6.5	183.75	3.3
3	Woodland	619.83	11	973.86	17.3
4	Bare Land	14.4	0.25	267.15	4.7
5	Farmland	3718.93	66.56	4466.19	79.4
6	Grassland	5.6	0.1	128.98	2.3
7	Water	18.9	0.34	6.49	0.11
	Total	**5623.29**	**100**	**5625.56**	**100**

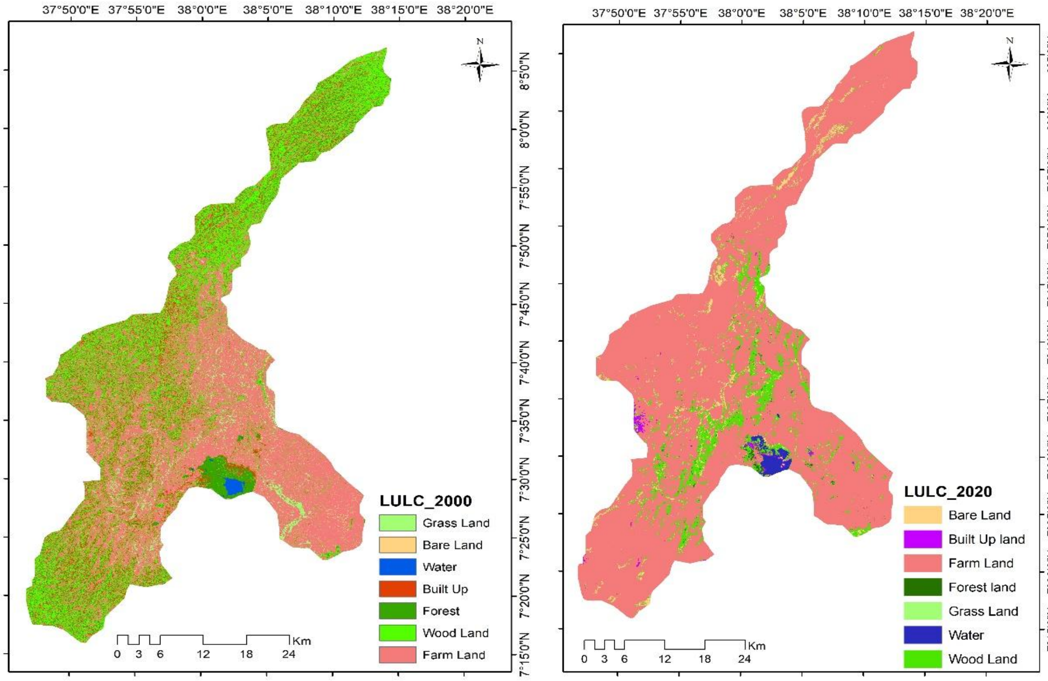

Fig. 3. Land use land cover map of North Bilate Watershed. (a) map of 2000 (b) 2020

Between 2000 and 2020, residential and farmland increased with a rate of 10.6 sq. km/year (61%) and 37 sq. km/year (16.7%), whereas forest and water class reduced with a rate of 9.1 sq. km/year (49.8%) and 0.6 sq. km/year (65.6%), respectively. (Table 1) shows that between 2000 and 2020, 6.1 sq. km/year (95%), 12.6 sq. km/year (94%), and 17.7 sq. km/year (36%) of grassland, bare, and woodland had been raised, respectively (Table 2).

The expansion of woodland, bare land, and grassland was by the outflow of forestland as is explained in the change matrix of (Table 2). This shows that there was a dramatic expansion of agricultural land and settlement within the specified period because of population pressure and poor land administration. The expansion of residential and farmland between 2000 and 2020 in the study area in general, could be directly related to rapid population growth and the clearing of trees for domestic uses (deforestation).

The severe and huge forest clearing causes soil erosion due to the rapid rate of deforestation (Birhanu., 2014). The ever-increasing demand for agricultural land and grazing land aggravates the problem of soil erosion which causes deterioration of the physical, chemical, and biological properties of soil.

3.3 Changes Detected by NDVI Differencing

The NDVI score was obtained between +0.91 and +0.64 as shown, and then statistics were calculated for each of the NDVI images (Table 3). The NDVI value response of the different cover types for the 2000 and 2020 images clearly show the highest value for vegetation cover change at +0.41 and +0.40 and the second lowest value for forest cover at -0.37 and - 0.38 for the two years, respectively. The spatial distribution of the NDVI values for the different land cover classes shows different patterns due to the continuous change of natural forest, shrubland, and woodland. The mean NDVI of the study area decreased from 0.28 in 2000 to 0.20 in 2020.

In terms of vegetation cover, a visual interpretation can be made and evaluated. Thus, the vegetation of the years 2000 and 2020 can be compared. This refers to shrubland or grassland at very high altitudes of more than 2000 m above sea level, common in all years, in the mid-northeast direction. Shrub tree vegetation is greater than that of forests in 2000, while forest area is decreasing. The opposite is true for 2000, where tree planting in the eastern part covered much of the watershed. However, in the central part of the watershed in 2000, vegetation can be seen very well and is also distributed in the central part showing disturbed vegetation in 2020. In addition, it is known that plantations, particularly eucalyptus, were well established south of the watershed in 2020, while natural trees were depleted due to the emerging development and conversion of scrubland to settlement and cropland from 2000 onwards.

Table 2. Area change in hectare and percentage of land classes

ID	LU/LC	2000 – 2020		
		Area change in km2	**Area change in %**	**Area change in km2/year**
1	Residential	213.94	61.76	10.6
2	Farmland	780.26	20	39
3	Woodland	354.03	36.35	17.7
4	Forest	-182.66	-49.85	-9.1
5	Grassland	123.38	95.65	6.1
6	Bare Land	252.75	94.61	12.6
7	Water	-12.41	-65.66	-0.6

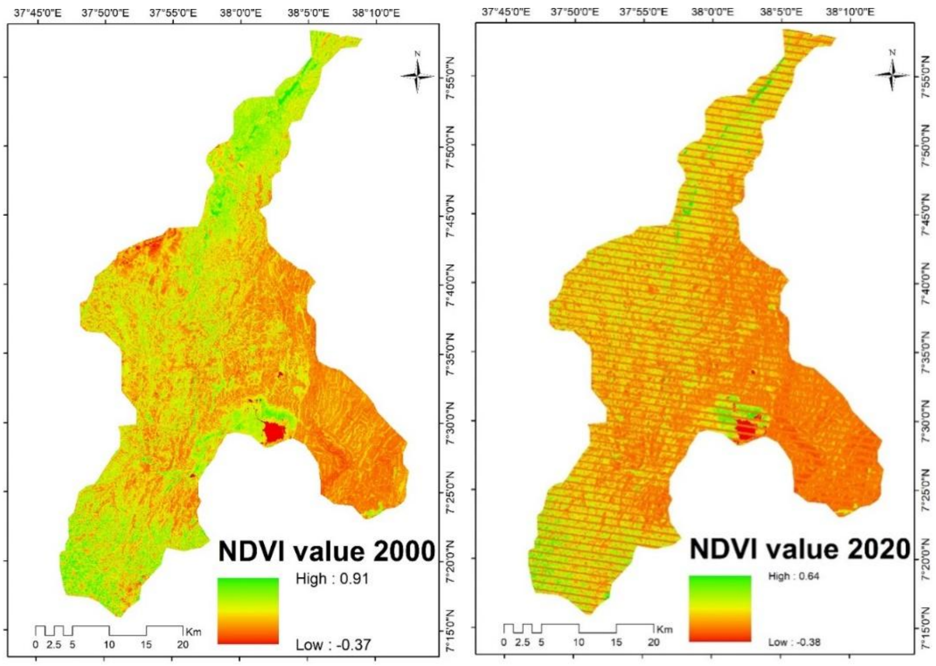

Fig. 4. The NDVI values vegetation cover maps of North Bilate watershed (a) map of 2000 (b) map of 2020

Table 3. Statistical data of the NDVI values vegetation covers in the North Bilate watershed

NDVI value	Year	
	2000	**2020**
Max.	0.91	0.64
Min.	-0.37	-0.38
Mean	0.28	0.20

NDVI values declined from the initial study period to (2020) (Fig. 4; Table 3). The depreciation rate from 2000 to 2010 was lower than in the study period from 2010 to 2019. The reason was the new expansion of settlement areas. In all nearby areas in the watershed, local governments gave land to the newly created households for settlement and arable land. After 2002, the government began distributing settlement and agricultural land to local youth. This also converted the forested area and scrubland into settlements and farmland with low NDVI values. This also implied that forest and scrubland are less susceptible to land degradation than settlement and cropland.

3.4 Deforestation and Soil Erosion

3.4.1 Factors of deforestation

The socio-economic data from the sample households, natural resource experts, and DA employees collected by questionnaire and interview on deforestation and its effects on soil erosion were analyzed and interpreted using statistical methods. The population growth of the study area had increased at an alarming rate as the district's population density was among the highest in the country. The people interviewed also showed that the population of the district has increased significantly. As a result, this reality causes forest clearing and deforestation of the population of the district to meet their needs e.g., for food, housing, settlement, for firewood, for timber and timber, and other forest requirements.

For example, an employee interviewed with a DA worker from the city of Hossana told us that about 90 donkey carts of cleared Ekualapthes trees arrive at a market each week from the surrounding forest areas, Most respondents (90%) also agreed with the DA -Employees to imagine that wood production for housing and construction is huge in the study area.

Due to the illegal land expansion for urban settlements in most of the urban centers of the study area, many forest areas were demolished during the study period (Fig. 4). The rural settlement also devastated many mountainous forested areas in the study area and surrounding mountains. Respondents in the sample agreed with the land resource experts' statement that settlement expansion, timber production, and charcoal production were the main causes of deforestation in the study area.

3.4.2 Major effects of deforestation on soil erosion

Deforestation can have various impacts on the environment, ecological function, and human livelihoods. The main direct impacts of deforestation are the lack of trees for housing, construction, timber production, and firewood. Some of the effects of deforestation indirectly lead to fluctuations in rainfall, flooding, water table reduction, runoff acceleration, soil erosion, and yield reduction. Based on the interviewed samples and experts and DA staff, some of the main impacts of deforestation in the study area are mentioned and described below. 78.75% of respondents answered that deforestation has exacerbated the natural process of soil erosion. The exploitation of the forest and forested areas by informal settlements and the expansion of farmland have serious ecological and biological disturbances. The majority of respondents also agreed on the destruction of forest resources, which is an indicator of deforestation in the district.

The change in vegetation cover of the study area has visible effects on water resources and the local climate of the watershed. This reduction in vegetation cover trend could reduce the rate of intrusion and seepage of stormwater into the soil and subsoil. Accordingly, the majority of respondents agreed that the destruction of forest resources for many purposes has led to a decline in surface and groundwater potential from time to time. Much of the water resources of the downstream Bilate Basin were received from this watershed. In addition, the current frequency and current density of this watershed of the study are higher due to its elevation and inclination. The interviewed experts also reiterated that the Bilate River (the largest river in the Bilate Basin) with its tributaries originates from this watershed. Half of the respondents and experts surveyed also agreed that precipitation was declining and showed a high degree of variability over the study period. Drying of wetlands, shortening of the growing season, cultivation of short-ripening crops, decrease in river volume; Decreasing surface and groundwater potential are the main indicators for the decreasing precipitation of the study area with simultaneous deforestation and erosion.

The sloppy nature of the topography and the relatively higher but decreasing amounts of precipitation accelerate the flow of water in streams, causing destructive runoff and flooding that absorbs and removes the fertile soil of the study area, respectively. Like deforestation, soil erosion brings with it various related problems that affect the quality of the environment and the socio-economic aspect of people, such as: As a result, the growing season of plants has been significantly reduced from seven to four months over the past 20 years. Consequently, soil erosion has been a precarious challenge of the study watershed, which overcomes various environmental, ecological, and socioeconomic problems. This indicates that the impacts of deforestation are complicated and widespread.

3.4.3 Effects of soil erosion

The study area was characterized by sloppy topography, higher and variable rainfall levels, high population density and pressure, and maximum clearing of forest resources, which are highly exposed to erosion and soil degradation. According to the majority of respondents, major deforestation, intense rainfall and very heavy runoff, and the steepness of the topography together were the main factors driving erosion in the watershed. The erosion process has also been aggravated by over-exploitation and improper use of land for settlements and construction. It was understood that the presence of soil erosion was perceived through various indicators and the physical situation of the soil was visualized. Based on the interviewed respondents, the main indicator of soil erosion in the study area was decreasing productivity, which accounts for 76.25%. Indeed, in the field area, the researchers observed exposed plant roots, increasing rockiness and changing soil color, indicating moderate soil erosion.

Soil particles are removed and transported and sediments are accumulated in the lower reaches of the Bilate watershed such as the Boyo and Abayata lakes. This condition is very serious in areas without vegetation cover and where rainwater moves rapidly downhill. Larger particles and rocks remain. Frequent flooding was a common watershed problem due to soil erosion (Fig. 4). As the interviewed experts clarified, flood vulnerability and vulnerability was identified as major concern of the district's local governments. Some previous studies conducted in the study area confirmed the seriousness of the flooding problem. The last but not the least serious problem was the loss of crops caused by sediment deposition on agricultural land. This condition destroys the crops and eventually the reservoirs. All of these are effects of soil erosion and the low mechanism of conservation measures in the study area.

3.4.4 Soil conservation practices in the watershed

Soil erosion is a serious problem on their farmland, causing erosion of the upper, more fertile soil and reducing the yields of their production. Many of those interviewed pointed out that erosion is a major challenge in agricultural crop production that follows low yield per hectare. Therefore, farmers believe that this problem can be mitigated by adopting effective conservation mechanisms to maintain their cropland's productivity and increase yield. According to the surveyed data and eyewitnesses of researchers in the field area, various conservation methods were used in the study area. Stone and earth walls, slope tracks, dams, contour plowing, and biological protection measures are the usual and dominant measures.

It is very important to construct the appropriate structures within and around the farmland, such as B. Earth and stone walls to protect the soil from being cleared by runoff, which is the main cause of erosion in sloppy areas. Biological conservation methods around the farmland have advantages in environmental balance, aesthetic value, and protection against land degradation. However, such measures were carried out at a very low level. Trees were planted in some areas but were sparsely distributed. 28.75%, 28%, and 18.75% of respondents also demonstrated that they used afforestation, contour plugging, and tracing for soil protection. This indicates that the majority of the population in the study area uses physical and biological soil conservation mechanisms.

3.4.5 Extension services

The application of agricultural practices requires adequate, relevant, and timely information to encourage the widespread adoption of new technologies to combat deforestation and soil erosion. Acceptance and sustainability of the technologies depended on the information farmers received from them. In the study area, information was disseminated by DA employees of the advisory service. The advisory service was offered to a group of farmers who have adjacent locations of their farmland in groups and on an individual basis. Technical and practical advice on afforestation, soil conservation practices, and productivity maintenance require technical skills and experience from DA staff and FTC. However, according to the majority of respondents, only a few farmers received the information. As with the DA staff interviewed, the farmer advisory service was occasionally offered outside of the regular program.

4. CONCLUSION AND FORWARDS

4.1 Conclusion

The rapid increase in population in the study area has led to extensive forest clearing for agricultural use, settlement, firewood, fodder, and building materials. As populations change at alarming rates, so do people's types of activities and consumption. This study aimed to analyze the impact of deforestation on soil erosion and soil loss prediction in the North-Bilate watershed. This study assesses deforestation and its impact on soil erosion. Land use Land cover change and NDVI assessments provide a good starting point for assessing deforestation. The results show that there have been significant changes in LULC and vegetation cover in the study area. LULC changes are part of the humanities quest to meet basic needs essential to human survival. Agricultural areas were predominantly enlarged, while forest and forest areas decreased in size during the study period. The study uncovered tremendous deforestation and soil erosion due to population growth, agricultural expansion, forest depletion, and mismanagement.

4.2 Forwards

Research into land degradation at higher altitudes in southern Ethiopia plays an important role in better management and use of land resources. Population growth is identified as a problem in the study area. The expansion of settlements and the increasing consumption of fuel wood led to land degradation in the watershed. To prevent population pressure and its impact on forest resources, thereby improving the living conditions of residents, campaigns to raise awareness of family planning with adequate health services should be introduced.

To solve the problem, the planting of various types of native vegetation and plantation tree species should be carried out with a workable program of afforestation and reforestation. Policies and measures promulgated should be implemented to use forest resources wisely. To protect the forest resources from further destruction, to recognize the effects of deforestation, and to use this valuable resource sustainably, awareness campaigns should be developed among the farmers living on the edge and in the forest areas, different ways will be used to reduce the occurrence of deforestation and the serious impact on soil erosion. It is known that everyone is responsible and must make their contribution to this dangerous and extravagant process.

COMPETING INTERESTS

We know no more conflicts of interest associated with this publication, and there has been no significant financial support for this work that could have influenced its outcome. As the corresponding author, we confirm that the manuscript has been read and approved for submission by the author/all of the named authors.

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