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Research article

GIS based soil loss assessment using RUSLE model: A case of Horo district, western Ethiopia

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ABSTRACT

Land degradation in the form of soil erosion is a worldwide challenge and make environmental problem that affects crop yields, makes livelihoods difficult, and creates crises. The main objective of this study was to measure soil loss using the Revised Universal Soil Loss Equation (RUSLE) Model in Horo district, Western Ethiopia. RUSLE with a Geographical Information System (GIS) was used to quantify soil loss using rainfall, soil, a digital elevation model (DEM), and satellite image datasets as factor value inputs. Those factors are erosivity (R), erodibility (K), topography (LS), cover management (C), and conservation support practice (P) layer values that can be interactively used using weighted overlay in ArcGIS 10.8. The result shows that the maximum and minimum potential annual soil loss of the study area ranged from nil (0.01 t/ha/yr) on plain surfaces to 216.01 t/ha/yr. The average annual soil loss rate in the study area was 13.27 t ha/yr. The highest mean annual soil loss of 216.01 t/ha/yr were observed from farmland and it was the largest portion of the study area, which covered about 64243.02 ha and represented about 73.75% of the total. As a result, forest land (16383.23 ha) was the second-largest, accounting for 18.81% of the total area. Consequently, the study revealed that the farmland was more vulnerable to erosion than other land uses and land cover types. Hence, information on average annual soil loss is important for selecting appropriate conservation measures to reduce on-site soil loss and its off-site effects. Therefore, farmers and other expected bodies should have focused on soil conservation and management practices at the highest soil loss severity classes, which must get priority for conservation by stakeholders, agents, and the government.

1. Introduction

1.1. Background of the study

According to Ref. [1] soil erosion caused by water is a severe environmental issue that has a negative impact on the nature of top soil, depletes vital nutrients, and reduces agricultural output [2]. In emerging nations like Ethiopia, where agriculture is the foundation of the economy, this issue is especially prominent [3]. According to rural land use systems, problems of soil disintegration,

Abbreviations: GIS, Geographical Information System.

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sedimentation, and cleaning in a certain part of Ethiopia are a chronic environmental problem [4–6]. In several highlands of Ethiopia, agricultural expansion and intensification, urbanization, and the extraction of timber and other distinctive resources will likely accelerate over the course of the foreseeable future in order to meet demand in the highland of Ethiopia [7].

The level of living for humans is determined by the sustainability of soil for agricultural production, which contributes over 95% to global food security [8,9]. The revised universal soil loss equation (RUSLE) is an empirical model that has been used all over the world to prioritize conservation efforts and predict soil erosion loss using GIS in high-erosional locations [5,9,10]. Determining the amount of soil loss, assigning a value to it, and prescribing conservation actions are therefore essential for resource management [2,11].

Soil erosion affected approximately 65% of the soil in Sub-Saharan African nations as a result of poor management [4]. The overall yearly soil loss for the entire Suha watershed grew from 1.22 million tons in 1985 to 2.43 million tons in 2019, according to research by Ref. [12]. Additionally, in the past, problems with soil pressure brought on by human population growth, excessive use of natural resources, a lack of soil management techniques like shifting cultivation and intercropping, and a lack of periods of fallow land were all contributing factors. In most cases, the amount of input into the soil is smaller than the amount of soil loss or takeaway from one area to another [4].

According to Ref. [13], Ethiopia is extremely vulnerable to climate change, which has a direct impact on soil qualities, particularly in the research area's highlands. One of Ethiopia's highlands, Horo district, is at risk of soil disintegration due to human causes brought on by population growth and other factors that depend on the soil and the natural environment. Some feeder streams that flow through the district are also typical aggravators of this problem. Due to the steep slopes present and the sensitive nature of the area recently formed on steep upper inclines, these areas are vulnerable to crevasse formation and sheet erosion.

This is clear evidence of high levels of soil erosion affecting soil efficiency for crop production and other services. But there is growing interest in land [11]. There is no doubt that this cycle is putting pressure on common assets through deforestation and overgrazing. In general, agricultural practices are the main cause of soil degradation in the highlands of Ethiopia [5]. The expanded population moved up the slopes of the woreda zone, clearing land to develop new agricultural land with extreme slopes of over 45% [14].

1.2. Statement of the problems

The present study was focused on the assessment and mapping of soil erosion hazards using the RUSLE model by the Geographical Information System (GIS) of Horo District, Oromia Regional State, Western Ethiopia. Soil is a crucial resource among natural resources for crop production and rearing livestock worldwide in general, and particularly in the study area. So, the RUSLE model is very important in estimating soil loss and identifying severity areas to map the area to control the severity problem, especially in Ethiopia's highlands. Ethiopia's Highland is known for its growing population, decreasing top soil due to water erosion, fertile soil, erratic rainfall, steep slope, and low infertility rate. These phenomena have contributed to further degradation and the loss of top soil, which hinder the sustainability of ecology for the coming generation.

Loss of soil by water is evedent in Ethiopia, and it is estimated that the country loses an estimated 1.3 billion metric tons of fertile soil each year [15]. Furthermore, numerous researchers have conducted studies in various areas of Ethiopia, yielding varying results and/or amounts of annual soil loss. As conducted by Ref. [5] found that soil loss ranged between 0 and 932.6 t/ha/year in the Anger River Sub-basin in Ethiopia, with a mean annual soil loss of 83.7 t/ha/year, and conducted by Ref. [16] found that 82% of the total area is at high risk and requires immediate measurement in the north side of the Lake Tana sub-basin in Ethiopia, Amhara region, at Megech watershed. Accourding to Ref. [17]. Estimated soil loss in Jabi Tehinan ranged from 0 in the south to 504.6 t/ha/yr in steeply sloping mountainous areas of the north and north-eastern parts of the catchments.

The study area is based on rain-fed agriculture (cultivation of various crops and animal husbandry). However, environmental conditions such as erratic rainfall and the topography (length of slope (L) and steepness of slope (S)) of the area are highly affecting soil nutrients due to the undulating nature of the land, continuous tilling of farmland, and overgrazing because of the scarcity of available land. However, no research was carried out in the study area. These phenomena were the primary focus of the research that was initiated, chosen, and carried out. By its nature, most of the area is challenged with landslides from time to time, and without any soil conservation measures in place for the area, this occurrence makes one worry about the future of soil sustainability. The good examination of which degraded and ranked-influenced territory by erosion was dependent on their danger level and used for the suggestion is significant in order to reduce those issues with the least expense and time. Since the study area lacks research conducted on the assessment of soil loss by the RUSLE model using GIS and the RS method at Horo district in western Ethiopia, Therefore, the main objective of this study was to measure soil erosion using a GIS-based RUSLE model in Horo District, Western Ethiopia.

1.3. Limitation and RUSLE concept to model soil loss of the study

While conducting the study and evaluating the results, the authors encountered several limitations, including a lack of measurement soil loss data to validate the delineated annual soil erosion rate and a lack of data from the Office of Horo from each kebele and their degree of soil erosion severity. The other limitation was the lack of a similar and global standard for soil severity classification ranges. Some scholars divide it into seven categories: low (below 10), moderate (10–20), high (20–30), very high (30–35), severe (35–40), very severe (40–45), and extremely severe (above 45) [16], Other classifications were as follows: 0–10 Low, 10–20 Moderate, 20–30 High, 30–50 Very High, and >50 Severe [11]. Another scholar classified it as 0–42 (low), 43–128 (medium), and >128 (high) [2]. Others agree on four levels: very low (0–15), low (15–45), moderate (45–75), and high (>75) ton/ha/yr [18] and the Other constraints were a lack of transportation to see all areas to identify what types of soil and water conservation work for later recommendations where the area exists under more severe conditions, and the final challenge was off and on the internet due to the insecurity and instability of Ethiopian politics that usually faced the authors.

2. Materials and methods

2.1. Discription of the study area

Location:Horo district is located in the Horo Guduru Wollega Zone, Oromia regional State, western Ethiopia, It lay between the range of 9°18′00″ and 9°50′00″ N direction and 37°00′00″ and 37°20′00″ E longitude (Fig. 1). It covers a territory of about 867sqKm.

2.1.1. Soil and topography of study area

The main soil types found in the study area include 73% clay, 25% loam, and 2% sand. The geology of the soil is assessed by providing the origin of the soil material, regardless of its agencies, such as chemical and physical agents of weathering. The agro-ecology of the study area is 1416–1500, 1500–2300, and 2300–3200 feet above sea level (Fig. 1), and the topography of the area is mostly undulating land, clif, and mountain, and at the bottom, some of the area is flat land [18].

2.1.2. Climate and rainfall of the study area

Climate, particularly temperature and rainfall conditions, are the main determinants of soil properties [8]. The study area has three climate zones ranging from 1416 to 3203 m above sea level. These are Kolla (tropical), which alludes to marshes somewhere in the range of 500 and 1500 m; Woina Dega (subtropical), which alludes to good countries somewhere in the range of 1500 and 2300 m; and Dega (calm), which alludes to high countries somewhere in the range of 2300 and 3200 m above sea level. The rainfall pattern of Horo district is characterized by a single (unimodal) maximum rainfall pattern with peaks in July and August. Ittropicalpiac highland is wet, and it gets an average annual rainfall of 1604 mm, and the mean annual temperature is 25 °C, with the mean monthly minimum and maximum temperatures being around 14.5 °C and 20 °C, respectively [19].

2.1.3. Land use and vegetation

The major land uses and land covers of the study area are cultivated land, which covered about 64250 ha, irrigated land, area closures, forest land, and homesteads; the study area also has grazing land, which covered 14% of total land. The major tree species are

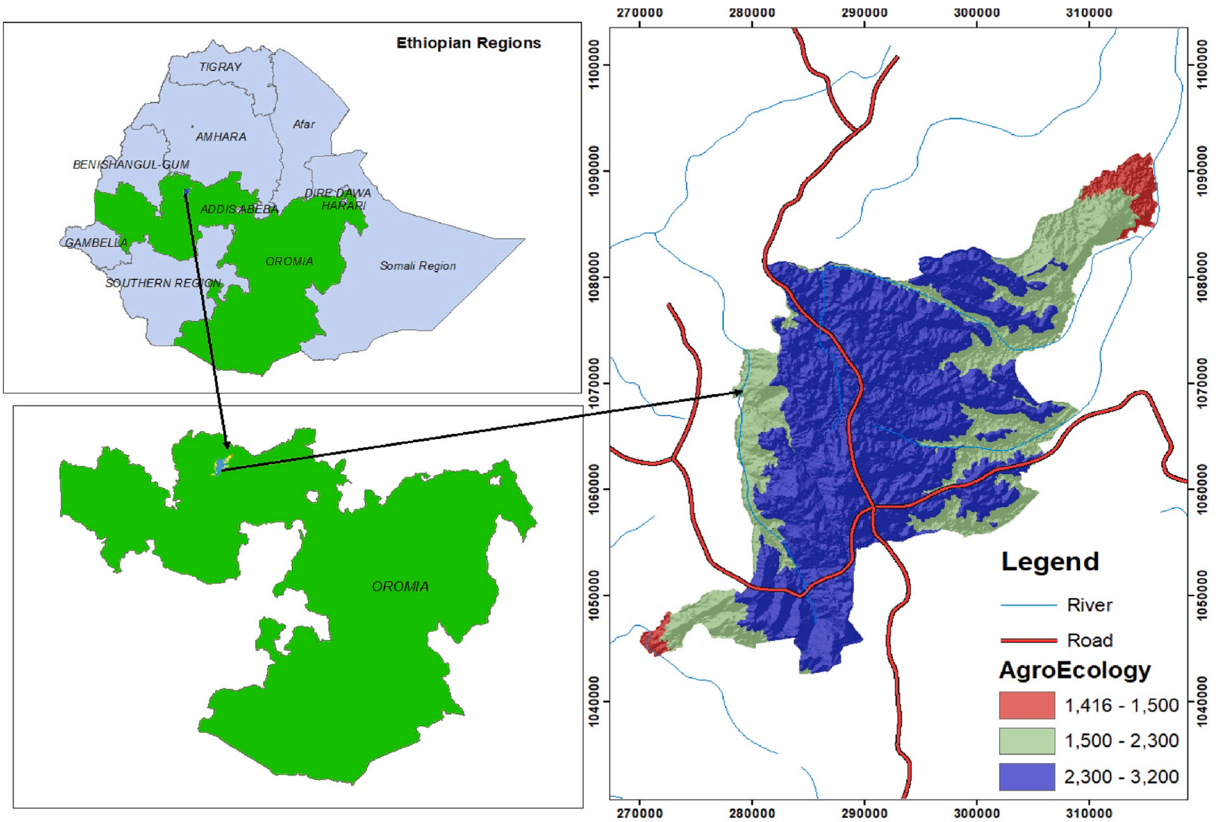

Fig. 1. Location map of Horo district, Ethiopia.

broad-leaved trees such as Ficus sur (or local name shola), wanza, debeka, and other exotic species such as Eucalyptus, Gravilia robusta, Susbania lesbian, Lusitania, etc. Mainly, the area is dominated by agro-forestry, which includes annual crops such as teff, barley, wheat, and corn. Peasants contribute to soil resource erosion and degradation through their extensive farming practices.

2.2. Methods

The study area was selected via purposive sampling techniques among 12 districts in Horo Guduru Wollega Zone because the district exists under the highest soil loss risk and also because this area depends more on crop cultivation than other activities with higher popularity. Similarly, Horo districts have been providing and supporting different crops for urban areas than other districts in Horo Guduru Wollega Zone, Oromia Regional State, Western Ethiopia (HGWZ of BOAU). These reasons were made as the researcher deliberately targeted this area to measure soil loss using a geographical information system and remote sensing techniques with the RUSLE model to control and search solutions for this problem.

2.3. Data analysis and derivation of RUSLE parameters

The annual soil erosion of the targeted study has been determined using the Revised Universal Soil Loss Equation (RUSLE), which was adjusted to Ethiopian conditions by Ref. [10] in an ArcGIS environment. RUSLE is an empirical model that has been applied worldwide to estimate soil erosion loss by using five input parameters. These five factors would be multiplied by applying the following empirical equation in Arc GIS 10 using a raster calculator. Mathematically, equation (1) is denoted as:ted as:

$$A = R * K * LS * C * P \qquad \text{equation(1)}$$

Where, A = annual soil loss (metric tons ha-1yr-1), R = rainfall erosivity factor (MJ mm h-1 ha-1 yr-1), K = soil erodibility factor (metric tons ha-1 MJ–1 mm-1), LS = slope length and steepness factor (dimensionless) C = land cover and management factor (dimensionless) and P = conservation practice factor (dimensionless).

2.3.1. Rainfall erosivity factor (R)

The ability of erosion agents to cause soil detachment and transport is erosivity. This erosivity factor R was calculated based on 25 years rainfall data recorded at six relevant stations, which exist around the study area (Shambu, Homi, Fincha'a, Neshe, Sibu Sire, and Alibo) in and nearby the study area. The mean annual rainfall of the study area was first interpolated to generate continuous rainfall data for each grid cell by "*Raster krigging Interpolation*" in ArcGIS environment. The continuous rainfall data was changed to R values by equation established for Ethiopian condition by Ref. [10] the basis of annual precipitation correlation using the raster calculator in ArcGIS environment as follows.

$$R = (0.526 * p) - 8.12 \qquad \text{equation (2)}$$

Where R = rainfall erosivity factor, P = mean annual rainfall (mm/yr).

To calculate R-factor, mean annual rainfall of 25 years were collected from six metrological stations, found within and around of the study boundary, from neighboring woredas. Those were: Fincha'a, Nashe, Homi, Shambu, Alibo, and Sibu sire (Table 1) and (Fig. 2). After calculating average 25 years of rainfall for each station, the R factor was computed using the above formula and converted in to raster surface using IDW (Inverse Distance weighted) interpolation methods in ArcGIS software (Fig. 2). The R factor values are higher in the south western part of the study area (areas susceptible to rainfall erosivity) and decline towards northeastern part of Horo District.

2.3.2. Soil erodibility factor (K)

The soil erodibility is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff [6]. It was estimated based on k values assigned and adapted to Ethiopia by Refs. [10,20] depending on different factors like contents of soil organic matter, soil structure, arrangement of soil, soil colour and texture through reclassifying and rasterization mechanism with a grid map of 30m-cell size in ArcGIS environment [21]. Soils having black, brown, red, yellow, grey, and white colour were assigned K values of 0.15, 0.20, 0.25, 0.30, 0.35, and 0.40, respectively. The majority portions of the middle parts of the study area were covered by dystric nitisols (28611ha) and orthic solonchaks (26030 ha), whereas the least portion of the south western study area was covered

Table 1
Rain gauge stations around the study area and mean annual rainfall and R-value of 25 years.

St_No	Station Name	Location		Mean Annual Rainfall (mm)	R-value
		latitude(Y)	longitude(X)		
1	Fincha'a	9.570	37.370	1559.78	868.48
2	Nashe	9.65	37.20	1539.62	857.15
3	Homi	9.621	37.241	1519.46	845.82
4	Shambu	9.571	37.121	1719.66	958.33
5	Alibo	9.745	37.068	954.26	528.17
6	Sibu sire	9.411	37.047	1510.94	841.03

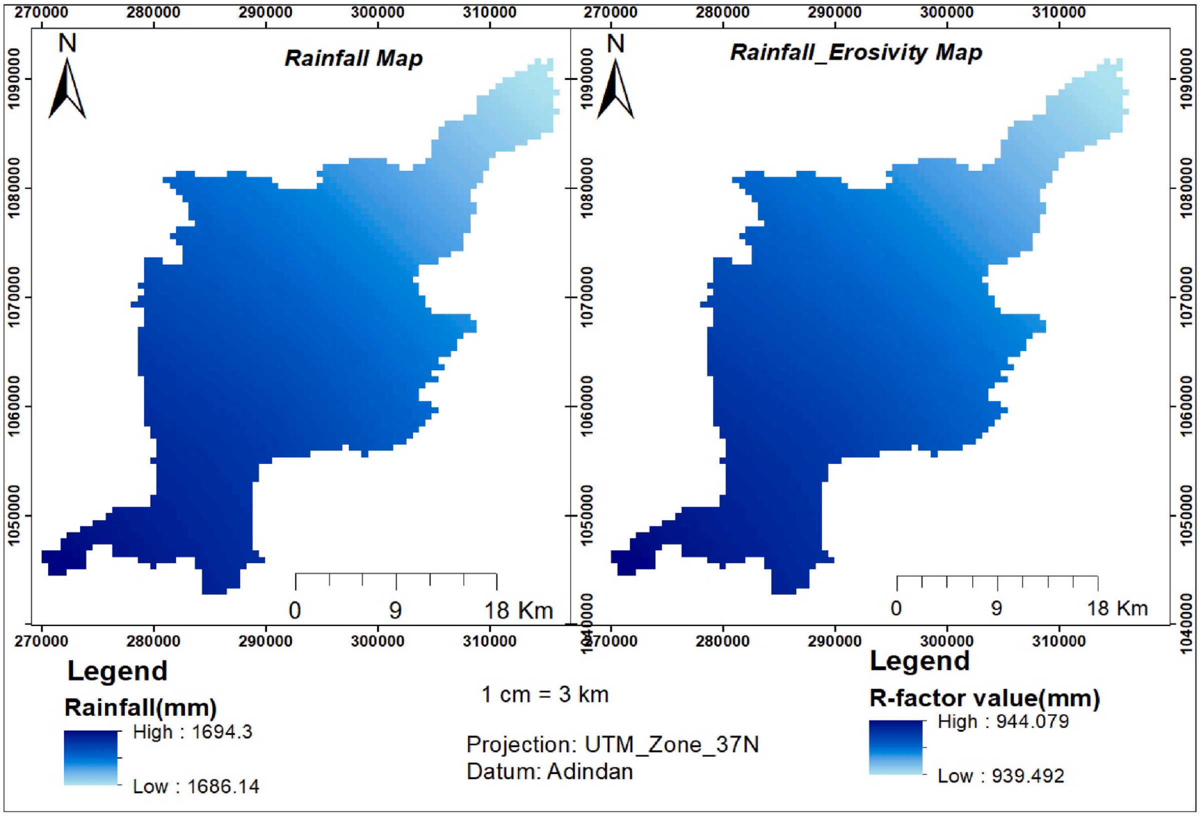

Fig. 2. Rainfall and rainfall erosivity factor (R-value) maps.

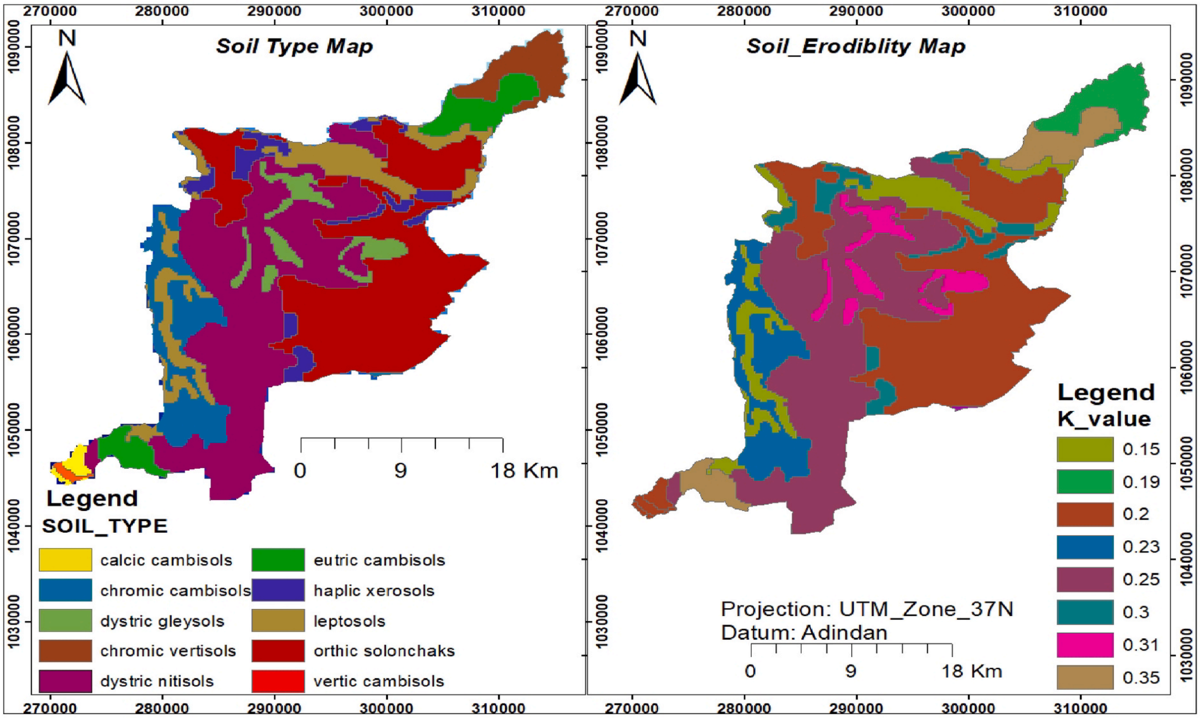

Fig. 3. Soil types and its erodibilty (k value) map of study area.

vertic cambisols.

A high K value implies more vulnerability to soil erosion whereas, a small k value indicates less vulnerability to soil erosion (Fig. 3). From (Table 2) eutric cambisols which account for about 4776 ha and covered the northern and southern part of the study area was highly correspondingly to erosion whereas leptosols which account for 8388.47 ha portion of the study area was less prone to soil loss relatively.

2.3.2.1. Topographic factors (LS factor). The effect of topography on soil erosion has been estimated by the slope length (L) and slope steepness (S). It was generated from Digital Elevation Model (30 m*30 m) resolution. Both Slope (%) and flow accumulation have been calculated using the spatial analyst tool of ArcGIS following the fill and flow direction process by employing the same tool. The slope length and slope steepness factor have been calculated as a single index, using the below formula defined by Ref. [22].

$$\text{LS} = \text{Power}\ (\text{Flow accumulation} * \text{cell size}\ \ / 22.1, 0.6)\ *\ \text{Power}\ (\text{Sin}(\text{Slope} * 0.01745)\ / 0.09, 1.3) \qquad \text{equation (3)}$$

where flow accumulation is the number of cells contributing to flow in to a given cell and derived from the DEM after conducting fill, flow direction and flow accumulation processes in ArcGIS. Cell size is the size of the cells being used in the grid based representation of the landscape. Finally, the LS factor map was derived using the above formula in ArcGIS spatial analysis raster calculator function. The value of the LS factor ranges from 0.427 to 6.634. As is shown in (Fig. 4) part of the study area which was assigned 0.427 was relatively not vulnerable. This area were the area mostly fragile and flat land when it was compared with other area in study. The dominant portion of the study area which exists at the stream line was assigned as 6.634. This indicated that this part was more vulnerable to erosion (see Figs. 5 and 6).

2.3.3. Land cover management factor (C)

The cover management factor represents the ratio of soil loss under a given vegetation cover to that of bare soil. The factor indicates the level of protection of soil under a certain land cover. This parameter has been generated by reclassifying and changing to the grid with a cell size of 30 × 30 m using a rasterization mechanism in a GIS environment corresponding to values assigned for each land use type [10].

The land use and land cover of the study area was categorized into seven land use land cover types namely farmland, grassland, forest, fallow land, bare land, town, and water body as indicated in (Table 3). The largest portion of the study area is dominated by cultivated land which covered about 64243.02 ha of total area and equivalently it represented about 73.75% of the total percent. Accordingly, the study area was covered by forest (16383.23 ha) or 18.81% was the second larger area, fallow land (3067.46 ha), water body (2089.6 ha), and grassland (72.51 ha) from the next largest to smallest coverage size in hectares respectively. The rest part was covered by town accounts (205.47ha) and bare land which covered about 1050.19ha.

2.4. Conservation practice factor (P)

The conservation practice factor is the ratio of soil loss for a given practice to that for up and slopes farming. Specific cultivation practices affect erosion by modifying the flow pattern and direction of runoff and by reducing the amount of runoff [1,23]. The p-value of the study area will be calculated based on [10] p-value provided for different supportive management practices and also it based on land use/cover type (Table 4).

3. Result and discussions

3.1. Estimation of annual soil erosion rate of study area

The annual soil loss rate of the study area was computed by multiplying the respective RUSLE factors erosivity (R), erodibility (K), topographic (LS), cover management factor (C), and conservation support practice (P) layer values interactively using Raster calculator in ArcGIS10.6 (see Fig. 7). The findings indicated that there was a possible risk of soil erosion in the study area, with values ranging from 0.01ton/ha/yr in plain areas to more than 50 ton/ha/yr in several steeper slopes and to well over 216.01 ton/ha/yr in

Table 2
Soil types and erodibility values.

No	Soil Type	K value	References	Area
1	dystric nitisols	0.25	[1,11]	28611.11
2	eutric cambisols	0.35		4776.09
3	orthic solonchaks	0.20		26030.36
4	chromic vertisols	0.20		3740.31
5	chromic cambisols	0.25	[17]	7321.31
6	Leptosols	0.15	[17]	8388.47
7	haplic xerosols	0.30	[1]	3894.40
8	vertic cambisols	0.20		269.81
9	dystric gleysols	0.3		3424.00
10	calcic cambisols	0.20		583.21

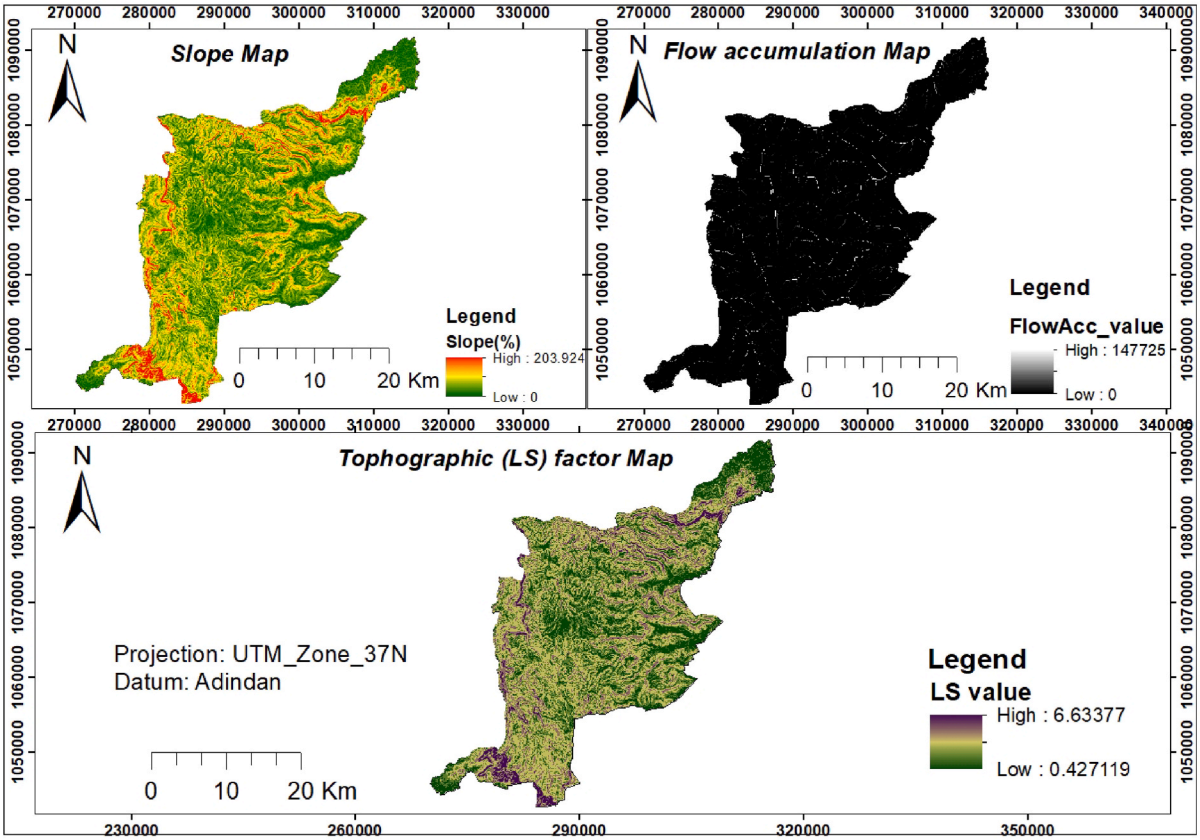

Fig. 4. Topographic factor (LS) map.

other areas (Figs. 8 and 9).

The average annual soil loss rate in the research region was 13.27 ton/ha/year, which is within the tolerable level of 2–18 ton/ha/yr adopted for Ethiopia conditions by Ref. [24] and is consistent with the yearly soil loss in Ethiopia's highlands reported by FAO [25].

There were various soil loss range in Horo district that exist between the maximum and minimum of 216.01 and 0.01 ton/ha/yr. This varation have been shown that there is different factor with different slope of the land like land use land cover, management practices, different climate condition, erratic rainfall, and soil types are makes variation of degree soil loss.

Soil erosion was classified into five severity classes based on the above (Fig. 9) and below (Table 5). These were; very slight (0–10), slight (10–20), moderate (20–30), severe (30–50), and very severe (>50). Based on this range, 1058 and 1599 ha of land were classified as very severe and severe respectively. The other area were 5610 ha was under moderate, 20833 ha was under slight, and 54653 ha was under very slight soil loss severity classes at study area (Table 5). Therefore, the value indicated that the study area was highly affected by soil erosion which leads to land degradation and loss of agricultural production. The spatial pattern of the soil erosion risk map observed at different slope (Fig. 9) showed that there is potentially prone to soil erosion risk. They need the immediate response of conservation practices at the study area specifically at steep slope area, which highly affected will get frist conservation measure.

3.2. Spatial variation of soil erosion with land use and land cover

The results revealed that cultivate land, which comprised the majority of the study area (64243.02 ha), had the highest mean annual soil loss (216.01 t/ha/yr) that observed in study area and the second higher range observed mean annual soil loss was 0.01–212.35 t/ha/yr shown on (Table 6). When compared to other land use types, forest land had the lowest annual soil loss of 3.7 ton/ha/yr. The mean annual soil loss of 4.5 ton/ha/yr from the forest and 65.9 ton/ha/yr from cropland reported by Ref. [26] was higher than the mean annual soil loss obtained during the present study for both forestland and farmland, respectively. The major causes of the high average soil loss rate from the farmland might be continuous tillage, removal of crop residue for different purposes, absence of contour farming, inappropriate farming practices, land renting, overgrazing by livestock, and collection and use of crop residues for fuel wood. From the total farmland, nearly 35140.93 ha, or 54.7%, was at high soil erosion risk. Compared to this, only 3.3% of the total forestland and 9.7% of the total grassland were under high soil erosion risk. Farmland with a high risk of soil erosion was also reported by Ref. [27]. This indicates that soil and water conservation measures such as mulching and conservation tillage are

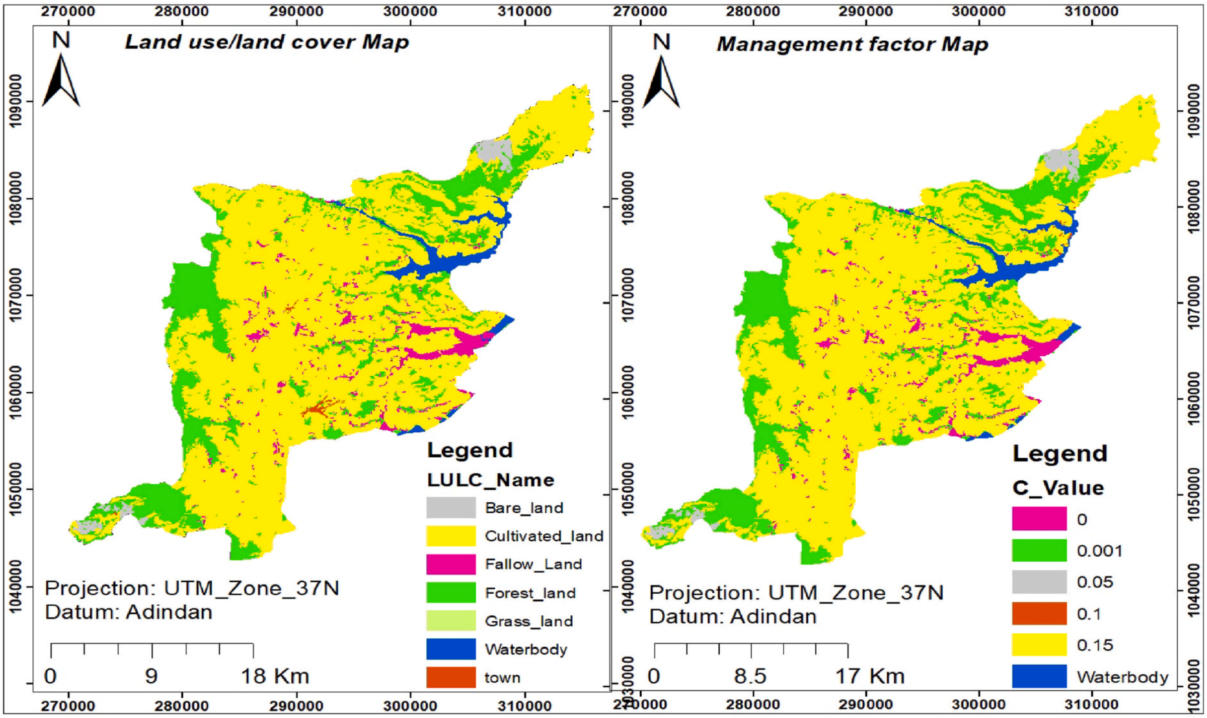

Fig. 5. LULC map and its management (C factor) Maps.

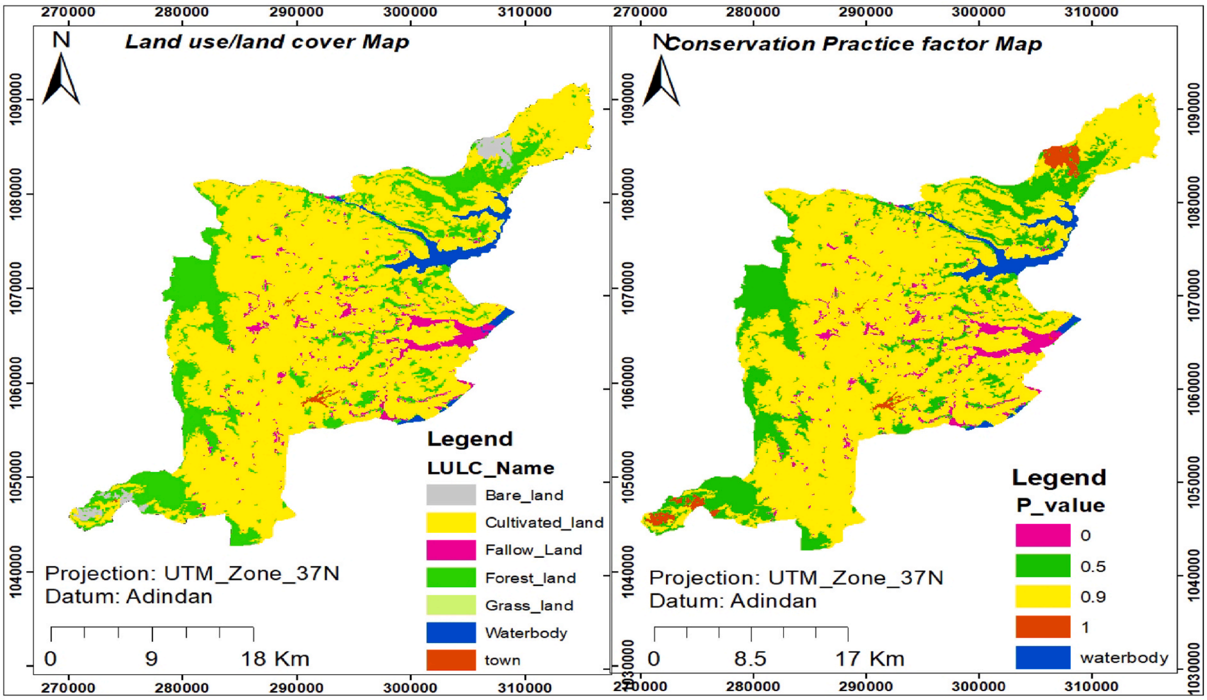

Fig. 6. LULC map and conservation practice (P factor) map.

Table 3
Land use and land cover and their management factor value.

No	LULC Name	Area (ha)	%Total	C Value
1	Forestland	16383.23	18.81	0.001
2	Waterbody	2089.6	2.40	0
3	Cultivated land	64243.02	73.75	0.15
4	Fallow Land	3067.46	3.52	0
5	Grassland	72.51	0.08	0.1
6	Town	205.474691	0.24	0.15
7	Bare land	1050.19	1.21	0.05

Table 4
Hans Hurni (1985) Calculated Conservation practice factor (Value of P).

No	LULC Name	P Value
1	Forestland	0.50
2	Waterbody	1.00
3	Cultivated land	0.90
4	Fallow Land	0.00
5	Grassland	0.90
6	Town	1.00
7	Bare land	1.00

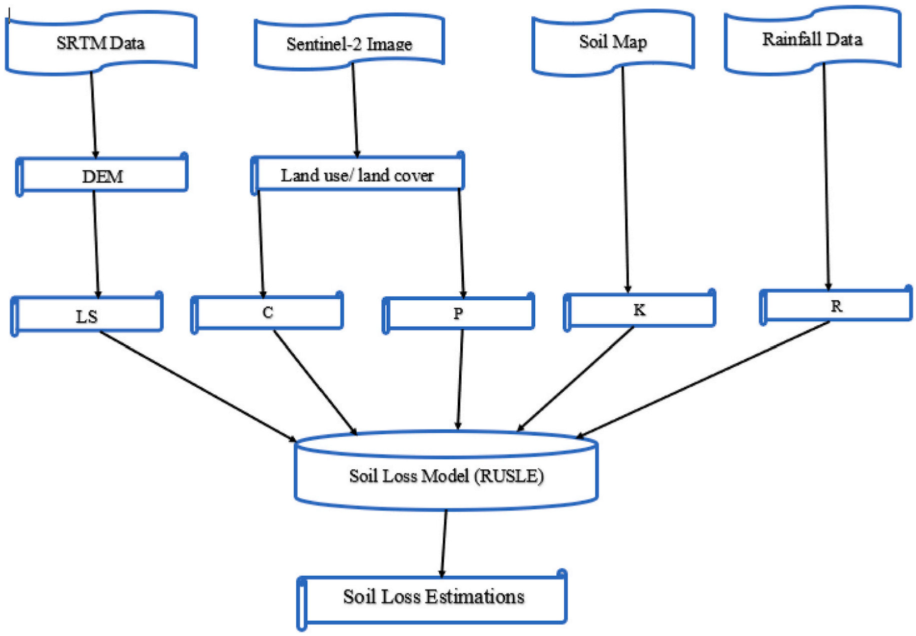

Fig. 7. Flow chart of the overall methology.

important to reduce soil erosion from farmlands [28].

3.3. Prioritization of the study area based on the soil loss rate

As indicated in Tables 5 and 6, based on mean and standard deviation values, study area soil loss rates are classified into 4 severity classes, which are labeled: very slight, slight, moderate, severe, and very severe. Very severe and severe show relatively more vulnerability, whereas slight and very slight severity classes indicate moderate and less vulnerability to soil erosion, respectively. Even if the average annual soil loss of all in the study area (Tables 5 and 6) clearly states that nearly the entire watershed requires the implementation of different types of soil and water conservation measures for sustainable land use and essential nutrient conservation, it is important to plan the activities on a priority basis for addressing the problematic areas to arrive at the necessary solutions.

Furthermore, the prioritization of the study area demonstrates the ranking of the specific area found in the Horo district based on its severity classes of soil erosion risk. As a result, shambu and sakela are classified as very severe, the mean soil loss were

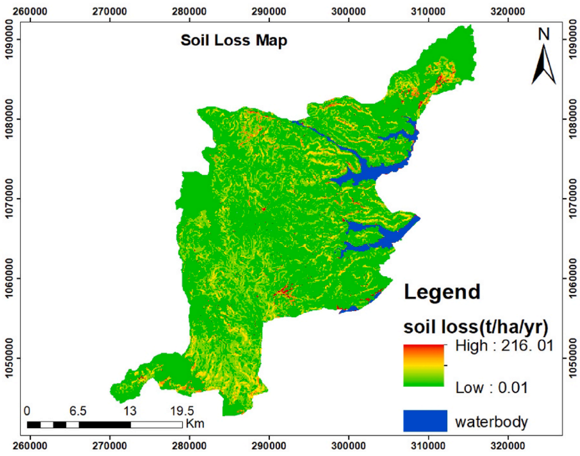

Fig. 8. Soil loss range of Horo district, Ethiopia.

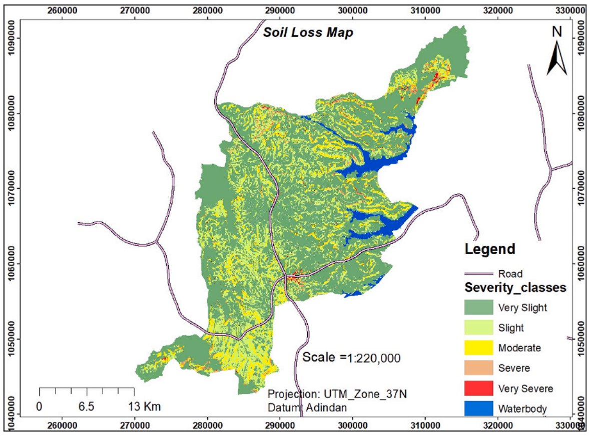

Fig. 9. Map of annual soil loss rate of Horo district, Ethiopia.

Table: 5
Soil loss range and their area coverage.

No	Soil loss classes	Severity-classes	Area (hac)	Percent
1	0–10	Very slight	54653	62.74
2	10–20	Slight	20833	23.92
3	20–30	Moderate	5610	6.44
4	30–50	Severe	1599	1.84
5	>50	Very severe	1058	1.22
6	Waterbody		3358	3.85

18.99–32.27ton/ha/yr or 30% of the total area. The other area like Burkitu abora, Bone abuna, Leku legu, Harbe kekelo, Haro aga, Gitilo dale, Lalu lgu, Refinti-chabr, and Ejersa Meca are classified as severe soil loss that account about 20% of the toal area, and these areas require critical attention to prevent its risk. Similarly, Tokomo Alshaya, Abi-leigu, Refinti gebero, Alshaya lgu, Kombolcha chancho, and Lgum, were fell under moderate soil loss which account 15% of the total. Likely, the study area such as Didibe kistana and Akaji sebet were the smallest in percent, which account 8% of the total area that categourized as slight soil erosion (Table 7).

4. Discussions

Soil Erosion vulnerability distribution in Ethiopia is spatial and temporal variation based on environmental conditions like the slope of the land, temperature, rainfall condition (amount and frequency), SWC practices, soil type, and including influence of humans on land. A research study conducted by Ref. [5] in the Anger River sub-basin showed that approximately 43.6% and 8.4% of soil loss were very severe and severe, respectively. A similar study also conducted by Ref. [29] in the Kulfo river catchment, rift valley southern

Table 6
Soil loss from study area.

Rank	Kebeles/Specific area	Area (Ha)	Mean Soil Loss (ton/ha/yr)	Ranges of Soil loss (ton/ha/yr)
1	Shambu	513.33	32.27	0.03–192.23
2	Sakela	88.04	25.86	1.88–151.75
3	Burkitu abora	2943.68	18.99	0.04–188.43
4	Bone abuna	3531.05	16.55	0.01–212.01
5	Leku legu	1892.81	16.26	0.01–151.76
6	Harbe kekelo	2603.6	16.23	0.03–151.75
7	Haro aga	6643.11	15.27	0.01–210.61
8	Gitilo dale	2895.17	15.1	0.00–192.23
9	Lalu lgu	2942.71	14.51	0.01–210.62
10	Refinti_chabir	2252.48	14.18	0.04–151.77
11	Ejersa Meca	4399.23	14.04	0.01–212.35
12	Tokoma Alshaya	4755.14	12.79	0.01–192.22
13	Gulfi ulanale	7038	12.71	0.00–192.16
14	Abi-leigu	2482.23	12.38	0.4–192.22
15	Refinti gebero	3672.39	12.36	0.1–176.80
16	Gudina abuna	3144.605	12.06	0.00–182.06
17	Ali shaya lgu	13278.54	11.87	0.01–216.01
18	Kombolcha chancho	1819.04	11.82	0.03–153.78
19	Akaji sebet	2342.01	11.75	0.01–182.13
20	Oda buluk	1904.14	11.66	0.03–188.16
21	Lgum	2520.9	11.5	0.00–192.19
22	Doyo bariso	2740.41	11.44	0.01–182.133
23	Didibe kistana	5112.92	10.7	0.01–188.19
24	Dacha Chabir	5595.95	7.64	0.2–192.17

Table 7
Severity classes and prioritization of Horo district.

Severity Classes	Priority classes	Mean Soil Loss ($tha^{-1}yr^{-1}$)	Kebeles	Area (Hac)	Percent
Very severe	I	18.99–32.27	Shambu and sakela	2196	30%
Severe	II	14.04–18.99	Burkitu abora, Bone abuna, Leku legu, Harbe kekelo, Haro aga, Gitilo dale, Lalu lgu, Refinti_chabr, Ejersa Meca	1463	20%
Moderate	III	10.7–14.04	Tokomo Alshaya, Abi_leigu, Refinti gebero, Alshaya lgu, Kombolcha chancho, Lgum,	1131	15%
Slight	IV	7.64–10.7	Didibe kistana & Akaji sebet	629	8%
Very slight	V	0.1–7.64	Oda Buluk, Doyo Bariso, Dacha chabir, Gulfi ulanale and Gudina abuna,	2025	27%
Total				7444	100

Ethiopia shows that the minimum and maximum soil loss was 0–1211 ton/ha/yr respectively. Particularly, Horo district faces topsoil loss mainly due to natural and anthropogenic activities and as the result accounting for 30% and 27% of the total area lost under very severe and very light soil loss, respectively, and the minimum and maximum annual soil loss were 216.01 and 0.01ton/ha/yr in the study area, respectively.

Estimated annual soil loss in Jabi Tehinan Woreda ranges from 0 in the south and 504.6 t/ha/yr in steeply sloping mountainous areas of the north and north-eastern parts of the catchments [17]. However, soil quality is affected by soil erosion, especially on steep slopes [30]. The severity of soil loss in the study area ranged from very severe to severe, moderate to slight, and very slight, contradicting research [29], which found that 0–42 ton/ha/yr (low), 43–128 ton/ha/yr (medium) and >128 ton/ha/yr (high) and the average rate of soil erosion is 68.47 ton/ha/yr. Similar to this finding, soil loss in the Huluka watershed was 400 ton/ha/yr [31]. As a result, agricultural production is declining in the study area due to nutrient loss from topsoil [32], which adds pollutants to the downstream of Finca'a, Amerti, and Nashe water bodies and causes dam sedimentation [21,33,34] and leads to a problem of reservoir erosion, which agrees with studies by Ref. [9].

To save such sedimentation, significant funding is required, which will have an impact on the economy. Likely, as conducted at the Fincha'a watershed, the mean annual soil loss rate was 33.66 ton/ha/yr [11] which confirms with this result finding. Similarly, at the Gudar sub-watershed, the mean annual soil eroded was 25.23 ton/ha/yr [9]. These researchers agreed with this result in the area that observed severe soil erosion, particularly at Shambu and Sekelaa, the mean annual soil loss was 25.84–32.27 ton/ha/yr that is more than severe in other areas. In the same way, near the study area in Fincha'a watershed as studied by Ref. [18] annual soil loss was categorized into four ranges: very low (0–15), low (15–45), moderate (45–75), and high (>75) for the past year that mostly agrees with this finding. Therefore, severity of soil loss in the country was differ from place to place [5,17,29].

5. Conclusions and suggestions

5.1. Conclusion

In this study, modeling and quantifying the annual soil loss rate of the Horo district provided several insights into soil erosion hazards and were classified into five classes. These were: very slight (0–10), slight (10–20), moderate (20–30), severe (30–50), and very severe (>50) severity of soil classes. As the result revealed that the amount of 62.75% were under very slight, 23.92% slight, 6.44% moderate, 1.84% severe, 1.22% very severe of soil erosion. The other parts were 3.85%, which is water bodies of the total area. Based on these, it can be concluded that soil erosion is very severe in the study area and ranging from 0.01ton/ha/yr to 216.01ton/ha/yr at the study area. According to the findings, the mean annual soil loss at Shambu and Sekela was 18.99–32.27 ton/ha/yr and at Burkitu abora, Bone abuna, Leku legu, Harbe kekelo, Haro aga, Gitilo dale, Lalu lgu, Refinti–chabr, and Ejersa Meca were 14.04–18.99ton/ha/yr indicating a very severe and severe severity of soil loss respectively. Also, the mean soil erosion observed in the farmland was also above the tolerable soil loss rate. As a result, the study area is prone to soil erosion, which can affect and challenges the sustainability of soil for agriculture in the area in the long run if the trend is continued without applying soil erosion control mechanisms. Therefore, using GIS technologies with the RUSLE model for erosion risk characterization is an effective and accurate assessment with a concern for cost-effectiveness and time duration. The model provides an erosion risk map for the analysis of planning and environmental protection for the sustainability of soil resources. Furthermore, the model can provide decision-makers with areas of high erosion risk so that they can develop soil and water conservation plans in general and specifically, for the study area to prevent soil erosion for the areas of high erosion risk.

6. Suggestion

Based on the result, the following are proposed for the study area, both non-governmental and governmental organizations should have the following points:

1 Local people, stakeholders, farmers, and experts should have to give prioritization the highest eroded area for conservation to reduce the effects of soil erosion.
2 Governments and non-governmental organizations must seek solutions for the local people to reduce such problems on the soil and reduce such environmental challenges and soil loss at each kebele, especially at the areas with the highest risk of soil loss.
3 For future researchers, integrated watershad management research projects at the highest soil erosion severity, such as Shambu, Sakela, Burkitu abora, Bone abuna, Leku legu, Harbe kekelo, Haro aga, Gitilo dale, Lalu lgu, Refinti-chabr, and Ejersa Meca, should be needed to save soil resources. Then come areas with moderate soil loss to control soil loss.

Author contribution statement

Gamtesa Olika: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.
Gelana Fikadu: Performed the experiments; Wrote the paper.
Basha Gedefa: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

Ethics approval and consent of participants

Not applicable.

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