HYDRO-GEOLOGICAL ERODIBILITY TREND AND PREDICTION WITHIN THE LOWER BENUE TROUGH, NIGERIA

By

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ABSTRACT

Soil erosion studies in Eastern Nigeria have continued to be centered on the areas already devastated by erosion that requires remedial measures. It becomes necessary to study the erosion rate on a regional scale given the magnitude of the problem and with the vegetation being disturbed for infrastructural development. The Revised Universal Soil Loss Equation and ASTM standards digitized in a GIS environment were used to study erodibility in Lower Benue Trough using 37 years (1970-2007) rainfall data, topography and soil properties. The result of the study shows that the soils in the area are highly erodible, belong to the same formation and thus have the same engineering behavior. The total rainfall for the period under study was 82273.3mm eroding 3.72×10^{10} tons of soil. The equation derived from this relationship is: ***Annual Soil Loss (t/ha) = 924.6912 + 0.9710*Precipitation (mm).*** *This equation could be used to predict the amount of rainfall and soil loss at a particular period for the study area and thus land use utilization. Furthermore, the information generated will assist in formulating policies and programmes that will minimize incidences of soil erosion.*

INTRODUCTION

Human-induced land degradation is one of the most destructive phenomena relating to natural resources in the world, and is recognized as a key issue for conservation in the 21st century **[1]**. Factors influencing/causing and types of soil erosion have been described in details **[2, 3, 4]**. Soil erosion is caused or influenced by rainfall **[5, 6]**, vegetation **[7, 8,]**, soil properties **[9, 10]** and topography **[11, 12]**.

Erosion prediction and assessment have been a challenge to researchers since the 1930's **[13]**. More recently, the need for dynamic approach in which both erosion features and the factors influencing them are mapped and the relationships sought has become apparent. The erosion assessment at regional scale is based on empirical models or expert evaluation, resulting in map consisting of regions with different susceptibility to soil erosion **[14]**.

The processes controlling sediment detachment, transport and deposition are complex and interactive **[15]**. This complexity results in the lumping of the many sub processes under the one term "erosion processes" in many erosion models.

Several soils erosion by water models using different Scientific methods and modeling approaches have been developed in the past decades. Models can be used as tools for understanding erosion processes and their interactions and for setting research priorities **[16]**.

In general, soil erosion models fall under three major categories-empirical, Physical and Conceptual. Erosion models can be used for many applications related to conservation planning and engineering design if natural data and model uncertainties are recognized , understood and accounted for, and if a continuous simulation models is used **[17]**. Empirical models are frequently utilized for modeling complex processes and, in the contest of erosion and soil erosion, particularly useful for identifying the sources of sediments **[18]**. The conceptual and data requirements for such models are usually less than for conceptual and physical based models **[19]**.

The validity of a model is judged by how well it serves its intended purpose **[15]**.

While it is likely that application of none complex models than RUSLE can provide more accurate estimates of soil erosion for specific sites, the data requirements of these models make them difficult to use on a regional scale **[20]**. By comparison data for utilization of RUSLE/GIS interface can be relatively easy to obtain.

Soil erosion continues to ravage most parts of eastern Nigeria. While soil erosion study continue to be centered on the areas already devastated by soil erosion, it becomes apparent the need to investigate virgin lands with a view to formulate policies and programmes that will reduce or minimize incidences of soil erosion given the fact that the vegetation in the study area is now being disturbed for infrastructural development.

The Study Area

The study area (Figure 1) is located within longitude $8^{o}\ 00^{1} - 8^{o}\ 30^{1}$ and latitude $6^{o}\ 00^{1} - 6^{6}\ 30^{1}$ is within the structural units of the Niger Delta area of South Eastern Nigeria.

The study area covers part of the eastern flank of Ebonyi State and part of the western flank of Cross River State of the lower Benue trough with a land area of $3249km^2$.

Geomophologically, the lower Benue trough consists of Southern transitional environment of beaches and bars, estuaries and mangrove swamps and the Northern continental hilly country [21]. The study area stratigraphically grades upwards with: South Regressive Tertiary Deltaic Sediments (Eocene – Recent), Transgressive low Tertiary Sediments (Paleocene – Eocene), Regressive Upper Cretaceous Sediments (Campion – Paleocene), Folded Cretaceous sediments (Aptian – Santonian) and Basement complex (Pre-Cambian).

The geology of the study area dates from the Precambrian period. The opening of the South Atlantic Ocean initiated tectonism in the region of South Nigeria and led to the development of the Benue Trough [22]. The development of the Benue Trough provided the main structural control and framework for subsequent geologic coalition of South Eastern Nigeria. The study area within the South Benue trough consists of the Abakaliki, Anticlinorium, Afikpo Syncline, Ikom-Mamfe embayment and Ogoja sub-basin.

The geological formation in the area is the Asu River Group, which consists mainly of shale, with siltstone and limestone horizons and with igneous bodies. The rocks are the most deformed by the folding and faulting.

The shale which cover almost all the basins have been aggregated to an almost flat topography, features have been created by sand bodies, which form occasional ridges in some parts of the project area, and by some isolated hill formed by igneous rock.

Lithologically, the study area is of poorly bedded sandy shale with fine to medium grained sandstone lenses with massively bedded, grey chalky limestone with fossils.

Also, Cross bedded coarse to medium grained immature sandstones with basal conglomerates and arkoses form the lithology.

Abakaliki and environs are within the Cross River basin that is notable for its ground water mineralization and poor yield **[23]**.

Furthermore, the area is underlain by Cretaceous shale of Albian-Senomian age which has been intensely folded and faulted, but which may be of local hydrological significance. The frequent occurrence of shale outcrops in the area promotes flashy and rapid run-off, resulting in the ephemeral nature of most of the streams draining the area. The major river in the area is Cross River that is oriented towards the sea.

The Cross River plains form a uniform, sandy sloping drainage basin, slightly tilted towards the south-east. It is underlain by folded argillaceous sediments of the lower part of the Cretaceous sequence and consists essentially of undulating lowland regions, the greater part lies between 60.96m and 91.44m above sea level **[24]**. The Turanian marine condition led to the deposition of the Eze-Aku shale and other faces which extended up to the Benue and Gongola valleys.

2.0 Methodology

Although the practical procedure in soil erosion mapping may be complex it invariably involves the major operations along with others.

i. The erosional features and landforms have to be identified, defined and or delimited in the terrain,

ii. The geodynamic process involved must be investigated and the impact of each assessed, and

iii. The delimited external features and landforms must then be described, measured and presented in the appropriate format.

RUSLE, because of its interface with GIS among other factors was used for this study.

In this study the C and P factors were assumed to be 1. This is to represent the worse condition. On regional scale mapping in developing countries where soil erosion parameters are unavailable C and P values are usually assumed to be 1.0 **[25]**.

2.1 Rainfall

Rainfall data, spanning over 37years (1970-2007) of Ikom and obtained from Federal Meteorological Centre, Oshodi were used to compute the Rainfall Erosivity Factor (R) for the study area. The equation as stated below **[26]** was used to calculate R:

R = 3786.6 + 1.5679* (Precipitation in mm) – 1.9809* Elevation in mm). -------------- (1)

2.2 Slope Length Factor (SL)

Topographical map sheet 303 (Abakaliki) on a scale of 1:50,000 were obtained from the Federal Department of Survey. The maps were scanned, digitized and a Digital Elevation Model (DEM) was created in a GIS environment.

Traditionally, the best estimates for slope length (L) are obtained from field measurements, but these are rarely available or practical **[11]**. The particular algorithms that have been developed to calculate slope length include grid-based method **[27]**. The RUSLE equation to calculate the LS values from the grid-based method that was used is:

$LS = (\ell/72.6)^m(65.41\sin^2\beta+4.56\sin\beta+0.065)$ ---(3)

Where ℓ is the cumulative slope length (ft.), β is downhill slope angle (degrees), m is slope contingent variables.

2.3 Field and Laboratory Investigations

Soil samples were collected during the field surveys carried out in October – November, 2006. The sampling points were determined in a near grid formation and a hand held Global Positioning System (Garmin GPSmap 76CSx) was used to locate and record sampling points. The soil samples collected during the field investigations were first air dried and laboratory tests were carried out in order to determine the soil group in accordance with the American Society for Testing of Materials **[28]**. The results from the laboratory investigations were used to determine the soil erodibility factor (K) using the Nomograph method **[29]**. In determining the soil boundaries, results from remote sensing survey were used based on a mosaic prepared from panchromatic aerial photographs.

4.0 Results and Discussions

4.1 Field Investigation

A total of 107 soil samples obtained in a near grid formation were investigated. The soil samples collected were mainly gravelly silt loam. The results of the field investigations showed that the soils in the study area are predominantly reddish brown gravelly sandy clay.

The natural moisture contents of the soil samples taken in-situ ranged between 3.2 to 19.0% with an average value of 11.91% and a standard deviation of 3.49. The soil colours were in combinations (mottled) of red, brown, grey, yellow and ash but mostly red, brown and yellow. Reddish soils are generally well drained while yellow and yellowish brown soils are poorly drained so also are blue and yellow mottled soils [30].

Thus, the soils in the study area range from poor to well drained but mostly poorly drained and therefore susceptible to erosion.

4.2 Topography

Figures 2 and 3 show the elevation and the hydro-geological flow direction of the study area in a grid cell of 4 X 4. The elevation ranges between 50m to 350m. The non-cumulative downhill slope length has a range of 0 to 5657m and cumulative range of 0 to 46,142m. Similarly, the slope angles have a range of 0^o to 2.86^o.

4.3 Laboratory Test Results

The laboratory test results have been used to classify the soils based on Textural and Unified classification. The results showed that the soil samples collected predominantly contain gravel. Sandy soil group accounted for 3.73% of the soil samples of which Gravelly Sandy Loam dominated. Similarly, the silt group constituted 74.75% of the soils and Gravelly Silt Loam (35.51%) was the major soil class within the group. Within the clayey soil group that accounted for 13.08%, Gravelly Clay Loam (6.54%) dominated.

Generally, soils with high silt content are most erodible [7]. These are silt, silt loam, silt clay and silt clay loam. Within the study area, these soils accounted for 74.75% of the soils analysed. In the most erodible group, those with appreciable gravel content constituted 57.0%. It has been acknowledged that gravel content reduces rate of erosion [2].

There is not yet a simple and universally accepted erodibility index for soils instead, various tests have been proposed for this purpose. However, a suggested hierarchy of erodibility soils based on the Unified Soil Classification System that is widely used grouped ML, SM, and SC soils as most erodible, MH, OH, CH and CL as moderately erodible soils, while GM, GP and GW are the least erodible soils. The most, moderate and least erodible soil thus accounted for 29.9%, 56.08% and 14.01% respectively. Consequently, using the unified soil classification system, the soils in the study area could be said to range from least to high erodible but mostly within moderate to high erodible.

The Plasticity Index that is an indication of the swell potential of any soil varies from 2.2 – 51.9 with a mean and standard deviation of 19.87 and 10.92 respectively. It is observed from the plasticity chart (Figure 4) that 88% of the samples are above the A-line. In addition, the plot tends to lie parallel to the A-Line. This implies that the soils are in the same formation. In other words, these soils tend to have about the same engineering behavior.

The soil eroded within the period (Figure 5) was 3.72×10^{10} tons. The range of the eroded soil was 9.86×10^{8} - 10.24×10^{8} tons with an average of 10.06×10^{8} tons and standard deviation of 9.24×10^{6}. Similarly, the total rainfall (Figure 6) for the period under study was 82273.3mm with a range, average and standard deviation of 1716.6mm – 2717.9mm, 2223.6mm and 224.7mm respectively. The minimum and maximum rainfall and eroded soil were recorded in 1989 and 1998.

The amount of rainfall plotted along with the corresponding soil loss (Figure 7), produce a linear relationship. The equation derived from this relationship is:

Annual Soil Loss (t/ha) = 924.6912 + 0.9710*Precipitation(mm)................ (3)

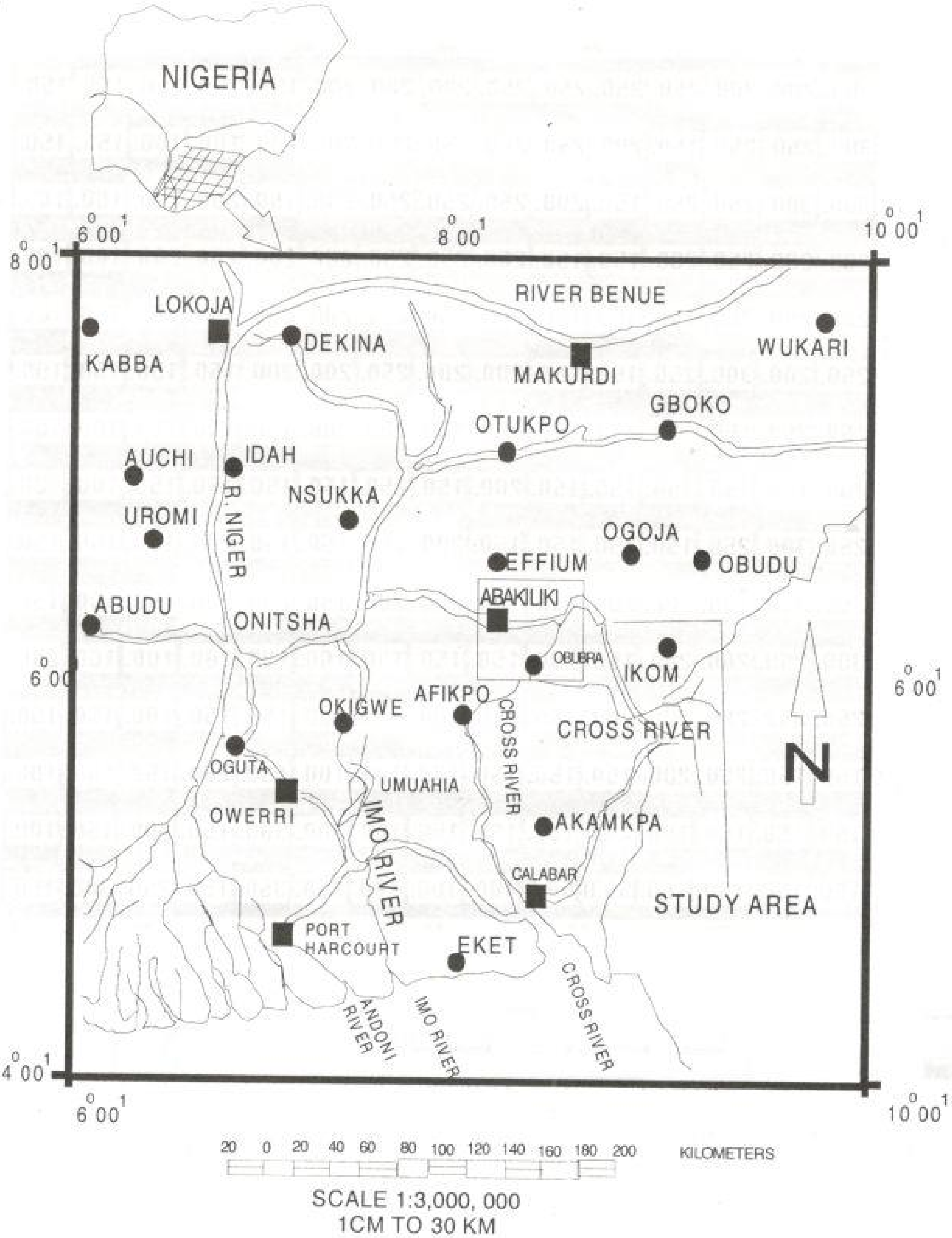
The regression value obtained is 0.880. This equation could be used to predict the amount of rainfall and soil loss at a particular period for the study area and thus land use utilization to prevent or reduce the incidence of soil erosion.

CONCLUSION

Soil Erosion in the Lower Benue Trough was modeled using topography, physical soil parameters and rainfall. Results of the study reveal that the soils in the area are moderately erodible. However, considering the other parameters of rainfall and topography, erosion rate in the area is very high. It thus implies that adequate precaution to include terracing, mulching, slope stabilization etc. needs to be taken when the vegetal cover is to be disturbed for infrastructural development and also taken into consideration other factors as the soil properties and topography.

Landscape change in response to climate is the result of the complex interplay between hydro climatic events and climatically-driven geomorphic processes. Soil erosion is a complex process determined by mutual interaction of numerous factors. The result from this study thus will contribute tremendously towards formulation of policies and programmes to minimize soil erosion in the area and as an aid towards actualizing part of the objectives in vision 2010 that include restoration of amenable erosion sites and enforcement of management practices at preventing/minimizing incidence of erosion.

1.



2. Figure 1 : Map of South Eastern Nigeria showing the Study Area

3.

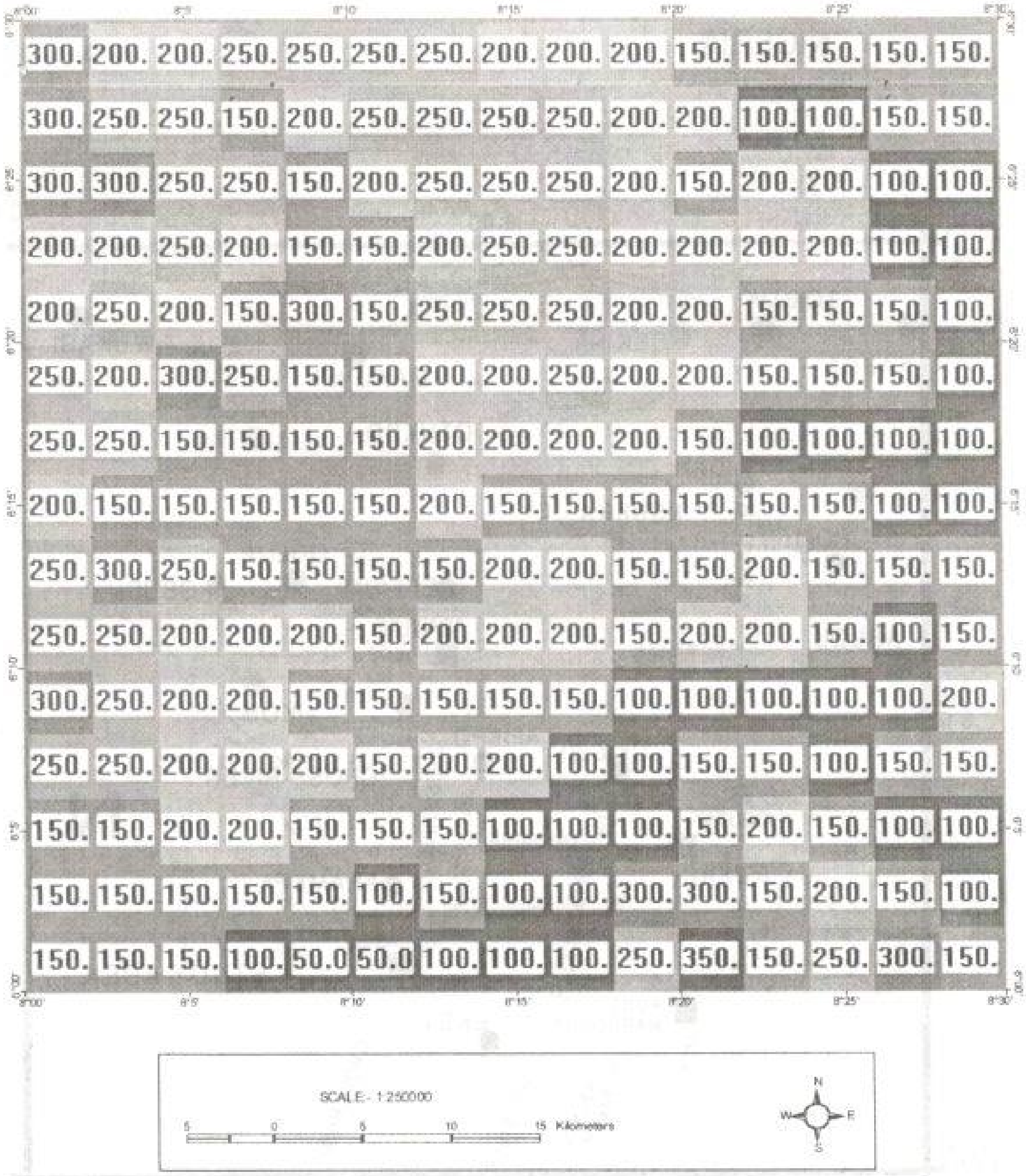


Figure 2: Height Map (m)

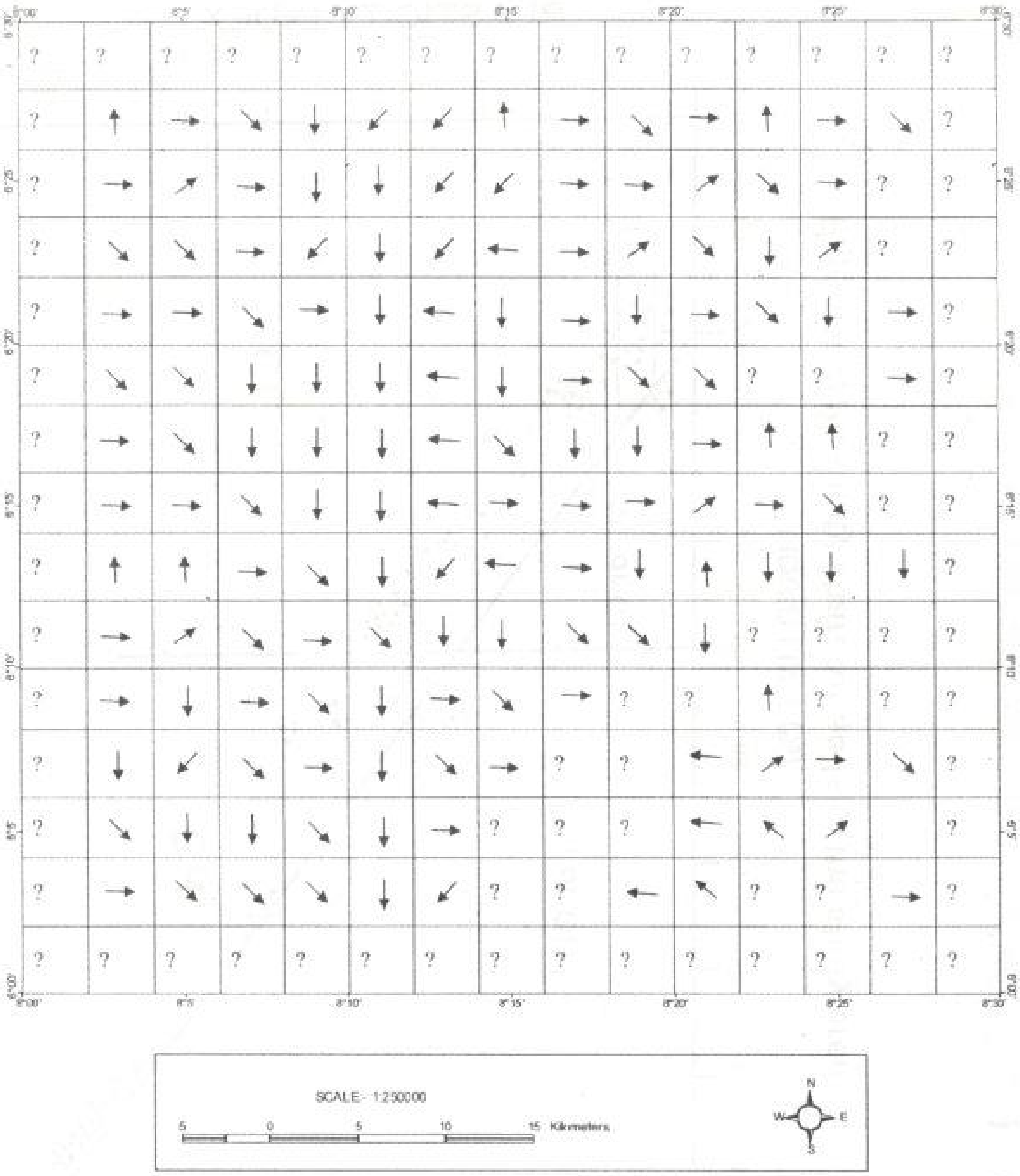


Figure 3: Flow Direction

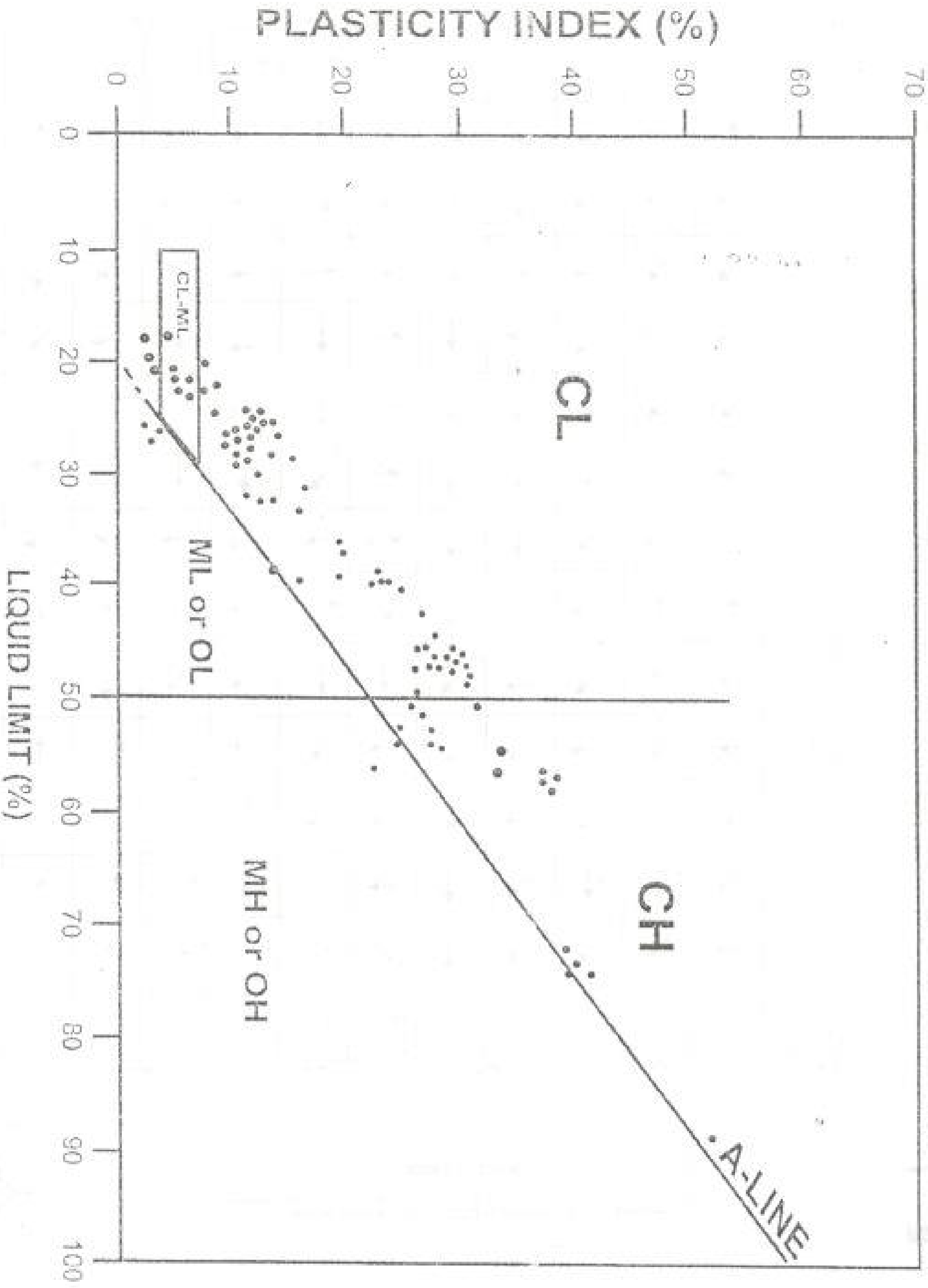


Figure 4 : Plasticity chart for soils in the study area

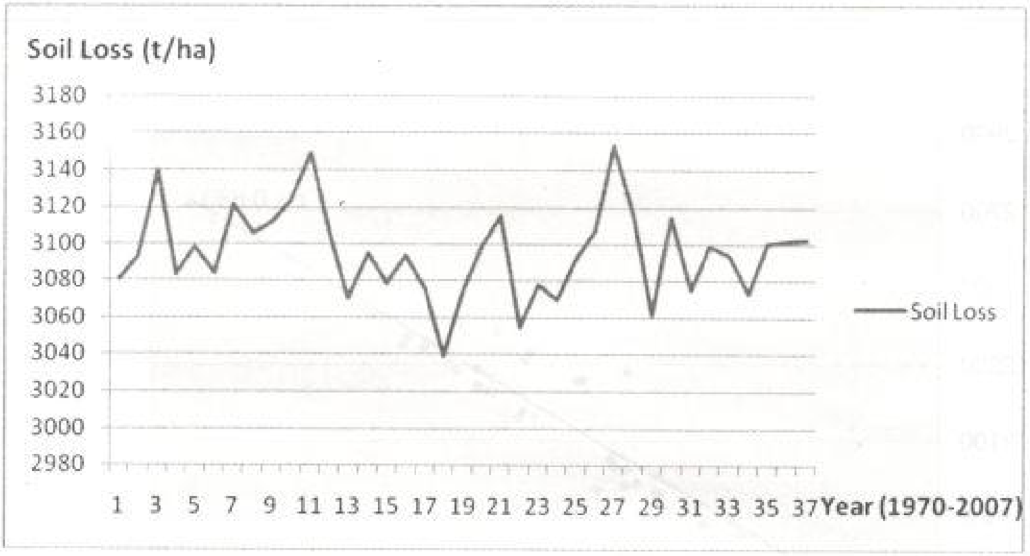


Figure 5: Annual Soil Loss (tons/ha)

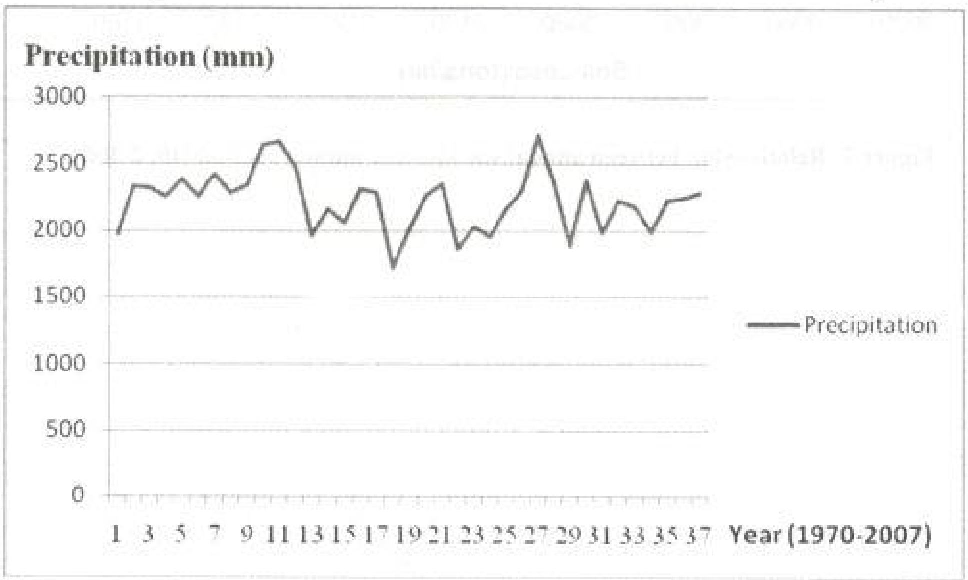


Figure 6: Annual Precipitation (mm)

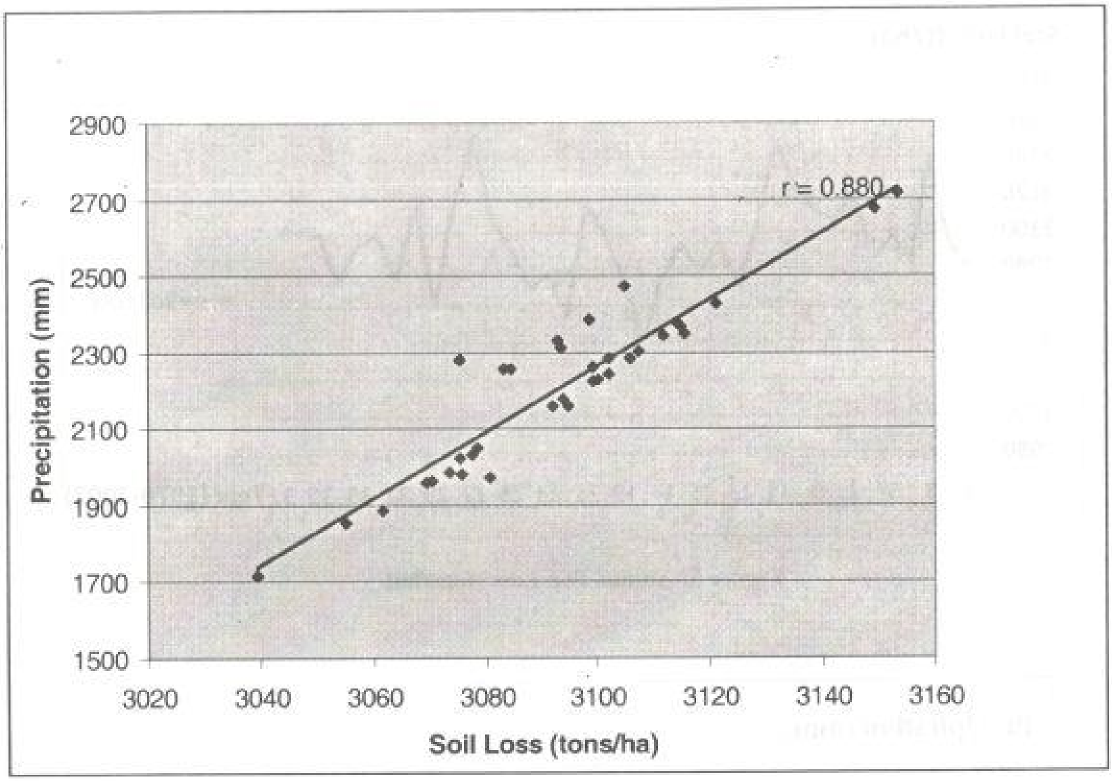


Figure 7: Relationship between annual soil loss and annual rainfall (1970-2007)

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