INTEGRATION OF REMOTE SENSING DATA AND FIELD MODELS OF IN-SITU DATA IN A GIS FOR ENVIRONMENTAL SENSITIVITY INDEX MAPPING; A NIGERIAN EXAMPLE

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ABSTRACT

Environmental Sensitivity Index (ESI) is used to measure the degree of impact of a hazard-causing event within a given environment, in order to be able to put in place an adequate contingency plan. Until recently ESI had mostly been calculated based on geomorphological concept, recently however the focus is on a combination of many factors that are directly or indirectly influenced by the focused activity, such as physical, biological and anthropological and socio economic factors.

The need to integrate data from different sources in the GIS platform brings up a question of efficiency of data integration. The varying data sources utilize different data models and accuracy level; it raises a methodology question on the proper integration of data from different platforms without introducing high error level of estimation.

The paper attempts preparation of ESI of an inland oil field based on a combination of remotes sensing data (SPOT XS) and sampled data collected from the field. The approach utilized map algebra in ArcView Spatial-analyst environment to combine unique indexes from various sources to arrive at a single ESI atlas. The paper also identifies contribution of such method in developing countries, where extensive part of the country does not have adequate information for preparation of such maps

INTRODUCTION

Environmental Sensitivity Index (ESI) is used to measure the degree of impact of a hazard-causing event within a given environment. The focus of most ESI is to measure the level of sensitivity of the environment to oil spill. ESI thus serves as a valuable approach to Oil spill risk assessment, as the result would depict the degree of risk of each environmental component to oil spill. Until recently ESI had mostly been calculated based on geomorphological concept. But the international standards stipulate that ESI should rather be calculated based on a combination of various parameters, such as physical, biological and anthropological and socio economic factors.

Prior to the advancement of GIS some form of environmental index mapping have been produced using a refined method of conventional map making. With the advent of GIS the research interest has been on the appropriate methods to integrate this new technology to the preparation of ESI mapping. ESI mapping is meant to be a unique surface interpolation of all the environmental components in the environment captured with a single index that represents the sensitivity level of different locations to particular hazard causing event such as oil spill.

Using GIS for ESI require some basic concepts and assumption especially as it relates to issues of index assignment and map generalization. The paper advances a procedure to map the resources in a given environment for the purpose of GIS based mapping of environmental components. It also ranks the resulting classification into different sensitivity index level.

Three issues were addressed in this paper.

1. Spatial interpolation of field data for mapping of environmental components.

2. Integration of data from different sources and level of occurrence to map environmental components
3. Environmental sensitivity classifications based on the Combined integration of different data and different weighting factors.

Theoretical Underpinning.

One of the goals of ESI is to establish in quantitative terms the value of the surrounding environment, generally referred to as Environmental Sensitivity Index (ESI). The definition of ESI of a particular zone provides an environmental state of reference that can be readily used for contingency planning and regularly updated as new elements or changes come into play.

Remote sensing has been acknowledged as invaluable in both preparation of ESI and surveillance of changes caused by hazard causing events. Remote sensing is particularly useful in areas with poor mapping materials like Nigeria.

However despite the valuable contribution of remote sensing to the preparation of environmental sensitivity index mapping; remote sensing on its own is not sufficient to estimate the sensitivity level of the environment. The in situ data such as soil survey, bacteria count, conductivity level of soil, socio economic characteristics of the inhabitant, animal habitat and count among others. Though some level of estimate by deduction can be done from the remote sensing products but ESI require such level of accuracy of estimate than can be deduced from the remote sensing data.

The need to integrate data from different platforms in the GIS environment brings up a question of efficiency of data integration. The variant data sources utilize different data models; it raises a methodology question on the proper integration of data from different platforms without magnifying the existing errors in constituent data. Data obtained from the field can be captured in GIS platform through different model approach. . In this study however the field model is adopted.

Goodchild (1993) describe field model as an attempt to represent the spatial variation of a single variable using a collection of discrete objects. A spatial database may contain many such fields or layers, each able in principle to return the value of one variable at any location (x,.y) in response to a query, and fields may be associated with variables measured on either continuous or discrete scales.
He identified six common field models in GIS, which are:

1. Irregular point sampling: the database contains a set of turples (x,y) representing sampled values of the variable at a finite set of irregular spaced location.
2. Regular point sampling: as above but with points regularly arrayed, normally on a square or rectangular grid (e.g Digital elevation model)
3. Contours: The database contains a set of lines., each consisting of an ordered set of (x,y) pairs each line having an associated z value; the points in each set are assumed connected by straight lines.
4. Polygons: the area is partitioned into a set of polygons such that every location falls into exactly one polygon (quardrant);
5. Cell grid: The area is partitioned into irregular grid cells the value attached to every cell is assumed to be the value of the variable for all locations within the cell.
6. Triangular net: the area is partitioned into irregular triangles; the variable is specified at each triangle vertex

The paper attempts preparation of ESI of a part of Nigerian Niger Delta with specific focus on oil related substances using a combination of remotes sensing data (SPOT XS) and sampled data collected from the field. The approach utilized map algebra in ArcviewSpatial analyst environment to combine unique indexes from various sources to arrive at a single ESI atlas.

One of the major problems faced in dealing with field data in a GIS is the adequate sample size to generate surface interpolation. What level of data can be measured to generalize the occurrence of environmental parameters. Generally speaking ESI indexing is an attempt to arrive at a singe quantitative value for a given space which represents the level of sensitivity to a particular human activity or natural phenomenon.

In other word it is essentially reclassifying the space into discrete groups of sensitivity levels. Classification in geography has been observed as the systematic grouping of objects or event into classes on the basis of properties or relationships that they have in common.

This can be done via logically, subdividing a population or agglomerating like- individuals (i.e. (1) subdivision methods (2) agglomeration methods.)

Subdivision methods: this is done through carefully defined criteria, usually which can be the purpose or absence of one or more attributes of classification purpose of focus often referred to as classification scheme.

Agglomeration methods: takes a number of individuals and assembles item into classes according to some grouping procedure.

One major attribute of classification is that it must be exhaustive. the simplest classification is the one that involve one criteria in which case the element involved are categorized into two in or out, yes or no, true or false. GIS packages readily classify issue, into this limited and simple scheme.

In any research therefore that involves classification the researcher must develop or adopt a classification scheme, which must be exhaustive on the basis of the project at hand.

The classification scheme can be project/research based or universal.

GIS in environmental researches brought about a basic question of integrating field dependent models, and classification scheme in GIS. It is impractical for a specific GIS to provide all analytical capabilities for all kinds of users. On the other hand, to produce a specific software for every field or project would not only be unreasonable but would further aggravate the problems of rigid boundaries between disciplines which GIS seek to reduce. Chud and Ding 1992 suggested that spatial analysts develop their own models and integrate those models with a GIS for their different purposes e.g. Willer(1990).

The various suggestions implies that each GIS user must be able to combine knowledge of spatial relationships with programming capabilities which will inevitably makes GIS to be an alienating approach. The focus of GIS is to reduce the rigid boundaries between geographers and other professionals that have interest in spatial attributes of the fundamental parameters of their subject.

In the process of classifying the space into groups based on the data obtained about objects of phenomenon in space it has been rightly established that some form of prediction is involved. Demers (2000). According to him spatial data taken from sampling yields three major types of manipulation: data at non-sample location can be predicted from sampled location in order words data from one set of spatial units can be converted to others with different spatial configuration.(Muehrcke and Muehrcke1992) The non sampled locations are predicted from the sampled areas. It is noteworthy however that the prediction of non-sampled spaces involves some form of assumption, which may miss or meet the target of spatial interpolation or extrapolation.

For a given ESI maps it is assumed that data of given index value are essentially uniform and homogeneous, but it is clear that this is not possibly true in any given context therefore some form of assumption and error limit must be set to establish a unique single index for each spatial units in the area of concentration. However the smaller the unit of aggregation the better for the GIS based index mapping. Sometimes grid or raster cell serves as units but it is clear that the cell values are essentially aggregated.

Since it is often impracticable to collect data from every spatial unit in the study area. of the
This paper seeks to devise taxonomy of spatial classification of environmental parameters in a GIS context and examine the level of accuracy of such classification.

We shall not attempt programming a new extension but would apply different methods of classification of field data to arrive at a given index. The paper represents a methodological contribution to spatial modeling in the GIS environment.

3.0 Methods.
The data ere obtained in-situ from the site with the use of GPS and a large image format to identify the area with the remote sensing images. The sample points were chosen based on random selection of point and the chosen point form site for data collection. The samples collected include soil, water and socioeconomic characteristics of the study area. Though remote sensing material used is adequate enough to examine the physiographic (above surface) component of the study area, the subsurface elements require in-situ data collected from the surface. The baseline data are equally important to the accurate estimate of the sensitivity index mapping.

The baseline data collected were analyzed in a commercial laboratory and a part summary of the result of the analyses was presented on Appendix 1. After different types of analysis were performed on the data components by soil and water experts. The result obtained was therefore tabulated in a spreadsheet format.

A principal component analysis was performed on the gamut of data obtained and this was done to extract components of variations across the surface. Those components that have eigen value above one were chosen as causing the greatest variation across the surface of the study area hence could be used as classifying components across the surface.

Principal component analysis is a widely used technique for collapsing a set of interrelated variables into a smaller or same number of uncorrelated dimensions or variates. These dimensions are also described as being orthogonal because they represent perpendicular variates in the domain of the transformed set of variables.
The purpose of using principal components analysis is to collapse the parameters into smaller components.
The Varimax method of rotation was used and the components with eigen value of one and above were selected from the data. Four components were selected and their receptive eigen values are presented below:

components	eigen value	% contribution
Ph value of soil	3.0706	38.4
Sulphate	1.74574	21.8
Conductivity level	1.08813	13.6
Phosphate	1.01451	12.7

The total percentage contribution of the components is 86.5 %. The vegetation and land use quality were derived from the remote sensing data which was classified based on major land use characteristics of the study area. A supervised classification of the SPOTXS image of the study area was carried out to identify the major land use classes. See Fig 1.

Consequently different types of sensitivity index maps were produced based on these five components/ dimensions viz. pH value, sulphate, conductivity phosphate and land-use types.

Through surface interpolation and kriging method of the data sets; a total of five Initial index maps were produced based on the five parameters viz, land use (human habitat and vegetation) pH values, Sulphate level, conductivity level and phosphate level. The five index maps were integrated in a single map through map algebra using the resulting components. This is adapted approach from Ginsburg's Atlass of economic development (Harman, 1960) .The resulting index maps from the five variables are presented in figure 3(a-e).

Environmental sensitivity index is heavily based on the effect of human and natural phenomena and activities on human habitat. Though consideration is place on the effect on animal and plant kingdom the ultimate measurement is on the resultant effect on human settlement.

To this end weighting factor was introduced to rank the land use index high in the study area before map algebra was used to find the index value for the study area. The final index map is presented in Figure 4.
It should be noted however that the indexing was not based on any project in view therefore the susceptibility to disturbance was generally considered

Conclusion
The paper demonstrates the immense contribution of in-situ data captured in a GIS environment integrated with remote sensing data in a GIS environment for environmental sensitivity indexing of areas of low mapping materials or areas that have not been properly surveyed or surveyed with some form of error.
Apart form the data models been useful for ESI estimate is also a tremendous eye opener to the mapping of earth phenomena as well as map generalisation.

Implication for researches in environmental sciences
The paper shows the following especially in environmental researches.

a. The data collected from the field can be translated across the surface for generalization ad deduction.
b. Spatial relationship of data can be integrated with minimum level of error

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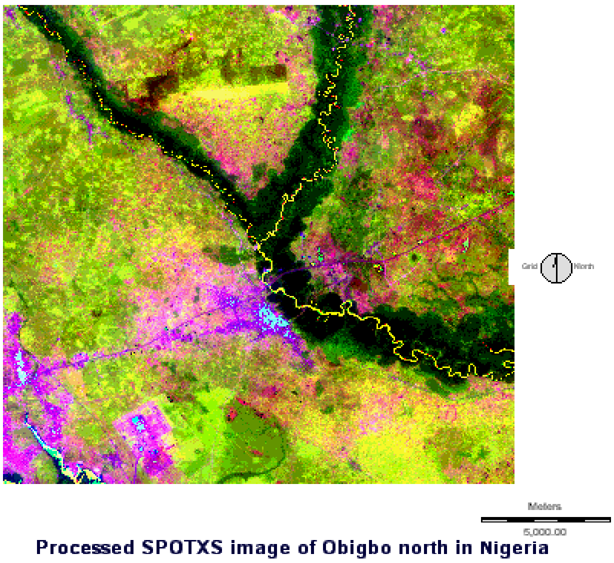


Figure 1. Processed satellite image (SPOTXS) of the study area

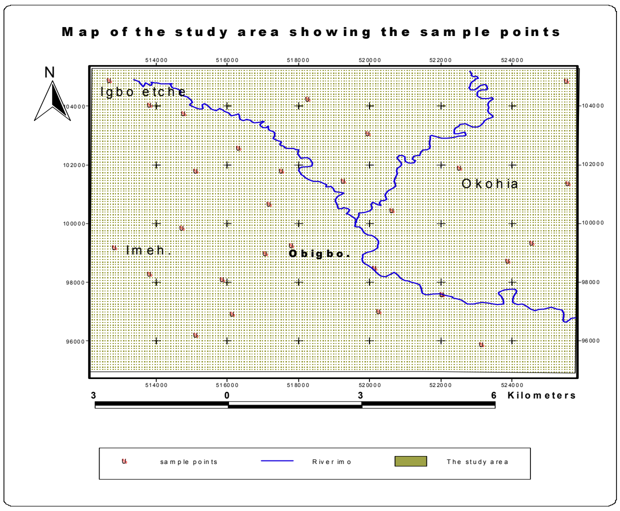
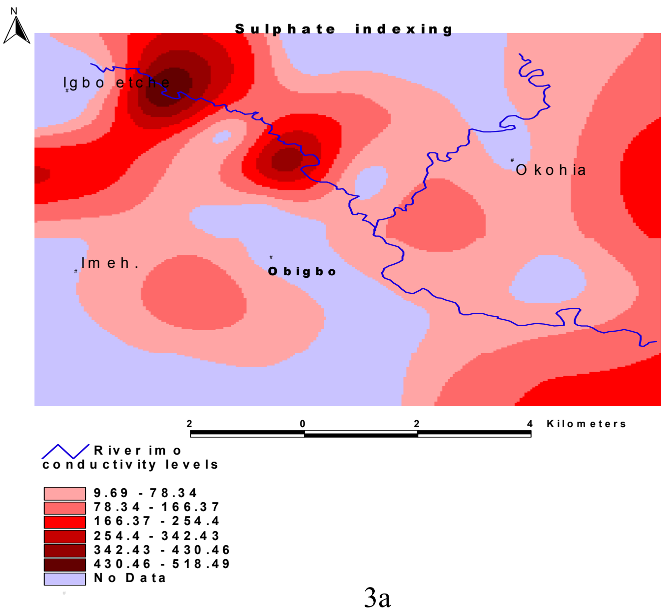
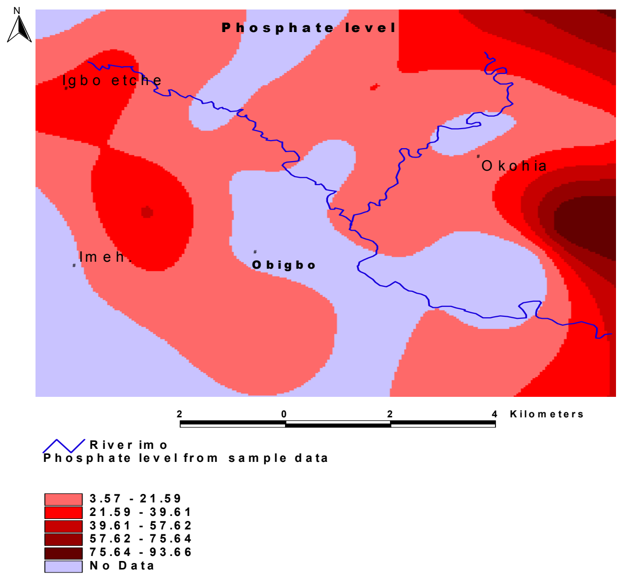


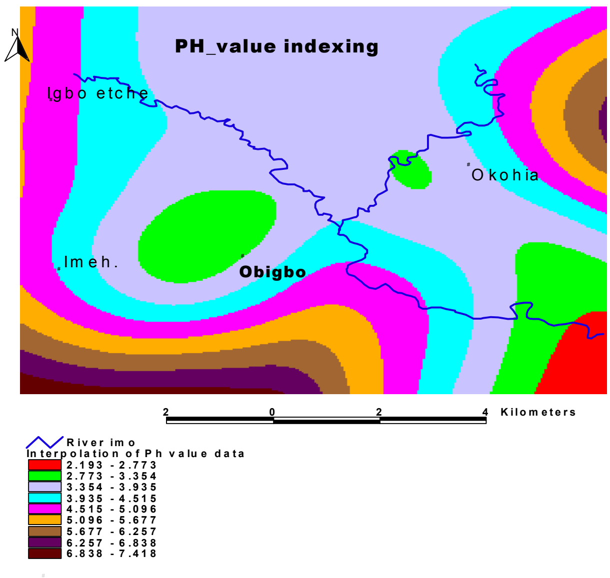
Figure 2. Location of the sample points



3a



3b



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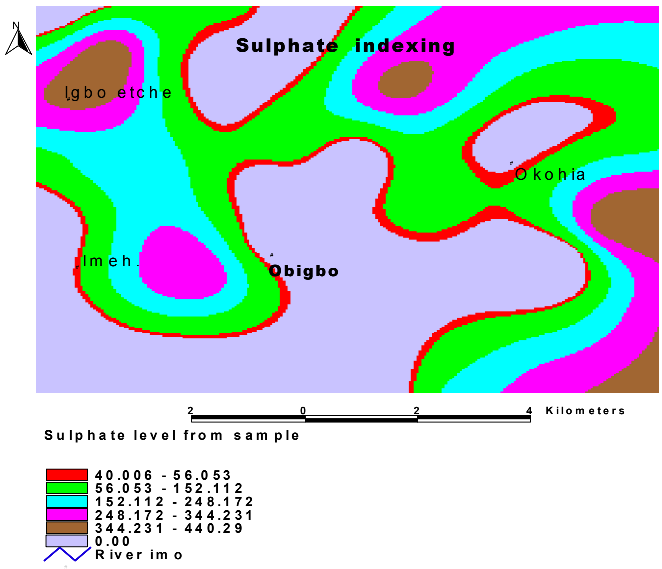

3d

Figure 3(a-d). Index maps based on environmental components

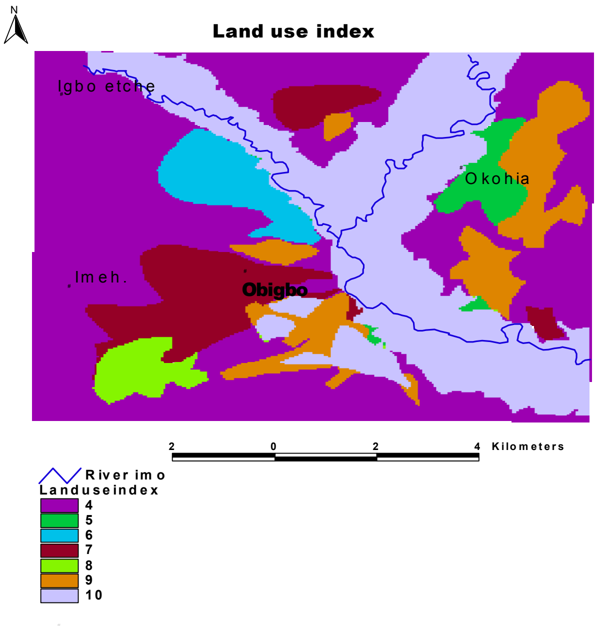

Figure 3e. Land-use index map of the study area from remote sensing data

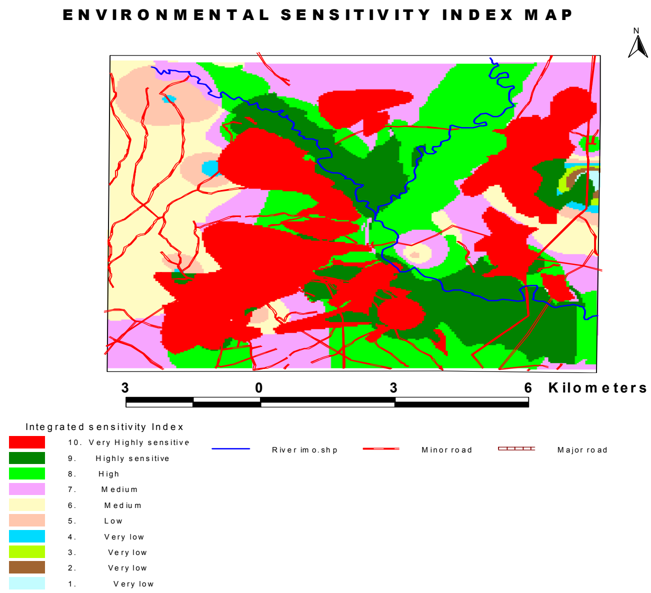

Figure 4. Final ESI map of the study area

Appendix 1

X	Y	SAMPLE_LOC	SOIL_TYPE	PH__VALUE	SULPHATE	COND	PHOSPHATE	NITRATE
517855.612	98807.829	Sample at location 8.	Loamy clay.	3.66	225.00	34.10	40.40	5.63
515401.831	98094.718	Sample at location3	loamy clay.	3.98	175.00	41.20	12.60	6.06
515521.689	98094.467	Sample at location 2	loamy clay.	3.22	325.00	138.00	17.40	6.37
516439.003	96034.403	Settlement / Iriebe.			0.00	0.00	0.00	0.00
516425.562	101573.018	Sample at location1	loamy clay.	3.99	150.00	76.30	12.10	5.63
518603.124	101221.380	Settlement / Umuebule.			0.00	0.00	0.00	0.00
518603.124	101221.380	Market at Umuebule			0.00	0.00	0.00	0.00
518363.521	101568.993	Sample at location13	loamy clay.	3.85	125.00	381.00	13.00	7.13
517385.381	102351.272	Settlement / Ikwerengo.			0.00	0.00	0.00	0.00
517041.720	103027.799	Pineapple farmland			0.00	0.00	0.00	0.00
516161.577	103511.926	Sample at location4	loamy clay.	3.98	150.00	508.00	19.40	6.07
515395.062	103817.657	Sample at location 5	loamy clay.	4.38	425.00	55.50	23.90	5.45
513468.607	99078.722	Settlement / Imeh.			0.00	0.00	0.00	0.00
517988.038	98777.452	Settlement / Oyigbo.			0.00	0.00	0.00	0.00
520544.525	96833.913	Oyigbo main market			0.00	0.00	0.00	0.00
523456.529	98539.085	Settlement/Ozuaku			0.00	0.00	0.00	0.00
520862.496	98664.078	Sample at location15	Sandy loam	3.47	125.00	133.00	19.30	7.30
524804.082	102231.773	Settlement /Okohia			0.00	0.00	0.00	0.00
524887.143	105275.743	Sample at location19	loamy clay.	4.85	250.00	85.70	70.30	7.67
524807.852	101178.145	Sample at location20	loamy clay.	5.95	150.00	217.00	30.50	6.81
523978.445	99152.409	Sample at location17	Alluvial clay .	3.56	375.00	80.20	80.20	7.07
512930.420	105315.858	Settlement/ Igbo etche			0.00	0.00	0.00	0.00
523002.390	94816.972	Sample at 14.	Clay loam.	3.54	225.00	150.00	13.80	7.71
517250.513	96736.185	Sample at 10.	Sandy loam	4.50	125.00	63.80	19.30	6.28
518363.521	101568.993	Sample 7(Quadrant).	Sandy loam loam	3.73	375.00	77.30	21.40	6.76
521963.035	97417.782	Sample at Imo River 1.		4.30	1.29	22.20	1.16	1.12
520455.038	98293.211	Sample at Imo River 2		4.50	2.97	22.30	1.18	1.34
521963.035	97417.782	Umuechem		3.50	2.27	33.20	0.86	1.11

Some sample data from the study area.