GIS Based Soil Erosion Model – A Case Study of Hanguranketha DS Division

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1. Introduction

Soil erosion is a natural process but it can be accelerated by human activity. Erosion is the removal of solids (sediment, soil, rock and other particles) in the natural environment. It usually occurs due to transport by wind, water, or ice; by down-slope creep of soil and other material under the force of gravity; or by living organisms, such as burrowing animals, in the case of bioregion.

Soil erosion by water is a serious problem in many parts of the world. It is categorized as the most serious environmental problem because it threatens agriculture and the natural environment (hago, d.w.1998). According to Hagos, the problem threatens to the condition of environment as well as to the productivity of land. Soil erosion represents one of the most serious depletions of natural resources in the world today on balance soil erosion damages both upland and lowland landscapes : habitat is lost, a productivity decline , carrying capacity is reduced , and the diversity of species is lowered marsh also described the threatens of environment by the soil erosion.

2. Objectives

The general objective of this research is to develop a GIS based model to identify soil erosion prone areas in Hanguranketha DS division area which are located in upper Mahaweli catchment area.

The specific objectives of this research are to:

01. Develop a GIS based model to identify soil erosion prone areas in Hanguranketha DS Division
02. Identification of the ability of geographic information system (GIS) to analysis and identify soil erosion in Hanguranketha DS Division
03. Identification of highly soil erasable area in Hanguranketha DS division

3. Methodology

3.1. Selected Area

Hanguranketha DS division has been selected for this study. It is located in Nuwara Eliya district which consist of 264 GN Divisions with an area of, 229 km^2. Selected area falls within the Mahaweli catchments. Soil erosion extensively takes place in the selected area due to various factors both natural and human influenced. Agricultural activities on steep slopes in the hilly area of the Hanguranketha DS division are common.

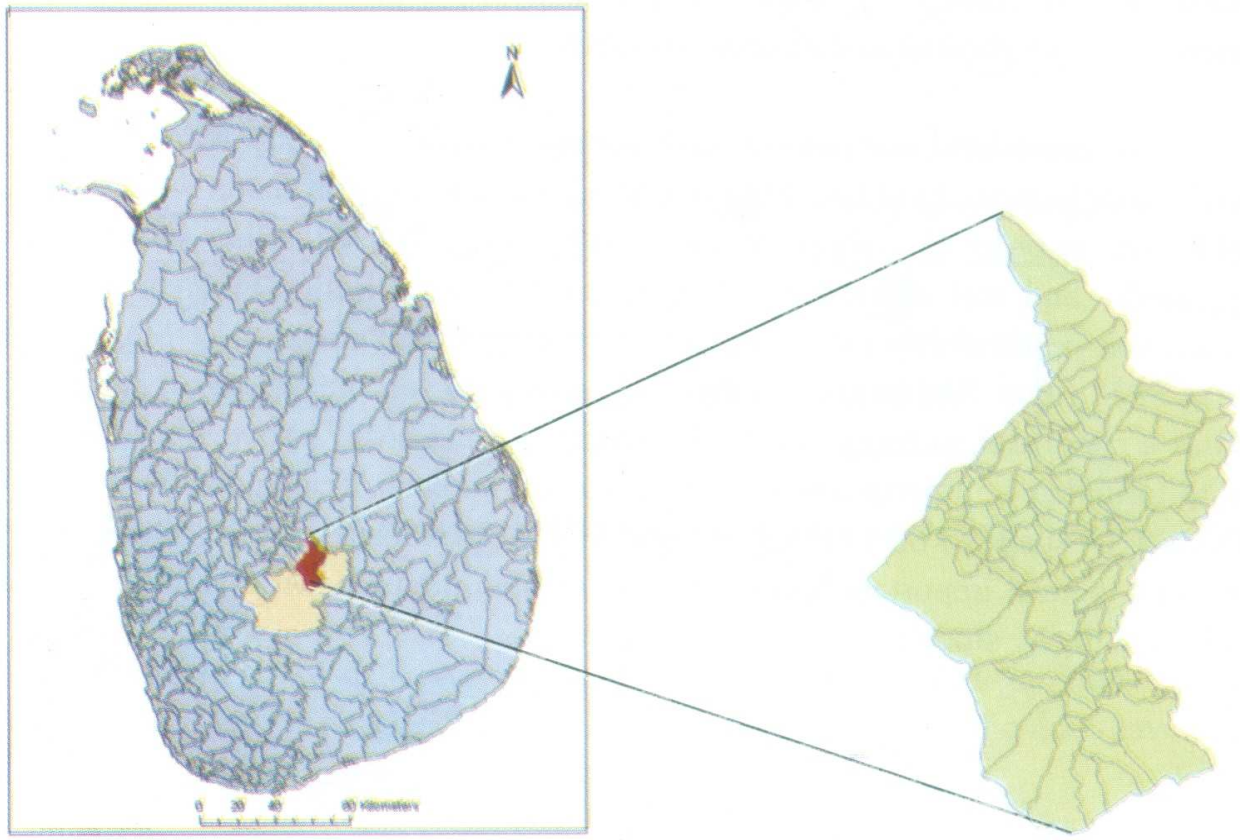

Figure 01- Selected Area

3.2 Data

1:50000 data of Hanguranketha DS division area, google earth data and 2009 rainfall data have been used for this activity as a secondary data. In addition to that field observation data were used as a primary source. Some land use patterns were updated after field observation.

3.3 Data analysis method

Four types of data sets (Land use, Rainfall, soil type, Contour) have been prepared using the above two data layer and Multi-Criteria Decision Making (MCDM) Suitable weight classes are used for this analysis. Figure 02 illustrates Conceptual framework which illustrated data analysis method.

All major land use pattern were considered for this study which are see in the selected area tocreate land Use Map (LUM) .Thiessen polygon maps were created using rainfall data in order to compile Water Volume Map (WVM) of the selected area. Soil permeability and soil strength maps were created using basic soil map of Sri Lanka. Further, soil permeability rate is used to formulate Soil Permeability Map (SPM) with help of SPT^1 value. Soil hardness is varying for soil to soil therefore soil hardness can be sued as a parameter to formulate Soil Strength Map (SSM). Above figure 02 illustrates how to formulate soil permeability map using soil hardens. Triangular Irregular Network (TIN) is a 3D shape of the contour line and TIN is a flat form to create Slope Maps (SM). Slope rate is most important part of the soil erosion model because soil erosion rate can accelerated the by slope of the land.

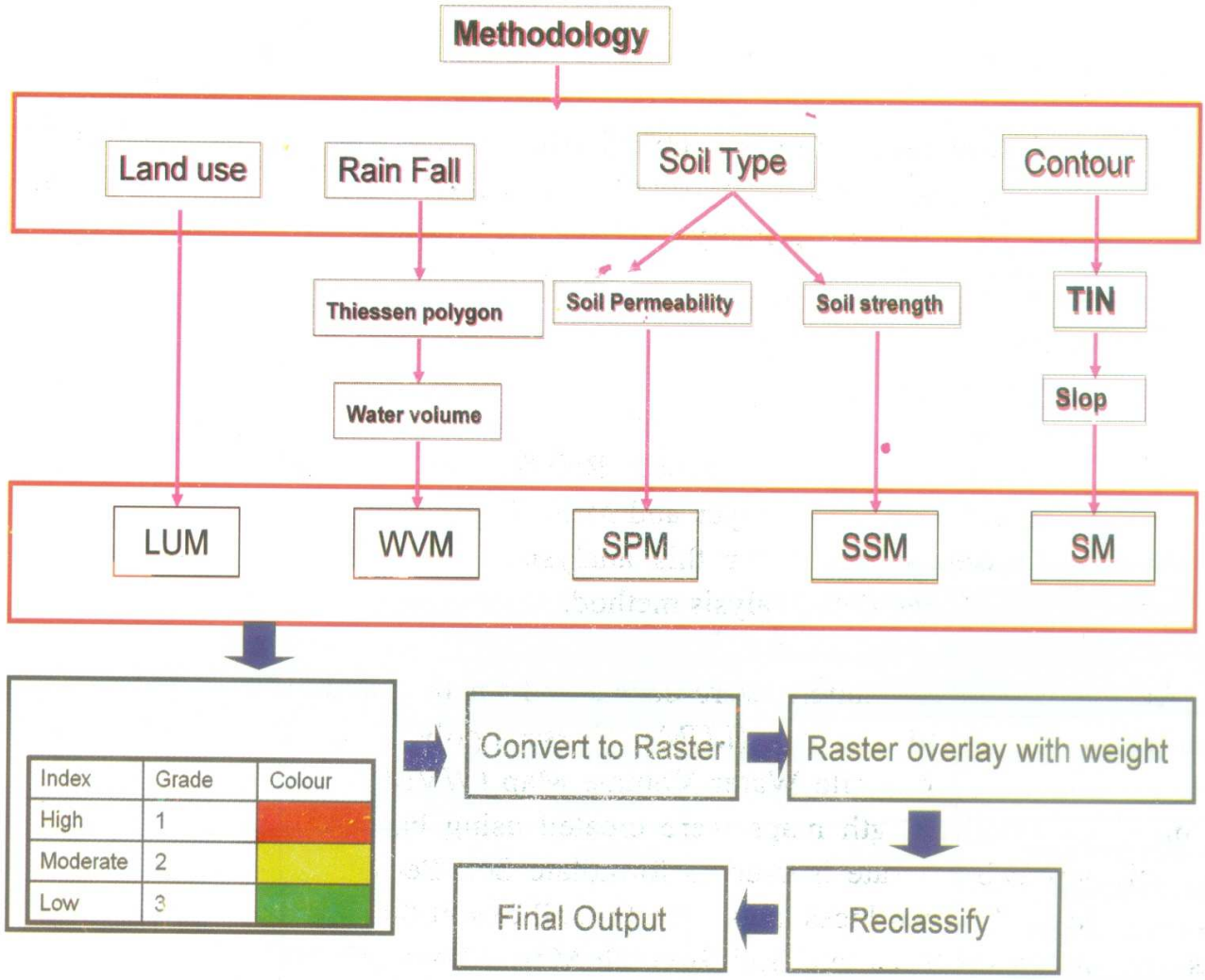

Figure 02 - Conceptual framework of data analysis

After creating a new data layer ranks are assigning to all data sets. Three kind of ranking have been used for ranking the each data set and three types of colour have been assigned for visual interpretation.

Each criteria is based on importance of the object. Following table 01 illustrates the ranking methods.

Table 01 – Ranking colour and value

Grading	Colour	Criteria
1	Read	High erodible
2	Yellow	Moderate erodible
3	Green	Low erodible

Sources – Central Environmental Authority GIS Laboratory

Following table 02 illustrates detail criteria list and each layer ranking category based on their importance which are discussed in table 01.

Table 02- Detail ranking table

No	Layer	Grade		
		1	2	3
01	Land Use	Chena, Other cultivation	Scrub land, Home Garden, coconut	Forest, Paddy, Reservoir
02	Water volume (Millimeter average water volume per Year)	>40000	30000-40000	<30000
03	Soil Permeability	Red-Yellow podzolic soils and mountain regosols Reddish brown letosolic soils, dissected hilly and rolling terrain	Immature brown loams, dissected, hilly and rolling terrain Reddish brown letosolic soils, dissected, hilly and rolling terrain Rendzina soils; undulating to rolling terrain Reddish brown letosolic soils, dissected, hilly and rolling terrain	Red-Yellow podzolic soils with prominent A1 or semi-prominent A1,\ Rendzina soils undulating to rolling terrain

04	Soil strength	Immature brown loams, dissected, hilly and rolling terrain Red-Yellow podzolic soils	Reddish brown letosolic soils, dissected, hilly and rolling terrain Rendzina soilsundulating to rolling terrain, Reddish brown letosolic soils, dissected, hilly and rolling terrain Rendzina soils; undulating to rolling terrain	Red-Yellow podzolic soils and mountain regosols Red-Yellow podzolic soils with prominent A1 or semi-prominent A1
05	Slop	60>	30 - 60	<30

Sources – Central Environmental Authority GIS Laboratory

After assigning ranks to each data layer, all data should be converted to raster. Hence, all data layers were converted to raster with 100 cell size. Next step of MCDM is raster overlay and weight assigning. Weights were assigned using pair wise comparison table in order to identify suitable index. Fallowing table 03 illustrates assigned weight class.

Table 03- Weight class and class normalization.

Attribute	Soil Permeability	Slope	Soil strength	Land Use	Water Volume	Total	Normalization
Soil Permeability	1	0.5	0.5	0.25	0.5	2.75	0.08
Slop	2	1	0.5	0.5	0.3	4.3	0.13
Soil strength	2	2	1	0.5	0.5	6	0.18
Land Use	4	2	2	1	0.5	9.5	0.29
Water volume	2	3	2	2	1	10	0.31
Total							1.00

Although other factors effect soil erosion, water is the major soil erosion agent of the selected area. Therefore, it has allocated higher weight for water volume. It is about 0.31 out of total. Preparing this table, importance of each criteria was considered and velocity of each criteria that affect soil erosion.

4. Out Comes

4.1 Soil Permeability

Soil Permeąbility is refers to infiltration rates of soil according to their soil types. If there is high soil permeability, there is less soil erosion because surface runoff determines soil erosion rate. That means high surface runoff can be created by high soil erosion. Soil permeability rate can vary according to types. Following figure 03 shows soil permeability ranking map which area based on soil types introduced by Agriculture department in Sri Lanka. Above table 02 (Detail ranking table) illustrate in detail how to classify soil types according to their soil permeability rate. This should that, more than 60% of the area ranked as exclusion area.

4.2 Soil Strength

Soil Strength means hardness of soil. Soil hardness is one of the components that effect soil erosion caused by water. If soil strength is high, there is less soil erosion and poor soil strength comes refers high soil erosion. Following figure 04 shows soil strength rates of the selected area.

Soil strength is determined by soil types. Some soil types refer to high soil strength and some refer low soil strength. As an example *Immature brown loams, dissected, hilly and rolling terrain* and *Red-Yellow podzolic soils* indicate very low soil strength. That means there can be high soil erosion. The Detail ranking table 02 illustrates in detail how to classify soil types according to their soil strength.

4.3 Land Use

Poor land use practices create high soil erosion or change soil parameters towards higher soil erosion. When considering land use pattern of the selected area, a large amount of area as chena can be seen cultivation. There is poor land conservation method in chena cultivation area and other cultivation area is also same. Therefore, these two types of land use are considered as high soil redoubles areas at the ranking stage. The rest of ranking is mentioned in detail in the Detail ranking table. Following figure 06 illustrates the land use map of the selected area. As could be seen more than 55% area ranked as exclusion area which belongs to Chena and Other cultivation.

4.4 Water Volume

Water, especially rain water is the major soil erosion agent in the selected area, but there is some area, which water is supplied for cultivation. High water volume area may be a high erodible area but it can depend of other factors like soil type, soil permeability....etc. However, in this study, high water volume area is considered as a high erodible area. The Detail ranking table illustrates in detail the water volume classification and ranking criteria. Following figure 07 shows a water volume map of the selected area.

4.5 Slope

Selected area is located in moutons area, therefore high slope areas can be seen these high slopes cause high soil erosion. The Detail ranking table illustrates in detail the slope classification and ranking. The following figure 05 illustrates the slop map of the selected area.

5. Final Output

21% of total area about 48km^2 is reported as highly reodible. 132km^2 area is reported as moderate soil erosion area. It is about 58% out of total area. About 21% is low soil erosion area according to this study.

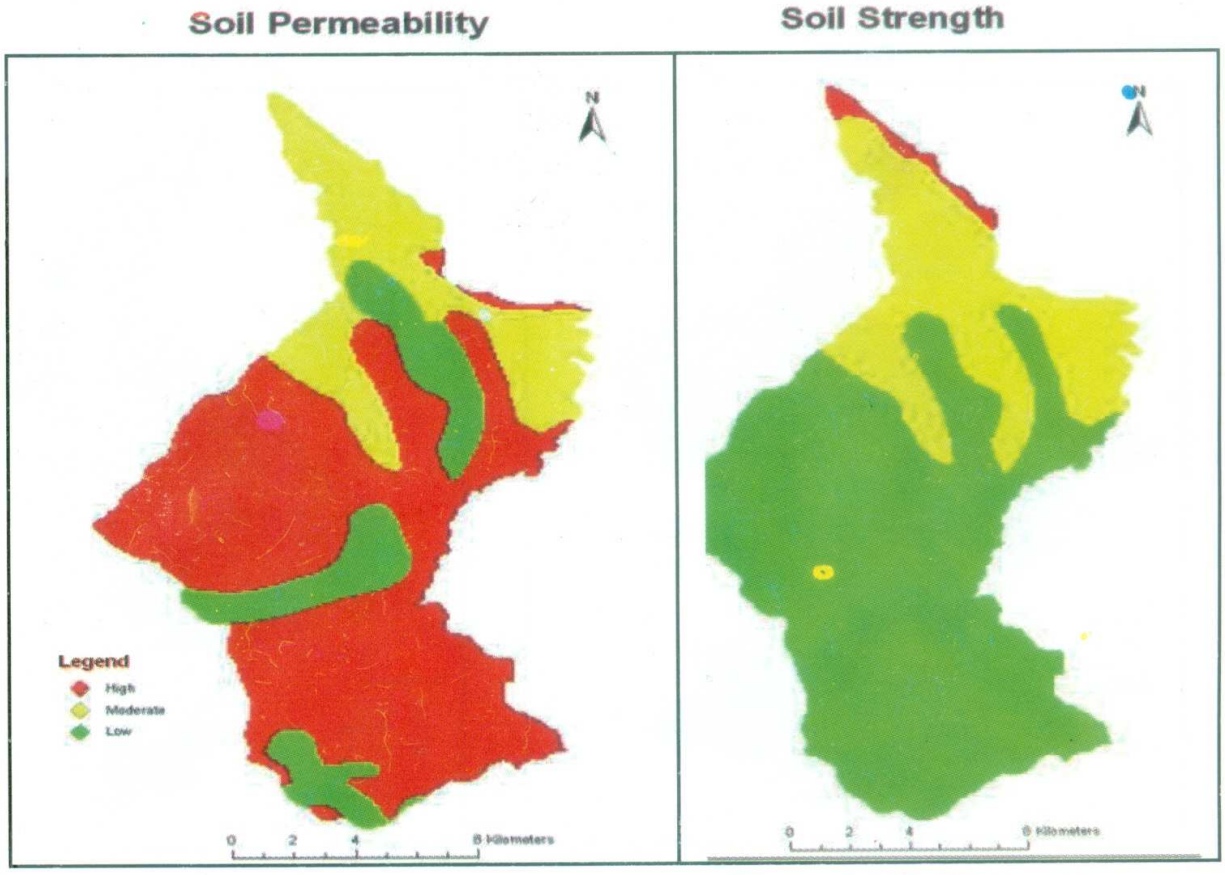

Figure 03- Soil permeability

Figure 04- Soil Strength

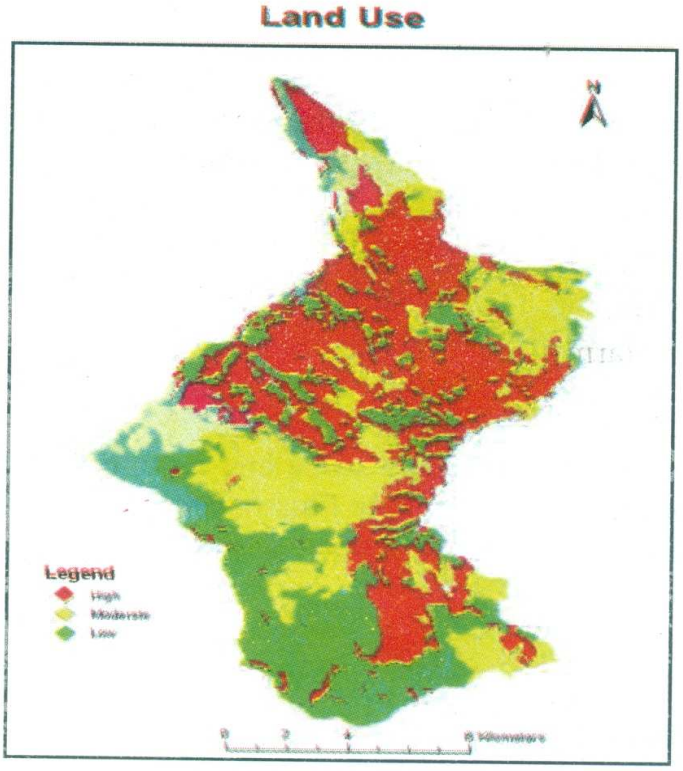

Figure 05- Land Use

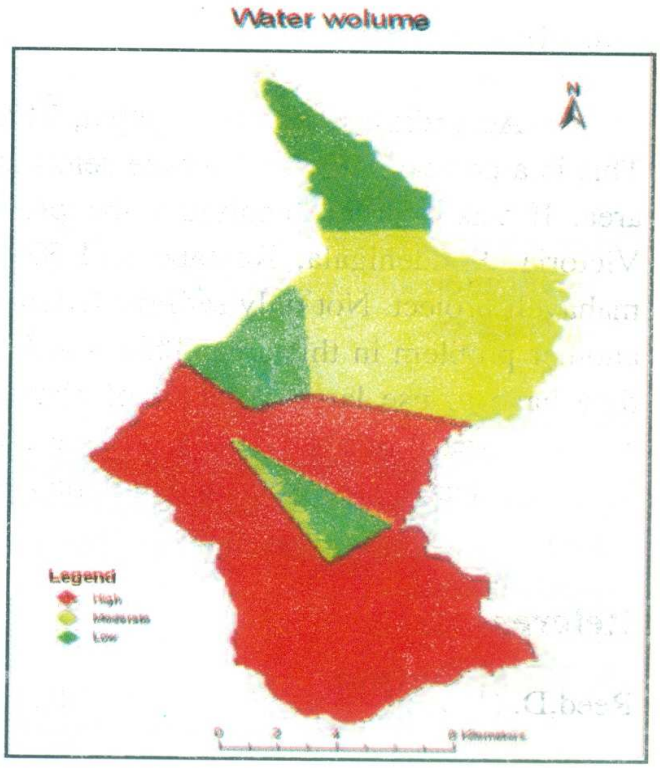

Figure 06- Water Volume

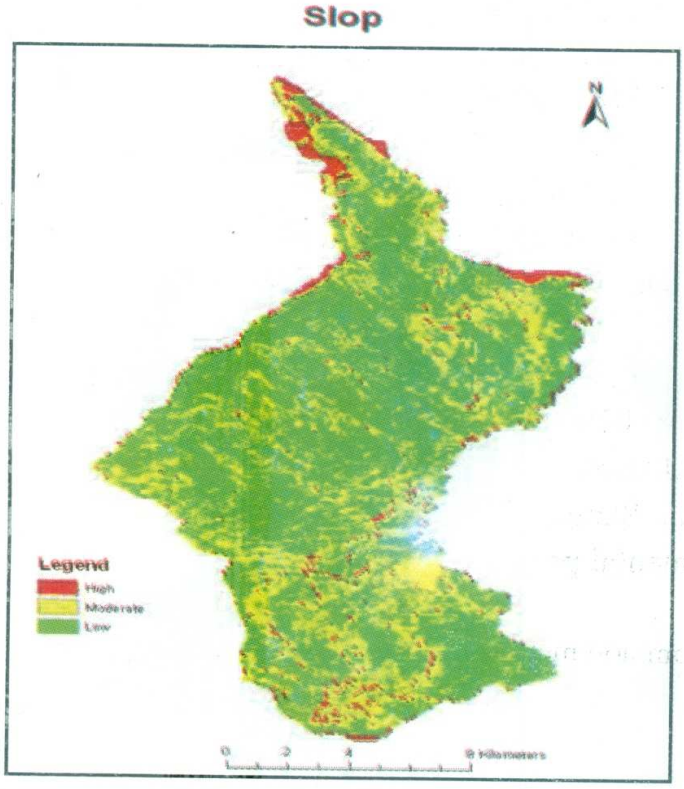

Figure 07- Slop

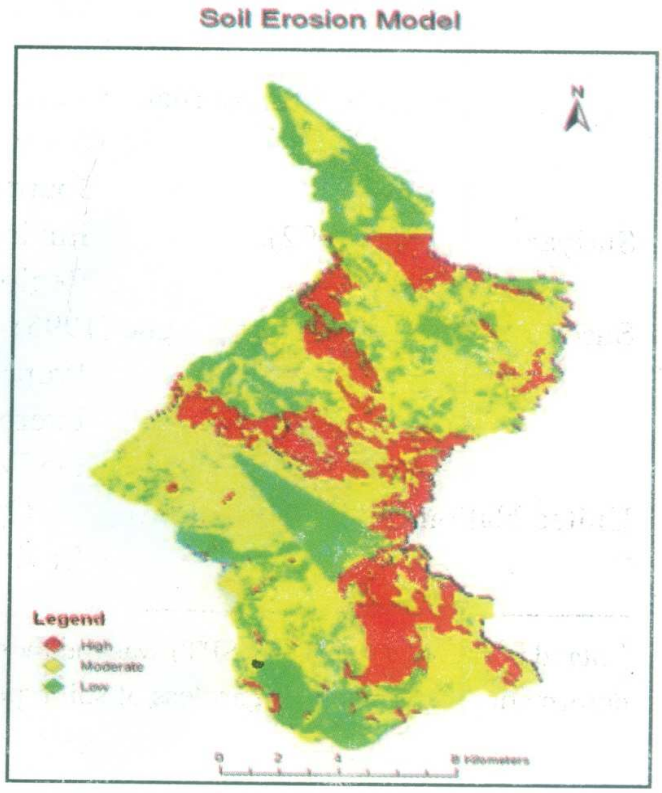

Figure 08- Soil Erosion Model

Conclusion

According to the final output, 21% area is found to be a high soil erodible area. This is a critical situation because selected area is located in upper mahaweli catchment area. If this situation continues the problem of sedimentation will be accelerated in Victoria, Randenigala, Rantabe and Kotmale reservoirs and it will be a distraction mahaveli project. Not only sedimentation problem, but also reducing soil fertility will be another problem in this area. This is a threat to farmers who cultivate this land because they have to use large volumes of chemical fertilizer to cultivate. More than half the selected area is formed as a moderate erodible area. This is not a favorable condition because selected area is located in highly sensitive area.

References

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[1] Standard Penetration Test (SPT) was the most common method for determining both strength and deformation parameters, regardless of soil type.