A DETERMINATION OF THE REVISED UNIVERSAL SOIL LOSS EQUATION (RUSLE) PARAMETERS FOR SOIL ERODIBILITY IN PARTS OF EASTERN NIGERIA.

By
F. O. Aitsebaomo*, S. C. Teme**, T. K. S. Abam**, and C. Eze**
*Nigerian Building and Road Research Institute, 3 Gabes Street, Wuse Zone 2, Abuja
**Institute of Geosciences and Space technology, Rivers State University of Science and Technology, Port Harcourt.

ABSTRACT
Soil Erosion is ravaging most parts of eastern Nigeria and the pressure on the land for infrastructural development is ever increasing and may not ease in the foreseeable future thus a study was carried out to determine the susceptibility of soils in some parts to erosion with a view to develop regional scale maps and identify combinations of soils, landforms and land cover that may respond to climate variability. The Revised Universal Soil Loss Equation (RUSLE) and Geographic Information System (GIS) were used to study the soil erodibility of the area. Field and laboratory investigations were carried out in line with American Standard for Testing and Materials (ASTM) D422-72:1984 procedures. The results obtained from the investigations, land use and land cover classifications as well as topographical maps were digitized in a GIS environment to determine the Actual soil losses. The actual soil eroded within the study area is 1725.13t/ha/yr. The results suggest that about 7.48% (243.04km^2) of the area is very susceptible to soil erosion. The cover practice significantly reduced the high risk of erosion to moderate and manageable level. Adequate precaution is therefore necessary if the ground cover (vegetation) is to be disturbed for any form of development especially in the high risk areas where the erosion rate is above 30 tons/ha/year.

Introduction
The United Nations estimated that excessive erosion rate (both wind and water) are severely affecting food production in some 415 million hectares in Africa [1]. The prevalence is summed that Africa has taken too much from its land; it has over drawn its environmental accounts and the results for much of the continent has been under environmental bankruptcy [2]. It is estimated that one sixth of the world's soils are affected by water erosion [3]. Globally [4], human impact on about 1,094 million hectares of land mass, of which 43% suffer from deforestation and the removal of natural vegetation, 29% overgrazing, and 24% from improper management of agricultural land and 4% for over exploitation on natural resources. Human-induced land degradation has been identified [5] as 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.

The present strategies and applied research on soil and water management and conservation conducted by national and international organizations reflect the lack of coordination between activities and the inappropriate use of resources not tailored to the need of end users [3]. While soil erosion based on field measurements is not available at catchment or regional scale, they may be surveyed to a small extent at the plot or field scale [6]. Even so, such data are often not comparable because of non-standardized methodologies and non-uniform experimental conditions.

The methodological and data required for assessing erosion rates and evaluating potentially useful sustainable land management and effective conservation practices are insufficient, both in quantity and quality. Thus the misinterpretation and erroneous conclusions [7], [8], are major worries when using such data for designing conservation measures for land use planning and for implementing resource management policies. Under these conditions, using highly detailed prediction models that require more hydrological, meteorological and soil data that are available is useless, and may lead to dangerous mistakes in land use and management decisions.

The ecosystem on which societies of eastern Nigeria depend is showing many signs of stress due to over exploitation. Of great concern is the magnitude of soil erosion. Thus a study was carried out to determine susceptibility of some parts of Ebonyi and Cross Rivers States in Nigeria using the Revised Universal Soil Loss Equation (RUSLE).

1.1 The Study Area
The study area (figure 1) covered by Nigerian topographic sheet no.303 is located within longitude 8° 00' – 8° 30' and latitude 6° 00' – 6° 30' is also within South Eastern Nigeria. The study area covers part of the eastern flank of Ebonyi State and also part

of the western flank of Cross River State with a land area of 3249km^2. The 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) [9]. 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 structure is controlled by the Abakaliki uplift and the Afikpo syncline.

The vegetation is fairly intensely cultivated and grassed open (upland) grassland. It is of wooded savanna with Daniellia-oliveri and oil palms, relic moist semi-deciduous forest of high level sites and well developed riparian forest in the valleys. The rainfall ranged between 2032mm – 2540mm with a mean temperature of 26.66°C – 28.89°C.

3.0 The Revised Universal Soil Loss Equation (RUSLE)

In the Universal Soil Loss Equation (USLE), five major factors are considered, from which input data can be obtained from the Digital Elevation Model (DEM) map, and cover values, soil properties and precipitation data within a Geographic Information System (GIS) environment. The USLE was developed initially as a tool to predict soil erosion from crop land on a hill slope and also to assist soil conservationists in farm planning [10],[11]. USLE cannot deal with deposition hence its applicability limits large areas and watersheds [12]. It is on the bases of these limitations that several other models were developed [13].

RUSLE is a revised equation of USLE and has been described in details [10], [11]. RUSLE updates the information in data required after the 1978 release, and incorporates several process-based erosion models [14]. RUSLE remains to be a regression equation of USLE;

$$A=RKLSCP \qquad (1)$$

RUSLE/GIS interface provides such a methodology for regional level analysis of soil erosion. While it is likely that application on non complex models than RUSLE can provide more accurate estimates of soil erosion from specific sites, data requirements of these models make them difficult to use on a regional scale[15]. By comparison, data for utilization of RUSLE/GIS interface can relatively be easy to obtain

3.2 Estimation for Eastern Nigeria

3.2.1 Rainfall (R) Factor

Average monthly rainfall data, spanning over 21 years (1980-2000) for Ikom and obtained from Federal Meteorological Centre Oshodi were used to compute the rainfall erosivity for the study area. The equation used to calculate R factor was;

$$R = 3786.6 + 1.5679^* \text{(Precipitation in mm)} - 1.9809^* \text{Elevation in mm)} \qquad (2)$$

The calculated R value had a range of 378.42 to 413.34 with a mean of 395.88 and a standard deviation of 11.64. The results show that the erosivity potential is higher at lower altitude than at higher altitude.

3.2.2 Soil Erodibility (K) Factor

A comprehensive field investigation was carried out to collect soil samples in a grid formation limited by ground situation. A total of 107 (figure 2) soil samples were obtained and the depth of boring was limited to 0.4m since the RUSLE is not applicable beyond this level. The soil samples were subjected to comprehensive laboratory investigations to determine their physical properties based on ASTM D422-72 (1984) standards[16]. K was determined using the Monograph [17]. The laboratory results (table 1) showed that the soil samples collected predominantly contain gravel. Silt soil dominated the soil analysed constituting 74.75% with Gravelly Silt Loam (35.51%) being the major soil class within the group.

Generally, soils with high silt content are most erodible [18]. The most erodible soils are categorized into 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 soil erosion [19], [20]. Although, the textural class group showed that the soils with high silt content (74.75%) is the most erodible, the gravel content could account for the high percentage of low to moderate erodibility as observed when the sand, silt and clay contents values were factorized to account for the gravel content.

3.2.3 Slope Length (SL) Factor

Topographical map sheet 303 (Abakaliki) of scale 1:50,000 were obtained from the Federal Department of Survey. The topographical maps were scanned using SCAN-PLUS IV 436Cx, digitized and a Digital Elevation Model (DEM) (figure 3) created using

ArcGis before the necessary computations. The RUSLE equation to calculate the LS values is:

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

The range of the elevation was 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 to 2.86. Cumulative slope-length is computed simply by summing the noncumulative slope lengths along the flow direction beginning at the high points.

3.2.4 Cover (C) Factor.

A Landsat Enhanced Thematic Mapper (ETM +) image covering the study area (path 202, row 055, acquisition date of December 17, 2000) was used in the analysis. The ETM+ was obtained from the United States Geological Survey (USGS). The image was obtained as geometrically and radio metrically corrected (level IG) data in digital number (DN) values. The image was rectified using 1st order polynomial rectification.

The satellite image was decoded using ERDAS software. Unsupervised classification was performed on the crisped, clipped image using the ISODATA procedure. Supervised classification was performed on the same image with random training samples digitized with the AOI TOOLS features. The desired classes assigned to the image undergoing supervised classification were: dense forest, gallery forest, bare land water, cultivation.

The vegetation (figure 4) was classified using satellite imageries however in computation of the C Factors were obtained from literature using the observed field vegetation and supplemented by results from the imageries. ArcGis programme was used to obtain the area and percentage occurrence covered by the different types of vegetation. The total area investigated was 3249km^2 of which 1139.42km^2 (35.07) was under cultivation while settlements (cities, towns, villages etc.) making up of built up areas covered 244.65km^2. Vegetation ranging from native Gallery to light vegetation covered 1576.09km^2 (48.51%). Gallery forests are original forests growing along a water course in a region. While light vegetation covered 1056.57km^2 (32.52%), water and wet lands occupied 288.84km^2 (8.89%). The area that could be subjected to erosion as at the time of investigation are the bare soil, area under cultivation and around built up areas occupying 1384.07km^2 (42.60%). Except for sampling point's 20 and 47, that recorded a high C-value of 0.69 and 0.85, others ranged between 0.14-0.45. This low value suggests a good ground cover that could control soil erosion. The lower the C-value, the better the ground cover [19].

3.2.5. Conservation (P) Factor

Practice that reduces the velocity of runoff and the tendency of runoff to flow directly down slope reduce the P-factor. The total area that could be affected by P-factor is the area under cultivation that occupies 1139.42km^2 (35.07%) of the total land area. The major crops grown are rice, yam, cassava and plantain. As observed, although growing yam and cassava requires roughening of the land, heavy equipment (tractors, caterpillars, graders etc) are not used in the study area that could suggest contour ploughing or up and down slope among others which is very unlikely given the farming system in the study area. Since no conservation practice was observed, P value of 1.0 was used. On regional scale mapping in developing countries where soil erosion parameters are unavailable P values are usually assumed to be 1.0 [3].

4.0 Discussions

The field sampling points with corresponding RUSLE factors derived from field and laboratory investigations as well as from other sources was used to determine the susceptibility of the study area to soil erosion. The main erosivity, soil erodibility and slope factors as elements of the RUSLE can be considered as naturally occurring factors determining the sheet and rill erosion process. Together they can be considered as susceptibility or soil loss [21].

The assessment approach for the study area involved the calculation of Actual Annual Soil Erosion as at November 2006 when the field parameters were measured using RUSLE and the resulting soil erosion layers presented in figure 5. The interval delineating the soil erosion classes are based on the values of Raghunath [21].

The erodibility class and the various proportions affected showed that the actual soil eroded is 1725.13t/ha/yr. Also, high and very high erodible soil was 243.03t/ha/yr (7.53%). Similarly, the mean actual loss was 53.14t/ha/yr and a standard deviation of 67.58. A total of 7.48% (243.04km2) of the area is very susceptible to soil erosion. Very low, Low and Moderate erodibility covered an area of 273.24km^2 (8.41%), 1487.72km^2 (45.79%) and 1245.02km^2 (38.32%) respectively.

It is observed that the very low erodible areas were places where elevation was 100m. The cover practice significantly reduced the high risk of erosion to moderate and perhaps manageable level and thus calls for caution if the area is to be disturbed. It could be posited that although on the average, soil erosion is significant, at the moment the study area is not under serious erosion threat.

5.0 Conclusion.

The four factors of vegetation, rainfall, soil types and topography that cause or influence soil erosion were modeled using RUSLE to determine the susceptibility of some parts of Ebonyi and Cross River States to soil erosion. The investigation showed that a total of 7.48% (243.04km2) was found to be actually endangered. The vegetation significantly reduced the high risk of erosion to moderate and perhaps manageable level. This implies that adequate precaution to include; terracing, re-vegetation and mulching among others need to be taken if the vegetation is to be disturbed for any form of development. A systematic understanding of the changes in the land use and land cover is critical to the understanding of the ecosystem functioning and services, and human welfare. A spatially explicit study of the land use, land cover, soil, topography and the rainfall pattern over the years can lead to a better understanding of the causes of change and their consequences on the environment and society. Such understanding will improve land use management and thus lead a sustainable development.

An important aspect of this study is a development of zoning that is shown on the soil erosion map. The generated information can be implemented for planning of the urban areas. Action plan can be created using the geo-database and total decision support system can be developed to depict location and type of action/control measures recommended for sustainable development plan for natural resource.

References

Hinrichsen, D. (1996). Computing the risks: A global overview of the world most pressing environmental challenges. *International Wildlife Magazine –World view.* International Wildlife Federation.

Darkoh, M. B. K. (1993). Desertification: The scourge of Africa. *Tempo Climate.* Cyber library. Issue 8.

Saavedra, C. (2005). *Estimating spatial patterns of soil erosion and deposition in the Andean region using geo-information techniques: A case study in Cochabamba, Bolivia.* Ph.D. dissertation, Wageningen University, the Netherlands.

Walling, D. E. and Fang, D. (2003). Recent trends in the suspended sediment Loads of the world's rivers. *Global and Planetary Change;* 39:111-126.

Reich, P., Eswaran, H. and Beinroth, F. (2000). *Global dimensions of vulnerability of wind and water erosion.* USDA, Washington DC.

Saavedra, C. P. and Mannaerts, C. C. M. (2003). Regional Scale erosion modeling and monitoring using remotely sensed data: Some spatial data scale issue. In: D. Gabriels and W. Cornelis (Editors). *25 years of Assessment of Erosion.* Universiteit Gent, Belgium, pp433-440.

Millward, A. A. and Mersey, J. E. (1999). Adapting the RUSLE to model soil erosion potential in mountainous tropical watershed. *Catena;* 38:109-129

Mitasova, H. (2000). Terrain Modeling and Soil Erosion Simulation. *Final Report, Geographic Modeling and Systems Laboratory,* University of Illinois, Illinois.

Short, K. C. and Stauble, A. J. (1967). Outline geology of Niger Delta. *American Association of Petroleum Geologists Bulletin;* 51:761-779

Renard, K. G., Foster, G. R., Weesies, G. A. and Porter, J. P. (1991). RUSLE: Revised Universal Soil Loss Equation. *Journal Soil Water Conservation;* 46(1):30-33

Renard, K. G., Foster, G. R., Yoder, D. C. and McCool, D. K. (1994). RUSLE revisited: Status, questions, answers, and future. *Journal Soil Water Conservation;* 49(3): 212-220

Saha, S. K. (2003). Water and wind induced soil erosion assessment and monitoring using remote Sensing and GIS. *Satellite Remote Sensing and GIS applications in Agricultural Methodology,* pp 315 -330.

Lal, R. (2001). Soil degradation by erosion. *Land Degradation and Development;* 12: 519- 539.

Renard, K. G., Foster, G. R., Wessis, G. A., McCool, D. K. and Yoder, D. C. (1997). Predicting soil erosion by water: A guide to conservation planning with the Revised Universal Soil Loss Equation

(RUSLE). USDA Agricultural handbook 703, USDA, Washington DC. pp6.

Blaszczynski, J. C. (2001). Regional sheet and Rill soil erosion prediction with the Revised Universal Soil Loss equation (RUSLE) – GIS interface. Resource Notes No 46. National Science and Technology Centre Denver, Co.

ASTM D422-72 (1984). Standard Test Method for Particle Size Analysis of Soils. ASTM, Philadelphia, 9pp.

Wischmeier, W. H. and Smith, D. D. (1965). Predicting rainfall-erosion losses from cropland east of the Rocky Mountains. Agricultural Handbook no. 282, U. S. Department of Agriculture, Washington DC. 4pp.

Morgan, R. P. C. (1986). Soil erosion and conservation. UK., Longman Group, 510pp.

Goldman, S. J. K., Jackson, K. and Burszynsky, T. A. (1986). Erosion and sediment control handbook. New York, McGraw-Hill Book Company, 410pp.

Erickson, A. J. (1977). Aids for Estimating Soil Erodibility "K" Value Class and Soil Loss Tolerance. US Department of Agriculture, Soil Conservation Service, Salt Lake City, Utah.

Raghunath, J. (2002). Potential erosion map for Bagmati basin using GRASS. Proceedings of the open source GIS-GRASS users' conference, Trento-Italy.

Table 1: Summary of Soil Classification

Classification System	Soil Group	% Occurrence
Textural (USDA)	Gravelly Sandy Loam	1.87
	Gravelly Sandy Clay	0.93
	Sandy Loam	0.93
	Gravelly Silt	0.93
	Silt	0.93
	Gravelly Silt Loam	35.51
	Silt Loam	8.41
	Gravelly Silt Clay	2.80
	Silt Clay	3.74
	Gravelly Silt Clay Loam	17.76
	Silt Clay loam	4.67
	Gravelly Clay	0.93
	Clay	1.87
	Gravelly Clay Loam	6.54
	Clay Loam	3.74
	Gravelly Loam	8.41
Unified	GC	13.08
	GM	0.93
	SC	25.23
	SM	2.80
	CH	12.15
	CL	38.32
	CL-ML	5.61
	MH	1.87

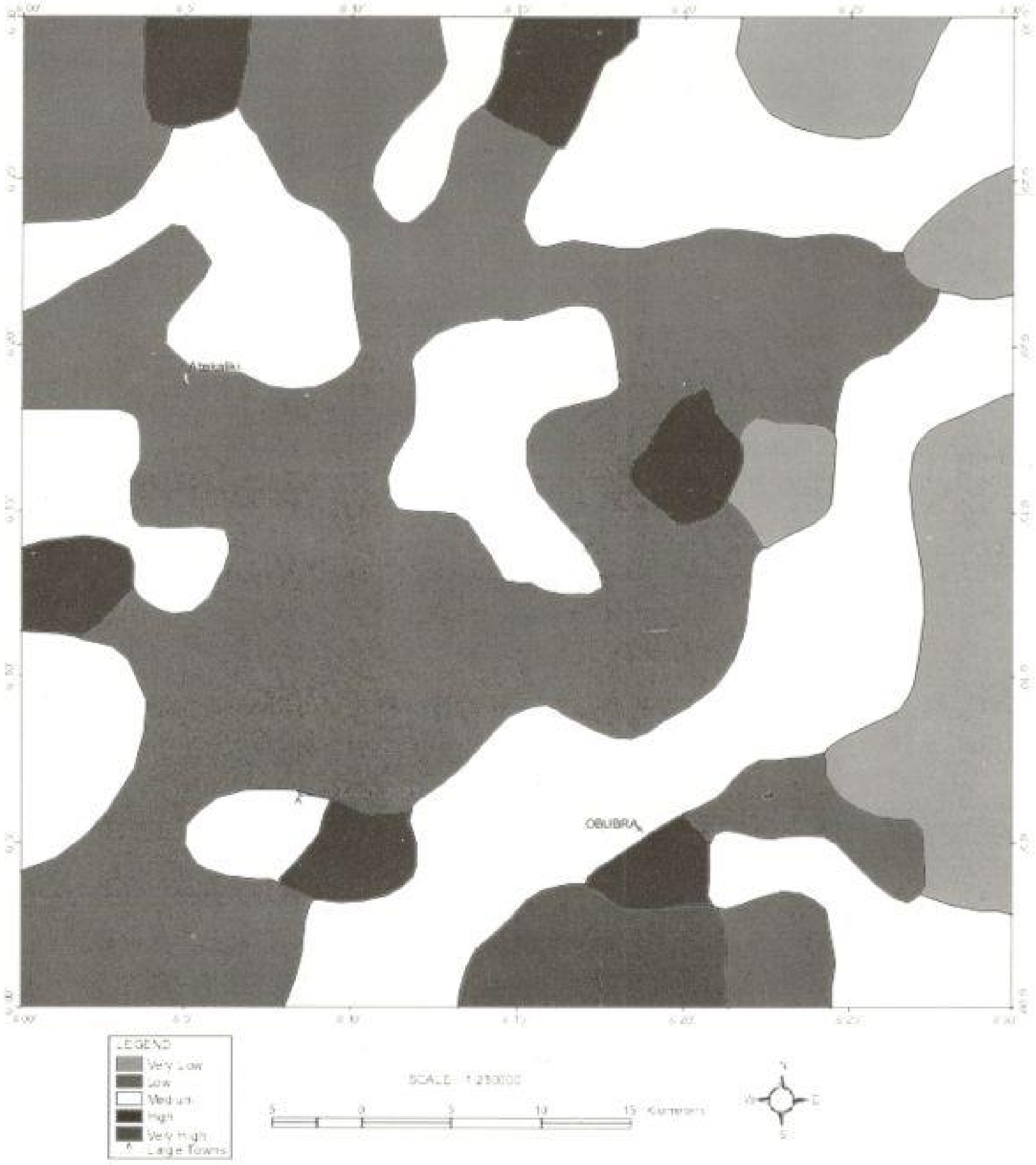

Fig. 5: Actual Soil Erodibility

Figure 5: Soil Erosion Map

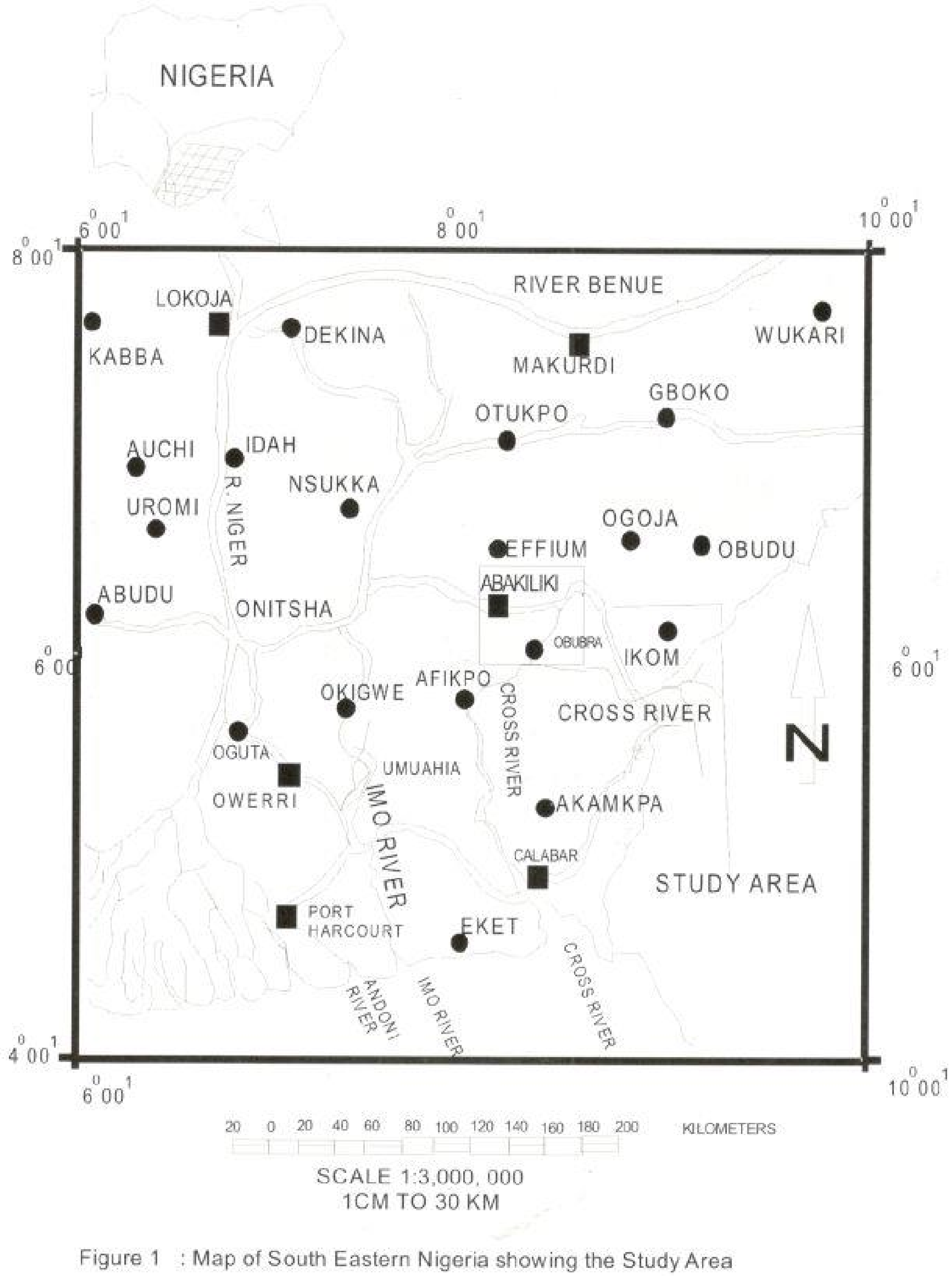

Figure 1 : Map of South Eastern Nigeria showing the Study Area

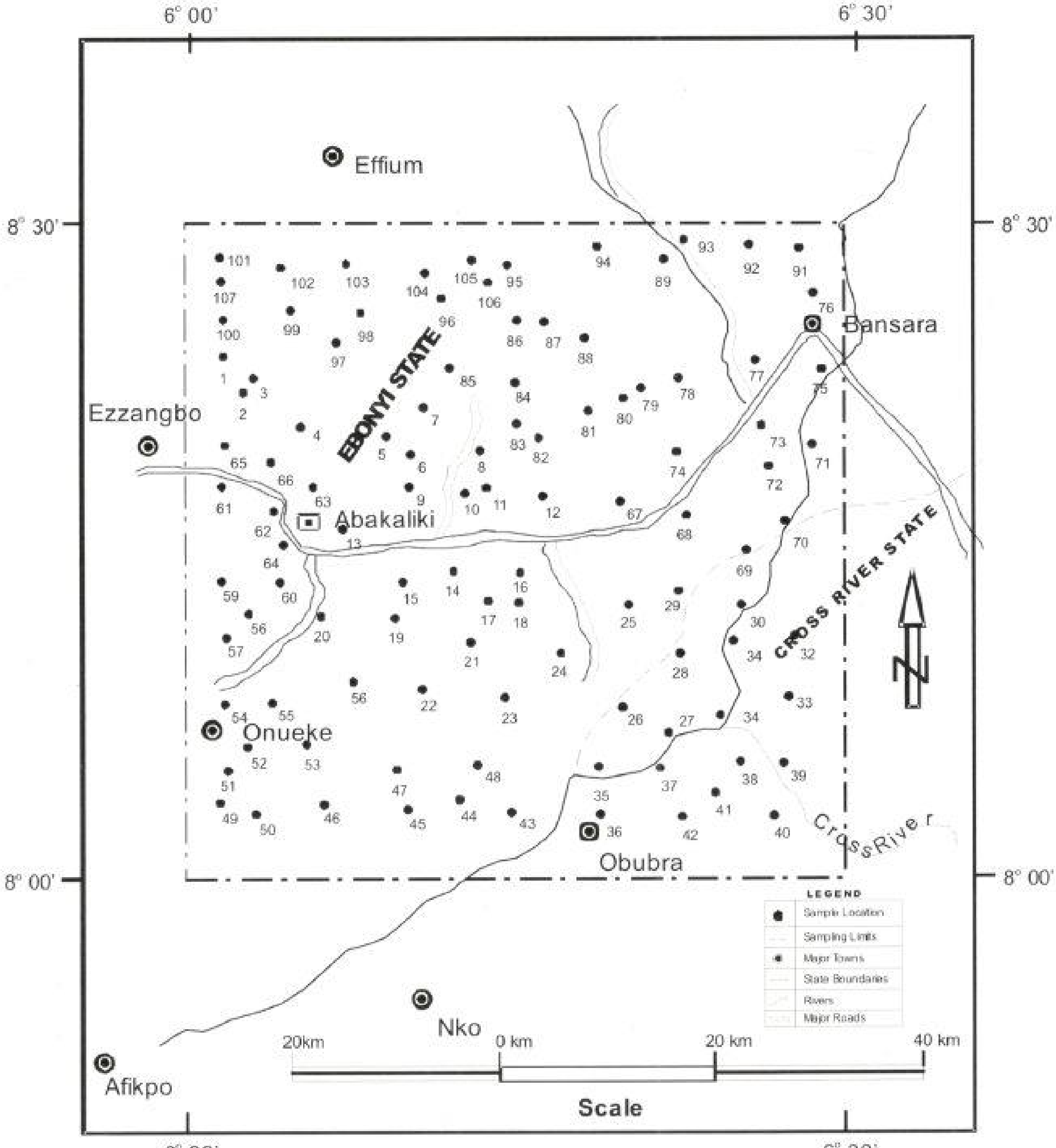

Figure 4.1: Sample Location