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Geomorphology and GIS Analysis for Mapping Gully Erosion Susceptibility in Taraba State, Nigeria

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ABSTRACT

This study aim at performing geomorphological and GIS Analysis to map gully erosion susceptibility in Taraba State. GIS and Remote sensing integrated with Erodibility Variables; Soil, Landuse and Erosivity Variables; Elevation/Aspect, plan Curvature, Stream Power index (SPI), Topographic Wetness Index (TWI), Length Slope Factor (LSF) were used in mapping gully erosion susceptibility. All Erosive Variables were automatically derived from SRTM DEM (http://earthexplorer.usgs.gov) and were analyzed using 3D Analyst and Spatial Analyst Extensions of ArcGIS 10.1.

The result shows that 2% are of very High Susceptibility, 33% High Susceptibility, 37% Moderate Susceptibility and 28% Low/no Susceptibility.

KEYWORDS: *GIS, Gully Susceptibility, Geomorphology*

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INTRODUCTION

Gully is one of the most important parts of soil erosion process which largely contribute to the sculpturing of the earth and its development have caused losses of a great amount of soil resulting to geo-environmental degradation (Shit el al. 2014, Vanwallenghem et al. 2005, marzolff et al. 2011). Gully erosion is an important sign of land degradation, rendering slopes unfit for agriculture, forming an important source of sediment in a range of environments and it is considered as one of the indicators of desertification. (Shruthi et al 2014). The configuration of gullies entails an amendment of overland flow, a reduction of runoff lag time and an increase in the runoff volume. (Shit et al 2015).

There have being growing interest in the study of gully erosion in the past decades in the world over, including Nigeria (Amanbagara et al 2015), which reflect the need to increase our knowledge on its impacts and controlling factors that vary under wide range of causes (conforti et al 2011). This knowledge is not only important from a scientific or geomorphological perspective, but also to enable land managers to develop sustainable planning strategies for appropriate utilization of land that include both gully stabilization and prevent gully formation. (Shruthi el al 2015).

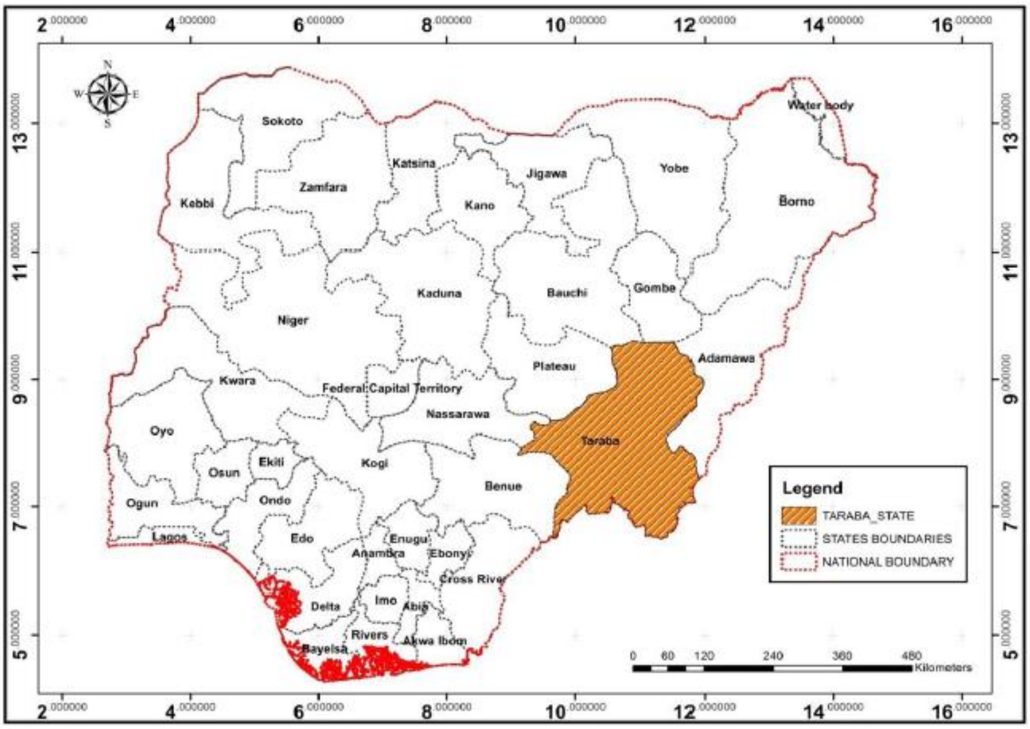
Recent technological advancement led to the development of numerous Stochastic process based models and erosion forecast model with the increasing emphasis on the use of the Geographic information System (GIS) and Satellite Remote Sensing (SRS), that not only approximate soil loss but also offer the spatial distribution of the erosion by generating precise erosion risk maps (Amanbagana et al 2015, Shit et al 2015)

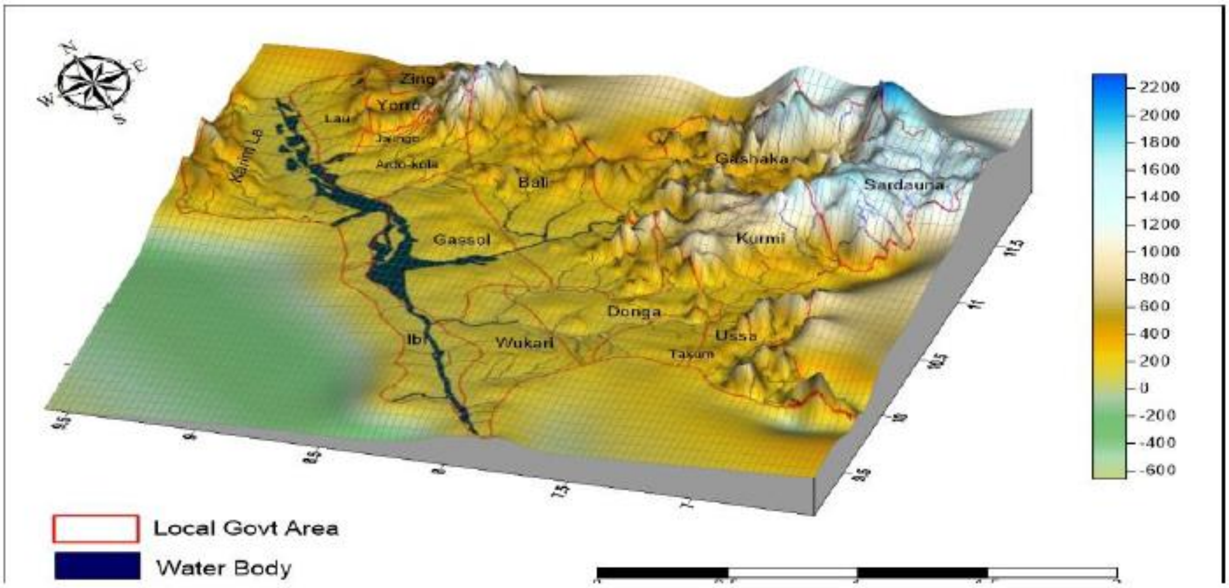
The GIS/SRS integrated with Erodibility Variables; Lithology/geology, soil, land use/land cover and Erosivity Variables; Elevation/Aspect, plain Curvature, Stream Power Index (SPI), Topographic Wetness Index (TWI), Length Slope Factors (LSF) (Conoscenti et al 2008, Conforti et al 2011, Dube el al 2014, Moore et al 1991) are used in mapping the Susceptibility of a place to gully erosion.

The aim of the study is to perform Geomorphological and GIS analysis to map gully erosion susceptibility in Taraba State.

THE STUDY AREA

The research was carried out in Taraba State, Nigeria. It is located at the North Eastern part of the country at 8˚00'N, 10˚30'E, covering a total area of 54,473 km^2





MATERIAL AND METHODS

In this research two variables were considered, under which some factors were analyzed. Erodibility variables – Soil and Land use, Erosivity variables – Elevation/Aspect, Plan Curvature, Stream Power index(SPI), Topographic Wetness index (TWI), Length Slope Factor (LSF). All the erosivity variables were automatically derived from Digital elevation Model DEM, provided by the Shuttle Radar Topography Mission (SRTM). The SRTM DEM was downloaded from USGS Earth Explorer: http://earthexplorer.usgs.gov. These were Analyzed using 3D Analyst and Spatial Analyst extensions of ArcGIS 10.1.

VARIABLE ANALYSIS

Land Cover:

Barren/Bare and sparsely Vegetated areas are affected by faster erosion and greater instability than forest (conforti et al 2011) and dense vegetative cover; because the later decrease effects of gully erosion susceptibility as surface runoff are reduced. In this study land use map was derived from image classification of Landsat 8 image (downloaded from USGS Earth explorer). The land use types were grouped into four classes, built-up area, vegetation, bare land and water body.

SOIL MAP

The soil map of Taraba was extracted from the Digital soil Map of the world (worldmap.havard.edu/data/geonage: DSMW_Rdy) which was grouped into four classes.

SLOPE

The steepness is one of the important factors that induce land evolution because it affects run off, drainage density and soil erosion. The steeper the slope the higher runoff velocity, consequent rill and gull initiation. (Conforti et al 2011, Valentin et al 2005). In this study the slope was generated from the SRTM DEM using surface tool, in the spatial analyst toolbox of the Arctool in ArcGIS and was reclassified into four classes using Classify tool, in the Spatial analyst toolbox of the Arctool in ArcGIS.

ASPECT

Aspect is also considered as an important factor in susceptibility studied of denudational process. It is expressed in degree from noerth clockwise, ranging from 0 to 360. (conforti et al 2011, Carrar et al 1991, Maharaj 1993, Guzzelli et al 2000).

PLANE CURVATURE

This is the rate of change of slope gradient or aspect, usually in a particular direction. The influence of plane curvature on slope erosion processes in the convergence or divergence of water during down slope flow. Positive (>0) value of plane curvature define convexity while Negative (<0) value define concavity (Willson & Gallant 2000, conforti et al 2011)

LENGTH SLOPE FACTOR

This is the relationship between surface runoff speed and sediment transportation which is determine using flow accumulation and slope using the equation described by moore and Bunch 1986):

$LS = (Fa \times cellsize/22.13)^{0.4} \times sinб/0.0896)^{1.3}$

Fa = Flow Accumulation

б = Slope in degree

The flow accumulation was generated using hydrology tool while the final equation was model using Raster calculator of algebra tool, all in the Spatial Analyst tool box for Arctool box of ArcGIS 10.1.

TOPOGRAPHIC WETNESS INDEX (TWI)

This is the effect of topography on the location and size of saturated source areas of runoff generation (Confeti et al 2011). Moore el al (1991) described the equation below for TWI:

$TWI = In(AS/tanб)$

AS = specific catchment area in meter (in the study case km)

б = Slope gradient in degree

RANKING/WEIGHTED OVERLAY

Ranking is the decision based on order of importance of criteria to be considered. In the first step, criterion are ranked in order of their importance, in the second step ranking method is used to obtain numerical weights from this order (Blistanova et al 2016, meyer 2007). Rank Sum Method (yahaya et al 2010) was used to calculate normalized weights of the criteria.

$W_j = n - r_j + 1/sum\ (n - r_k + 1)$

W_j is the normalized weight of each factor

n is the number of factors under consideration (k = 1,3…n)

r_j is the rank position of the factor

Weighed overlay is the overlay of criterion based on assigned weight to map the final susceptibility. The following equation was adopted

$GS = sum\ (F_1 * W_{J1} + F_2 * W_{J2} \ldots\ldots\ldots\ldots\ldots F_7 * W_{J7})$

GS = Gully Susceptibility

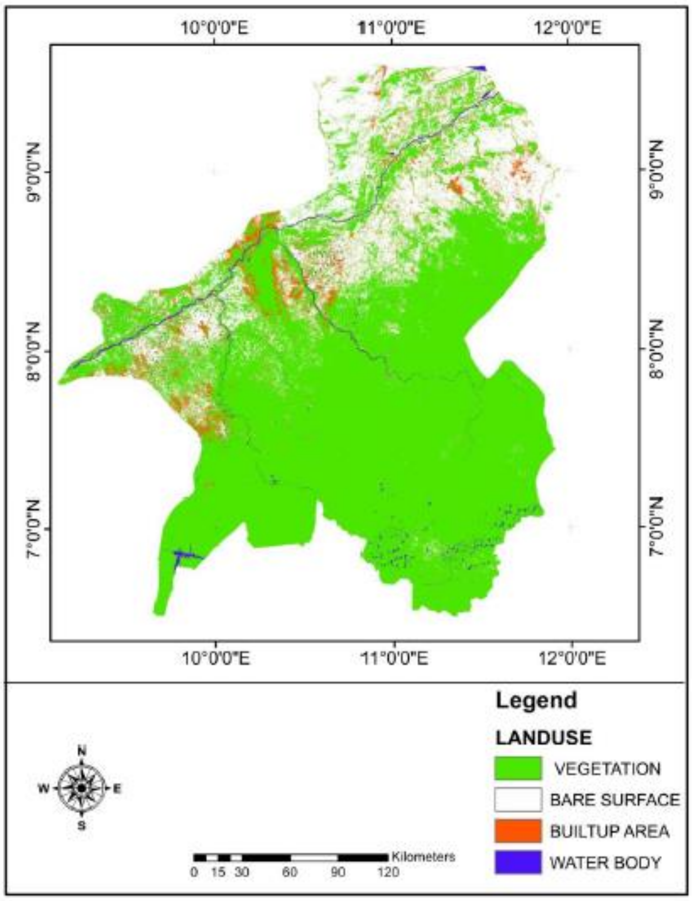
$F_1, F_2 \ldots\ldots F_7$ = respective factors

$W_{J1}, W_{J2} \ldots\ldots W_{J7}$ = the normalized weights

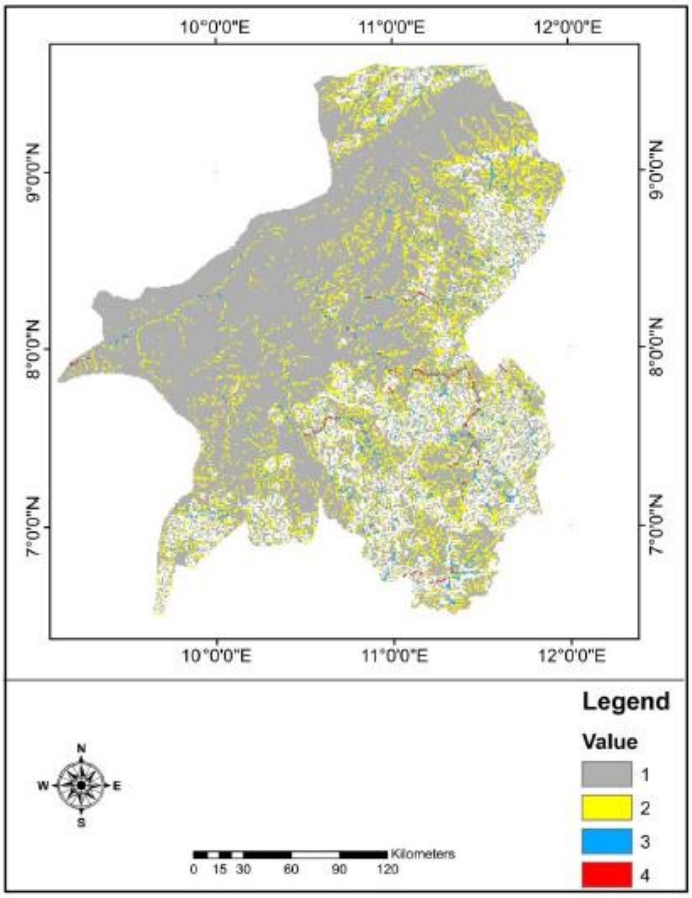
RESULT AND DISCUSSION

FACTORS	FACTOR,S CLASSES	RANKS
Land use	Water body	1
	Builtup Area	2
	Vegetative Area	3
	Bare land	4
SOIL	Acrisols/Leptosols/Arenosols/Lithosols	1
	Nitisols	2
	Luvisols	3
	Vertisols/fluvisols	4
Topographical Wetness Index (TWI)	0.804 –9.857	1
	9.857 –11. 339	2
	11.339 –12.738	3
	12.738 –21.790	4
Plane Curvature	Flat	2
	Convex	3
	Concave	4
Length Slope Factor (LSF)	0 – 1,543.3	1
	1,543.3 –6,834.6	2
	6,834.6 –19,180.8	3
	19,180.8 –56,219.9	4
Slope	0 – 1.875	1
	1.875 –5.0887	2
	5.0887 –9.6417	3
	9.6417 –22.7650	4
Aspect	Flat	2
	Convex	3
	concave	4

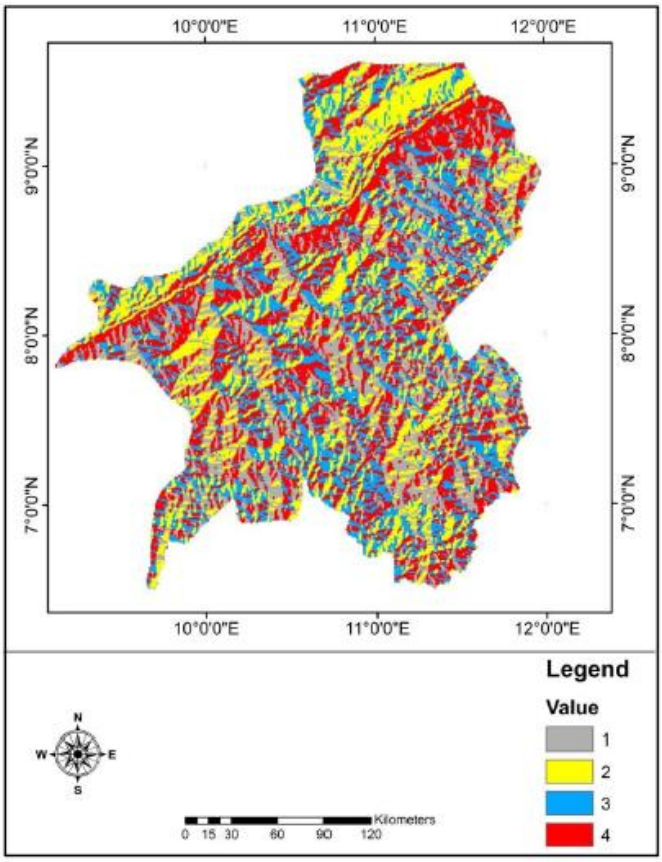
LAND COVER



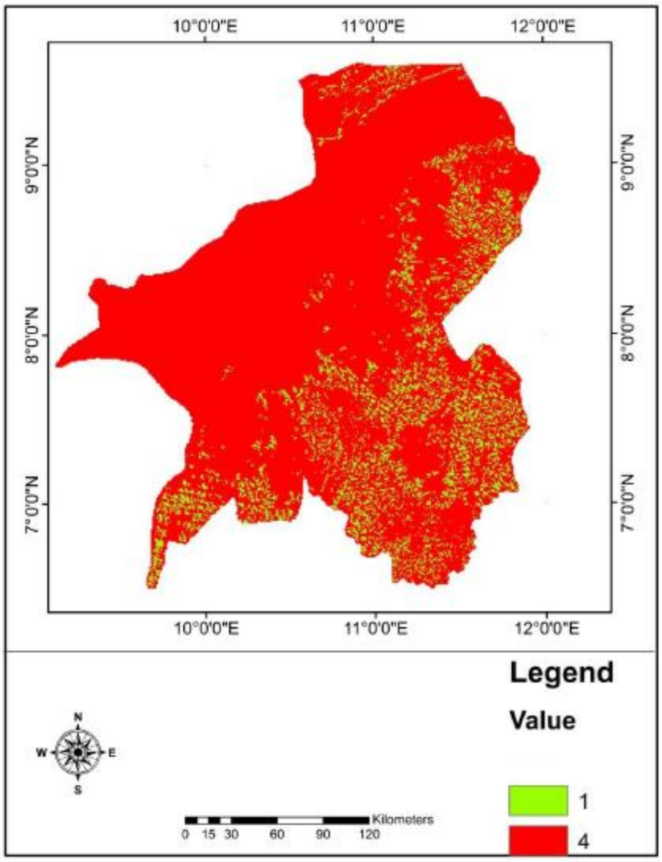
LENGTH SLOPE FACTOR



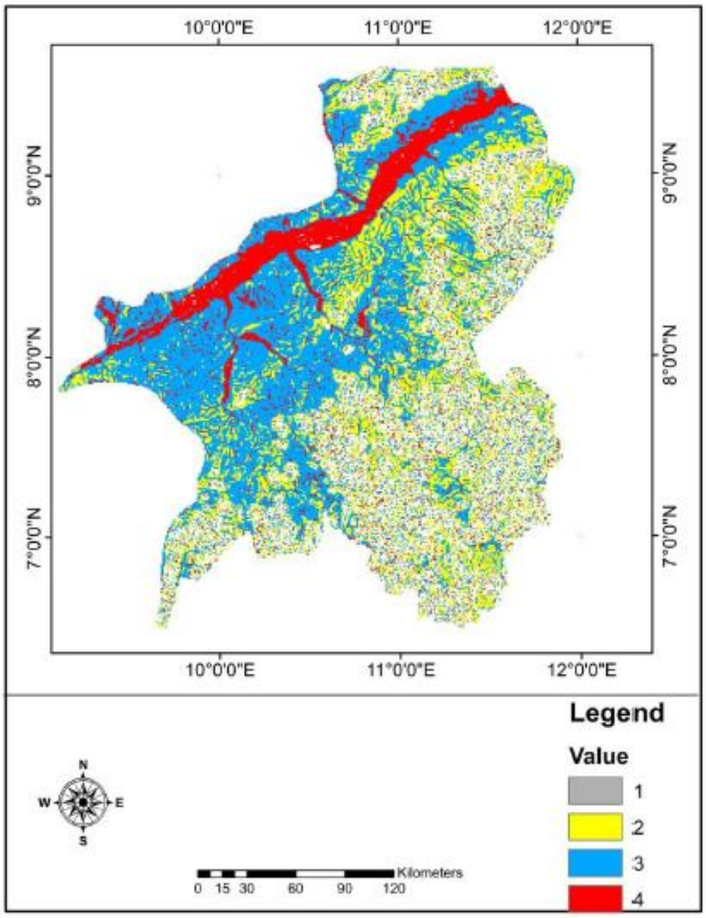
ASPECT



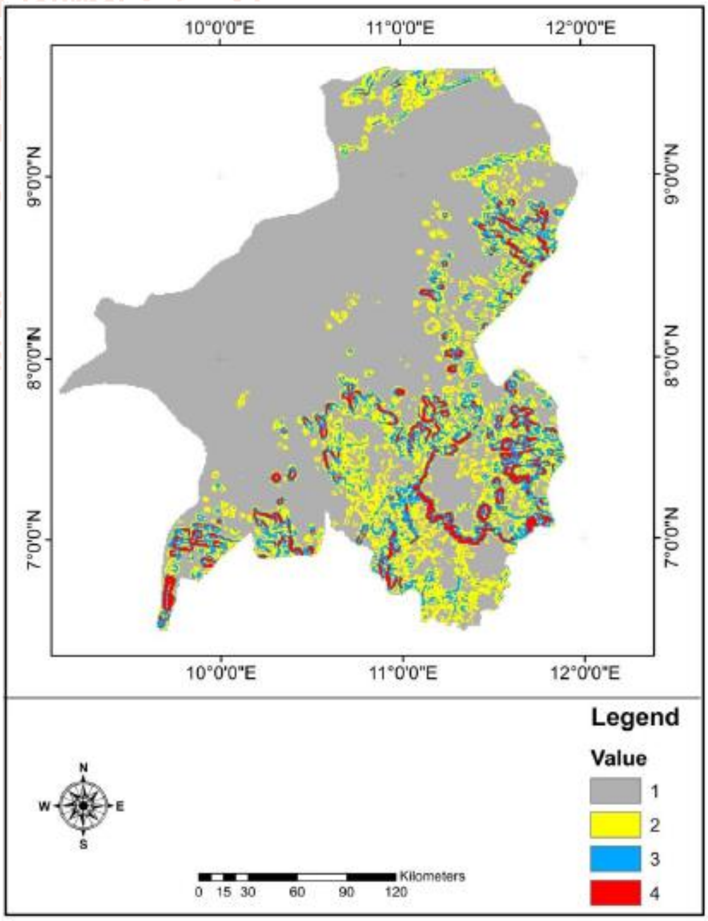
PLANE CURVATURE



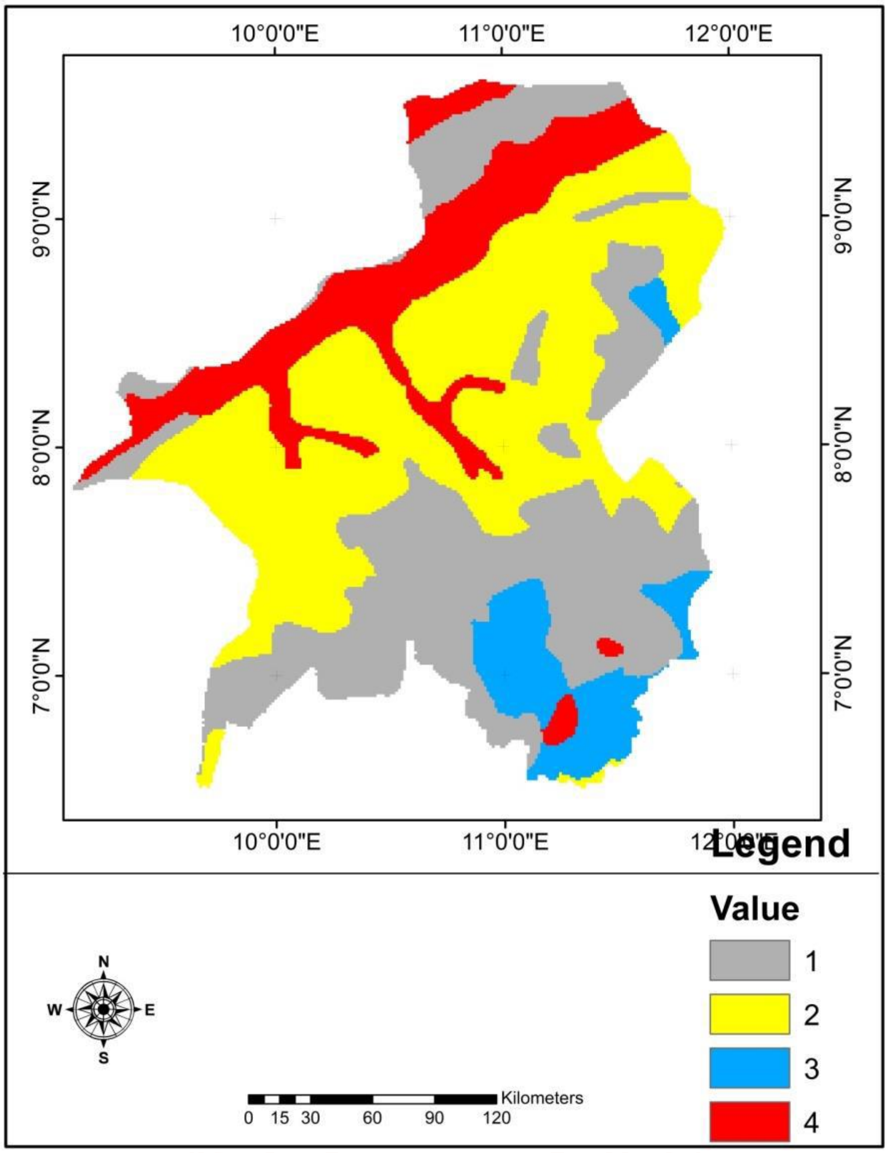
TOPOGRAPHIC WETNESS INDEX



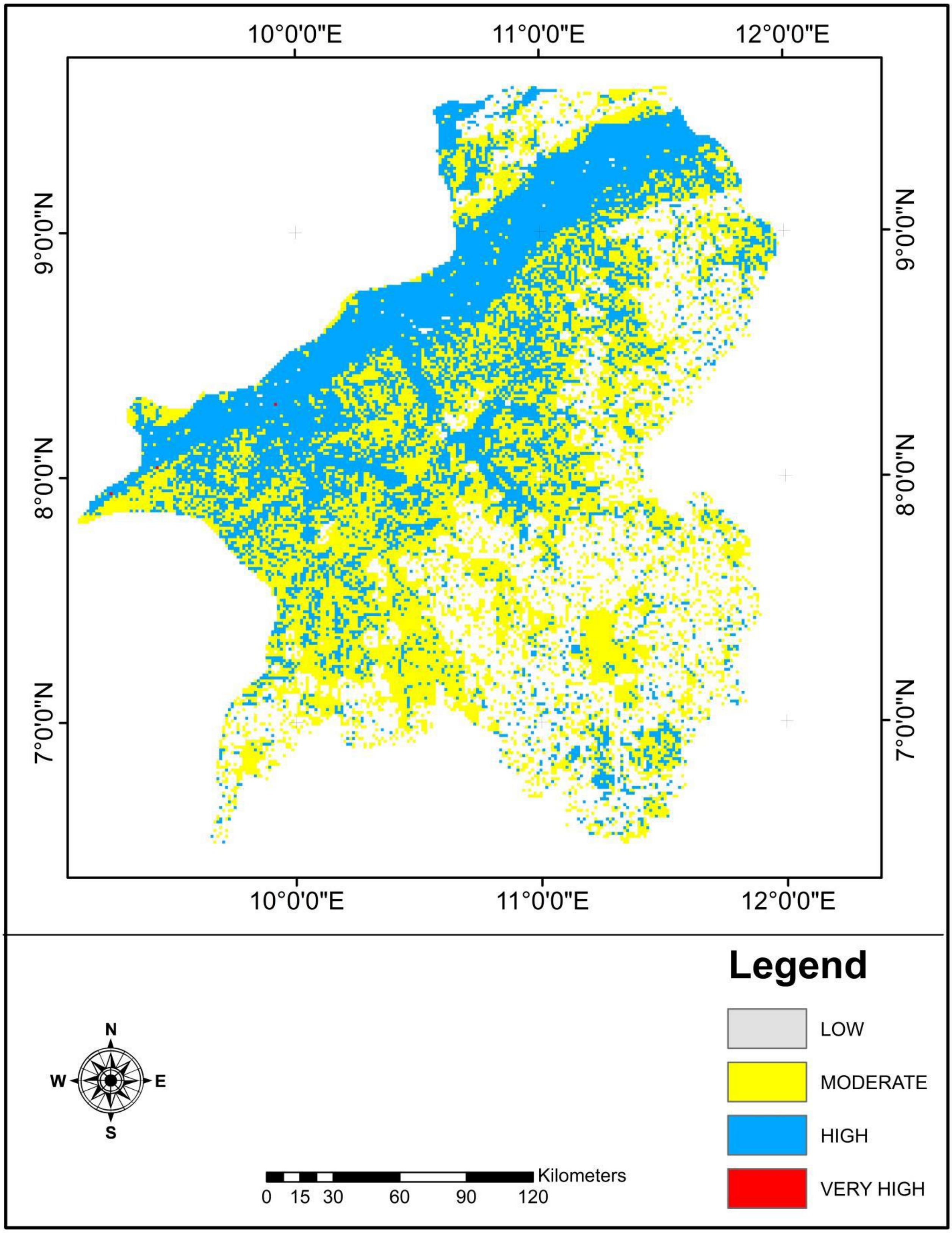
SLOPE



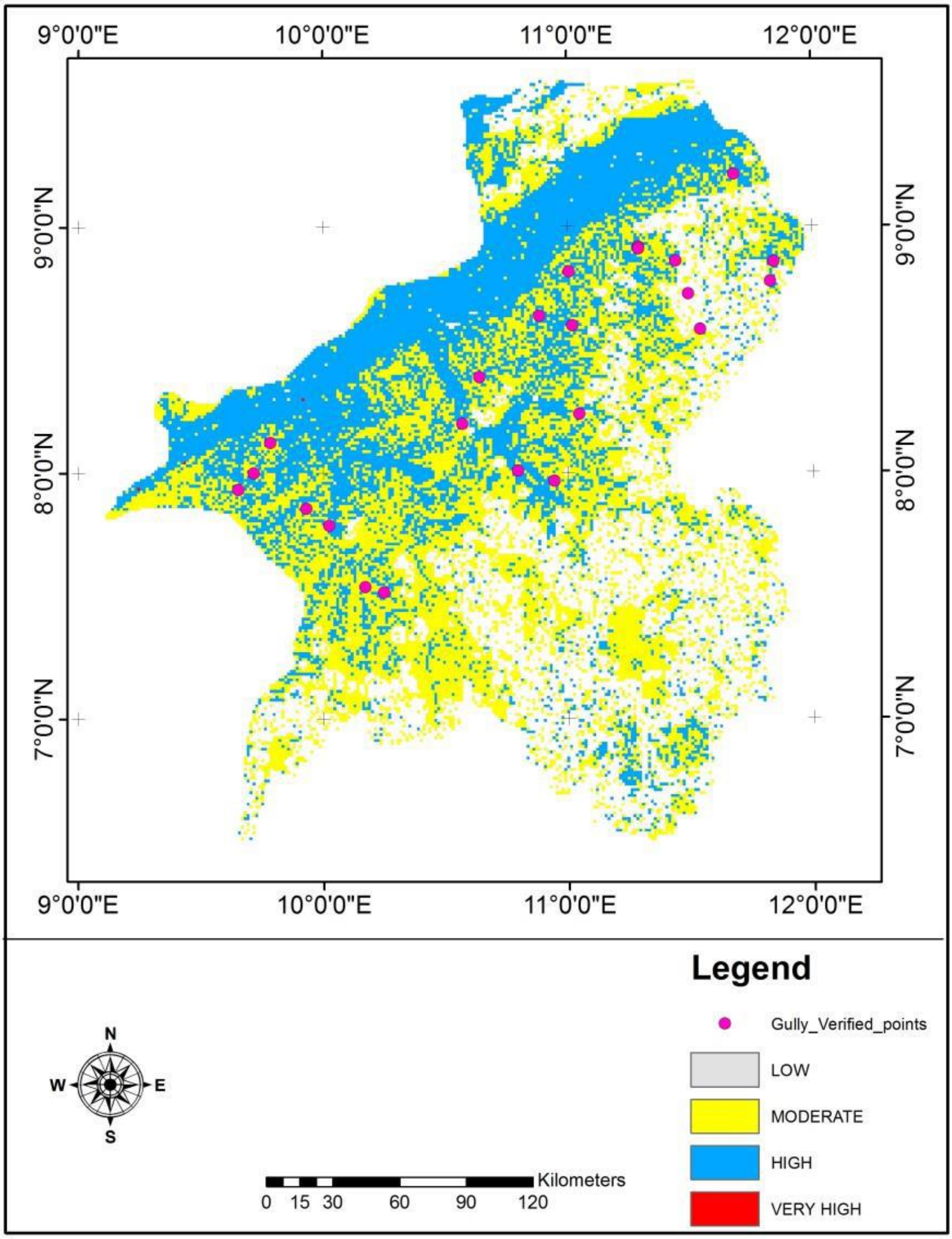
SOIL



FACTOR	RANK	ASSIGNED WEIGHT	WEIGHT %
Topographic wetness index	1	0.25	25
Length slope factor	2	0.2142	21
Land use	3	0.1785	18
soil	4	0.142	14
Plane curvature	5	0.1071	11
aspect	6	0.0714	7
Slope	7	0.03571	4
		0.99891	100



SUSCEPTIBILITY	AREA (HECTARE)
LOW	169
MODERATE	224572
HIGH	2011945
VERY HIGH	507



VALIDATED GULLY	CORRECT	FALSE	ACCURACY OF VISUAL INTERPRETATION
20	17	3	85%

In the field validation work, 20 gullies were observed and later study showed that 18 gullies were captured correctly, while 3 points were false. Nevertheless, the overall accuracy of gully interpretation reached 85%

Conclusions

In this study, the geomorphological and GIS analyses were used to characterize the morphological features and spatial distribution of gully areas and the most influential factors of gully erosion development. Gully susceptible areas were delineated Considering Erodibility and Erosivity features of Taraba State, the analysis shows the relationship between Erodibility Variables; Soil, Landuse and Erosivity Variables; Elevation/Aspect, plan Curvature, Stream Power index (SPI), Topographic Wetness Index (TWI), Length Slope Factor (LSF) and how they influence gully development. From the result it shows the 507 hectares of Taraba state have very High Susceptibility to Gully development, 2011945 hectares are highly susceptible, 224572 Hectares are moderately susceptible while 169 hectares have low susceptibility to gully development.

As such, the proposed model helps to decision makers to delineate the high and low susceptible areas in relation to gully erosion and to develop suitable soil and water conservation practices. The Validation data shows satisfactory accuracy of 85% between the gully erosion prone map and gully location data obtained from the field. This methodology can also be used in the other areas to delineate the gully susceptible zone.

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