

# ISSUES IN REGIONAL DEVELOPMENT IN NIGERIA

Festschrift in Honour of  
**PROFESSOR ANONGO A. LYAM**



**Edited by:**  
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First Edition 2019

Printed by

**ERDOOZY PRINTS**

No. 4 Calabar Street, High Level,

Makurdi, Benue State-Nigeria.

07032140771, 08116973734

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SBN 978-978-975-661-2

## Chapter Five

### MAP ALGEBRA TECHNIQUES OF LAND SUITABILITY ASSESSMENT FOR WETLAND RICE IN NORTHERN AKWA IBOM STATE, NIGERIA

Uwem J. Ituen and Emmanuel P. Udofia

#### Introduction

In most developing countries, a greater proportion of the population lives in rural areas. In Africa, Okai (1993) quoted by Adeniyi (1997) remarks that 71% of the total population lives in the rural areas; 66% of the total labour force is engaged in agriculture, while agricultural land per head of population decreased from 0.37ha in 1960 to 0.16ha in 1989. This may be attributed to the prevalent freehold land tenure system dominant in this area, which encourages land fragmentation. Also, agricultural land per head of labour force in agriculture decreased from 1.00ha in 1960 to 0.55ha in 1989, while cultivated land per head of labour force in agriculture decreased from 0.55ha in 1960 to 0.13 in 1989. Therefore, in the face of rapidly growing population but dwindling agricultural production, the question of food supply and general rural development becomes critical. In Nigeria, the discovery of crude oil as the mainstay of the national economy in the early 1970s brought a level of neglect to the agricultural sector. During this period, a lot of attention shifted from agriculture due to excess revenue that accrued from sales of crude oil. The on-going agricultural re-engineering efforts by all levels of government are a sudden realization of this status quo. In fact, Akwa Ibom State has a history of dependence on neighbouring states including Cross River State for even staple food crops like cassava, rice, yam, etc. whereas there is great potential for sustained agricultural production. Therefore, research effort is needed if the problems of the area with such history are to be taken serious. As such, this study is relevant.

Agricultural lands are being haphazardly allocated to alternative uses such as settlement, rural industries, etc. Population pressure resulting in the need for infrastructures has also led to rich agricultural lands being used otherwise. To aggravate this problem is the presence of scant knowledge on the suitability of land areas for the production of crops amongst most rural farmers in Nigeria. This results in inappropriate use of land resources, which invariably affects

agricultural production. In view of this, Adeniyi (1997) suggested optimal land uses and as such stressed that, land use planning involves spatial allocation decisions. Such decisions may involve the individual land holding of a single farmer, a rural or urban community or an entire region. Geographic Information System (GIS) can assist planners to decide on land allocation in a scientifically sound and societally acceptable manner. It uses specific information, such as land resource information, and the value of existing or proposed uses to decide on existing or future land use.

In the rural area of northern Akwa Ibom State, land is utilized for different purposes without consideration of the suitability of such land areas for such purposes. Continuous use of the land with no attention to sound land management practices to compensate for any form of change, or perhaps degradation that might have occurred over time may permanently limit the ability of such land area to continue to yield the much needed productivity given such usage. Therefore, there exist scant knowledge of land suitability status and the overall suitability of the area for the crops planted. There is heavy reliance on indigenous knowledge without a combination of scientific approach in deciding land allocation.

Cools et al., (2003) acknowledged that, by experience, often going back for generations, farmers have developed land use systems that are well adapted to the potentials and constraints of their land since they have the best knowledge of their local environments. They certainly have a comparative advantage to assess land use systems they are familiar with, but their socio-economic conditions can play significant role in preventing or promotion of land degradation (Daba, 2003). However, when it comes to adopting new technologies and new management practices, they have few reference points to guide their decisions and actions. This is why any serious land use study has to necessarily incorporate the socio-economic dimension of the current and intended users of the land.

Resource allocation is a fundamental issue in agriculture and rural development because all developments take place within a multipurpose environment (Adeniyi, 1997). The components and attributes of these environments exhibit complex interdependences, interrelationships, interactions and functions over space and time. Resources are defined by cultural appraisal. Resources are dynamic as they change in response to natural processes and in accordance with societal needs, aspirations and knowledge. Therefore, "the allocation of land to one particular use, without full consideration and understanding of the functions, which can be derived from the area, may permanently alter the ability of the area to serve other, better and



more sustainable functions and needs of current and potential users" (Manning, 1994). Sequel to this and in view of the rapid population growth and consequent increases in economic activities, the proper allocation of land becomes a priority for sustainable agricultural and rural development. This is why suitability assessment of land in the study area becomes a major focus in this work, especially with the use of Multi-Criteria Evaluation techniques in GIS.

Of what use is a combination of geophysical, socio-economic, technological and policy framework in gaining deeper understanding of the area for proper land management decisions?

For the production of rice, which areas of land are best suited? It is here believed that answers to the above research questions will put this work on the right perspective.

### **Objective of the Study**

To attempt a land suitability assessment (LSA) of the area in a spatially explicit manner in order to determine the current status of the land and how it could be optimally utilized.

### **Study Area**

The study area for this work is northern Akwa Ibom State, Nigeria. It is located within latitudes 5° 00' and 5° 45' north of the equator, and longitudes 7° 30' and 8° 10' east of the Greenwich Meridian. The area lies to the southern fringe of Nigeria. It shares a common boundary with a number of states as shown in Figure 1. In the strictest sense, Akwa Ibom State may be viewed as a region within the Nigerian nation, while the Local Government Areas are regional development areas (Peter, et al., 1988). Therefore, the seven local government areas selected for this work are viewed as regional development/land management centres/zones for rural development convenience. Since the areas are similar geographically, economically and socio-culturally, they will be treated as a geographic region in this work.

The area described as northern Akwa Ibom State in this work comprises Ini, Ikono, Itu, Ibiono Ibom, Ikot Ekpene, Essien Udim and Obot Akara Local Government Areas. It is dominantly rural and the major occupation of the inhabitants is farming. This area holds a great promise for agricultural development owing to its rich potentials. Contrary to this, almost every attempt to develop the area agriculturally and agro-industrially has failed. Thus Peter et al.' (1988), in a survey commissioned by the government of Akwa Ibom State remarked in the following excerpt:

*World history is rich in the failure of agricultural projects resulting from either complete ignorance of soil resources or failure to follow scientific advice on soil management for crop production. In Nigeria, there have been traumatic examples of this in Anambra State (Agulu-Nanka) and Imo State (Amuchi) and in Obotme, Uyo and a number of places in what now constitutes Akwa Ibom State. These are less traumatic but nevertheless equally devastating examples of soil conservation problems caused by lack of adequate conservation measures that could only be obtained through sufficient knowledge of the soils. This project is therefore sensible in its potentials to avoid failures in Agriculture and agro-industrial ventures as a result of inadequate knowledge of the soils. Accurate and current information on land use is essential for many planning activities. Land use is dynamic and requires a mapping method that could rapidly obtain information over a large area.... Remote Sensing methods of which aerial photograph interpretation is one, have proved the most adaptable for land use mapping particularly in areas of inter-mixed land use such as Akwa Ibom.*

Coincidentally, the concern expressed in the above excerpt has manifested in an alarming proportion in northern Akwa Ibom State today. Thus, it is no exaggeration that the investment of the Federal Governments in rice cultivation in Ini LGA has so far failed to yield the expected result. This is because the rice-assisted project has been abandoned, while peasants manage to produce for subsistence. All agro-industries established in this sub region have failed. Nigerian Newsprint Manufacturing Company (NNMC) at Oku Iboku has since the past 10 years folded up. Biscuit and Sunshine Battery Industries at Ikot Ekpene are also gone and forgotten. Quality Ceramics Plant at Itam, Itu LGA and a host of others are no more producing.

This lends credence to the fact that the rural economy, which should be driven by a combination of agriculture and agro-industries, has virtually collapsed. The seemingly lofty projects have failed to yield the desired result. In the face of this, rural planning and reconstruction is needed. Appropriate diagnostic tools land suitability assessment seem the option left for efficient planning and development of this area that is widely acclaimed the 'food basket of the state'. With this in mind, this study area has been carefully selected in an attempt to examine holistically what should be done to exploit on a sustainable basis, the potentials of this area, thereby contributing to rural planning in particular and national development in general. In so doing, land use change detection and land suitability assessment for rice, using MCE in GIS, form the main issues this work sought to unravel.

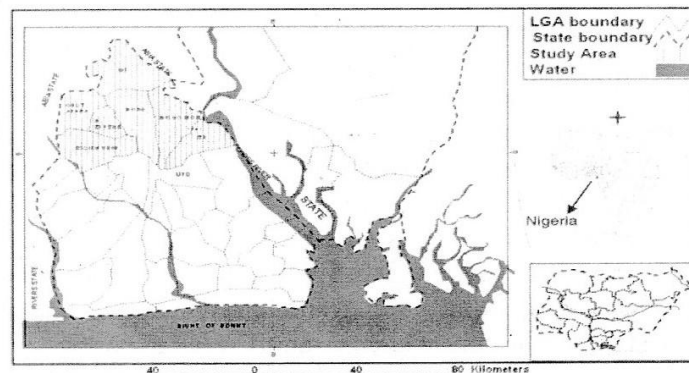


Figure 1: Akwa Ibom State Showing the Study Area

Akwa Ibom State enjoys a tropical climate with distinct and well-marked wet and dry seasons. The monthly variation of rainfall reveals that there is no month without rainfall amount of less than 25mm. Thus, the wet season lasts from April to early November while the dry season lasts between late November and early April. January, February and December are the driest months, however rainfall in these months typically ranges between 25mm to 100mm depending on local variations. In contrast, monthly rainfall runs to a peak in July, a decrease in August and another peak in September or October before it finally decreases to its lowest in December. This August break phenomenon is always present in southern Nigeria (Peter et al., 1988), within which this study area is located. The annual range of rainfall varies between 1900mm and 4035mm, while the rain days range from 116 to 170 annually. The area records mean monthly temperature value of 26.00°C plus or minus 2°C.

The potential evapotranspiration in the study area is relatively high. This is an effect of the high monthly rainfall on the one hand, which guarantees water supply and the closeness of the area to the Equator on the other. This area is characterised by thunderstorms; cumulus and cumulonimbus clouds give fairly heavy and thundery rains, usually in the afternoons after thunderstorms have passed. Relative humidity varies from 95% in the mornings to 65% in the afternoons.

This area belongs to the coastal plain relief region of the nation. However, a cursory look at the landscape depicts an area with highly contrasting relief features unlike the southern part, which is generally referred to as being monotonously flat. Therefore, the following three relief classes could be derived

from the area: gently undulating sandy plains, sandstone hills and ridges with steep-sided hills and valleys and Obotme Isolated steep-sided hills (See Figure 2 for details).

Northern Akwa Ibom State is drained by a number of rivers. On the eastern and south-eastern part of this study area is Cross River, which drains most part of Itu and Ibiono. Also draining the area is the Kwalboe River. This is the main drainage system of Akwa Ibom State. It has a total drainage basin of 3899km<sup>2</sup>. This river takes its source around Isuikwato LGA in Abia State and flows southwards through Ikot Abia, Utu Etim Ekpo, etc. before discharging into the Atlantic Ocean west of Ibeno (Ituen and Johnson, 2004). Kwa Ibo River drains half of the state and has mean annual runoff value of 6586m<sup>3</sup> x 10<sup>6</sup>.

Enyong Creek takes rise from Umudike. Around Ikot Uko in Ini LGA, it is called Inyang River. It drains most of Ini and Ibiono Ibom Local Government Areas largely responsible for the wetlands here. Its flood plain forms part of the rice growing area in Ini LGA. The river flows from northwest towards east; and is joined downstream by a tributary called Idim Ibom, before joining Cross River north of Itu. It has a total basin area of 1865km<sup>2</sup> and mean annual runoff of 2374.00m<sup>3</sup> x 10<sup>6</sup>. Ikpa River is another major river in the study area. It takes its source north east of Ikot Ekpene flowing south-eastwards east of Uyo in the Cross river.

Generally, there is high drainage density in the area. This is attributed to the high rainfall and the sedimentary nature of the underlying rocks. Values as high as 2.15km/km<sup>2</sup> are recorded in the upper segment of the drainage basins (Peter et al, 1988). The state is therefore blessed with abundant surface water supply system (Figure 2).

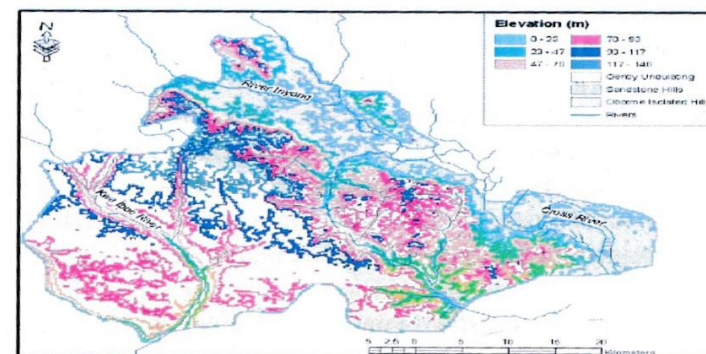


Figure 2: Northern Akwa Ibom State; Showing Relief and Drainage



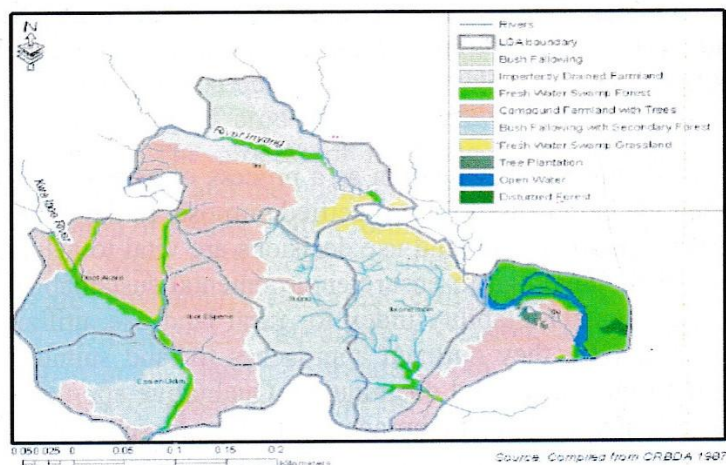


Figure 3: Northern Akwa Ibom State; Showing Vegetation and Land Use

Originally, in terms of vegetation, this area belonged to the tropical rainforest belt of Nigeria. On account of prolonged human occupation and resource exploitation (mainly through slash and burn mode of land preparation, firewood gathering and lumbering) (Ituen, 2010), the forest cover has largely been removed leaving the vegetation and land cover summarized in Fig 3.

The farming calendar of the area is based around the dry and wet seasons. During the dry months between December and March, the farmland is cleared and burnt in readiness for planting at the onset of rains in late March. This means that the preparation of farmland for cultivation is mainly by slash and burn process. This is one of the reasons for increasing rate of deforestation in the area and hence increasing rate of perceived land cover change. Actual planting takes place between March and May. After planting, crops are routinely checked and maintained through weeding, which may be done 3 times before the crops are harvested in October. However, some farmers do undertake late planting starting from August, either on different farmlands or inter-spaced with first season crops.

The farm family unit is one man plus his wife/wives and children. Each family (household) has 3-5 farm holdings with a mean distance of 1-3.5km from home (Peters, et al., 1988). The average size of a farm holding is below 1 acre. Individual farmers and their families pool their labour to work on each other's farms. The fallow period is between 3 to 5 years.

Cassava, yams, maize, cocoyam, fluted pumpkin are widely grown in Akwa Ibom State, while rice is restricted to the poorly drained swamps of Ikpe

Ikot Nkon, Ibam Ukot, Mbiabet and a few other areas. Moreover, swamp rice cultivation in the adjoining Ibiono Ibom and Itu along the flood plains of Enyong Creek is gradually developing.

### Theoretical Issues

FAO (1985) defines land suitability evaluation as a process of assessment of land performance when the land is used for a specified purpose. In the light of this, Baja et al., (2006a) remarked that land use decisions are vital to achieve optimum productivity of the land and to ensure environmental sustainability. While modelling environmental suitability index for rural land use, utilizing fuzzy set methodology in GIS, they outlined approaches to land suitability assessment as being both qualitative and quantitative. Qualitative approaches are used to assess the potential of land at a broader scale or as a preliminary to more detailed investigation, while quantitative approaches use parametric techniques involving more detailed land attributes, which allow various statistical analyses to be performed (Dent & Young, 1981). In a parametric approach, the evaluation procedure generally involves deductive, inductive or simulation modelling systems to quantify the potential of land for specific uses (Shield et al., 1996 in Baja et al., 2006a). A deductive approach deals mainly with the estimated yield as an index relative to a standard yield, while the inductive technique utilizes land characteristics as evaluation or assessment criteria to establish land management indices. Pierce et al., (1994) noted that inductive approach involves such arithmetical operations as additive, multiplicative, etc.

Land evaluation is the process of predicting the physical and economic performance of land under a variety of actual and potential land uses (Rossiter, 2003) in (Rojas, 2004). Land embraces all aspects of the earth's surface that enable, support, constrain or influence actual and/or alternative uses. These however include climate, geology, terrain, soils, surface and sub-surface hydrology, vegetation, fauna and physical results of human activities (Huizing, 2003). In the context of land suitability assessment, land qualities are measured as classified severity ratings (also known as factor ratings), and therefore express the ability of the land to fulfil specific requirements for a land use (Rojas, 2004). He went ahead to note that, "due to the abstract nature of land qualities, they cannot be measured directly, rather inferred from a set of land characteristics (LC)." LC are therefore simple land attributes that can be measured directly or estimated in routine survey (an example is site slope gradient). Land characteristics almost always act in complex ways to affect land suitability, due to their influence on several land qualities. Rojas (2004)



therefore stressed that the procedure for comparing land characteristics (qualities) and land demand (requirement for use) may be carried out either by simple matching, based either on previous experience or scientific knowledge, or by modelling of crop or animal growth and development in a particular environment. The process of matching these depends on the purpose, the amount of detail and the quality of information of the land use study. On the presentation of results, matrix format and series of maps are generally accepted and used. Maps are however considered the most convenient as suitable land areas are conveniently, easily and readily observed.

On the basis of the above discussion, land evaluation could be seen as a tool to predict land performance both in terms of the expected form and constraints to productive land use, as well as the expected environmental degradation due to these uses (Rossiter, 1996). Therefore, Baja (2006a) stressed that, 'for land to be suitable for a given purpose, and for the use to be sustainable, it must address the values that are related to both the degree of suitability, and potential degradation resulting from land management practices'. Basic (2003), in his contribution on demand driven land evaluation noted that information technology continues to improve rapidly, in particular GIS and remote sensing as well as expert systems. In the context of participatory land evaluation, these should be used as much as possible in the whole process, while taking into account local conditions.

It has long been recognised that land suitability is assessed as part of the 'rational' cropping systems (FAO, 1976), and optimising the use of a piece of land for a specified purpose (Sys et al., 1991) should be based upon its attributes (Rossiter, 1996). Although criteria may differ, they are essentially based on climate, soil topography and water availability which are the most important categories of environmental information required for judging land suitability (Ghaffari et al., 2000).

The integration of climate-soil-site modelling using GIS is finding increasing application in crop-specific modelling of agricultural production.

Imhof et al., (2000) in their contribution stressed that enhancement of the existing mapping is required to allow for improved matching of land use with land suitability and capability and the identification of areas where higher value sustainable land uses can be promoted. This information will also be needed to provide the basis for disseminating information on best management practices that allow increased production while enhancing the quality of land resources and preventing off-site degradation. Baja et al., (2006b) argues that traditionally, LSA requires the comparison of the land qualities with the requirements or limitations of a specific land use to determine the overall

potential of the land. The results are expressed as a spatial distribution of suitable classes or indices for a given purpose. The work further stressed that the assessment of land quality for a specific type of land use should be based on land use requirements and constraints. According to them, such requirements and constraints are then used as the basis for establishing evaluation/decision criteria

## Materials and Methods

### Materials

#### a. Soil Parameters

The Akwa Ibom State soil survey data was used in conjunction with the analogue soil map from Cross River Basin Development Authority (CRBDA) to derive the important soil parameters for inclusion in the MCE LSA model. Important soil parameters relevant to land suitability assessment, and extracted from this derivative include:

- i. *pH of flooded soils* - used as an indication of nutrient sufficiency (Dent and Ridgeway, 1986).
- ii. *Soil drainage class* - used as an indication of moisture sufficiency
- iii. *Texture* - used as an indication of moisture sufficiency
- iv. *Erosion hazard* - used as an indication of nutrient sufficiency and to indicate land surface characteristics. Please refer to Table 1 for the requirements for wetland rice cultivation.

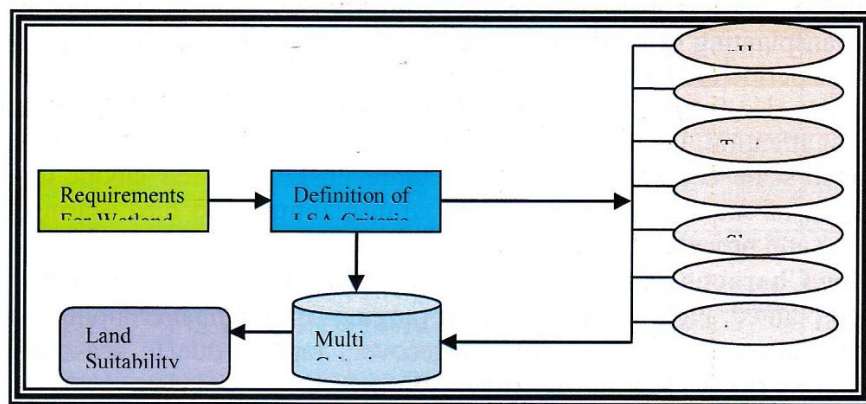
#### b. Land Characteristics

A digital elevation model (DEM) was acquired from the USGS at 90m resolution. It was purchased as a raster with lat. /long. georeferencing but re-projected on WGS, UTM Zone 32N. This was necessary in order to enhance data integration in GIS interfaces. The following terrain characteristics were derived from this layer.

- i. *Slope*: This is measured either in degrees from 1° through 90° or in percentage. A 45° slope is the same as 100%. For this study, slope was calculated in degrees, and was used as a proxy for ease of water control as shown in Table 2
- ii. *Elevation*: This is a measure of height (depth) above (below) a given datum; in this case sea level. Elevation data was used as a measure of energy sufficiency (FAO, 1976; Dent & Ridgeway, 1986).
- iii. *Aspect*: Aspect which is measured in degrees from 0 (due north) to 360 in a clock-wise direction is an indication of slope face/direction. This has



important information on; solar illumination (McCoy & Johnston, 2001) and therefore the amount of insolation for each location, vegetation characteristics, wind etc. It is also useful in determining areas likely to be flooded.



LSA of each  
Land xtics

**Figure4:** Schema for Land Suitability Assessment

Source: Ituen, Whyatt, Blackburn & Inyang (2006)

### c. Land Use Management Practices for Wetland Rice

- i. **Production and Marketing arrangements:** This study area is within the forest agro-ecological zone of Nigeria. This zone records the highest amount of rainfall in the country with an average of 2900mm. The rainy season is usually not less than 6 months. The prevalent rice production system is rain fed lowland with few attempts at irrigated lowland system. Flood plains of major rivers are used for this purpose. Yield is usually about 2.0 tons/ha. Local markets located within 3km from homes form major sale outlets/collection points to both farmers and traders mainly on weekly basis.
- ii. **Management units:** Small-scale rice farming with holdings of about 1-2ha predominate this area. Farm ownership is largely individual except for a few plots acquired by Federal Government for the defunct Federal Assisted Rice Farms at Mbiabet in Ini zone of this region. This project was abandoned for reasons of poor turn-over blamed on mismanagement. Estimated distance to farms is put at 0.5-2km.
- iii. **Cultivation Practices and Inputs:** Here farmlands are cleared with locally fabricated cutlass and machete while the debris is heaped on the boundaries of plots for ownership identification. From findings made, rain-fed lowland

rice farmlands are not subjected to bush burnt except diseases were noticed the previous farming season. Mainly seedlings are transplanted from seed beds nurtured prior to actual planting. Use of fertilizer and agrochemicals is yet to be fully accessed by local farmers. Solar illumination provides the main source of power. Farmers need to monitor weather closely especially during transplanting of seedlings since excess of rainfall and temperature during this period brings huge losses. Pests like birds and rodents are major problems to rice farming in the area. Consequently, bird scaring requires additional attention. Labour is manual and mainly family based. However, most small-scale commercial farmers require unskilled hired labour for preparation of seed beds, bush clearing, transplanting, and bird scaring, harvesting and processing operations.

**Cropping Characteristics:** Monoculture is practised. Rice is therefore the sole crop planted. Fallow period is short ranging from annual cropping to 2-3 years fallow period. Soil fertility recovers rapidly due to seasonal deposition of materials from the rivers. Water is stored in water bonded fields with little or no control mechanism. This means farmers operate at the mercies of the vagaries of climate.

### Methods

#### a. Land Suitability Classification (Adapted from FAO, 1976)

The following land suitability classification has been adopted and simplified for the suitability assessment.

**Table 1: Land Suitability Classification**

Code	Suitability Class	Description
S1	Highly suitable	Land without significant limitations. Include the best 20-30% of suitable land as S1. This land is not perfect but is the best that can be hoped for.
S2	Moderately suitable	Land that is clearly suitable but which has limitations that either reduce productivity or increase the inputs needed to sustain productivity compared to those needed on S1 land.
S3	Marginally suitable	Land with limitations so severe that benefits are reduced and/or the inputs needed to sustain production are increased so that this cost is only marginally justified.
N	Not suitable	Land that cannot support the land use on a sustained basis, or land on which benefits do not justify necessary inputs.

**Table 2: Requirements for Wetland Rice (Modified from Dent and Ridgeway, 1986 and FAO 1976)**

Land Quality	Land Quality/Layers	Weights (in bracket)			
		S1	S2	S3	N
Sufficiency of Nutrient	pH of flooded soil	6-7 (1)	5-6 (2)	4.5-5 (3)	<4.5 (4)
		6-7	7-8	8-8.5	>8.5
Water Sufficiency	Soil drainage class	Poorly drained (1)	Imperfectly Drained (2)	Moderately well drained (3)	Excessively drained (4)
	Soil texture	C, ZC, ZCL, L (1)	SC, SCL, ZL, Z (2)	SL (3)	S, LS (4)
Ease of Water Control	Erosion Hazard	Danger of Flooding	No Hazard of Erosion	Hazard of Erosion	High Hazard of Erosion
Energy Sufficiency	Elevation (m)	0-50 (1)	50-70 (2)	70-90 (3)	90-144 (4)
Ease of Water Control	Slope angle (degrees)	<1 (1)	1-2 (2)	2-6 (3)	>6 (4)
	Aspect (degrees)	45-135 (NE-E, E-SE)	0-45, 135-180 (N-NE, SE-S)	180-225, 315-360 (S-SW, NW-N)	225-315 (SW-W, W-NW)

**Table3: Standardization of Scores/Weightings of the Individual Layers**

S/N	Layers	Weights	Percentage Contribution
1	pH of flooded soil	0.2	20
2	Soil drainage class	0.2	20
3	Soil texture	0.1	10
4	Erosion Hazard	0.1	10
5	Elevation	0.2	20
6	Slope	0.1	10
7	Aspect	0.1	10
	<b>TOTAL</b>	<b>1.0</b>	<b>100</b>

#### e. Multi Criteria Evaluation of Land Suitability for Wetland Rice

Due to the nature of the problem, the Single Output Map Algebra algorithm was used. To this end, all the layers were converted to raster format using data conversion tools. After this, the soil layers were extracted by attributes from the database after which all the layers were then reclassified in line with the predetermined suitability rating. This process however gave rise to the land suitability index of the individual layers. Finally, single output map algebra tool was used to obtain the final multi criteria land suitability index for rice thus combining the seven layers according to the determined contribution of each layer in the model. McCoy and Johnston (2001) stress that single output map algebra runs a single Expression built with the map algebra language.

#### d. Standardization of Scores/Weightings of the Individual Layers

Under this, the different layers were assigned weights as their respective contributions to the final model. pH, drainage and elevation layers were assigned 0.2 (20%) each due to their importance in rain-fed lowland rice cultivation (Table 3). pH which was diagnosed as an indication of nutrient sufficiency is very important in the growth and productivity of wetland rice, hence its emphasis. Since this crop thrives on flooded soils when other conditions are right, the importance of soil drainage class in determining suitability therefore cannot be overemphasized. Elevation plays a very important role as an indication of energy sufficiency. In the absence of temperature in the data sets used, this was heavily relied upon [Please refer to Figures 5-11 for the land suitability maps for the individual land characteristics (layers) used in the model].



Layers	Highly Suitable (S1)		Moderately Suitable (S2)		Marginally Suitable (S3)		Not Suitable (N)		No Data (Open Water)	
	No. of Pixels	Area (km <sup>2</sup> )	No. of Pixels	Area (km <sup>2</sup> )	No. of Pixels	Area (km <sup>2</sup> )	No. of Pixels	Area (km <sup>2</sup> )	No. of Pixels	Area (km <sup>2</sup> )
Soil pH	4865	237	16960	828	14016	684	3229	158	562	27
Soil pH	4865	237	16960	828	14016	684	3229	158	562	27
Soil Drainage	7764	379	539	26	2438	119	28329	1382	562	27
Soil Texture	7101	347	1007	49	28429	1387	2533	124	562	27
Erosion Hazard	539	26	24742	1207	1221	60	12568	613	562	27
Slope Angle	152249	1233	33745	273	45546	369	7229	59	-	-
Elevation	61030	494	38421	311	82480	668	56838	460	-	-
Aspect	64153	520	61207	496	64349	521	49060	397		

**Table 4: LSA: Input Parameters (Layers)**

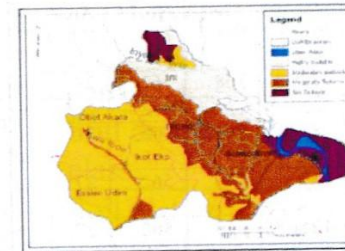
## Results and Discussion

It is convenient to present the results of land suitability assessment in a series of maps and suitability matrices. Since the entire process is location-specific, it becomes much meaningful to use maps so that results obtained can be directly linked to the corresponding ground locations. The location of each suitability class is therefore easier to read and understand for proper land allocation decisions. Consequently, the result of the land suitability assessment carried out is presented here. Since the modelling was done in stages, for clarity, the result is also presented to reflect those stages. First is the result of the individual layers used in the model. Following this are the results of the multi criteria technique and zonal distribution of suitability in the study area. These aim to demonstrate how suitability study can enhance rural land use planning which is the challenge for all levels of government in Nigeria.

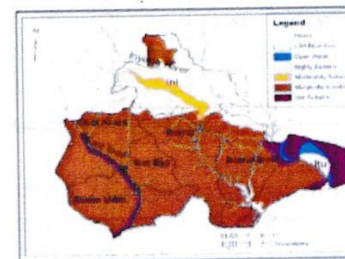
**Table 4: LSA: Input Parameters (Layers)**

As discussed in the previous section, multi-criteria evaluation technique in GIS was used to model the suitability index of the area for wetland rice. Seven biophysical parameters were utilized and each prepared into a layer in line with the research schema earlier shown in Figure 4 and individually evaluated for suitability before used in the GIS-MCE model. The result of this assessment is presented in Table 4. The suitability index maps for these parameters are also shown in Figures 5 to 11.

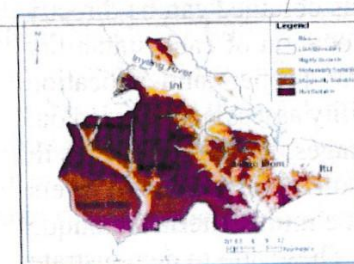
## b. Assessment of Individual Parameters for Land Suitability



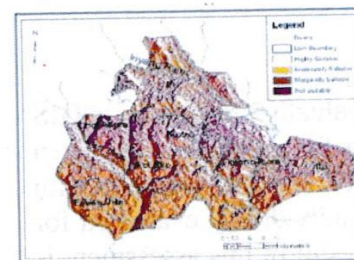
**Figure 5: Soil pH Layer**



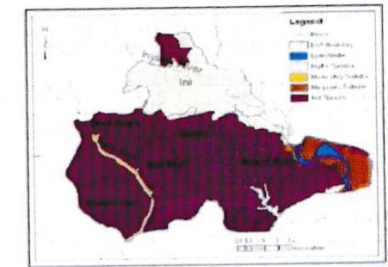
**Figure 7: Soil Texture Layer**



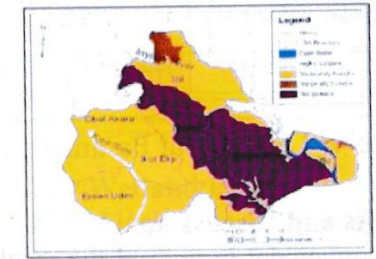
**Figure 9: Elevation Layer**



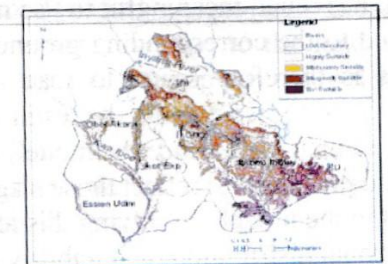
**Figure 11: Aspect Layer**



**Figure 6: Soil Drainage Layer**



**Figure 8: Erosion Hazard Layer**



**Figure 10: Slope Layer**

A close look at the suitability matrix in Table 4 reveals that, of the seven layers, slope angle has the highest value for highly suitable areas covering about 64% (1233km<sup>2</sup>) of the entire study area. This means that slope angle as an indication of ease of water control does not constitute a major limitation to wetland rice farming in the area, apart from a few areas with slope angle exceeding 20°. However, slope angle as high as 39° is rare in the area. On the other hand, erosion hazard and soil drainage are serious limitations. From the table, only 1% (26km) of land was diagnosed as being highly suitable, while moderately suitable areas altogether cover about 62% (1207km<sup>2</sup>) of the area. In terms of soil drainage, over 71% (1382km<sup>2</sup>) of the area was rated not suitable. Other layers vary in their respective effects as the table indicates. Generally, the suitability indexes for the individual layers reveal that highly suitable areas are found mainly in the northern extreme of the area, and also along river courses. Consequently, a combination of these layers can indicate the actual locations of the four suitability ratings and the inter-zone variations which is the focus of the next subsection.

c. **Multi Criteria Evaluation: Final Land Suitability Index for Rice**  
Figure 12 is the result of the MCE of the land suitability index for wetland rice. As discussed in the previous chapter, suitability rating here ranges from highly suitable (S1) to not suitable (N) classes. This LSA index presents a scenario as a result of the combination of seven land and soil characteristics considered important for wetland rice (Table 5). For explicitness, this result is discussed according to the different suitability ratings and in the light of the limitations responsible for such ratings.

**Table 5: Multi Criteria Evaluation: Land Suitability Ratings.**

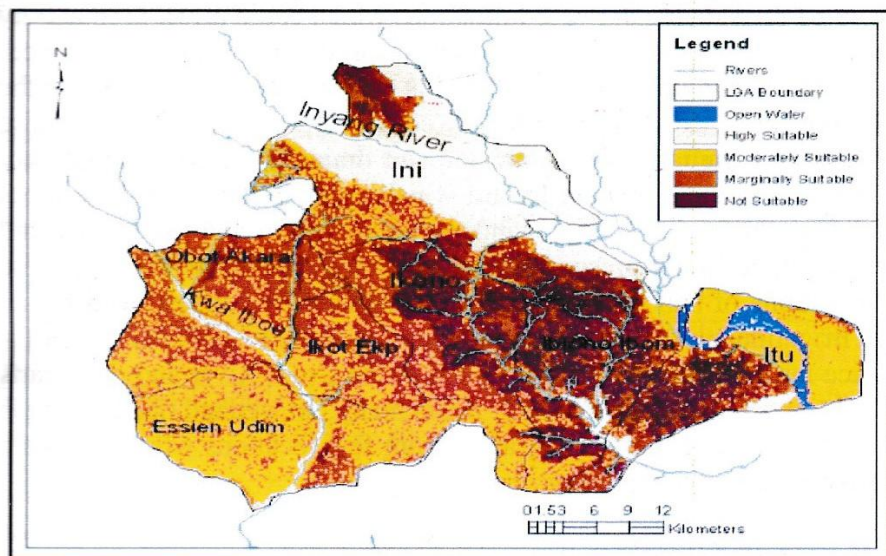
Suitability Classes	Number of Pixels	Area (KM <sup>2</sup> )	%
<b>Highly Suitable (S1)</b>	6248	305	16
<b>Moderately Suitable (S2)</b>	12369	603	31
<b>Marginally Suitable (S3)</b>	15382	751	39
<b>Not Suitable (N)</b>	5182	253	13
<b>No Data (Open Water)</b>	450	22	1
<b>Total</b>	42227	1934	100

i. **Highly Suitable (S1)**

From the suitability matrix above, 16% (305km<sup>2</sup>) of the area is rated highly suitable (S1). This land may not be perfect, but it is the best that can be hoped for. Considering the parameters used, it does not have significant limitations, and is the best for the area. S1 areas are found mostly to the north of the study area. Out of seven parameters used, all were rated highly suitable at corresponding locations excepting erosion hazard, which indicated that most of these highly suitable areas are moderately suitable. However, productivity could be high and sustainable as expected benefits outweigh inputs needed. The social survey conducted in April and May 2006 also reveals that part of this highly suitable land is currently being used for wetland rice cultivation, predominantly in Ini LGA. Highly suitability areas are also found along the flood plains of major drainage systems in the study area as the final suitability index map and chart in Figures 12a and b has respectively indicated. This is very clear along Kwa Ibo River and a few others.



**Figure 12a: MCE Land Suitability Index Figure**



## ii. Moderately Suitable (S2)

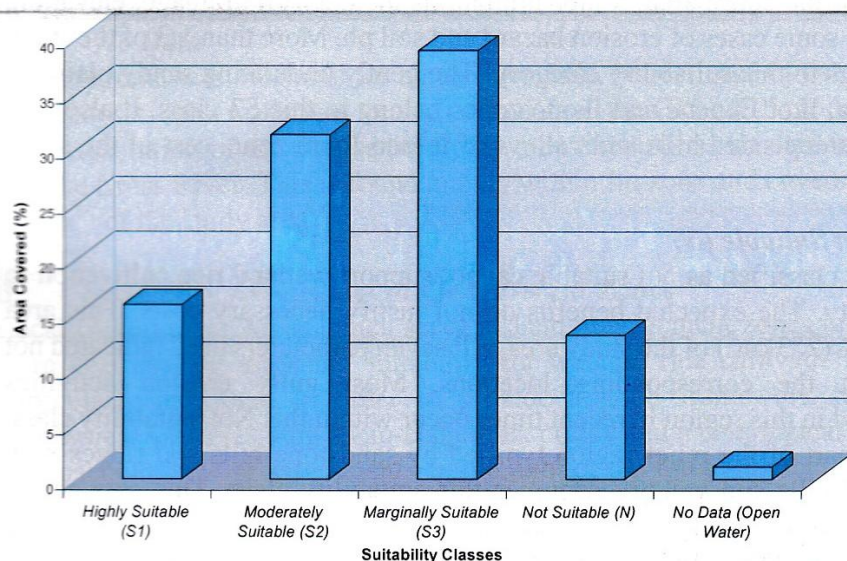
Areas rated S2 are suitable but with limitations which could affect productivity and therefore require additional inputs before production may be sustained. Generally, in this suitability category, benefits prevail over costs only when the required inputs are used. This S2 category covers 31% (603km<sup>2</sup>) of the entire study area. Major limitations here include soil drainage which is largely not suitable, soil texture and erosion hazard which combine to make these areas moderately suitable. On the other hand, slope, elevation and aspect are land characteristics that do not present limitations to the suitability status of these areas. Limitations of soil drainage and texture therefore suggest need for an extensive irrigation system should any attempt be made to utilize this area for wetland rice farming. The entire flood plain of the Cross River and most parts of Essien Udim belong to this category. Incidentally, no wetland rice farming is taking place in most of these areas, apart from few locations which the State Government is currently exploring.

## iii. Marginally Suitable (S3)

These are land areas with severe limitations that benefits are grossly reduced. Input requirements here are only marginally justified. This covers about 39% (751km<sup>2</sup>) of the entire area. Major limitations include soil drainage, elevation, texture and some cases of erosion hazard and soil ph. More than 1/3 of the study area belongs to this suitability category. The gently undulating sandy plains of Obot Akara, Ikot Ekpene and Ikono zones belong to this S3 class. It also cuts across the steep-sided hills and valleys of Ibiono Ibom zone, east of the study area.

## iv. Not Suitable (N)

Land areas classified as not suitable cannot support wetland rice cultivation in any capacity. The expected benefits do not justify necessary costs. This area covers 13% (253km<sup>2</sup>) of the study area. All seven parameters used indicated not suitable at the corresponding locations. Most gully erosion activities experienced in this region in recent times occur within this Not suitability class. A greater part of the relief region typified by sandstone hills and ridges with steep-sided hills and valleys, occupies this suitability class. This cuts across most parts of Itu, Ibiono Ibom and Ikono. Although presently used for the cultivation of other crops, the severity of these limitations indicates serious ecological problems requiring deliberate intervention. Evidence from the field survey carried out confirms this result indicating complete absence of land management strategies to mitigate this problem. Threat of serious ecological



**12b: Percentage Distribution of Suitability Classes**



problems is imminent since the form of land preparation aggravates degradation and nutrient loss in the already loosed and sandy soils of this area.

**Table 5: Suitability Assessment of the Different Zones**

Suitability Ratings	Highly Suitable (S1)		Moderately Suitable (S2)		Marginally Suitable (S3)		Not Suitable (N)		No Data (Open ater)	
	No. of Pixels	Area (km <sup>2</sup> )	No. of Pixels	Area (km <sup>2</sup> )	No. of Pixels	Area (km <sup>2</sup> )	No. of Pixels	Area (km <sup>2</sup> )	No. of Pixels	Area (km <sup>2</sup> )
<b>Zones (LGA)</b>										
Essien Udim	107	5	4168	208	1476	74	13	1	0	0
Ibiono Ibom	623	31	907	45	2745	137	2151	108	38	2
Ikono	4	0.20	1041	52	2931	147	1413	71	0	0
Ikot Ekpene	33	2	985	49	1563	78	14	1	0	0
Ini	4791	240	922	46	1658	83	533	27	0	0
Itu	316	16	2302	115	1513	76	909	45	423	21
Obot Akara	163	8	2032	102	3284	164	114	58	0	
<b>Total</b>	<b>6037</b>	<b>302</b>	<b>12357</b>	<b>618</b>	<b>15170</b>	<b>759</b>	<b>5147</b>	<b>257</b>	<b>461</b>	<b>23</b>

**v. No Data**

Actually, data was available for all the locations, but for ease of data handling and analysis, open water was treated as no data in the GIS-MCE model. In view of the resolution of the data set, the only area captured as no data in this case was the Cross River. This is found mainly within Itu zone and covers about 1% (22km<sup>2</sup>) of the study area.

**d. Suitability Assessment of the Different Zones**

Local Government Areas which serve as land management zones in this work were also used in assessing suitability for wetland rice cultivation. This is particularly important in order to provide a good framework for linking biophysical variables with socio-economic, policy and technological indicators at household level of assessment. In the light of the foregoing therefore Table 5 summarizes this assessment.

From the inter-zone suitability distribution in Table 5, it is obvious that highly suitable land areas are highest in Ini Zone accounting for 79% (240km<sup>2</sup>) of total S1 areas. As mentioned earlier, this area is intensively used for wetland rice cultivation. At the moment, both early and late cultivation are carried out yearly within this zone which is entirely rain fed. With the present suitability level of this zone, there is great promise for large-scale production of rice, especially if irrigation facilities are provided to compensate for any soil water (drainage) deficit. However, the socio-economic reality coupled with land tenure system is a serious constraint which the state/potential investors need to give some consideration. Other areas with sizeable plots are Ibiono Ibom and Itu zones with 32km<sup>2</sup> and 16km<sup>2</sup> respectively. On the other hand, S2 category is highest in Essien Udim, accounting for 34% (208.40km<sup>2</sup>) of the total areas rated as moderately suitable. This is followed by Itu and Obot Akara with 19% and 16% respectively. Other zones account for average of 7.5% each. Consequently, Essien Udim, Itu, Obot Akara and parts of Ibiono Ibom zones have potential for wetland rice cultivation if the limitations described earlier are taken into consideration. Zones with appreciable size of land rated as marginally suitable class include Obot Akara 22%, Ikono 19%, Ibiono Ibom 18%, while the other three zones have an average of 10% each. Also, Ibiono Ibom has the highest percentage (42%) of not suitable land. This is however not a surprise since the area falls within the region of the sandstone hills and ridges with steep-sided hills and. However, this does not mean that the entire zone is not suitable at all.

**e. MCE LSA: Different Scenarios**

In order to assess the effects of the individual land parameters, validating the outcome of the final model, the model was subjected to an iterative ('jackknife') process through systematic removal of one layer before each round of iteration, and generating a single output with the remaining 6 layers. The process also helps to determine the contribution of each layer in the model. An additional benefit of this approach is seen applying the result for actual land allocation decisions. Limitations of specific areas become very obvious and therefore easy to decide on input requirements. Figures 13 to 19 illustrate these different scenarios, while Table 6 summarizes the variations in ratings associated with these land characteristics.



Suitability Ratings	Highly Suitable (S1)		Moderately Suitable (S2)		Marginally Suitable (S3)		Not Suitable (N)		No Data (Open Water)	
	No. of Pixels	Area (km <sup>2</sup> )	No. of Pixels	Area (km <sup>2</sup> )	No. of Pixels	Area (km <sup>2</sup> )	No. of Pixels	Area (km <sup>2</sup> )	No. of Pixels	Area (km <sup>2</sup> )
Scenario 1 Without pH	5646	282	5050	253	19425	971	8579	429	380	19
Scenario 2 Without Drainage	4827	241	6234	312	17620	881	10019	501	380	19
Scenario 3 Without Texture	5359	268	8105	405	16065	803	9171	459	380	19
Scenario 4 Without Eros. Hazard	5126	256	5222	261	19105	955	9247	462	380	19
Scenario 5 Without Slope	4273	214	5072	254	16918	846	12437	622	380	19
Scenario 6 Without Elevation	5349	267	17768	888	7555	378	8028	401	380	19
Scenario 7 Without Aspect	3445	172	2528	126	22210	1111	10517	526	380	19

Table 6: LSA: Summary of Different Scenarios

From the different scenarios summarized in Table 5, it is apparent that the model is very sensitive to elevation and aspect layers. The removal of elevation in scenario 6 results in most areas previously rated S3 to become S2. This places emphasis on the importance of elevation, which in this case indicates energy sufficiency. In the case of aspect which is a measure of the slope face, there are tiny variations within short distances throughout the study area. Although its removal from the model has not significantly upset the previous results, it is found to be responsible for the speckles noticed in the final index. Its removal from the model therefore reduced the noise problem in the index as seen in Scenario 7 (Figure 19). Other parameters are seen to be equally important since their exclusion from the model only account for slight variations

in the final result. Again, as discussed in the previous sub-section, areas rated S1 and N appears highly consistent in all the scenarios throughout the study area. This is so because their locations in all the zones have not varied significantly from scenario to scenario.

The LSA index has revealed the land qualities and their associated limitations. With this spatially explicit information, the requirements of individual zones are very clear. Inputs needed could therefore be channelled to the appropriate zones. For instance, as is summarized in Table 6 under LSA, moderately suitable areas in Essien Udim zone are so classified mainly due to soil drainage and texture deficit. If such area is to be used for rice cultivation, irrigation facilities become a priority. Apart from this, land tenure system presents another challenge.

The 208km<sup>2</sup> assessed as moderately suitable in this zone may be highly fragmented and therefore in the hands of hundreds of small holder farmers as the social survey has revealed. Again, the LUCC results show that such land area is predominantly covered by compound farmland and bush fallow which suggests degradation due mainly to slash and burn form of land preparation associated with these LUC types, especially with the reduction in fallow period. This work has therefore shown that apart from the LSA indicating that such area is moderately suitable, issues such as land tenure (ownership), agricultural practices and land use/cover information are quite useful in land allocation decisions. Therefore, although the size of this area is large, large-scale farming here would mean resolving land ownership issue and pulling such fragments together. This seems a difficult task unless the benefits are quickly outweigh the limitations otherwise farmers may be reluctant to let go of their farmlands. Apart from the above facts, it becomes easy to identify the needs of individual communities and actually direct resources and efforts with good understanding of the land characteristics and socio-economic realities towards meeting set goals instead of relying purely on political considerations. In fact, such suitability index maps should be used as baseline information for land related planning activities.



## MCE LSA: Different Scenarios

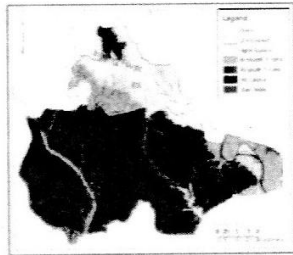


Figure 13: Scenario 1:  
Without pH

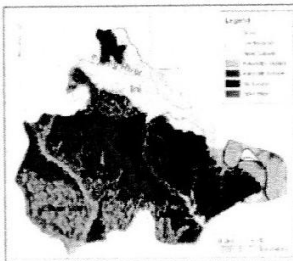


Figure 18: Scenario 15:  
without Soil Texture

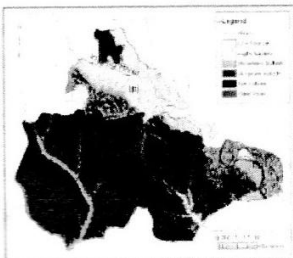


Figure 17: Scenario 5:  
Without Slope

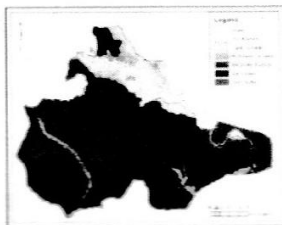


Figure 19: Scenario 7: Without Aspect

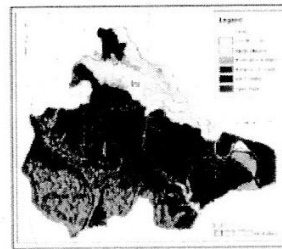


Figure 14: Scenario 2:  
without Soil Drainage

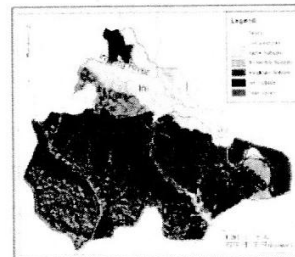


Figure 16: Scenario 4:  
without Erosion Hazard

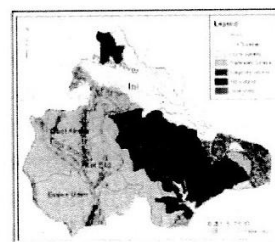


Figure 18: Scenario 6:  
Without Elevation

## Conclusion and Recommendations

This study which relied mainly on MCE techniques in GIS to gain an understanding of the issues involved in land utilization in northern Akwa Ibom State, has revealed a number of trends and patterns. It has also provided the basis for optimal land use planning in this rural area

It is obvious that the only land management strategy adopted here is the rotational bush fallow system. This has failed to guarantee sustainable use of land resources in the face of reduction in length of fallow and land preparation techniques. Consequently, the individual land characteristics used in the MCE model confirm serious limitations in most zones. This coupled with high rate of land fragmentation and multiple holdings which characterises this area presents serious land management problems. The total reliance on indigenous knowledge without a cross pollination with scientific understanding merely aggravates land management problems. The prospects for improved food production therefore seem bleak unless these issues are resolved.

In view of these unfolding issues, the LSA aspect of the work therefore provides useful insight to the suitability status of the land with a demonstration on rice, one of the staple food crops in the area. Of particular significance is the spatially explicit, local-scale information provided about the limitations associated with each land class across all zones. This has relevance both for policy makers as well as small holder farmers. Consequently, at the policy level, informed decisions can be taken on how to tackle such physical land limitations, in view of past and present practices and with good understanding of the socio-economic characteristics of the target population towards meeting their needs and at the same time sustaining the use of land. The research has therefore combined information from the important components always needed for land use decisions. This approach consequently presents a realistic approach which researchers and policy makers should always utilized in gaining deeper understanding of the land which should guide their decisions and guarantee trade-off from investment.



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