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Assessing the Impact of Soil Erosion on Residential Areas of Efon-Alaaye Ekiti, Ekiti-State, Nigeria

Olusa Adekemi Opeyemi[1, *], Faturoti Helen Abidemi[2], Otokiti Kolade Victor[3]

Department of Urban and Regional Planning, Federal University of Technology, Akure, Nigeria

Abstract

Soil erosion is a persistent process that continues relatively unnoticed, or at an alarming rate causing serious threats to soil. About 84% of the global land loss has been attributed to erosion. Accordingly, erosion is one of the most significant environmental problems worldwide. In this paper, Revised Universal Soil Loss Equation (RUSLE) and Geographical Information Systems (GIS) were used to assess the impact of soil erosion on residential areas of Efon-Alaayee Ekiti, Ekiti State, Nigeria. Soil erodability, slope, land cover and support practice factors were the variables used to investigate the impact of soil erosion in the study area. As an output, a soil loss map was developed and the total land area at risk of being lost to erosion was estimated from the analysis. The soil loss map was calculated to be between 0 to > 756.60 tons per hectare (31.9 sq.km) in a year. The soil map was classified into four categories based on erosion risk classes, namely: slight, moderate, high and very high. The result indicates that 21.8 sq.km area is under slight class, 6.5 sq.km area is under moderate class, 2.7 sq.km is under high class while, 0.54km sq.km area is under very high class.

Keywords

Land, Land Use, Residential Land Use, Erosion, Soil Erosion, Rusle Model

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1. Introduction

Soil erosion is a persistent process that continues relatively unnoticed, or at an alarming rate causing serious threats to soil [1]. Soil erosion is "the resultant effect of the cumulative rainfall and surface runoff. If rain hits bare soil with sufficient intensity, the raindrops' kinetic energy causes the detachment of soil particles (splash erosion), moving them at short distance (on-site effect). When surface runoff begins (shallow, uniform flow with no erosive ability), it can only "wash away" these particles (sheet erosion). As overland flow concentrates, it gradually obtains erosive characteristics (increasing discharge, turbulence), forming channels of progressive size (inter-rills; rills; gullies) and being able to detach more particles on its way to the water bodies. Detached soil descends as sediment downstream, where is eventually deposited in reservoirs, lakes, river beds or coastal areas" [2].

Soil erosion is one of the serious and continuous endemic environmental problems with various social and economic impacts [3]. All over the world, soil is being swept and washed away 10 to 40 times faster than it is being replenished, destroying cropland the size of Indiana every year. Regional soil loss historically plagued societies around the world and continues today at a very high pace due to the fact that the rate of soil loss is far above rates of soil production [4].

Land degradation, soil fertility loss and river siltation are the major manifestations of soil erosion [5]. By and large, land

* Corresponding author
E-mail address: Kemiogundiran2001@yahoo.co.uk (Olusa A. O.), faturotiellenah@gmail.com (Faturoti H. A.), otokitikolade@gmail.com (Otokiti K. V.)

degradation is caused by water and wind erosion. About 84% of the global land loss has been attributed to erosion. Accordingly, erosion is one of the most significant environmental problems worldwide [6]. If the current trend of soil degradation continues, Africa as a continent would not be able to feed 25% of its populace [7].

The manifestation of erosion affects several land uses such as agriculture, commercial and residential which leads to destruction of landed properties like real estate among others, the manifestation is also visible on roads which as lead to their deterioration [8, 9]. It was discovered that, soil erosion problem is more severe in an environment that is characterized by chain of hills in form of ridges, steep slopes, undulating topography and precipitation. These are glaring landforms in Ekiti State as well as Efon Alaaye that are capable of increasing the effect of soil erosion.

All these effects of erosion call for action and there is urgent need to investigate the reasons for erosion occurrence on the different land uses especially on the residential land use, which has led to some of effects explained above. There is also a need to determine possible ways of reducing the effect of erosion on the land uses which could be through development control policies, which could check development in areas susceptible to erosion.

The Universal Soil Loss Equation (USLE) was developed by Wischmeier and Smith of the United States Department of Agriculture as a field scale model in the 1960s [10]. The model was developed to estimate erosion risk. However, the model was revised by Renard in 1997 in an attempt to better estimate the values of the various variables in the USLE and consequently, RUSLE model (Revised universal soil loss equation) was developed [11]. In this study, RUSLE model was integrated with GIS so as to estimate the impact of erosion on residential areas of Efon-Alaaye Ekiti, Ekiti-State, Nigeria.

2. Study Area

The history of Efon-Alaaye, as an ancient town, dates back to 1200 A. D. In accordance with the historical facts, the founder and the first Alaaye of Efon-Alaaye was Obalufon Alaayemorea generation of Oduduwa. Efon is arranged in the tropical zone. In the dry season, the town encounters exceptionally extreme harmattan with temperatures high in the evenings yet low in the nights. The dry season starts towards the end of October and closes in right on time March; the drizzling season starts in April and closes in October; Efon Alaaye atmosphere supports a rich timberland development.

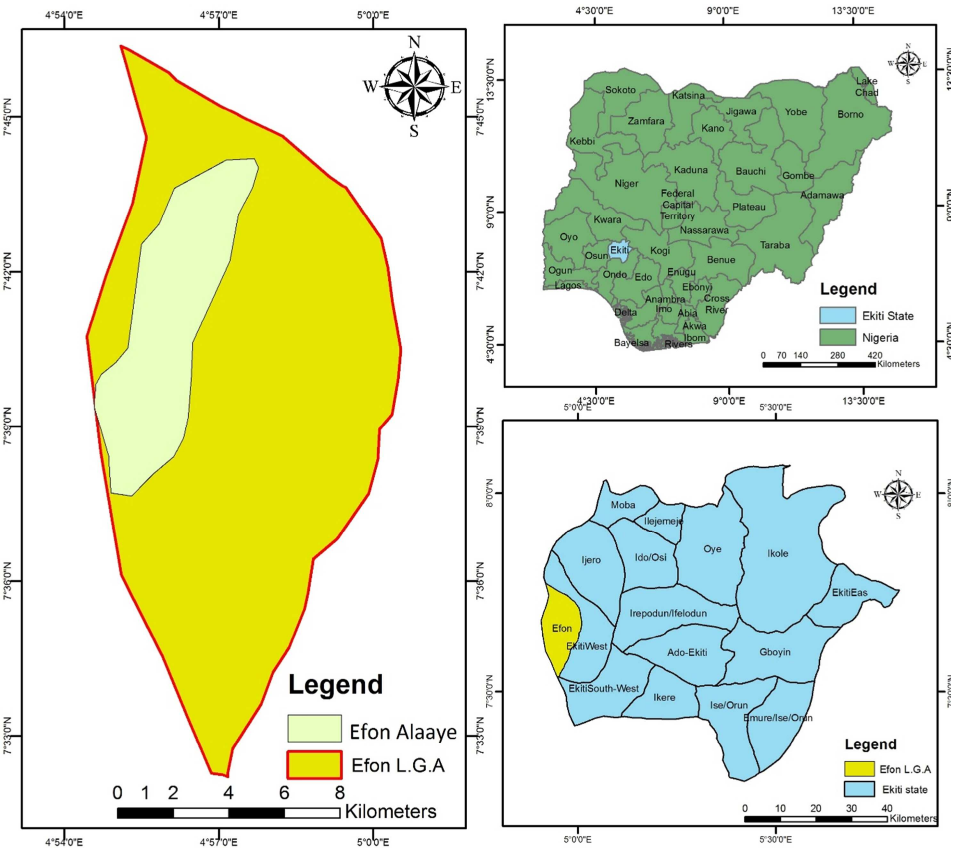

Figure 1. Efon-Alaaye in its National, Regional and Local Settings.

Source: Ministry of Surveys, Abuja (Digitized in ArcMap, 2018 by Authors)

Efon-Alaaye has a population of about 120,000 people [12]. Efon-Alaaye, the headquarters of Efon Local Government Council, Ekiti State is about sixty kilometers North of Akure, the Ondo State capital and about two hundred and eighty-six kilometers North East of Lagos, erstwhile capital city of Nigeria which can be seen on Figure 1. Efon-Alaaye situates in a valley and spreads over an area of about 31.9 squares kilometers. It is bounded round by chains of ridges rising to an average height of about 2000 feet above sea-level. Efon-Alaaye is located between latitude 7°40'N and 7°54'N and longitude 4°52'E and 5°0'E. It is situated on an elevation of about 500 metres above sea level. It is a very large town covering several hills, hill sides, plains and valleys.

3. Conceptual Frame Work

The conceptual framework for the study presents the components and relationships that are to be used as a framework to examine the effect of erosion on land. The conceptual model provides a working strategy for this study and contains general concepts and their interrelations. It orients the research towards specific sets of research questions and provides a baseline for the current research [13]. This study involves the mapping of erosion affected areas to determine the rate and the types of effect of erosion in the study area.

Calculating the amount of erosion on soil, could be carried out through the use of revised universal soil loss model. The essential qualifications of a science are the ability to define and to measure the causes and effect of the natural phenomena related to the subject, and the ability to predict what will happen in given circumstances. Measuring the effect of erosion is straight forward and measurements of weight of soil loss have been carried out as far back as a century ago by Wollny. RUSLE equation A = K x S x L x C, [14] this equation takes into account soil erodibility (K), slope steepness (S), slope length, (L) and cover factor or land use (C). The RUSLE is a revision of the Universal Soil Loss Equation (USLE), which was originally developed to predict erosion on croplands in the United States.

The RUSLE would be integrated into GIS environment to reduce the complexity of use. The model uses physically meaningful input variables that can be easily obtained from DEM and satellite images. RUSLE is the most suitable practical erosion prediction model that can be easily applied at both local and regional level [15]. Also, the slope map, soil type map, and LULC (land use land cover) derived from DEM were integrated with RUSLE.

With the revision, the equation can be employed in a variety of environments including rangeland, mine sites, construction sites, etc. The RUSLE is an empirical equation that predicts annual erosion. The RUSLE is factor-based, which means that a series of factors, each quantifying one or more processes and their interactions, are combined to yield an overall estimate of soil loss. It is the official tool used for conservation planning in the US and many other countries have also adapted the equation.

$$A = R * K * L * S * C * P$$

Where, A = Annual soil loss (tons/hectare) resulting from sheet and rill erosion.

R= Rainfall - runoff erosivity factor

K= Soil erodibility factor.

L= Slope length factor.

S = Slope steepness factor

C = Cover management factor.

P = Erosion control factor

The socio-economic impact of the effect of erosion on the people will be determined through the use of questionnaire. This method enables or encourages the active participation of people in the research. Information about the planning policy in this area could be gotten through a secondary means of data collection.

4. Methodology

This research made use of primary and secondary sources of data collection. Questionnaires which includes close and open ended questions were administered to the respondents. Primary data provides information on the social economic characteristics of respondent and the adopted mitigation measure and some other information used for the research.

Secondary data are gotten from internet, intellectuals and ministries, which provides information on the study area and provides information on some other fact. Data acquired from primary and secondary sources were analysed to achieve the aim and objectives of the research. The method of analysis for this research was actualized using two approaches that is, the statistical based and the GIS based analysis, used for the soil loss model.

4.1. Research Population

A total number of 4553 buildings which was determined through the digitization of a satellite imagery of Efon-Alaaye was used as the research population for this study,

4.2. Sampling Frame

The total number of buildings (4508) represents the sampling frame.

4.3. Sample Size

In selecting the sample size, 4% of the building was chosen. This sample size was selected using the Krejcie and Morgans principle of 1970 which assumes a precision of 0.04 margin of error which is equal to 4% which is applicable to social science researches

$$\text{sample size} = \frac{4 \text{ x } 4508}{100} = 180 \text{ questionnaires}$$

4.4. Sampling Techniques

Systematic sampling technique was adopted for this research, which required the selection of housing units from the total housing population of 4508 at a sample interval (k=25), to obtain the total sample size of 180. In the process of this sampling, the first building was selected randomly.

4.5. Data Collection Instrument

For the purpose of this study, data was collected using the field observation technique, questionnaire, and satellite imageries. The questionnaires prepared contained both closed and open ended questions, which covers the earlier stated sample size.

4.6. Procedure for Data Collection

For the purpose of this research, data needed were obtained from both primary and secondary sources in order to study the implication of erosion on land. Secondary data were acquired from various journals while the primary sources of data involved direct contact with the residents (respondents) in the study area to elicit information through questionnaire administration. The primary method of data collection used in this research work is questionnaire administration.

4.7. Method of Data Analysis

Data acquired from primary and secondary sources required analysis to achieve the aim of the research. The method of analysis for this research was actualized using two approaches: the statistical based and the GIS based analysis. The data obtained from the questionnaires was processed with the chi-square. Data are presented using charts tables map figures pictures and percentage frequency table.

5. Result and Discussion

5.1. Social Characteristics

The result of research showed in Table 1 reveals that 1% of the respondents had only primary education, 11% of the respondents had just secondary education, 22% of the respondents' level of education was technical or grade II, 15% of the respondents had tertiary education, and 18% went through other forms of education. About 33% of the respondents had no formal education. The low level of education can be a contributing factor to erosion due to lack of knowledge on how to go in order to avert disasters.

The length of the stay of the respondents in the community, 23% 5 years and below, 5% for 6-10 years, 8% for 11-15 years, 11% for 16-20 years and 53% of the total respondents have being residents for over 20 years, the highest percentage have stay in this community for a long time to have experience series of erosion occurring which they can provide adequate information on.

The research indicated that 51% of the respondents earned below 10, 000 which was the average income level of all the respondents, 23% earned between 10,001-30,000, 10% were between 30,001-50,000, 9% earned between 50,001-70,000, 7% of the respondents' income level was within the range 70,001- 90,000. Low income of the respondent could be a contributing factor to the type of construction and the type of erosion mitigation technique that is adopted in the area, which have not in any way reduce erosion risk or susceptibility.

Table 1. Social Characteristics of the Respondents.

Variable	Frequency	Percentage (%)
Level of education		
No formal education	60	33.3
Primary education	2	1.1
Secondary school	20	11.1
Technical/grade	39	21.7
Tertiary	27	15.0
Others	32	17.8
Duration of stay		
<5yrs	42	23.3
6-10yrs	8	4.4
11-15yrs	15	8.3
16-20yrs	20	11.1
20yrs	95	52.8
Income		
<10,000	92	51.1
10,001-30,000	41	22.8
30,001-50,000	19	10.6
50,001-70,000	16	8.9
70,001-90,000above	12	6.7

Source: Authors' Fieldwork, 2018

5.2. Rusle Model

The Universal Soil Loss Equation (USLE) was first developed in the 1960s by Wischmeier and Smith of the United States Department of Agriculture as a field scale model. It was later revised in 1997 in an effort to better estimate the values of the various parameters in the USLE.

There are five major factors that are used to calculate the soil loss due to erosion for a given site. Each parameter is the arithmetic estimate of a specific condition that affects the severity of soil erosion at a particular location. The calculated erosion values reflected by this model can vary significantly due to fluctuating weather conditions. Thus, the erosion values obtained from the RUSLE (Revised Universal Soil Loss Equation) more accurately represents long-term averages [16].

5.2.1. K factor

The soil erodability factor is an empirically derived index that indicates susceptibility of soil to rainfall and runoff detachment and transport (rates of runoff) based on soil texture, grain size, permeability and organic matter content. The soil erodability factor (K) represents the effect of soil properties and soil profile characteristics on soil loss. Soil high in clay tend to have low K values (0.05-0.15) because they are more resistant to detachment. Figure 2 shows the raster created for the K factor, which is sandy loam which has low K which composes of 50% sand. Note, this could be a result of the topography of this area. The K value for sandy loam was 0.13.

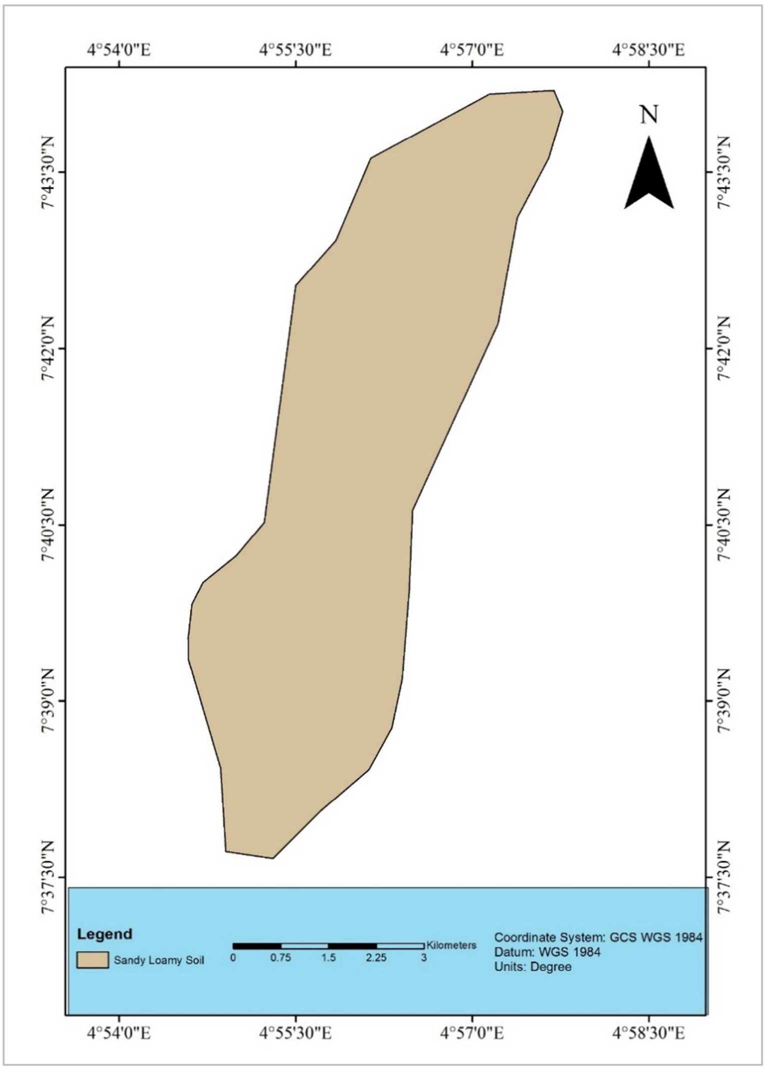

Figure 2. Map Showing Soil Type in the Study Area.

Source: Authors' Field Work, 2018

5.2.2. Slope Length and Slope Steepness Factor (LS)

The effect of topography on soil erosion is accounted for by the (LS) factor in RUSLE, which combines the effects of a slope length factor (L), and a slope steepness factor (S). According to Table 2, it was illustrated there the amount of building that falls within the different slope classification, slope 0-6.16 which was classified to be low, which means the erosion level in this area will not be as much as other categories. Medium which slope ranges from 6.16-18.88 next which is high with slope length 18.88-45.48 category and the last category which was classified as very high with slope length 45.48-98.28 all things been equal the rate of erosion increases simultaneously with the increase in the slope length and steepness.

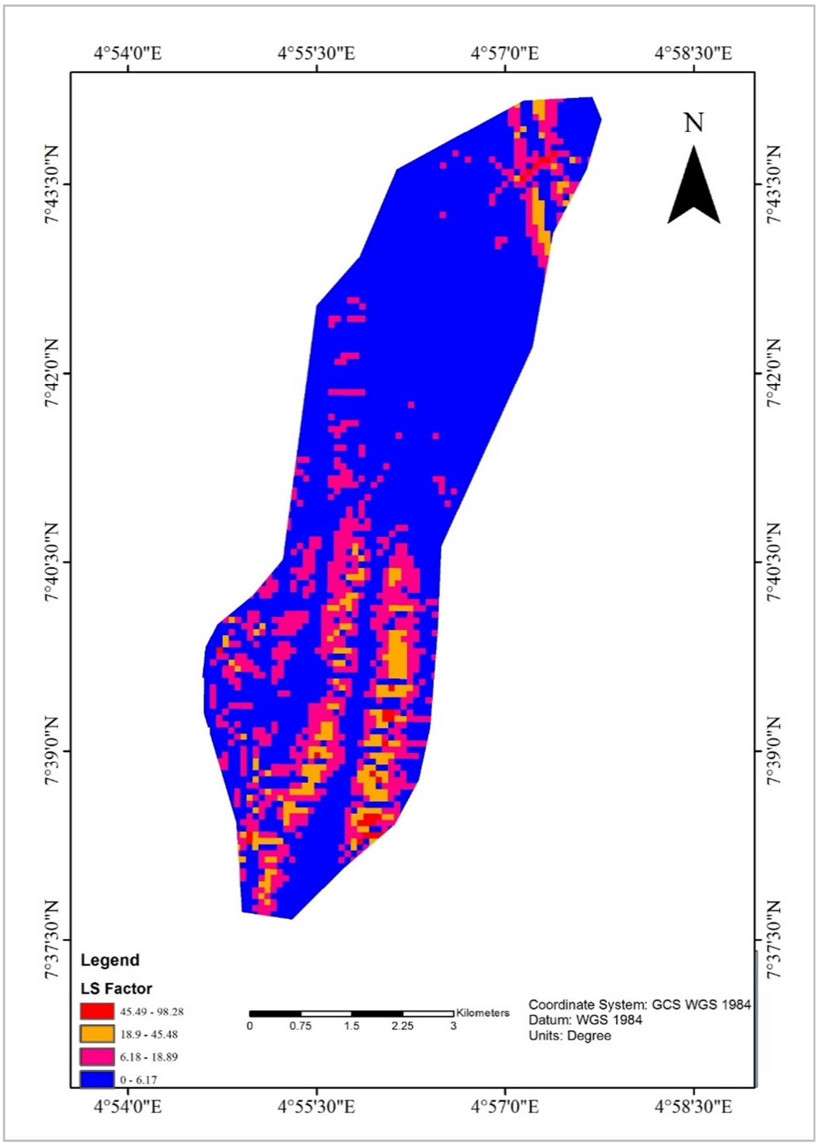

Figure 3. Slope Length and Slope Steepness Factor.

Source: Authors' Field work, 2018

Table 2. Slope Length and Slope Steepness.

S/N	Rate	Slope	Number of Buildings	Area (in sq. km)	Percentage (%)
1	Low	0-6.17	3511	23.10	78.0
2	Medium	6.18-18.89	928	5.80	20.5
3	High	18.90-45.48	59	1.78	1.2
4	Very high	45.49-98.28	10	0.2	0.2
Total			4508	31.9	100

Source: Authors' Field work, 2018

5.2.3. Land Cover and Management Factor (C)

The land cover and management factor represent the effects of vegetation management and erosion control practices on soil loss, the value of which ranges from 0 in water bodies to slightly greater than 1 in barren land. According to Table 3 the classification was in 3 different categories; high medium and low vegetative cover. The Rate of erosion in area with low vegetative cover (0.049-0.500) is higher than places with higher vegetative, medium vegetative cover (0.003-0.049) then followed by high vegetative cover with 0-0.003.

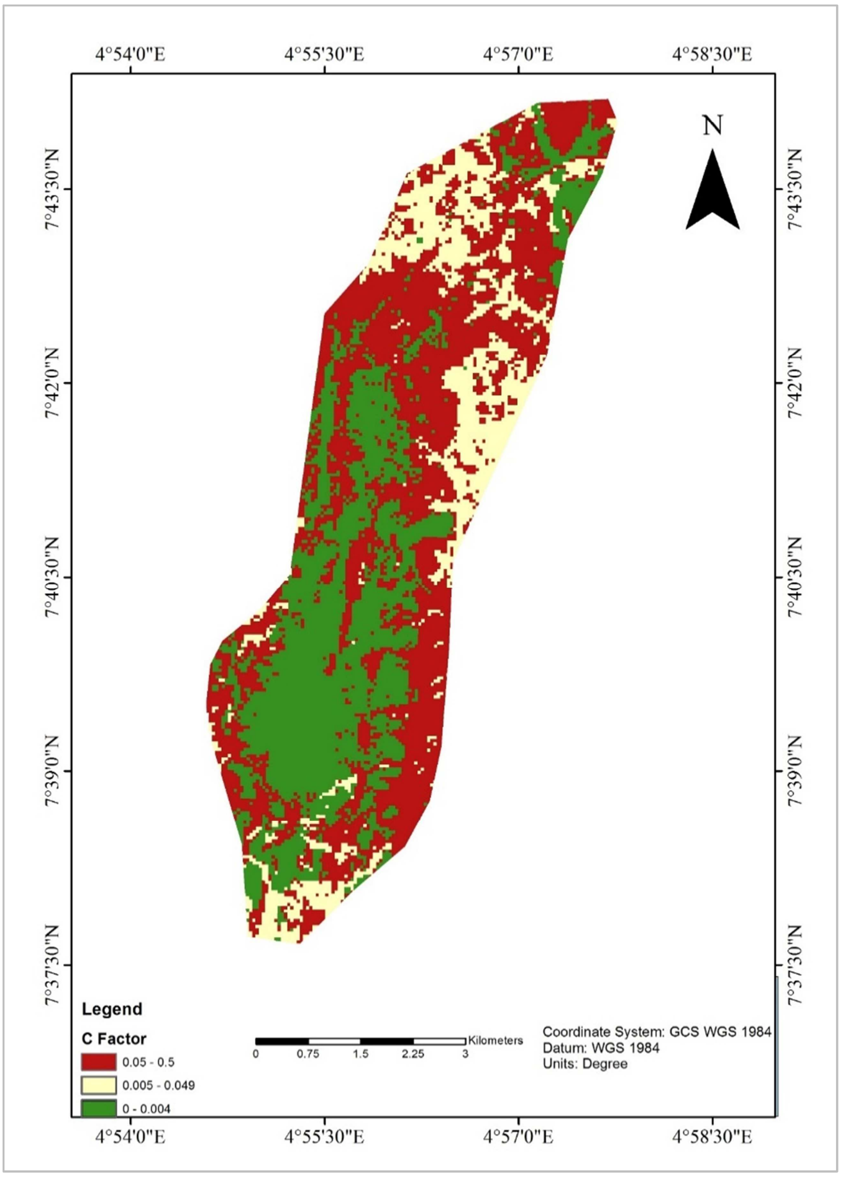

Figure 4. land cover and management factor (C value) of the study area.

Source: Authors' Field Work, 2018

Table 3. land Cover and Management Factor (C value) of the Study Area.

S/N	Rate	Vegetation cover	Buildings	Area (in sq. km)	Percentage (%)
1	High	0-0.004	214	11.1	93.9
2	Medium	0.005-0.049	4024	5.6	0.2
3	Low	0.050-0.500	270	15.1	5.7
Total			4508	31.9	100

Source: Authors' Field work, 2018

5.2.4. Support Practices Factor (P)

Erosion control practice factor (P-factor) is the ratio of soil loss with a specific support practice to the corresponding loss with up slope and down slope cultivation. The P-factor map generated is used for understanding the conservation practices being taken up in the study area. The erosion control practice factor accounts for the control practices that reduce the erosion potential due to runoff. Table 4 shows the distribution of support practices, factor 0.200-0.337 was discovered to have little contribution to erosion control, its effect covers total land area of 21.8km unlike band 0.695-1.092 which as more effect than every other category. Its effect covers 0.54km land area.

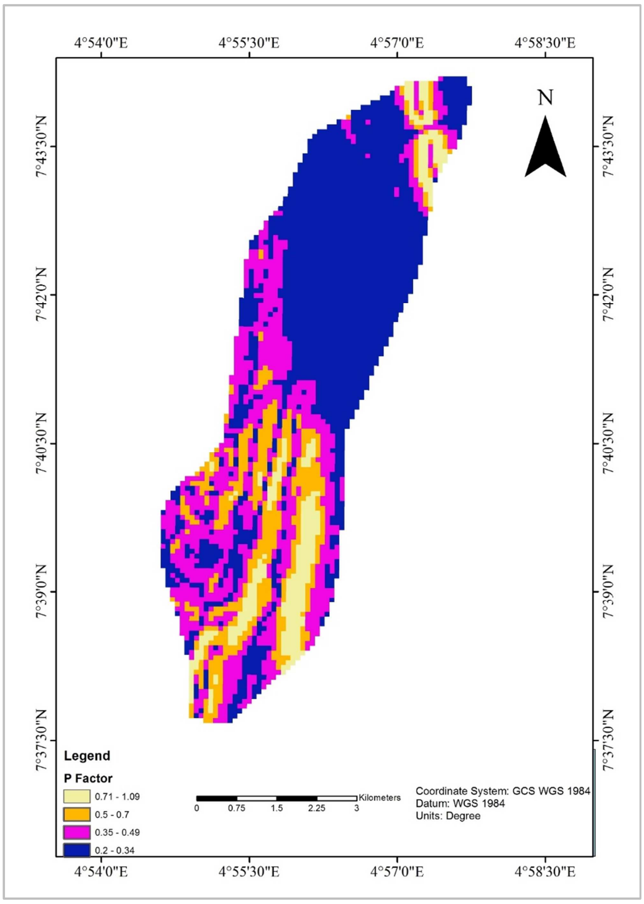

Figure 5. Support Farm Practise Factor.

Source: Authors' Field Work, 2018

Table 4. Support Farm Practise Factor.

S/N	Rate	P Factor	Area (in sq. km)	Percentage
1	Low	0.20-0.34	21.8	68.3
2	Medium	0.35-0.49	6.7	21.3
3	High	0.50-0.70	2.7	8.4
4	Very high	0.71-1.09	0.54	1.7
Total			31.9	100

Source: Authors' Field work, 2018

5.2.5. Soil Loss

Soil loss to erosion which also shows the erosion risk varies within a geographic area. The occurrence of soil loss due to soil erosion has a close relationship farm practices along with topographical characteristics such as slope length and steepness [16] this reason could be related to all the variables already discussed in, the above figures all this factors together gives the total soil loss.

Table 5 shows the soil loss in Tons per hectare in a year alongside the land area. The prediction goes this way, land area of 21.8km will lose about 0-23.74 tons/ha/yr. 23.75-106.81ton/ha/yr. will be lost from land area of 6.5km, 106.82-329.34 tons/ha/yr. will be lost from land area of 2.7km and 329.35- >756.60 tons/ha/yr. 0.54km. This implies that about 0.54 km is at very high risk of soil erosion and this area of land could be lost to erosion if proper care is not taken.

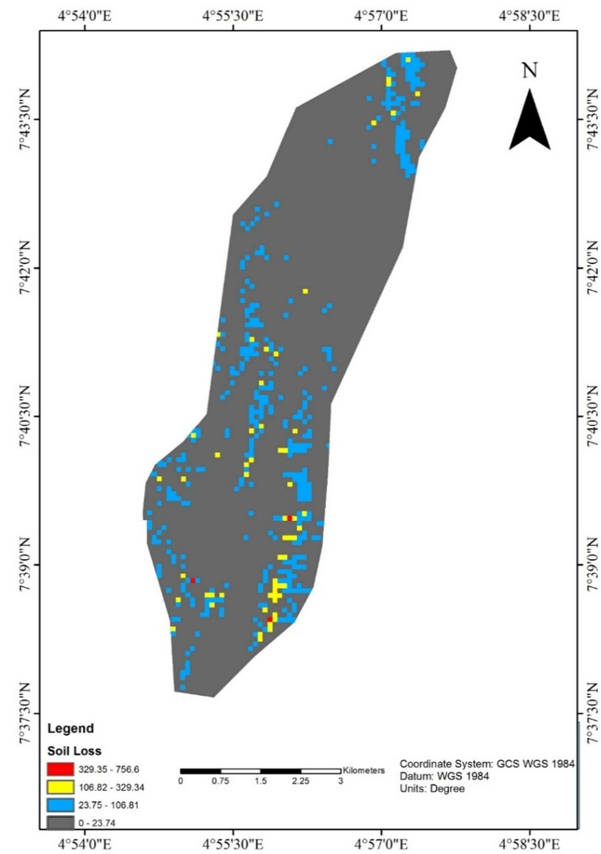

Figure 6. Total soil loss.

Source: Authors' Field Survey, 2018

Table 5. Total Soil Loss.

S/N	Rate	Soil loss per ton/hectare/yr.	Number of buildings	Area (in sq. km)	Percentage (%)
1	Slight	0-23.74	4416	21.8	98.0
2	Moderate	23.75-106.81	70	6.5	1.6
3	High	106.82-329.34	15	2.7	0.3
4	Very high	329.35-756.60	6	0.54	0.13
	Total		4508	31.9	100

Source: Authors' Field work, 2018

6. Conclusion

This research was embarked on due to the desire to provide a residential environment that has low susceptibility to soil erosion. In this study socio economic characteristics of the respondent were investigated, the soil loss map or erosion risk map of the study area was developed, and the estimate of the total land area at risk of being lost to erosion was determined.

Through the research it was discovered that all the land area experience soil loss due to erosion but at different magnitude. Implementation of some preventive measures like; Consideration of soil property, Control of slope and steepness, Adoption of proper drainage system, Drainage construction and maintenance, Adoption of surface cover could help to reduce erosion vulnerability.

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