GIS ANALYSIS OF DRIVERS OF EROSION AND GULLYING IN SOUTHEAST NIGERIA

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Outline

- Background
- Methodology
- Results
- Conclusions

Background

- The Southeast (SE) States of Nigeria is the area most affected by erosion in the country

- The erosion and gully problem has a long history - dated back to over 100years (Igbokwe *et al*. 2008),

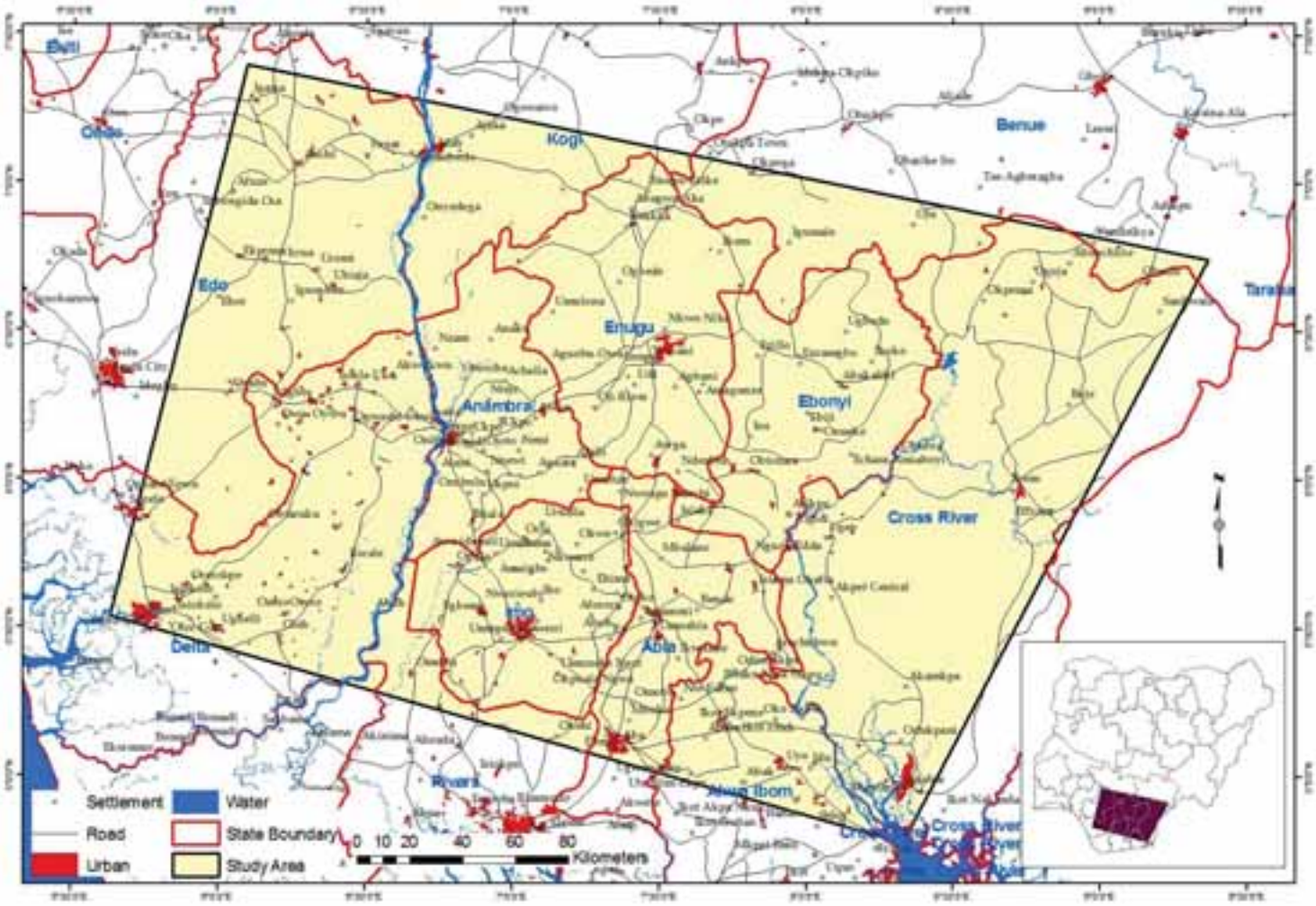
- About 2500 Active gully sites and gullies in different stages of development in the SE States

- The Agulu-Nanka-Ekwulobia-Oko gully complex (in Anambra State) covers over 1000km^2 and expanding at about 20-50m per year (Ajaero and Mozie, 2011; Egboka & Okpoko, 1984)

Part of Agulu-Nanka-Ekwulobia-Oko gully complex, Anambra State

Erosion threatens the Natural and Built environment

Nigeria showing the erosion prone states



The study area in SE Nigeria

- The interplay between physical and human factors - as the key drivers of erosion and gully

- Key variables identified –

- Complex hydro-geological and geotechnical properties of underlying aquifer system
- Soil – friable, unconsolidated
- Surface runoff from high intensity rainfall
- Vegetal removal
- High population density - Land-use pressure
- Poor design of roads, culverts and gutters

Objectives

- To explore an integrated data modeling approach using GIS to explain some of the drivers of erosion and gully formation

- To explore if canopy ecosystem management possesses any potential for erosion remediation and management

Methodology

Some of the spatial data used

Data	Description	Scale/resolution	Date	Source(s)
Topographic maps		1:100,000	1965	Federal surveys
Landsat MSS imagery	Path 202 Row 55 and 56	79mX59m	1972 and 1976	http://www.landcover.org
Landsat TM and ETM imagery	Path 187 Row 55, 56 and 57 Path 188 Row 55, 56 and 57 Path 189 Row 55 and 56	30mX30m	Between December 1986 and 1987 And between November 2006 and January 2007	http://www.landcover.org
Landuse and vegetation map	Digital Landuse and Vegetation map	1:250,000	1975/76 and 1995/1996	FORMECU
Terrain Data	SRTM-DEM STRM_ffB03_Path 188 Row 055, 56 and 57 and Path 189 Row 55, 56 and 57	90m		www.landcover.org
Geology map	Generalized Geology map of Nigeria	1:1,000,000	1962	Nigeria Geological Surveys
Soils map	Generalized Soil map of Nigeria	1:1,000,000	1990	Soils Survey Division, Min of Agric and Natural Resources

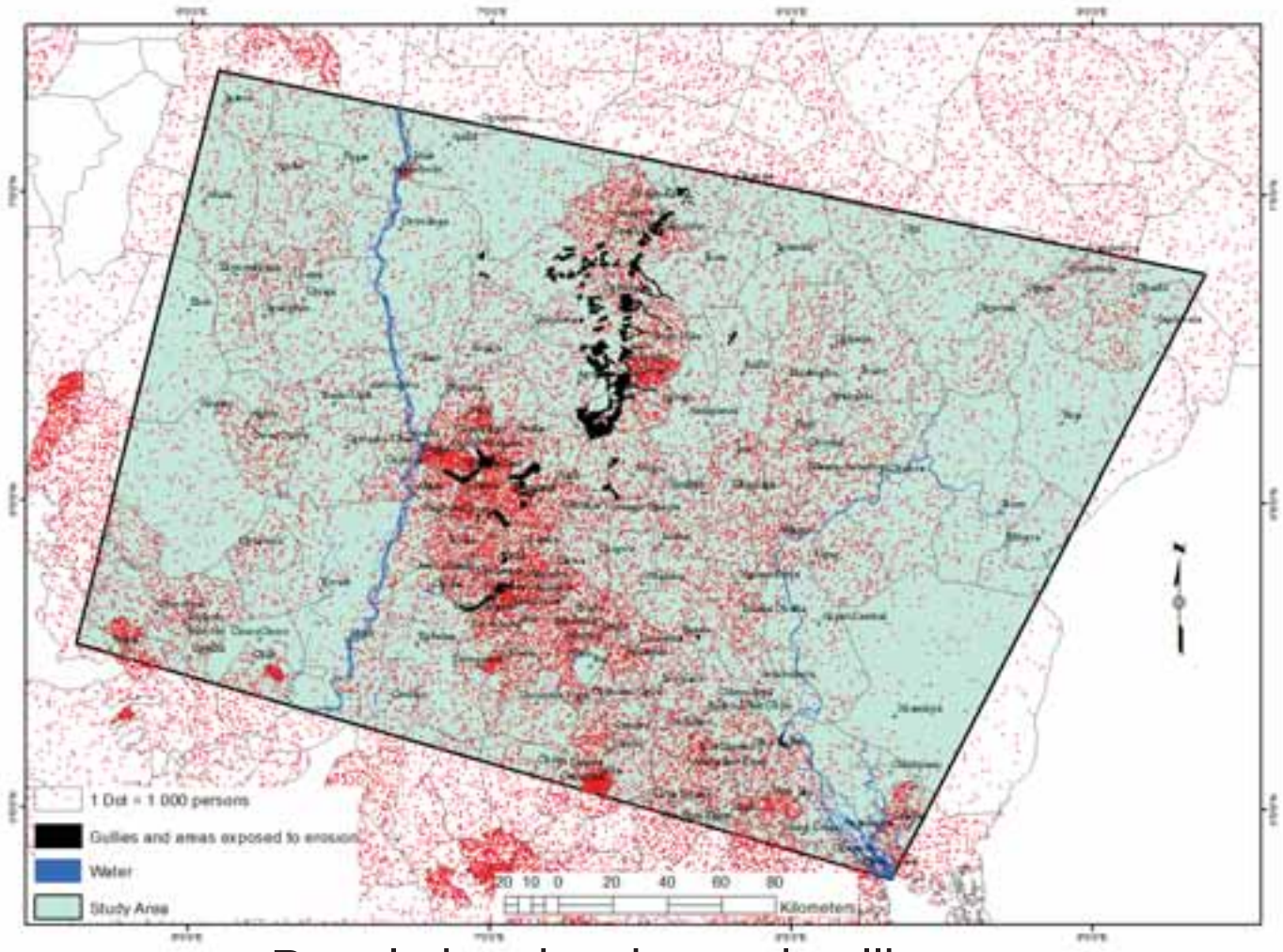
- Other data utilized include:

- Average rainfall data
- Population data
- Drainage from drainage maps
- Road network data

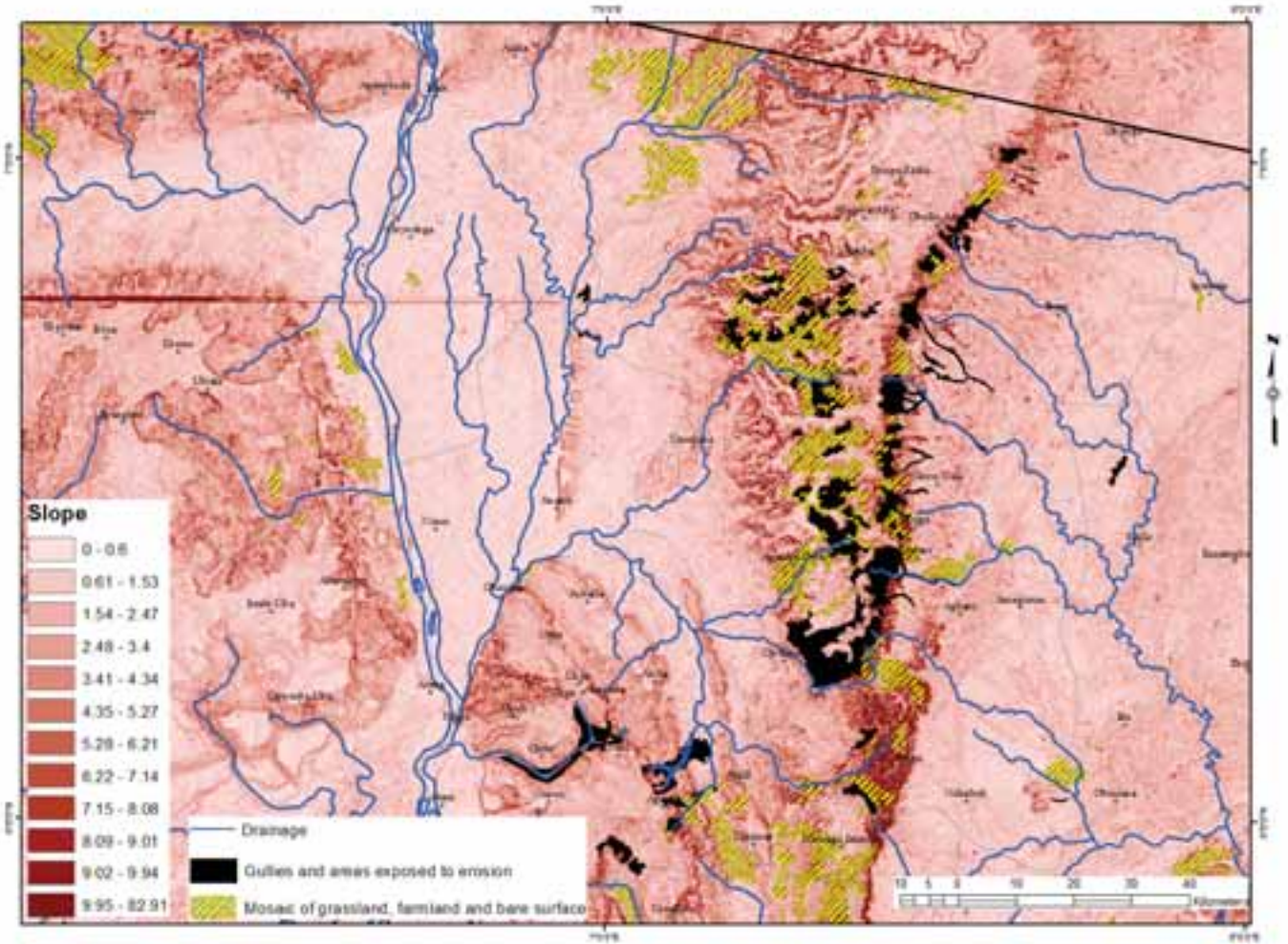
Procedure

- Conversion of data to GIS format include: Landuse/landcover mapping
- Second level derivatives e.g. slope,

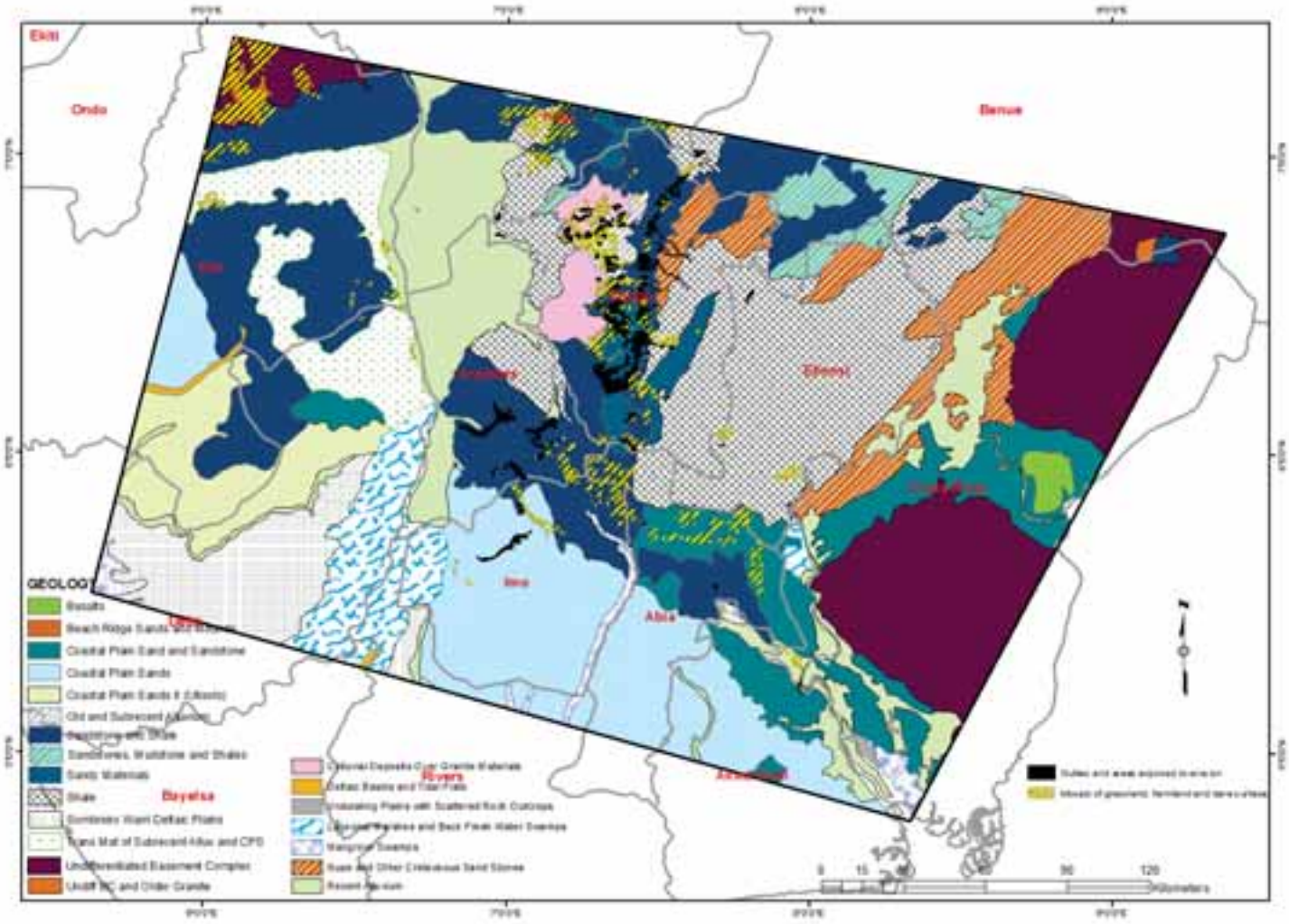
- Parameterization and assignment of scores to candidate drivers based on susceptibility to erosion:
  - Elevation
  - Slope
  - Geology
  - Soil
  - Population distribution
  - Drainage network
  - Road network
  - Rainfall
  - Canopy cover



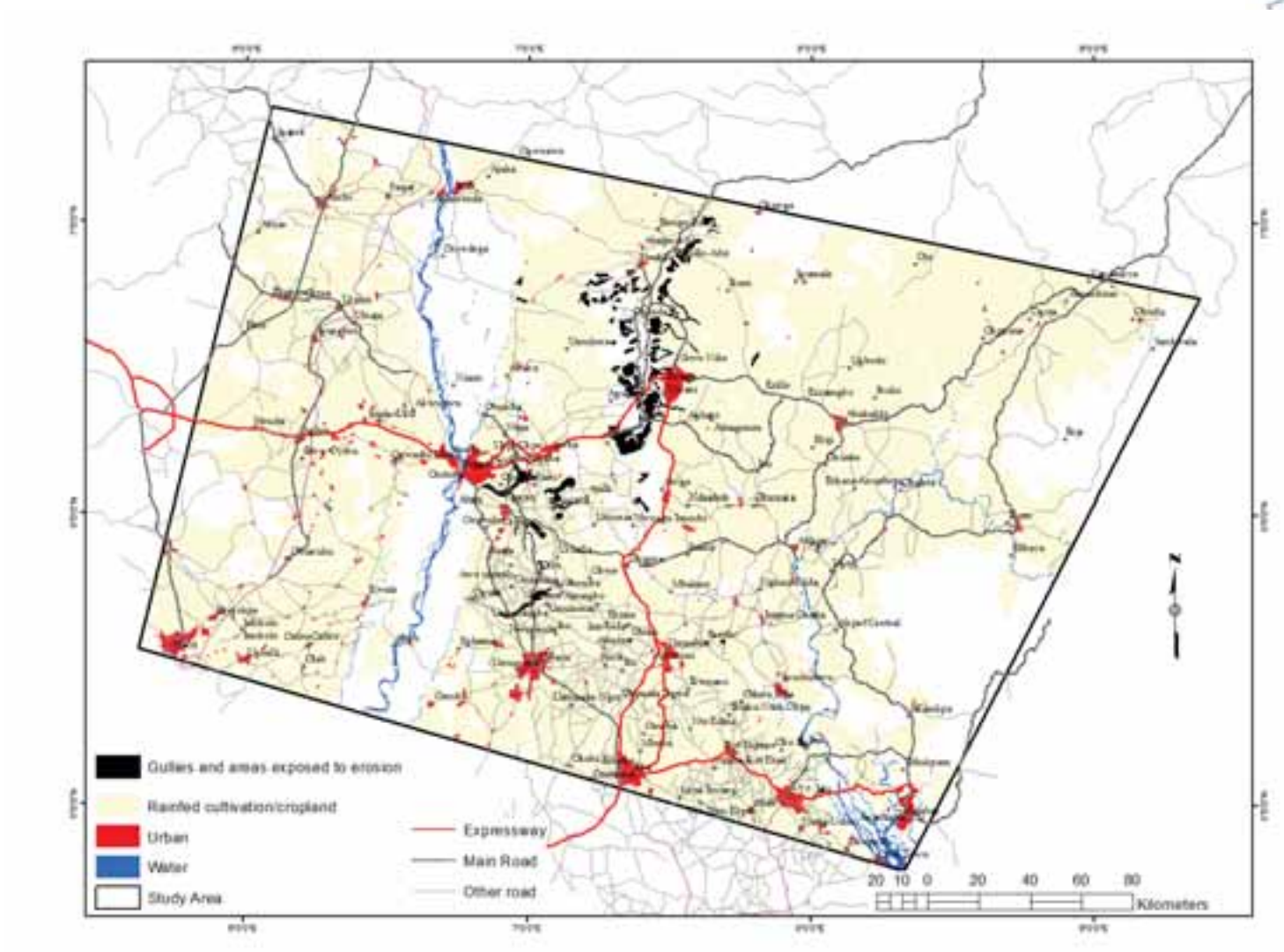
Population density and gullies



Slope map, drainage network and gullies



Geology and gullies



Road Network and gullies

- Scenario outlook for canopy cover under modelled under:

- Business as usual scenario - gullies and areas exposed to erosion assigned **0%**

- Medium intervention - gullies and areas exposed to erosion restored from **0% to 20%,** mosaic of grassland, farmland and bare surfaces from **20% to 40%**

- Strong intervention - gullies and areas exposed to erosion restored up to **60%,** and mosaic of grassland, farmland and bare surface to **80%**.

Canopy Cover Scenarios

LULC	Cover – business as usual	medium intervention	Cover – strong intervention
Alluvial	30	30	40
Floodplain agriculture	40	50	60
Forest	100	100	100
Gullies and areas exposed to erosion	0	20	60
Mosaic of Woodland and Shrub	80	80	90
Mosaic of grassland, farmland and bare surface	20	40	80
Plantation	100	100	100
Rainfed cultivation/cropland	40	50	50
Urban	30	30	40
Water	60	60	60
Wetland	60	60	60

Sample of the integrated PAT for generated analysis

LULC	Population density	Slope	Elevation	Distance from river	Distance from road	Geology	Soil	Boolean	Rainfall	Cover- no intervention	Cover – Medium intervention	Cover- strong intervention
Mosaic of grassland, farmland and bare surface	191	4.692	244	10	10	10	10	1	2177	20	40	80
Forest	191	12.354	342	10	10	10	10	0	2178	100	100	100
Forest	191	5.4276	374	10	10	10	10	0	2173	100	100	100
Rainfed cultivation/cropland	129	2.8202	336	10	10	10	10	0	2151	40	50	50
Rainfed cultivation/cropland	209	5.7683	138	10	10	100	100	0	2157	40	50	50
Forest	191	3.2832	307	10	80	40	40	0	2183	100	100	100
Water	191	0.9279	268	10	10	10	10	0	2176	60	60	60
Wetland	129	0.464	115	10	10	10	10	0	2134	60	60	60
Forest	129	0.6752	64	10	10	100	100	0	2126	100	100	100

Analysis

- Landuse/Landcover Change Analysis

- Transfer of the spatial driver values to the Polygon Attribute Table of the LULC map by collocation

- Transfer of the PAT to Statistical Package

- Logistic Regression Analysis to derive importance of the drivers and Simulation of Probability Surface Map of Erosion and Gullying

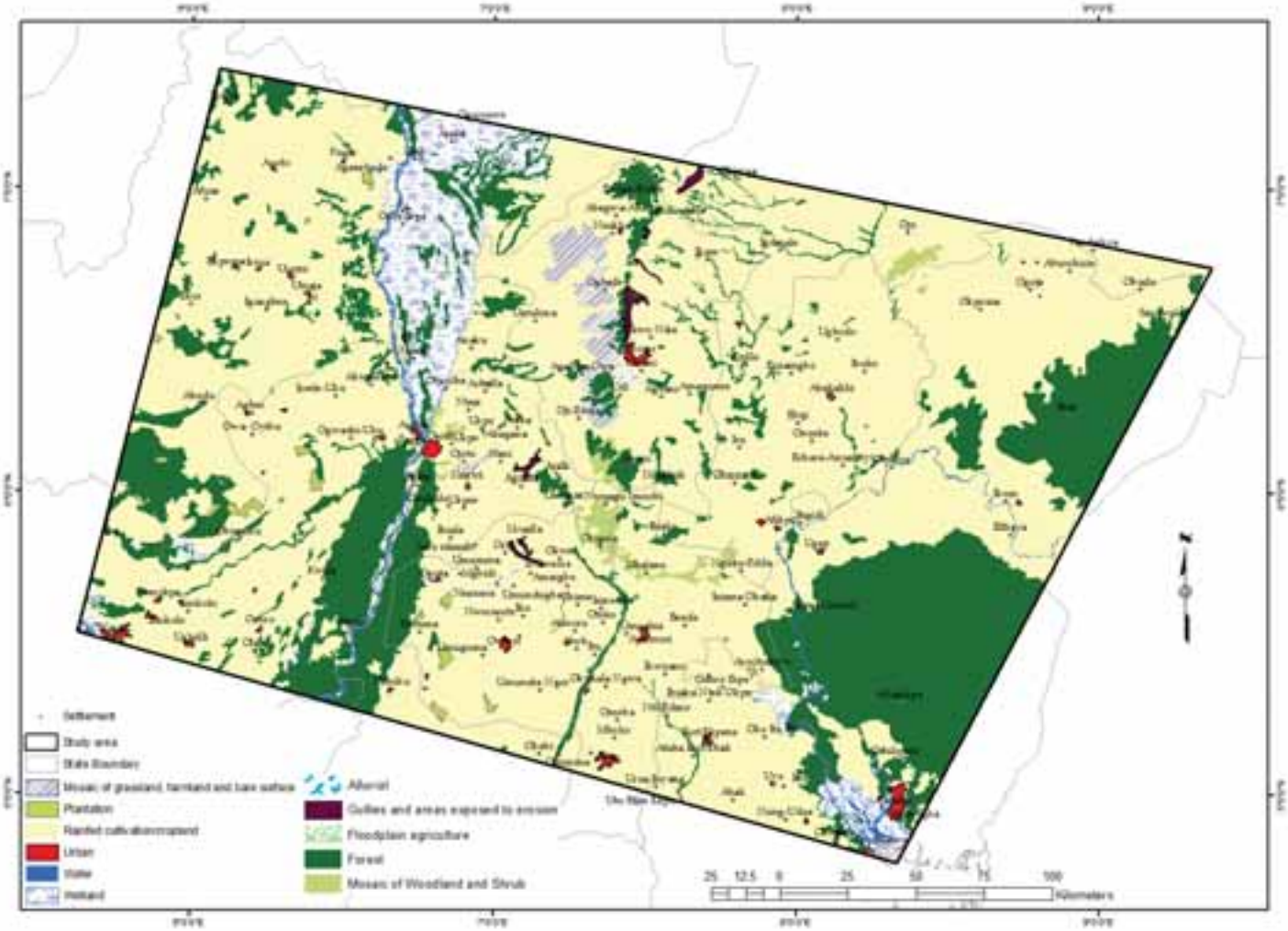
- Principal Component Analysis (PCA) to derive the relationship between Canopy Cover with other drivers under different scenarios

Results

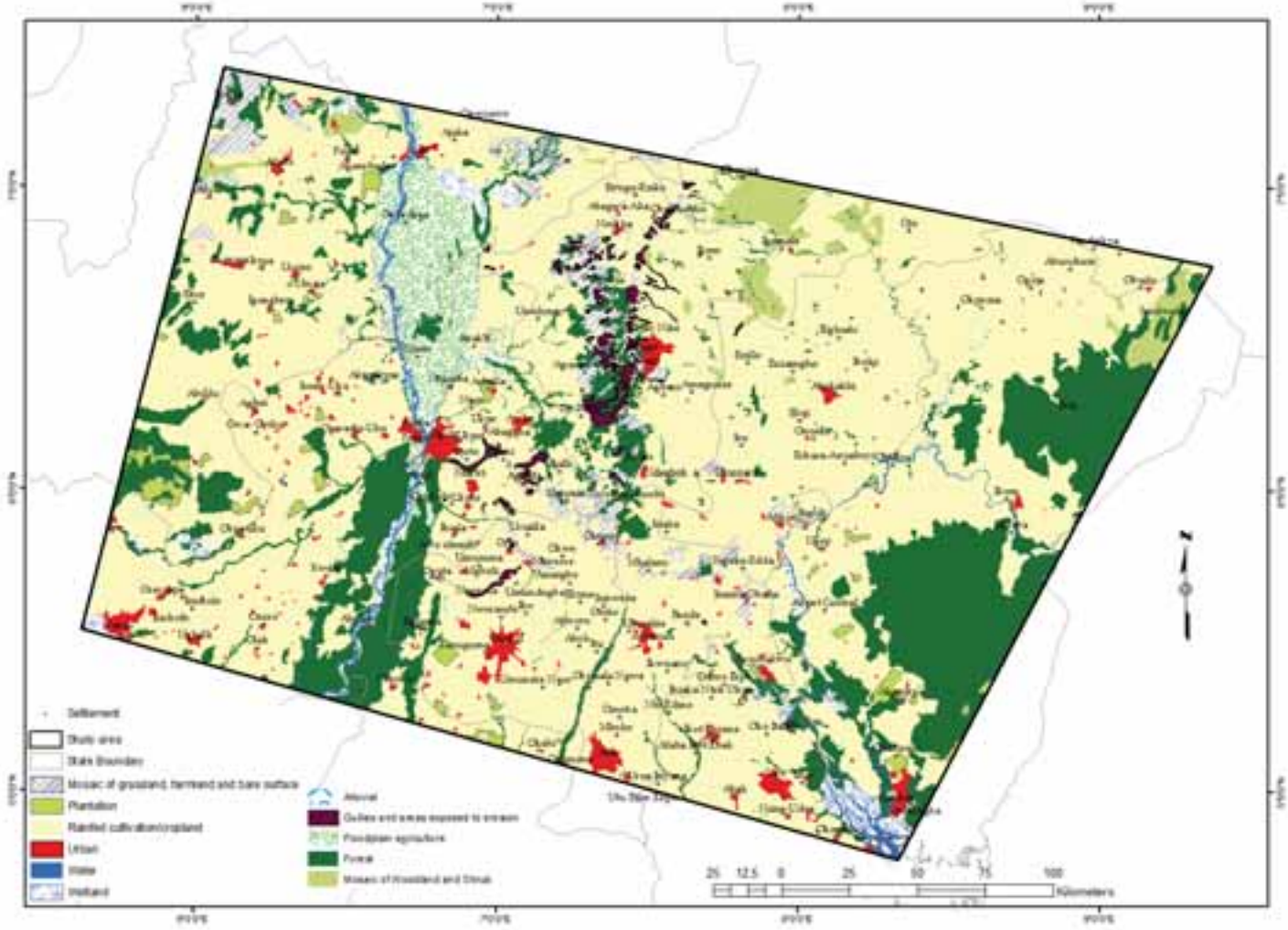
LULC statistics (in Percentage)

LUC	LULC Category	1976	1986	1996	2006
1	Urban	0.42	1.32	1.21	2.13
2	Mosaic of Woodland and Shrub	0.85	1.10	0.60	2.17
3	Forest	21.87	18.02	16.11	17.89
4	Mosaic of grassland, farmland and bare surface	1.12	1.61	2.03	2.92
5	Wetland	4.66	3.74	0.91	1.26
6	Rainfed cultivation/cropland	69.53	66.51	74.90	66.73
7	Floodplain agriculture		2.71	1.45	3.79
8	Water	0.93	0.90	1.19	1.10
9	Gullies and areas exposed to erosion	0.21	1.18*	0.59	0.76
10	Alluvial	0.11	0.34	0.03	0.20
11	Plantation	0.30	2.58	0.99	1.06

**The relatively higher figure (1.2%) for gullies and areas exposed to erosion in 1986 may have been due the excessive dryness of the decade 1980s which increases the likelihood of mapping very dry exposed farmlands as gullies on landsat image. This is consistent with decline in rainfed cultivation/cropland from 69.5% in 1976 to 66.5% in 1986.*



LULC map for 1976



LULC map for 2006

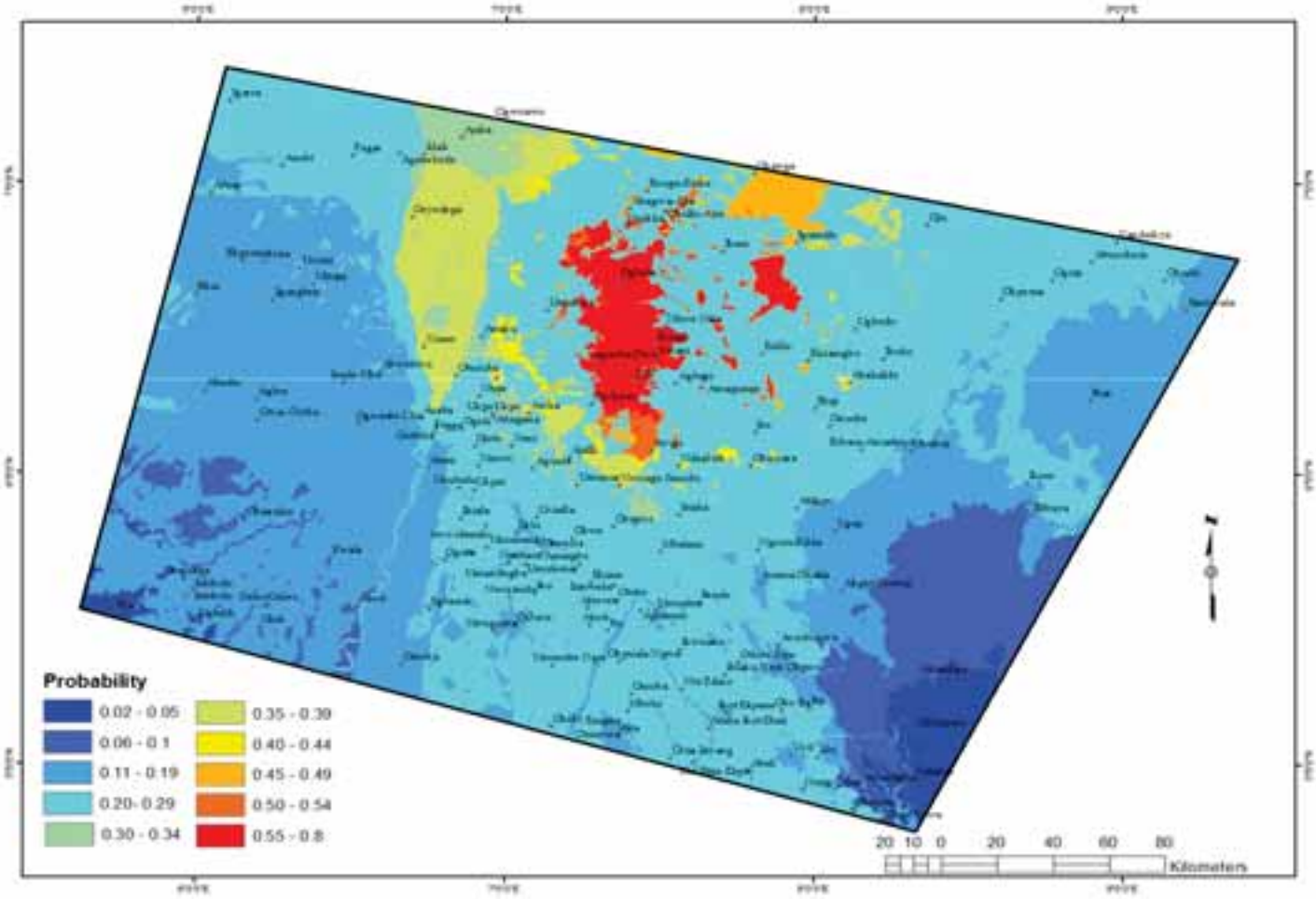
Logistic regression of Erosion Drivers

	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
							Lower	Upper
Population Density	.000	.000	3.751	1	.053	1.000	1.000	1.000
Slope	.090	.027	10.968	1	.001	1.094	1.037	1.153
Elevation	.003	.001	14.008	1	.000	1.003	1.002	1.005
Drainage distance	-.003	.004	.568	1	.451	.997	.988	1.005
Road distance	-.011	.004	7.787	1	.005	.990	.982	.997
Geology	.149	.116	1.661	1	.197	1.161	.925	1.456
Soil	-.132	.116	1.313	1	.252	.876	.699	1.099
Rainfall	-.003	.000	38.921	1	.000	.997	.996	.998
Constant	2.338	1.143	4.185	1	.041	10.362		

The function for constructing probability surface maps for erosion and gully formation process in the SE was written as:

$$P=1/[1+\exp(-1*(2.338 + 0.000(p\text{-}density)+0.09(slope)+0.003(elv)–0.003(riv\_d)-0.11(rd\_dis)+0.149(geol) – 0.132(sol) – 0.003(rain90)$$

…….



Simulated probability surface map of erosion and gullying

Principal Components – Canopy cover vs Others

PCA extracted for the different intervention scenarios

	Cover - Business as usual			Cover - Medium intervention			Cover - Very Strong intervention		
Variables	**PC1**	**PC2**	**PC3**	**PC1**	**PC2**	**PC3**	**PC1**	**PC2**	**PC3**
Population	-0.023	0.363	0.21	0.02	0.421	0.075	0.185	0.161	0.754
slope	0.613	0.007	-0.034	0.604	-0.016	-0.019	0.581	-0.037	-0.065
Elevation	0.839	0.091	0.135	0.835	0.052	0.159	0.814	-0.22	-0.083
Drainage	-0.254	0.085	-0.624	-0.233	0.115	-0.676	-0.191	0.645	0.253
Road	-0.094	0.205	0.79	-0.1	0.301	0.761	-0.038	-0.754	0.304
Geology	0.516	0.062	0.183	0.516	0.048	0.17	0.537	-0.075	0.095
Boolean*	0.506	0.668	-0.203	0.585	0.526	-0.224	0.664	0.127	0.084
Rainfall	-0.806	-0.059	0.045	-0.807	-0.003	0.029	-0.789	-0.017	0.084
Cover	-0.042	-0.9	-0.01	0.002	-0.877	-0.031	0.215	0.326	-0.627

*refers to the odd of erosion/gullying

Conclusions

- The results suggest the trend of eroded areas has been on the increase

- Geology, slope, elevation and population density emerged as the most important predictors of erosion.

- Results suggest that improved canopy cover has strong potentials to mitigate erosion in the SE Nigeria

- A GIS-based integrated and holistic basin-wide approach to erosion and gully management offers a promising strategy to provide data to support point-based structural measures in the SE

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