RESEARCH ARTICLE

Soil erosion impacts on crop productivity and its implications on food security in Kechabira district, Southern Ethiopia

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Soil erosion is one of the unresolved problems of rural agriculture in many less developed countries like Ethiopia. Soil degradation in the form of soil erosion and decline in soil fertility is the main problem of the research area, which has influenced the environmental quality and productivity of land. The topsoil conducive to crop productivity is gradually detached by soil erosion that directly impacts soil productivity and results in the issue of food security. Hence, this study investigated the soil erosion problem and its impacts on land productivity and food security implications. The household survey, in combination with field-based geospatial techniques, was applied to assess and analyze the research data. It was surveyed that soil erosion is an acknowledged problem of agricultural activities among the farmers of the study area. The soil of the study area was moderately acidic, with a low category of OM and organic carbon content, a low proportion of available phosphorus, and a very low to low range of total nitrogen. Results of morphometric analysis revealed that the topographic nature of the surface, slope gradient of the area, drainage feature of rivers, and land use/land cover conditions of soil surface were naturally facilitating factors of soil erosion. Most household respondents also confirmed that over-cultivation, cultivation of steep slopes, deforestation, over-grazing, unreliable soil management practices, and poor agricultural techniques are the leading anthropogenic factors for soil erosion in the farm field. About 91% of the interviewed households have observed a decline in land productivity in their farm field. The crop productivity per hectare for selected dominantly produced crops was found to be decreased over five consecutive cropping years between 2013-2017. Hence, most of the surveyed households were food insecure due to the loss of agricultural productivity by soil erosion. From the result, it was concluded that the impacts of soil erosion on the productivity of land was known to be paramount, and the same was confirmed with the basic properties of soil analyzed in the soil laboratory. The crop productivity in the study area declined, so most farmers were impacted by food security problems. It was recommended that combating the severity of the soil degradation problem by applying various soil management practices should be critically considered. Finally, the researchers forwarded that more studies on the issue of climate change impacts on agricultural productivity would be considered for further assessment of the environmental problems in the study area.

Key Words: Soil erosion; Crop productivity; Food security; Agriculture

INTRODUCTION

Land degradation is currently one of the serious global problems because of its adverse impact on agricultural productivity, food security, and environmental sustainability. Due to land degradation in the form of soil erosion in most developing countries, agricultural productivity declined beyond the subsistence requirement of a household [1]. Soil erosion is a critical global land degradation phenomenon affecting human beings since human's primary sources of livelihood are from the land [2]. Degraded soil is unproductive, which is also determined by the degree of severity of land damage. Soil erosion affects 25-30 percent of India's total cultivated land. In Africa, over 70% of the nation's land surface has been impacted by varying levels and types of soil erosion [3]. On a global scale, the Food and Agriculture Organization (FAO) estimates that the loss of productive land through soil erosion globally is about 5-7 million ha/year.

Soil erosion can cause the gradual detachments of particles of topsoil, which are transported by agents of denudation, such as water and wind, and subsequently deposited in low basin areas. According to Thesis and Aberha, soil erosion's implication extends beyond removing valuable soil nutrients from topsoil [4]. Crop emergence, growth, and yield are directly affected by the loss of natural nutrients, which results in food security. Hence, soil erosion problems have received much attention from different scholars and scientists in environmental concern.

The future world population requires increased food production because the rapidly growing world population needs increased agricultural production to feed the population [5]. On the other hand, land resources have been under alarming rate of degradation due to human abusive actions, causing the reduction of land resource productivity to grow substantial foods for an additionally growing world population [6]. If the growth of the population goes beyond the carrying capacity of the environment, the needs of the human population cannot be fulfilled from natural resources. Hence, the damage to soil resources through soil erosion and other forms of soil degradation can damage agricultural production and ultimately cause food insecurity.

The most pressing environmental problem in the least developed countries is soil erosion, prevalent in rural areas where many populations live and whose livelihood depends on agriculture and related activities. Large areas of sub-Saharan African countries, in particular, are highly affected by various types of land degradation, which directly cause the decline in soil fertility [7]. Inappropriate land resource conservation practices in areas with high population density and fragile ecosystems further increase the loss of productivity of land resources. These, in turn, affect food security and livelihood. The productivity of land in Africa has declined by 50% due to soil erosion and desertification. Yield reduction in Africa due to past soil erosion may range from 2% to 40%, with a mean loss of 8.2% for the continent [8].

Since Ethiopia is a less developed country, the economy and livelihood for the majority of the population are generated from land resources such as land, water, and forest resources. Declining land productivity, natural resource degradation, high population growth, and food insecurity are crucial challenges facing Ethiopia today [9]. There is a direct link between the most basic needs of human beings and natural resources in Ethiopia. On the other hand, agriculture is predominantly a crucial economic sector in Ethiopia, which supports about 85% of the rural population. Agriculture

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provides about 52% of the country's gross domestic product, 80% of its employment, and 90% of its export earnings. The type of agricultural economy in the country is characterized by subsistence in nature, and crop and livestock farming are principal practices in the sector. Such a subsistence agrarian economy results in excessive soil erosion and land degradation [10].

Soil degradation is Ethiopia's most immediate environmental problem, with exceptionally high land areas. Soil erosion in Ethiopia can also be seen as a direct result of past agricultural practices, mainly in the country's highland areas. Over 80% of the human population and 90% of total farm production are located in highlands in Ethiopia [11]. The high-land areas have been experiencing severe land degradation problems emanating from the demands of the growing human and livestock populations. The decline in agricultural productivity on high land has primarily been associated with high population density, deforestation, and intensive cultivation of steep slopes without effective conservation measures. According to research findings in Ethiopia, land resources are under intense challenge due to the rapidly growing population and inappropriate farming practices. Soil erosion is most significant in cultivated land, where the average loss is 42 tons/ha, compared with five tons/ha from pastures. As a result, nearly half of the soil loss comes from land under cultivation, so the country's decline in agricultural productivity is directly linked to the loss of topsoil and the deterioration of its fertility [12].

Similarly, population pressure, over-cultivation, overgrazing, deforestation, and other related problems are the main factors for soil erosion in southern Ethiopia. Soil erosion is a severe problem in the central zones of southern Ethiopia, such as Kambata Tambaro, Hadiya, Wolaita, and Alaba, including the study district with its sloppy nature and excessive cultivation of the land due to the high pressure of the population of the area. There is an urgent need to identify the severe problem of soil erosion, which directly results in land degradation, loss of land productivity, and food insecurity. So, understanding the current status and causes of soil erosion and its effects will be essential to bring environmentally sustainable development. The watersheds and river catchments of the district were highly degraded due to excessive tillage by their high population and mismanagement of land resources, which resulted in soil erosion and soil fertility decline in the study area. Therefore, this study focuses on assessing the impacts of accelerated soil erosion on crop productivity, which results in food insecurity in the Kechabira district in the Kambata Tambaro zone, southern Ethiopia.

MATERIALS AND METHODS

Location of study area

Kachabira district is located in the Kambata Tambaro zone, SNNPR, Ethiopia. The Doyogana district borders it to the north, the Boloso Sore district to the south, the Kadida Gamela district to the east, and the Hadero Tunto Zuria district to the west. Geographically, the study area is located between 7°10'00"N-7°20'00"N and longitudinally it is located 37° 39'30"E-37°51'30"E (Figure 1).

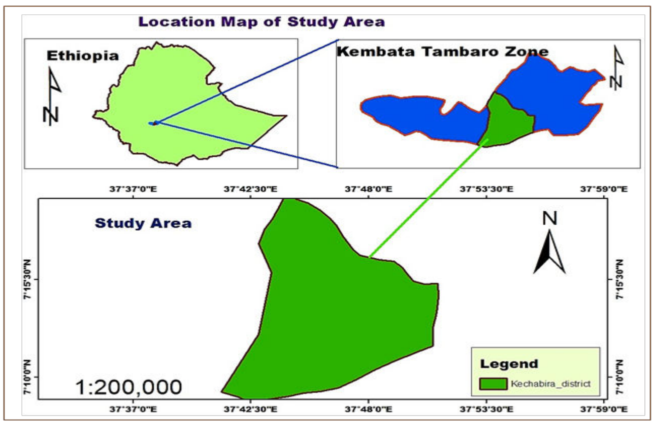

Figure 1) *Map of the study area*

Sources of data: The study has used two data sources for collecting research data. These were primary and secondary data sources. The preliminary data were collected from farmers, agricultural experts, kebele leaders, soil and water conservation supervisors, and DAs'. The secondary data sources used for the study include published materials such as research articles, books, and data files from the internet or web pages and unpublished documents such as official records, census records, project reports, and other official data. For geospatial and image analysis, topographic maps, SRTM digital elevation data, FAO/USDA soil map of the world, and land use land cover data of FAO map catalog are secondary data sources.

Data gathering instrument: Detailed information on household demographic characteristics, soil erosion impacts, land characteristics, agricultural productivity, food security status, and other related information was collected using questionnaires, focus group discussions, and interviews. Moreover, personal observations and informal interviews were also done through transacting walk. Finally, the researchers used soil sample experiments to identify soil productivity from selected sample areas for laboratory analysis of essential macronutrients and micronutrients.

The sample size and sampling procedures: The study considered the law of probability for the sampling study site and sample population. Therefore, two-stage sampling designs were used to determine sample villages and household heads. The sample kebeles from the study area were selected in the first stage. Kechabira district contains 16 Kebeles. From the total 16 kebeles of the district, two Kebeles, namely Mino and Zogoba, were selected randomly for household survey and soil sample collection. The second stage involves the preparation of a list of household heads from each selected Kebeles. Hence, the size of household heads in sampled Kebeles (Mino and Zogoba) was 2121 household heads. Out of total household heads, 121 sample household heads were selected using systematic random sampling techniques.

Soil sampling and laboratory analysis

The soil sample for analyzing soil nutrients in the district was collected from sample soil fields by considering simple random patterns across uniform areas. The soil sample sites were selected using Global Positioning Systems (GPS). A total of six soil samples were collected randomly from two kebeles chosen from 0-20 cm depth. About 5 to 10 sub-samples from each field were taken to form one kg composite sample. The sample was collected using tools like corer of 50 mm steel tubing and a stainless-steel soil sampling probe. The soil probe provides a continuous soil core with minimal disturbance to the soil that can be readily divided into various sampling depths. Other tools include plastic sample buckets, shovels or spades, sample bags, and markers for identifying samples on sample bags.

After soil processing (drying, grinding, and sieving), soil physicochemical properties such as texture, pH, soil Organic Carbon (OC), bulk density, and soil macronutrients such as Nitrogen (N), Phosphorus (P), Potassium (K) and Sulphur (S) were tested and analyzed to identify the nutrient status of the soil. Determination of particle size distribution was made by the Hydrometer (Bouyoucos) method as described by Robert Okalebo, et al.[13]. The bulk density of soil was determined by the core method. Soil pH was determined using a pH meter with a combined glass electrode at a 1:2.5 (Soil:Water) ratio. The Walkley and Black method (1934) determined organic carbon, as cited in, and organic matter was multiplied by 1.724 value with organic carbon percentage [14]. The soil's total N content was determined using the Kjeldahl procedure, and available P was determined using the Olsen method [15].

Methods of analysis

The data were analyzed both qualitatively and quantitatively. The household survey data were coded and entered into the Statistical Package for Social Scientists (SPSS). Then, the computation of frequencies and percentages was demonstrated using.

Morphometric analysis

Morphometric analysis of aspects of relief features such as topography and slope gradient were described and evaluated for identifying the effects of slope and related morphometry of the land features on the occurrence of soil erosion in the district. Moreover, the morphometrics of the drainage system of river catchments were analyzed using SRTM DEM using TNT Atlas 2013 software. The stream order's Bifurcation Ratio (Rb) is computed using the law of stream numbers and orders to determine the ratio for stream orders and the risk of soil erosion.

Analysis of land use/land cover dynamics

The district's land use/land cover change conditions were analyzed by considering 25 years of land use/land cover satellite images of 2005, 2015, and 2020. The supervised classification techniques of images using Arc GIS 10.8 version were applied for analyzing land use/land cover change in the study area. To detect land use/land cover dynamics in the study area, Landsat 4-5-TM C2L2 images between 2005 and 2020 were drawn from USGS Landsat data sets and analyzed accordingly.

RESULTS AND DISCUSSION

Topography of the district

The topography of the study area is generally characterized by plain, plateau, ridges, and rugged terrain, which are the extension of the Hambaricho Mountain. The Hambaricho Mountain is the highest in the region, with an elevation of 3025 m above mean sea level. The altitude of the study district lies between 1619 and 2701 m above sea level (Figure 2). The contour and hill shade maps in the figure below show that the terrain features of the district are mainly occupied with hills, various ups and downs, and river gorges, which are formed by rivers and run-off in the past long history of landform formations. The unstable terrain features of the area exacerbate soil erosion rates in the farm field of the study area. Therefore, with the sloppy nature of the site, the relief feature is considered to be one factor for soil erosion in combination with human abusive actions in the area.

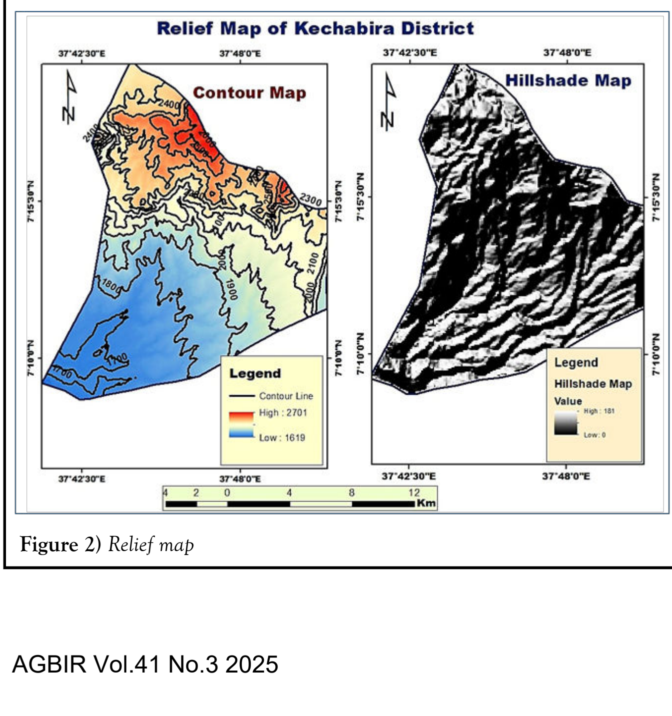

Figure 2) *Relief map*

Slope features and their effects: The slope is defined as the inclination of the land surface from the horizontal. Slope in percentage is calculated by dividing vertical distance by horizontal distance and multiplying by 100. The slope of the study area is discussed by classifying it into five slope classes based on the percentage of slope gradient (Figure 3). According to the study area size, these are slope gradients between 0-3%, 3-8%, 8%-15%, 15-30%, and >30%. Generally, the slope gradient of the study area is between 0% to greater than 40%, of which the majority of land area lies between 3-8% of slope gradient. Out of the slope classes, about 68% of the land surface of the study area is at a 3-15% slope gradient, and 22% is occupied under 0-3% slope classes.

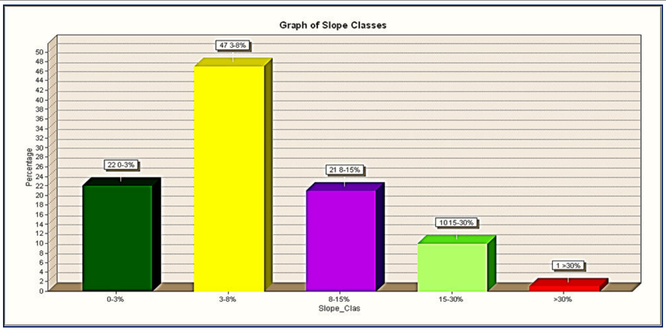

Figure 3) *Slope classes of study area*

Therefore, according to the slope classes of the USDA natural resources conservation service, most of the study area is categorized as undulating and strongly sloping or rolling slope classes. The slope has a significant role in the farming process and for landowners because it influences erosion potential. Steeper slopes aggravate the rate of erosion through run-off when precipitation reaches the soil.

The University of Wisconsin extension findings on agricultural studies suggest that soil slopes that exceed 2% are typically eroded if cultivated [16]. Contrary to this, all slope categories in the district, including steep mountain tops and deep gorge areas, are under the process of cultivation. It is concluded that the slope nature of the land area and the cultivation of undulating to steep slope soil surface in the district can be assumed to be causes for the occurrence of soil erosion in the study area (Figure 4).

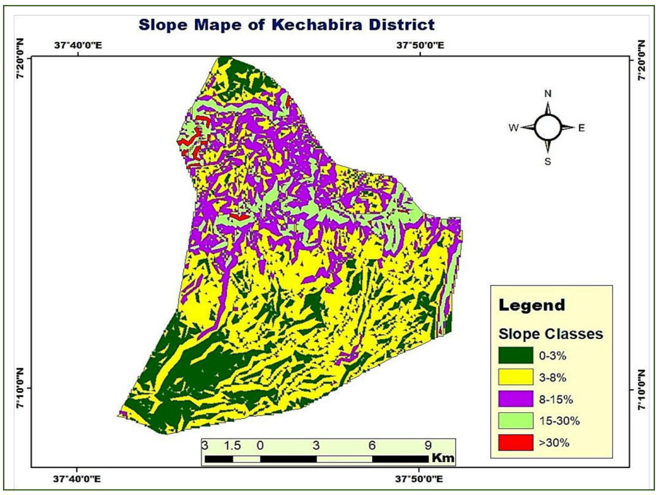

Figure 4) *Slope map*

On the other hand, household surveys on the farm plots of cultivation lands in the study area also showed that out of the total sample plots, about 40% are moderate, and 32% are steeply sloping farm plots (Table 1). This also indicates that farmers in the study area are cultivating soil surfaces exposed to erosion.

TABLE 1

Slope of cultivation field

Slope farm plots	Frequency	Percent
Flat	26	21.5
Undulating	7	5.8
Moderately sloping	49	40.5

Drainage feature and its effects on soil erosion

The district has various streams and a more significant number of perennial rivers. The rivers of the study area drain towards the Ajora Falls *via* the Omo River. Ajora Falls is the most tremendous twin waterfall in Ethiopia. The twin is formed by two significant rivers, Ajacho and Soke. The main perennial rivers of the district are the Ofute, Sanbata, Ketala, and Ajacho rivers, starting from the highlands of the district. The rivers in their upper course are joined by many small streams (Figure 5). In the upper course, the rivers pass steep slopes and undulating slopes by forming gorges and rapids, which accelerate the rapid loss of soil in the hillsides of the district in which agricultural activities parallelly dominate. Moreover, the district's river network densities are also more remarkable, ultimately facilitating the rapid loss of soil resources.

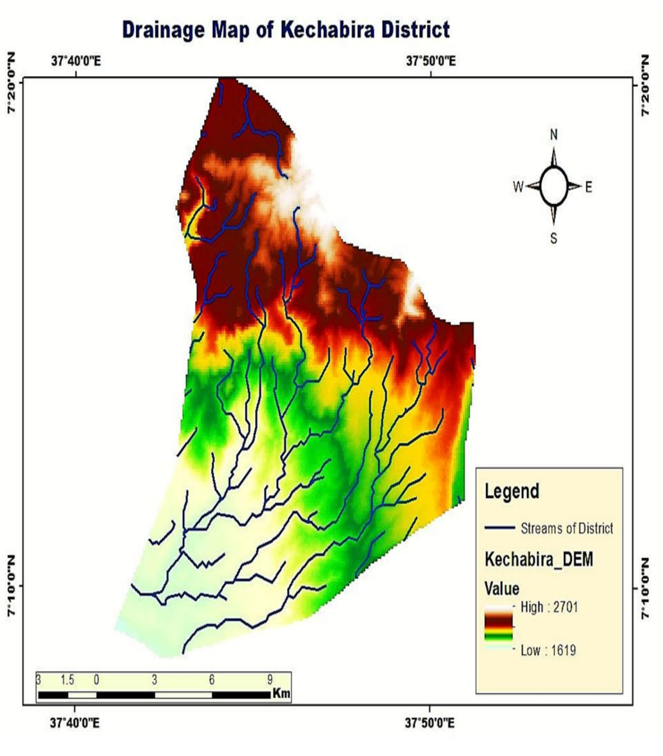

Figure 5) *Drainage map of study area*

The Strahler stream ordering map indicates that the principal rivers of the study district are made of more than three orders of streams, and the maximum stream order is four orders in one of the big rivers that cross the central part of the district (Figure 6). Based on the Strahler stream numbering and ordering system, the mean bifurcation ratio of the stream order was calculated to identify the relationship between the number of first-order streams and those of the next higher orders. Accordingly, the mean bifurcation ratio of drainage is 3.3, which is at a lower level than the mean ratio. The mean ratio indicates that the risk of soil erosion is potentially greater due to higher frequencies of rivers at first-order streams. Therefore, the drainage feature of the district is also the main exacerbating factor for soil erosion.

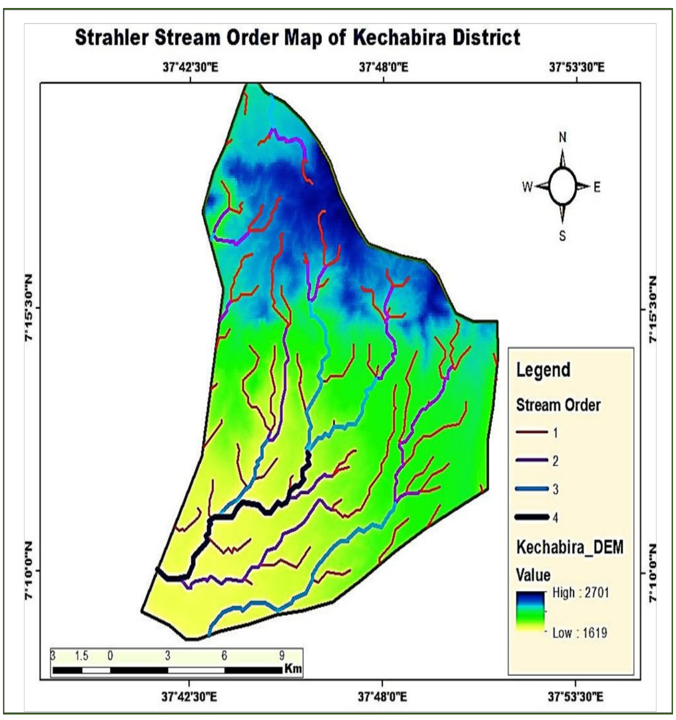

Figure 6) *Streams Oder map*

Land uses/land cover dynamics and its effects on soil erosion

According to land use/land cover change detections using geospatial techniques, the dominant land use types observed in the study area are croplands, settlements, grasslands, forest lands, and bushlands (Figure 7).

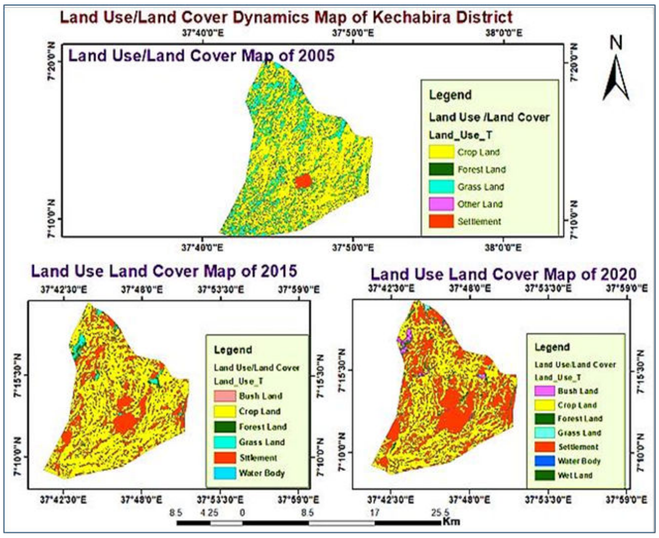

Figure 7) *Land use/land cover map*

Although the total share of the land area varies among land use types, the principal land uses covered during 2015-2020 in their sequential order are croplands, settlements, and forest lands (Figures 8 and 9).

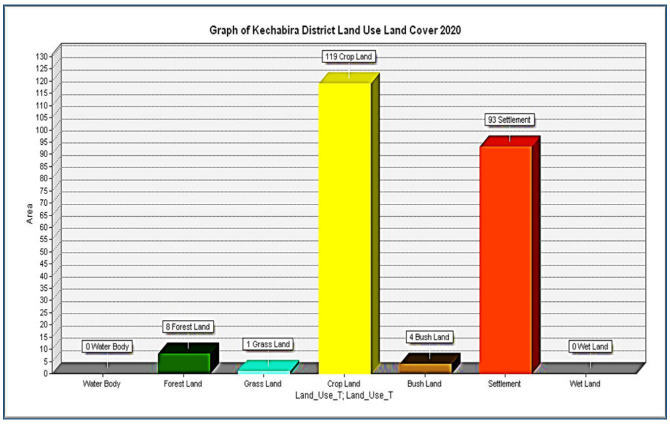

Figure 8) *Land use/land cover areas*

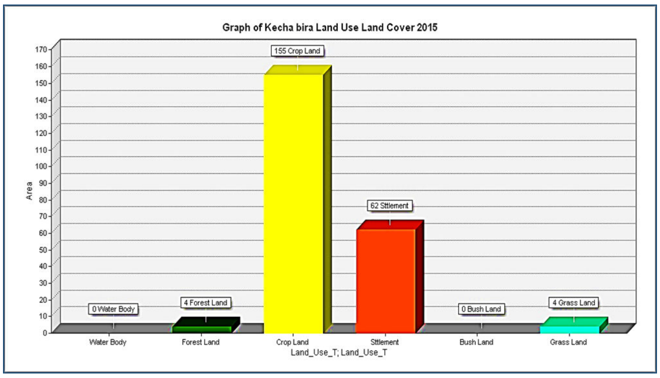

Figure 9) *Land use/land cover areas*

The major land use land cover types during 2005 in sequential order are cropland covers 165 km^2 of land, grasslands cover 58 km^2, and settlement covers 3 km^2 (Figure 10).

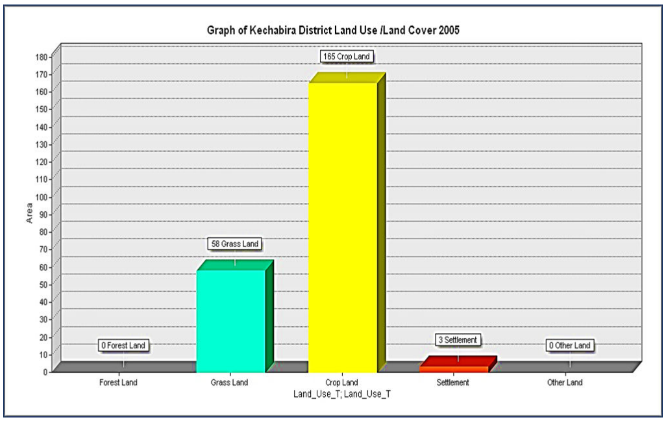

Figure 10) *Land use/land cover areas*

Concerning the dynamics of land use/land cover in the study area, crops and grasslands have shown decreasing trends, while settlement, forest, and bushlands have shown increasing trends during 2005-2020. As indicated in Table 2 below, the croplands decreased by 20%, and grasslands decreased by 25% in the past 25 years in the district. However, settlement lands increased by 40%, and forest land increased by 4%. This shows an increase in settlement due to the expansion of urbanization and unplanned informal urban settlement around peri-urban areas by replacing former croplands in the district. During household surveys and discussions with key informants, it was also found that the croplands are replaced by bushland whenever the cultivation lands are degraded due to loss of soil productivity by soil erosion. Thus, bushlands are relatively increasing in the study area, mostly around eroded riversides and hilly regions. Similarly, it was also observed that some farmers were forced to shift their cultivation lands into agroforestry when farmlands were degraded, which, on the other hand increased forest land in the district. The grasslands in the study area are declining due to the expansion of crop and forest lands to grazing grounds and the expansion of settlement.

The land use land dynamics of the district is the implication for the occurrence of soil erosion. As discussed earlier, some land use/land cover types are changed due to land degradation by soil erosion, like changing cultivation land into bush and forest lands. On the other hand, it is also found that the prevalence of soil erosion is used as a reason for the expansion of some kind of land use/land cover like the settlement land, which causes the disturbance of the land surface, resulting in soil erosion.

TABLE 2

Observed land use/land cover changes

Land use/land cover types	Area coverage in km^2 2005
Crop land	165
Grass land	58

Settlement	3
Forest land	0
Bushland	0
Water body	0

The soil of the study area is derived from highly weathered rocks, mainly sedimentary rocks and basalts. The dominant types of soils covering the study area are Eutric Nitosols, Ochric Andosols, and Plinthic Ferralsols. Of these soil types, Eutric Nitosols are the major soil types covering large areas of the district (Figure 11). By nature, Nitosols are deep, well-drained, and red-colored tropical soil with defused horizon boundaries. They are strongly weathered soil with a high erodibility rate in intensified agricultural soil. The soil textural class is categorized under clay type with 47% clay, 26%, and 27% sand fractions.

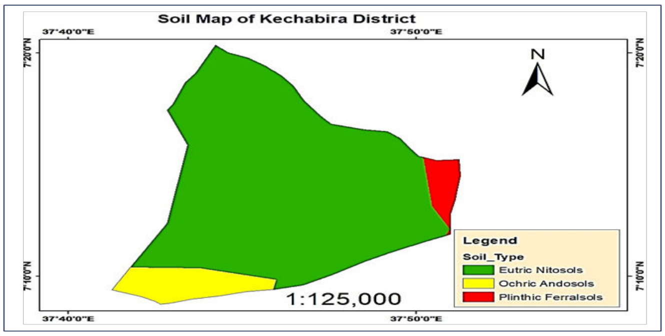

Figure 11) *Soil types of study area*

Farmers also identified the soil color of the study area as black 35.5 %, reddish 46.3 %, and brown 18.2% (Table 3). Generally, soil color in the study area is dominated by reddish color.

TABLE 3

Soil color of cultivation

	Variables	Frequency	Percent
Soil color	Reddish	56	46.3
	Brown	22	18.2
	Black	43	35.5
Total		121	100

Soil physical properties

Soil texture: The laboratory results of soil textural classes indicate that the particle size distribution of samples from six soil samples is dominated by clay fraction with a mean value of 54% clay, 20% silt, and 26% sand textures (Table 4).

Soil bulk density: Soil Bulk Density (BD) of study sample areas ranged from 1.23 to 1.25 gm/cm^3 with an average value of 1.235 gm/cm^3 (Table 4). Bulk density is an indicator of soil compaction. According to Hazelton and Murphy, the critical BD value for clay texture soils is 1.4 gm/cm^3, most rocks have a bulk density of 2.65 gm/cm^3, and for medium textured soil with about 50 percent pore space have a bulk density of 1.33 g/cm^3. However, the bulk density value in the district is lower than that of the critical bulk density value for clay texture soil. This shows that the ground of the study area is loose, porous, and not compacted, which is most susceptible to soil erosion.

TABLE 4

Soil texture and bulk density

Soil sample sites	Textural fraction (%)			Texture class	BD (gm /cm^3)
	Sand	Clay	Silt		
Zogoba kebele, 01	28	52	20	Clay	1.24
Zogoba kebele, 02	26	54	20	Clay	1.23
Zogoba kebele ,03	30	52	18	Clay	1.25
Mino kebele, 01	24	54	22	Clay	1.23

Mino kebele, 02	24	56	20	Clay	1.23
Mino kebele, 03	24	56	20	Clay	1.23
Mean value	26	54	20	Clay	1.235

Soil chemical properties

The chemical properties of soil are the levels and availability of nutritional mineral elements for the plants and the chemical parameters of soil in connection with their restoration or availability. Soil chemical properties include soil pH, cation exchange, base saturation, salinity, sodium adsorption ratio, enzymes, and electrical conductivity. These properties affect nutrient cycling, biological activity, soil formation, pollutant fate, and erosional processes [17]. Hence, to find soil chemical properties, soil macronutrients such as phosphorus, nitrogen, carbon, calcium, magnesium, sodium, potassium, and sulfur are tested and analyzed (Table 5).

Soil pH: Soil pH refers to a soil's acidity or alkalinity and measures Hydrogen Ions (H^+) in the soil. The soil pH is highly affected by soil erosion. The soil experiment result in the sample area shows that soil pH is between 5.06 and 7.05, with a mean value 5.85 (Table 5). The average pH indicates that the study area's soil is moderately acidic. On the other hand, about 33% of sample areas were found under firm acidity (pH<5.5), 50% of sample sites were moderate acidity (5.6-6.5), and 17% of areas were alkaline. The observed pH value in the study area is associated with removing bases through topsoil erosion and leaching by solid rainfall.

Soil Organic Carbon (OC): The OC content soil in the study sites varies between 0.93-1.56%, with the mean value of OC of 1.22% (Table 5). According to the soil organic carbon rating cited in the research finding by Getachew and Mamo, the range of soil OC content in the study area falls under low to very low, which is <2% [18].

Total N (TN)

The total nitrogen contents of soils in the study area vary between 0.066-0.132% with a mean value of 0.084%, which shows that the total nitrogen content of the soil lies under very low to low according to EthioSIS cited at Balasubramanian [19]. The very low to low range of TN in the study area is attributed to the complete removal of biomass and soil organic content due to intense cultivation and soil erosion (Table 5).

Available P

The available phosphorous contents of soils in the research lie between 0.32-5.48 ppm (Table 5). The mean value of available phosphorus is 3.01 ppm, which shows a very low to low range of content compared with the critical limit description established by Cottenie cited.

Soil organic matter

The organic matter of soil ranges between 1.603% to 2.689%, with a mean value of 2.095%. Hence, according to M. Getachew, all study area soils are classified as low in their OM contents [20]. This is mainly due to the loss of top fertile soil by intensified cultivation practices and the prevalence of soil erosion in the study area.

Electrical conductivity

The electrical conductivity values of the soils of the study area, according to Ethio SIS cited by Balasubramanian, show that the soils of the study area are salt-free (Table 5).

TABLE 5
Soil macro-nutrients and chemical properties

Soil sample sites	pH (1:2.5)	EC (µS/cm)	% TN	Available P (ppm)	% OC	% OM
Zogoba kebele 01	5.91	47.8	0.118	3.06	1.43	2.465
Zogoba kebele 02	7.05	42.2	0.097	2.19	1.25	2.155
Zogoba kebele 03	5.06	42.9	0.132	5.48	1.56	2.689
Mino kebele 01	5.37	58.8	0.089	0.32	1.15	1.983
Mino kebele 03	6.04	50.6	0.072	5.64	0.97	1.672
Mino kebele 02	5.72	54.5	0.066	1.39	0.93	1.603
Mean value	5.85	49.46	0.084	3.01	1.22	2.095

Causes of soil erosion

The household survey result shows that soil erosion is mainly caused by over cultivation, cultivation of steep slopes, clearing of forests, overgrazing, over cultivation, and Poor agricultural practices (Table 6). It is also found that soil erosion is caused by other facilitating factors such as the topographic nature of the surface, slope gradient of the area, drainage feature of rivers, and land use/land cover conditions. Due to the above-listed causes, soil erosion can affect the land's production potential, households' livelihood, and environmental quality.

TABLE 6
Causes of soil erosion

Causes of soil erosion	Ranks in percentage					
	1st	2nd	3rd	4th	5th	6th
Deforestation	12	10	70	11	10	20
Overgrazing	31	33	13	57	22	13

Over cultivation	67	19	29	22	6	5
Poor agricultural practices	15	14	10	39	59	17
Cultivation of steep slopes	12	65	7	8	23	16
Other factors	10	11	17	10	27	76

Severity of soil erosion

All respondents in the study acknowledged that soil erosion was a problem, at least in one of their plots (Table 7). According to critical informants during focus group discussions, the indicators of soil erosion include a decrease in the capacity of soils to grow a variety of crops, a reduction in the depth of topsoil, a decline in the water-holding capacity of soils, a decrease in yield from the farm, etc. In addition, households were also interviewed about the severity of soil erosion in their farm plots. Thus, about 79% and 21% of the respondents acknowledged that soil erosion risk in their farm fields is severe and moderately severe, respectively. The remaining (9%) of farmers rated the problem as minor on their farm plots. From the result, one can conclude that soil erosion is a severe problem in the study area.

TABLE 7
Respondents view on soil erosion

Variables	Options	Frequency	Percent
Soil erosion	Yes	121	100
	No	0	0
Erosion severity	Severe risk of soil erosion	79	65.3
	Moderate risk of soil erosion	21	17.4
	Minor risk of soil erosion	11	9
	No risk of soil erosion	6	5
	Others	4	3.3
Total		121	100

Consequences of soil erosion

Regarding the consequences of soil erosion, about 68% of respondents forwarded that land productivity (yield) decline, change in the type of crops grown, and reduced farm plot size by declining land productivity are the main consequences of soil erosion (Table 8).

TABLE 8
Consequences of soil erosion

Consequences	Frequency	Percent
Land productivity (yield) decline	11	9
Change in type of crops grown	10	8
Reduces farm plot size by declining land productivity	18	15
All	82	68
Total	121	100

Soil erosion impacts on soil quality

Out of the total respondents interviewed concerning soil fertility status, 78.5% confirmed that soil fertility in the study area is declining. However, a few respondents answered that soil fertility is the same through time intervals (Table 9). On the other hand, most respondents (89.3%) also found that the decline of agricultural productivity is one of the most critical indicators for loss of fertility in the study area. Regarding soil fertility decline, most respondents (55%) replied that the loss of topsoil by erosion is the primary cause of soil fertility decline. Other reasons for soil fertility decline in the study area include over-cultivation and overgrazing.

TABLE 9
Fertility of soil

	Options	Frequency	Percent
Fertility status	Improving	4	3.3
	The same	22	18.2

	Declining	95	78.5
Total		121	100
Indicators of fertility decline	The decline in agricultural productivity	108	89.3
	Devoid of vegetation cover	3	2.5
	Size and color of seedlings	10	8.3
Total		121	100
Reasons for fertility decline	Losses of topsoil by erosion	67	55
	Over cultivation	34	28
	Overgrazing	20	17
Total		121	100

Soil erosion impacts on changes in land productivity

As discussed in Table 10 below, about 91% of the interviewed households have observed a decline in land productivity over the last five years, and 9% of respondents have not observed any changes. Regarding the decrease in land productivity, most respondents (88%) responded that land productivity decreases from time to time in their farm fields (Table 10). The reasons responsible for the decline in land productivity are soil erosion and loss of soil fertility, as most respondents responded. This result indicates that a production shortage influences farmers in the study area.

TABLE 10
Change in crop productivity

	Options	Frequency	Percent
Change	Yes	110	91
	No	11	9
Total		121	100
Types of change	Decreasing from time to time	106	87.6
	Increasing from years onward	6	5
	Neither increasing nor decreasing	9	7.4
Total		121	100
Reasons for change	Decline in soil fertility	16	13
	Soil erosion	40	33
	Both	65	54
Total		121	100

Soil erosion impacts on yields of cultivatable crops

The croplands in the district are planted for annual food crops, including cereals (Maize, Teff, Wheat), pulses (Haricot beans, Beans, and Peas), root crops, and cash crops.

As shown in Figure 12 below, the crop productivity per hectare for selected dominantly produced crops in the study area has decreased in the past five years. The amount of productivity of Teff per ha in the past 2005 EC was 27 kg/ha, but it declined to 23.5 kg/ha in 2009 EC. It indicates that productivity has reduced by 13% in the past five years. Similarly, wheat productivity decreased by 12%, Maize by (5%) and enset by (7%). According to a focus group discussion with the selected stakeholders of the kebele members, significant causes for the decline of crop productivity in the study area were the continuous occurrence of massive erosion, climate variability, and unwise land management.

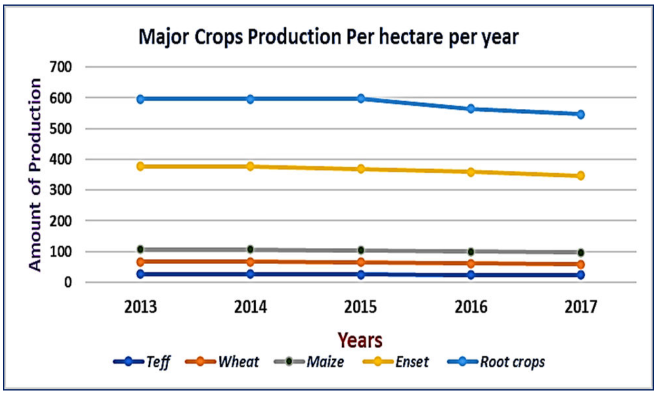

Figure 12) *Crop productivity per hectare*

The chief impact of soil erosion, mainly the depletion of the productive capacity of land under cultivation, affects food security. Cultivating marginal land exacerbates the problem by altering landforms and changing land use. Soil erosion means households must invest additional expenses to purchase chemical fertilizers. Table 11 below shows the respondents' views on the effect of soil erosion on food security and the indicators of food security in the study area. Most respondents (79.3%) reported that they were food secure. As it was revealed by focus group discussion, the farmers of the study area were seriously affected by reduced numbers of daily meals, reduced quantity of food per meal, withdrawal of children from school, and marginal land cultivation had to be adopted.

Regarding the reasons for food insecurity, about 46% of respondents answered that soil fertility decline due to soil erosion is one of the significant factors for food insecurity in the study area. Moreover, 24% of respondents answered that the shortage of productive land causes food insecurity. Nevertheless, a few respondents (10%) found that rapid population growth is one of the factors for food insecurity (Table 11). Therefore, it is clear that the effect of soil erosion on livelihoods by affecting the soil fertility of farmers in the area is one of the remaining problems.

TABLE 11
Food security status

Variables	Options	Frequency	Percent
Food security	Food secured	25	20.7
	Food in secured	96	79.3
Total		121	100
Reasons for food insecurity	Soil fertility decline due to erosion	55	45.5
	Shortage of productive land	29	24
	Rapid population growth	12	9.9
Total		121	100

CONCLUSION

Soil erosion is a threat to the economic development of southern Ethiopia as it affects the agricultural sector significantly. The primary sources of income for households in the study area are sales of crop production and animals. The dominant types of soils covering the study area are Eutric Nitosols, Ochric Andosols, and Plinthic Ferralsols. The study area is mainly occupied with hills, various ups and downs, and river gorges, formed by rivers and run-off in the past long history of landform formations. The slope gradient of the study area is between less than 3% and greater than 40%, of which the majority of the land area lies between 3-8% of the slope gradient. The analysis of three periods of land use land cover types during 2005, 2015, and 2020 using geospatial techniques shows that croplands, settlements, grasslands, forest lands, and bushlands are the dominant land use types observed in the study area. The land use land cover dynamics in the study area indicate that crop and grasslands have shown decreasing trends while settlement, forest, and bushlands have been showing increasing trends during 2005-2020. The soil laboratory experiment result indicates that the particle size distribution of soil in the study area is categorized under clay textural classes, and soil Bulk Density (BD) is found in the range from 1.23 to 1.25 gm/cm^3 with an average value of 1.235 gm/cm^3.

Moreover, it is also analyzed that soil pH is found between 5.06-7.05 with mean value of 5.85, OC content of soil vary between 0.93-1.56% with mean value of OC is 1.22%, total nitrogen contents of soils vary between 0.066-0.132% with mean value of 0.084% and organic matter content of soils is found at the range between 1.603% to 2.689% with mean value of 2.095%. About 65% of respondents in the study area confirmed that the soil erosion in the farm field is severe. The perceived leading causes of soil erosion in the study area are over-cultivation, cultivation of steep slopes, poor agricultural practices, and deforestation. The topographic nature of the surface, slope gradient of the area, drainage feature of rivers, and land use land cover conditions are the potentially facilitating causes for soil erosion in the study area. The main consequences of soil erosion in the study area are a decline in land productivity, a change in the type of crops grown, and reduced farm plot size by declining land productivity. It is also analyzed that soil erosion impacts land productivity, crop yields, and soil quality or nutrient loss. It is confirmed that the productivity of crops per hectare per year for selected dominantly producing crops in the study area has been decreasing in the past five years. The amount of productivity of Teff declined by 13%, wheat by 12%, maize by (5%) and enset by (7%). Most respondents in the research area are reported to be food insecure. The main reason for food insecurity is the loss of agricultural productivity due to soil fertility decline, soil erosion, shortage of productive land, and rapid population growth.

The researchers recommended that the acidity nature of soil should be improved by adding carbonate minerals and enhancing the organic matter content of soil by developing and applying composts and organic decompositions. The prevalence of drought due to a shortage of rainfall and an increase in temperature in recent decades resulted in the decline in production and loss of formerly available root crops like sweet potato, yam, and Ensat. Therefore, the impact of climatic variability on crop production and loss of crop species should be assessed by researchers in the study area.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable to this research.

CONSENT FOR PUBLICATION

The authors obtained permission from all participants in the Kechabira district, Durame Campus, and Wachemo University to publish the research work.

COMPETING INTERESTS

The author has not declared any conflict of interest in this research work.

AVAILABILITY OF DATA AND MATERIALS

The corresponding author will provide data upon reasonable request

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AUTHORS' CONTRIBUTIONS

Mr. Abera Abiyo Dofee contributed to designing data collection and analysis tools, undertook fieldwork, wrote most of the analysis, and developed the manuscript. Mrs. Firehiwot Goshu participated in data collection and analysis of soil laboratory work. Both authors participated in editing the manuscript. Finally, both the authors read and approved the final manuscript.

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