Using Remote Sensing and Geographic Information System in Predicting Area Vulnerable to Gully Erosion

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***Abstract*-The rate at which gully erosion destroy land and properties in our environment is so alarming and this is as a result of deforestation, bush burning, land clearing for agricultural purposes and road construction which resulted into wide spread of soil erosion and later metamorphose into gully erosion if not restricted. This research tends to map out areas vulnerable to gully erosion in Mubi Local Government of Adamawa State using Revised Universal Soil Loss Erosion Equation (RUSLE) model. The rate at which the top soil is been washed away by rain water through the initial development of rill erosion and at large to gully erosion will be dangerous to human existence in the years to come by the increase in rainfall due to the change in the ozone layer. The False Colour Composite (FCC) of 1999 LandSAT ETM image was derived by the use of band 4, 3, 2 RGB of the multi-spectral scene so as to identify different features in the area of interest. The composite image was classified into six and reclassified to enable assigning of the index values to individual classes as derived using Agricultural Handbook 703, the Cover Management (C- factor), the support Practice (P-factor), Soil erodibility (K-factor) and the Rain Erosivity (R-factor) were derived using the same reclassification process. The integration of RUSLE and Geographic Information System (GIS) enable the mapping, prediction and calculation of annual Soil Loss. With the current depletion in the ozone layers, deforestation, bush clearing and agricultural activities going on in Mubi and its environs, it is expected that rainfall will increase and rill erosion routes will develop into gullies in the years ahead.**

Keywords-Gully erosion, Soil loss, Soil erodibility, Rain erosivity, Digital Elevation Model,

INTRODUCTION

The interaction between environmental change in Land use, Climate and Land degradation assume an important role for environmental manager, scientist and the policies maker. Lang and Bork (2006) states that "Gullies are part of the morphological proves of past soil erosion with impacts on environmental change in the landscape". Moreover, there are evidence that gully erosion occur in various parts of the world and study reveals that increase in gully erosion in an environment induced by socio-economic changes, such as forest to cropland. Gullies are stream channels which their width and depth does not allow farming process. An arbitrary depth of 0.5 meters therefore has been established to differentiate between gullies and rills which resulted from concentrated flow process. Rills are water dependents from inter rill areas and behave as river channels than gullies. Hudson (1964)

Imeson and Kwaad, (1980) exert that enlarged ephemeral (cropland) gullies occurred due to filled rills by normal farming (tillage) process but are more complex and usually involves the relationship between the volume, speed and types of runoff; the susceptibility of the materials to erosion, or gully erodibility; changes in cover caused by land use and conservation practices. Gullies plays an important role in the development of land and its degradation process, it represents a vital sediment source in a range of environmental gullies and effective in transferring runoff and sediment from the uplands to the lowland valley bottoms and permanent channels where it aggravates the effects of water erosion. Grove 1951, Cater 1958 and Simson 1954 portrayed the development of valley is a risk to environment because they increase their links on the landscape and causes siltation of rivers and reservoirs'. Most of agricultural land, houses, and infrastructures are destroy on yearly bases.

Akpokodje, et al. (2010) says 'the potent movement of surface runoff upon rainfall events of high intensity, localized occurrence for frequently short duration, is of great concern, in that the erosive power usually finds focus relative to the differential erodibility of surface materials which gives room for the processes of gully erosion and when not checked in the early stages of badland formation, it change the topography and affect the relationships between the surface and subsurface circuits of the hydrologic cycle', and promote other types of soil degradation. The nature of these processes acertain that they are seldom seen right away as disasters in the making, which merit management in the form of corrective measures.

He also specify that gullies begins with the formation of rill, while the erosion progress downwards by cutting vertically walls in a cemented lateritic soil formation, one rainy season is enough to establish the formation of rills and when not control can progress into severe gullies which are not easily control or mitigate.

The rate of gully growth is governed mostly by the geotechnical properties of the soils and the energy of the surface run-off. Gully growth rates and initiation have increased in recent years because of increased population pressure and resultant vegetation cover denudation. Natural Resources and Water facts (2006) claimed that gully erosion is a highly visible form of erosion that affects soil productivity, restricts land use and can threaten roads, fences and buildings. Gullies are relatively steep-sided watercourses which experience ephemeral flows during heavy or extended rainfall.

The most common method for spatial erosion assessment is through integrating spatial data on erosion factors. The widely used is the Revised Universal Soil Loss Equation (RUSLE) Wischmeier and Smith, 1978), although many other erosion models exist that allow spatial mapping of erosion (Merritt et al., 2003). However, erosion models are all developed for a certain region and scale, and transferring a model to other scales or regions is not straight forward and may give poor or erroneous results. Furthermore, many erosion models require a large amount of detailed data on a wide variety of rainfall, soil, vegetation, and slope parameters. In data-poor environments like the developing countries, these data are often not readily available, or only at very coarse scales. Qualitative data integration methods that allow some flexibility in the selection and combination of erosion factors can provide a good alternative to erosion models. Selection of erosion factors can be region-specific, depending on the processes that occur and the key parameters that explain the variability of these processes within the region. Local or expert knowledge can provide important input to such qualitative approaches (De la Rosa et al., 2001; Sonneveld, 2003). Outcomes of these methods are generally a qualitative measure of erosion risk, which is the relative risk that erosion will occur at a certain location as compared to other locations in the region mapped.

Spatial data are needed for the application of both erosion models and qualitative methods. The scale or resolution of these data should correspond with the desired output scale of the mapping exercise (Woodcock and Strahler, 1987).

THE STUDY AREA

As stated by Max Lock Group (1973-1976), that Mubi lies in the Mandara hills, close to the Camerouns border.

Mubi Local Government Area lies between latitude 10º11'N and 10º16'N of the equator and longitude 13º20' E and 13º35' East of Greenwich Meridian in Adamawa State, Nigeria (Figure 1).

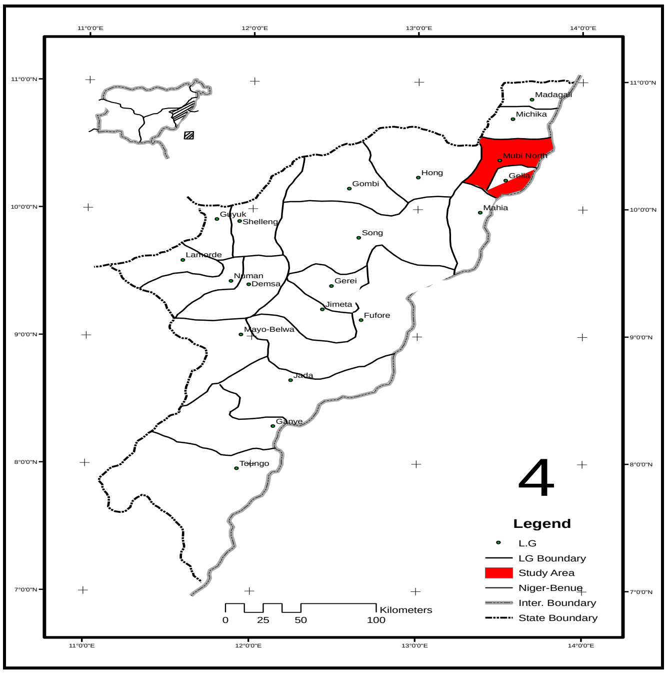


Figure 1: Map of Adamawa State showing the Study Area

It has had a chequered history since it first grew up as a settlement of the Ilega'en Fulani in the eighteen century. These people coming as pastoralist developed a symbiotic relationship with local tribes, exchanging their produce with that of the cultivators of crops. Sometime this lead to the Fulani settling more permanently themselves, cultivate the land and intermarrying with the local families. Each settlement was under the Ardo (or headman) who owed allegiance to a Lamido (chief) but it was not until the Jihado 1804-10 that the Fulani usurped power and claim suzerainty over local tribes. In this area their sovereignty was frequently challenged by the continued independence of spirit of the hill people which continue to-day.

Mubi was never an emirate and after the jihad came under the Lamido of Adamawa who added it to his kingdom with the approval of the sarkin Musulmi. The area seems to have been troubled by the second emir, Hamman, warring against the Fali of Mubi. In 1959 a plebiscite was held to decide on their future; as this was indecisive a further plebiscite was held in 1961 when a majority vote decides on incorporation into Nigeria. But instead of returning this land to Adamawa, a new province of sardauna was created to administer the erstwhile trust territorie, and Mubi became the capital of the province. The mainstays of Mubi economy are trade, agriculture,and its position as an administrative, service and institutional centre, there is a large central market held one day a week on Wednesday. Many of the market traders will move round from village market to village market during the rest of the week and Mubi relief and drainage comprised of predominantly upland and lowland with maximum and minimum height of 1036m and 523m above sea level, respectively with some few outcrops of hills around Vimtim in Mubi and Michika.

METHODOLOGY

The methodology for this research involved the use of RUSLE in a GIS environment. It include the use of Rainfall erosivity factor (R), Soil erodibility factor (K), topographical factor (DEM), Land cover factor (C), Conservation practice factor (P), and satellite imagery. Each GIS layer was developed for each factor and combined using the ArcGIS 10 software.

The land use map of the study area was classified from (Landsat TM, 1999) satellite imagery for information on different land uses classes of the studied area, ArcGIS 10 software was used to extract land data using the supervised method of remotely sensed data. By this method, ground truthing was used to compare the classified image with the real data relatively to the land cover of the study area. Supervised classification was used to control the classes by integrating classified image with the visual interpretation techniques. Meanwhile; the P-factor was also classified by assigning index values to represent the management practice within the area of study while the K, R-factor reclassified to match the index values of the soil erodibility and the rainfall erosivity factors. Hence the raster calculator was used to achieve the soil loss map by multiplying these factors using RUSLE equation.

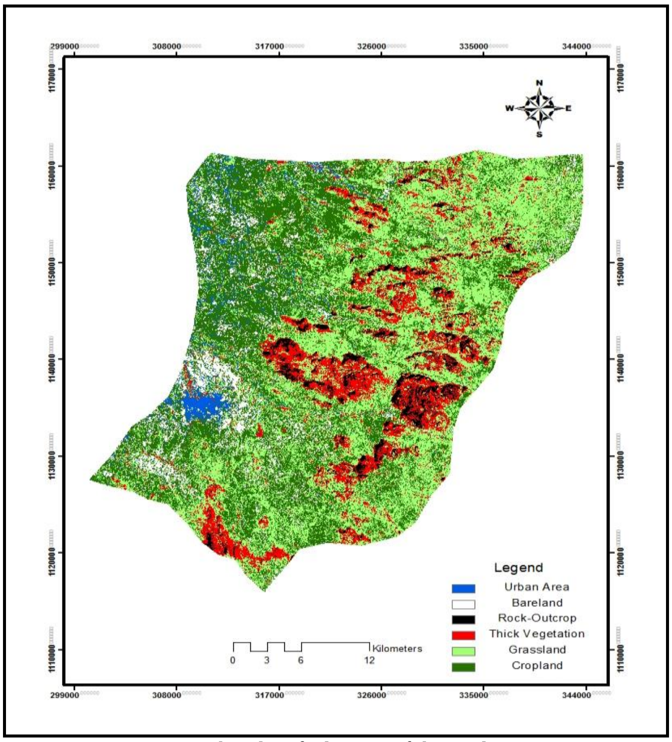


Figure 2: The Classified Image of the Study Area

Cover Management (C-factor)

The land cover reduces the rainfall energy with infiltration which is the ratio off soil loss of the same consequence bare fallow condition (Renard, Foster, Weesies, Mc Dool and Yonder, 1997). The parameters of the C-factor are influenced by anthropology which in turn enhances the erosion development.

The landSAT ETM image of December 1999 with resolution of 30mm was processed and classified, the C factor index that represent each land cover was calculated using Agricultural Handbook 703, and assigned the derived index values to their respective classes.

Soil Erodibility (K-factor)

The Rain factor (K) depicts how susceptible the soil is to the erosion and the rate at which the sediment are transported, the quantity and the quality of the runoff the K-factor image was prepared using the same classified image by reclassifying the image into relative soil type and assigning the index parameter of the respective soil type. For the purpose ot this research, the area covered has an homogenous type of soil and therefore the K- value selected for Mubi is 0.12mm. The rate of runoff measured under the Standard Unit Plot of Environment for soil with high clay deposits ranges from 0.05 to 0.15 because the resist detachment.

Rain Erosivity (R-factor)

The quantity of rain in an environment determines the modification of the R-factor, soil erosivity is the annual summation of the energy and the intensity (EI) value of a normal year rain. When other factors remain constant, the storm losses from rainfall are directly proportional to the kinetic energy of the storm (E), multiplied by the maximum 30 minute intensity (I). The annual rainfall of Mubi ranges from 750mm to 1050mm with an average rainfall index of 123mm.

Digital Elevation Model (DTM)

The Digital Elevation Model represent the topography of an area, it shows the nature either undulating or flat terrain. A DEM is a numeric representation of the spatial variation in the land surface elevation which represent the land surface as a matrix of elevation value (Z), implicitly located by their geographic coordinates (X,Y).

Support Practice (P) Factor

It is the ratio of soil loss with contouring and or strip cropping to that with straight row farming up-and-down slope. As with the other factors, the P-factor differentiates between cropland and rangeland or permanent pasture

Table 1: C and P factor of Mubi determined by using Agricultural Handbook 703)

Classes	C-factor index	P-factor index	Percentage Cover%
Urban Area	0.01	1.00	3.281
Bare land	1.00	0.70	51.037
Rock- Outcrop	0.90	0.60	4.694
Vegetation	0.03	0.04	8.963
Crop land	0.24	0.38	13.956
Grass land	0.12	0.42	18.069

The index value for C and P-factor were assigned to their classes on the images as slated in the table above.

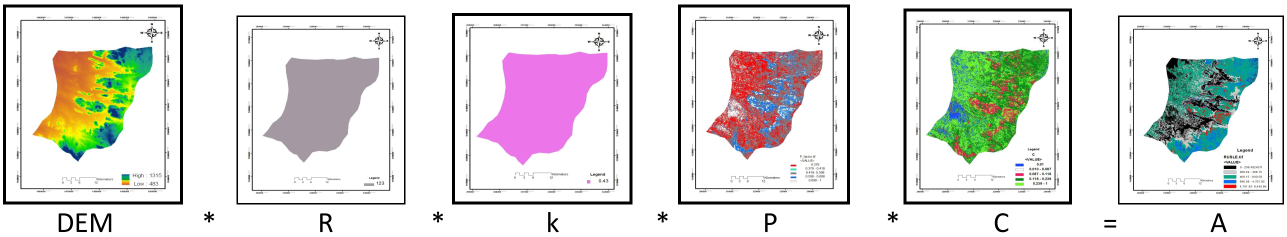
RESULT

The RUSLE equation A= C*P*LS*K*R was used to determine the annual average soil loss rate in ton/ha/year by the use of raster calculator of ArcGIS 10, the final output image depicts the vulnerability rate relatively to its locations in degree of effect from to the environment. The red portion of the map depicts the area with the highest vulnerability effect due to the runoff rate taking place on the slope of the mountain and the effects gradually transcend to other areas and if not mitigated or control, the rill erosion will metamorphous into gully erosion in a twinkle of an eye. The average Soil Loss for Mubi Local Area was determined to be 757.26 tons/acre/year and the maximum soil loss rate which is 9440.86 tons/acre/year. Gully erosion is a complex and heterogeneous hydrological process with hazardous effect to land and properties and the algorithm used for this research is widely used to calculate soil erosion of undulated areas, it is conceptually easy to use and to understand.

CONCLUSION

It was discovered that with the increase in rainfall in years ahead due to global warming, there is need to put in place measures to mitigate the effects of gully erosion within the study area, such as good afforestation, drainage system, excavations round the mountains to collect runoff water.

Therefore, the image multiplication that resulted into the vulnerability map are identify below.



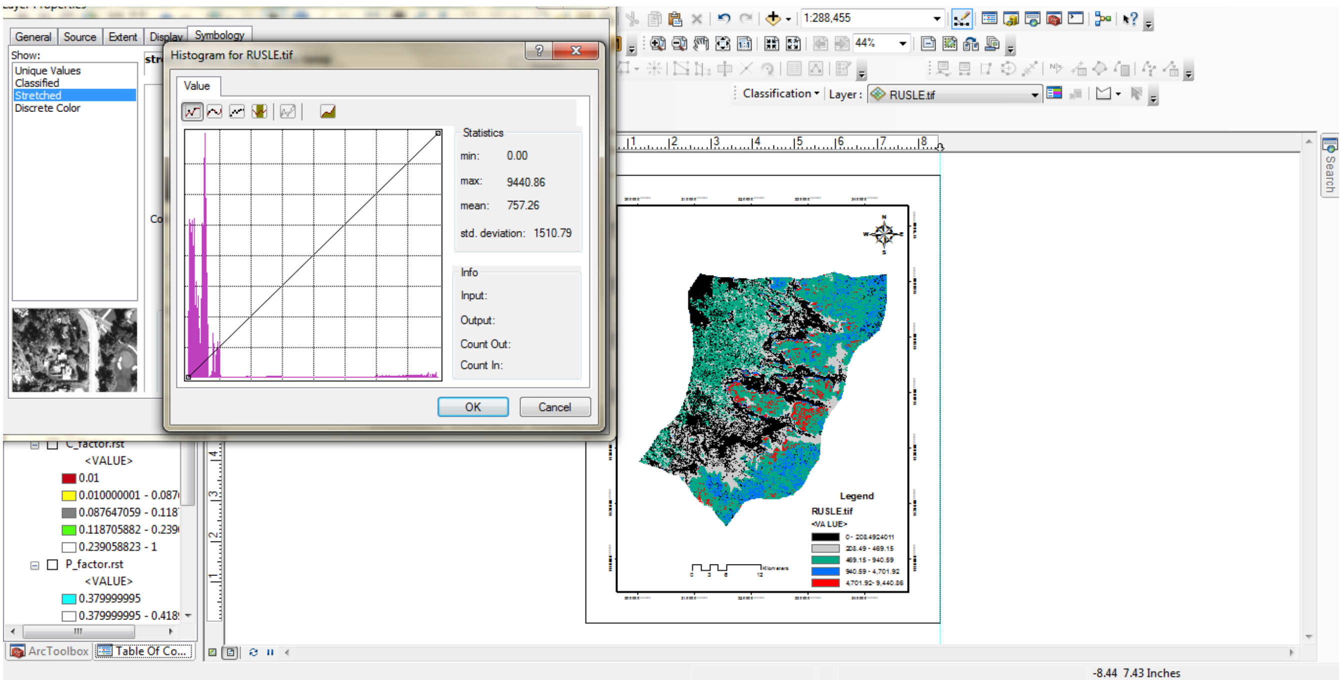


Figure 4: Histogram Display of average and maximum soil loss rate in ArcGIS 10

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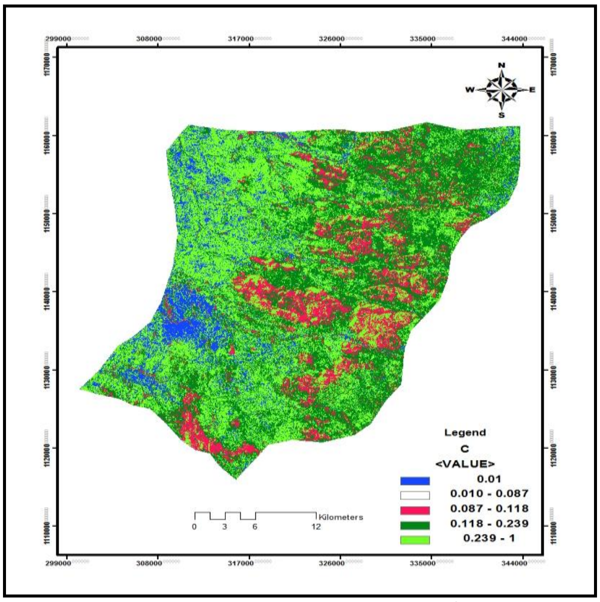

Figure 5: Cover Management Factor map of the study area.

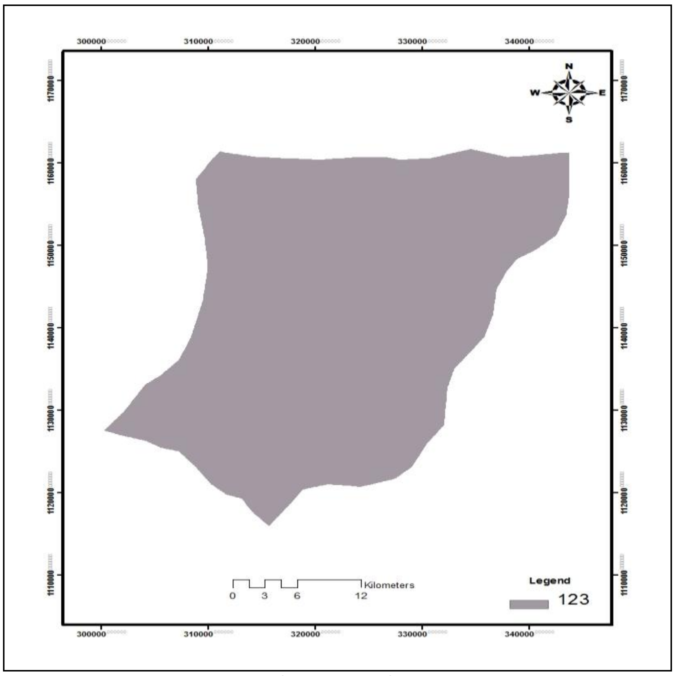

Figure 7: Rain factor map of the study area.

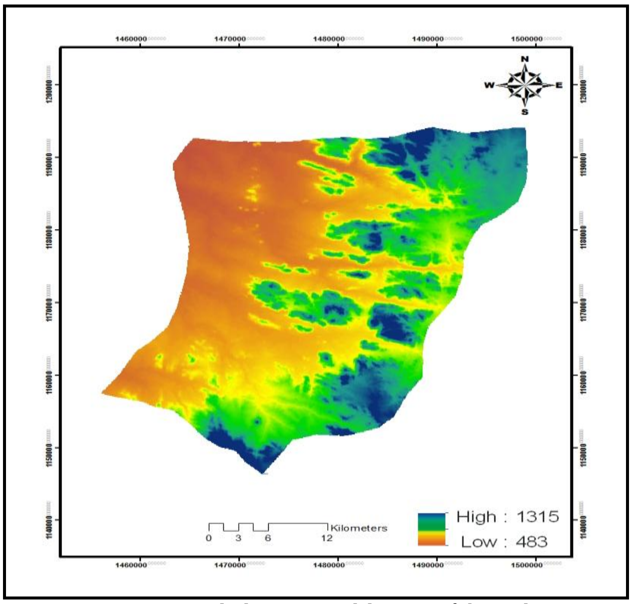

Figure 6: Digital Elevation Model Factor of the study area.

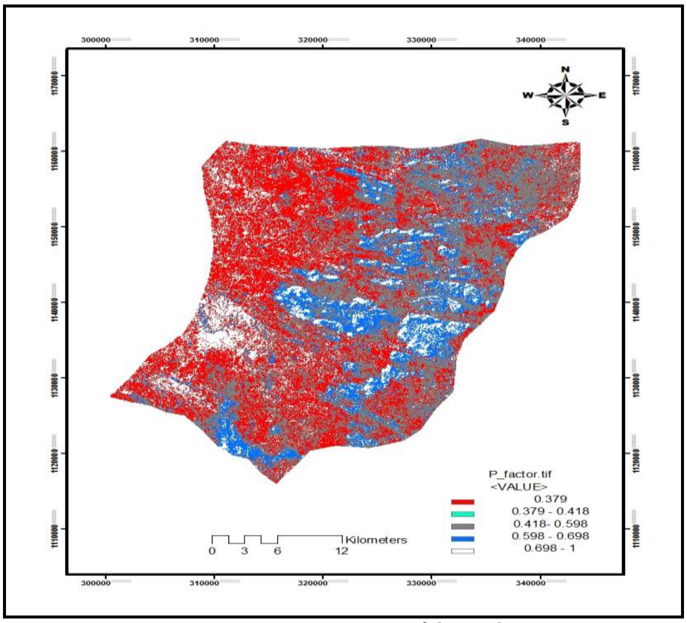

Figure 8: Support Practice Factor map of the catchment area

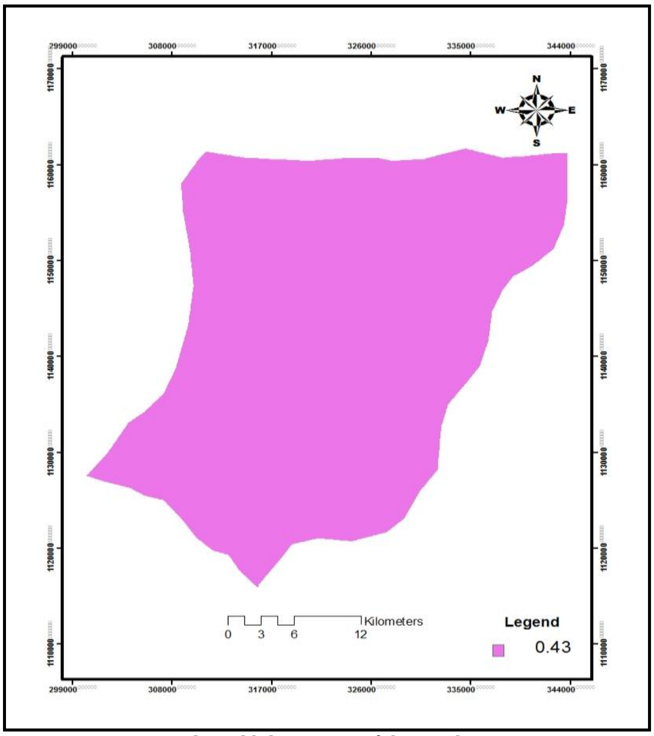

Figure 9: Soil Erodibility Factor of the Catchment Area.

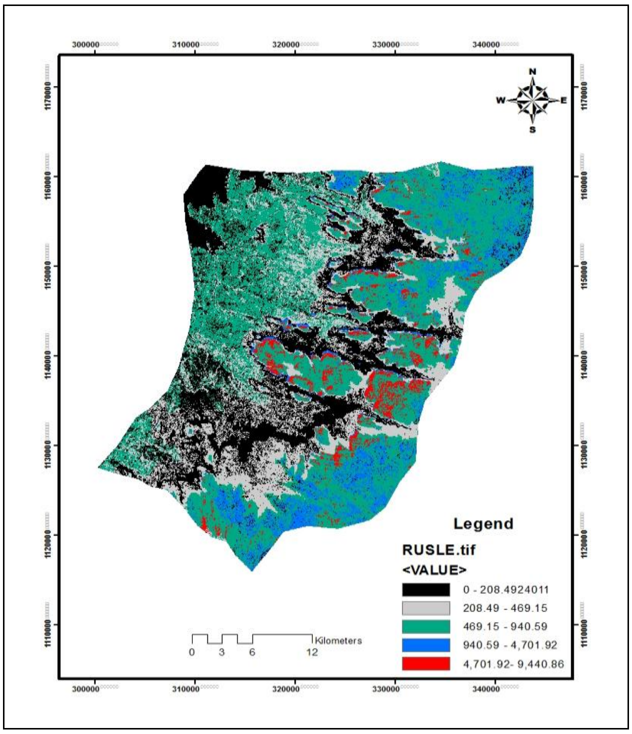

Figure 10:Map showing Areas Vulnerable to Gully Erosin