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TOWARDS A RELEVANT LAND EVALUATION FRAMEWORK FOR NIGERIA: AN EXPERIENCE WITH THE OYO NORTH EVALUATION SYSTEM (ONLES)

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ABSTRACT

Oyo North Land Evaluation System (ONLES) evolved from series of modifications of the existing systems using the principles of FAO guidelines for land evaluation. The system is an index of suitability based on land super qualities, qualities, sub-qualities and characteristics that are relevant to crop production in Nigeria. The class limits and values of the land characteristics are based on experience and research reports in this zone. The system was tested on two-year maize grain yield. The result showed that the new system is practically relevant for assessing the potential of the soils for rainfed arable crop production ($r = 0.70$; $p \leq 0.01$ in 1988 and 1989 respectively). The practical application of the system was further tested by comparing the yield index obtained under this system with the recommended yield index, the result also showed that the predictive power of the system is very high.

INTRODUCTION

Land resources survey started in Nigeria in the early 60s with the survey of the soils of the cocoa growing area of the Western Region (Smyth and Montgomery, 1962). Since then, almost all other parts of the country have been covered by land resource surveys.

However, only in a few of these surveys has an attempt been made to determine the potential of the soils and their spatial distributions. Little or no efforts were made to determine the use to which the soils can be put.

With greater awareness of the importance of land evaluation in the

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70s, attempts were made by soil surveyors to evaluate Nigeria soils for agricultural purposes. Many of the existing land evaluation systems have been used. These systems were used for evaluation without any modifications despite the fact that they were developed in different environments with different farming systems, crops, management skills and soils. There has never been a test of the relevance of theses systems in Nigeria, although recent research findings (e.g. Bleeker *et al* 1984, Oluwatosin, 1991) revealed poor correlation between the systems and actual crop yield. This may not be surprising because the land use type on which the systems were based in their countries of origin are different from what obtains here in Nigeria.

Thus, the Land Evaluation Systems currently used in Nigeria suffer from two major limitations:

(i) They are not sufficiently detailed for assessing land suitability for specified crops.

(ii) Reports on the testing of these systems in Nigeria have shown that their accuracy is low.

There is, therefore, a need to develop a system that is more relevant to the Nigerian local environment.

As a test case, Oyo North was chosen because detailed and up-to-date data are available on soils, landscape, climate and crop yield. Thus, Oyo North Evaluation System (ONLES) is developed to assist farmers in this zone to optimize the use of their land resources, and to promote sustainable farming systems that are economically viable, socially acceptable and environmentally sound. The system is indeed for use at semi-detailed and detailed land evaluation studies for rainfed agriculture.

Specifically, this paper reports:

(a) the description of Oyo North Land Evaluation System (ONLES).

(b) the results of the test of its practical value in terms of actual crop yield prediction.

DESCRIPTION OF THE SYSTEM

The Study Area:

Oyo North falls within the savanna region of Oyo State of Nigeria. The area falls between longitude 2°30′ and 5°E and latitude 7° and 9°31′N (Fig. 1). The North and Central part of the area have a periodically dry savanna climate but the Southern part is tropical rainforest. The main feature of the area is high temperature and a constant mean annual rainfall of 1120-1150mm during the past two decades. Wet and dry seasons are marked. The wet season starts in the Southern part in the first week of March and in Northern part in early April. It ends in mid-October, so that the Northern part has 30 - 40 days longer dry season than the South.

The System:

Oyo North Land Evaluation System is an index of suitability using a parametric approach. Classes are defined with regards to the intensity of the limitation(s). They generally relate to a specific value of land index calculated from individual rating of characteristics according to the formular:

$$IS = A \times \frac{B}{100} \ldots\ldots\ldots \frac{n}{100}$$

where :

IS = Index of suitability.

A = Index of the most limiting characteristic.

B = Index of a characteristic (e.g. nutrient retention)

n = Index of nth characteristic.

For example, using Table 5, the index of suitability for Igboho series is calculated as:

Actual: IS = 57 × I × I × I × .95 × .80 = 43 (S3)
(f) (t) (w) (o) (s) (n)

Potential: IS = 80 × I × I × I × .95 = 76 (SI)
(n) (t) (w) (o) (s)

The system is based on information on land characteristics gathered partly from international and national literature , and partly from relevant research work carried out in this zone. The main focus has been to evolve a system capable of guiding the land users (farmers) as efficiently as possible on the relative suitabilities of parcels of land in an area of interest for specified uses.

This system presents two relevant super land qualities, 12 land qualities, 32 sub-land qualities and 35 land characteristics (Table 1).

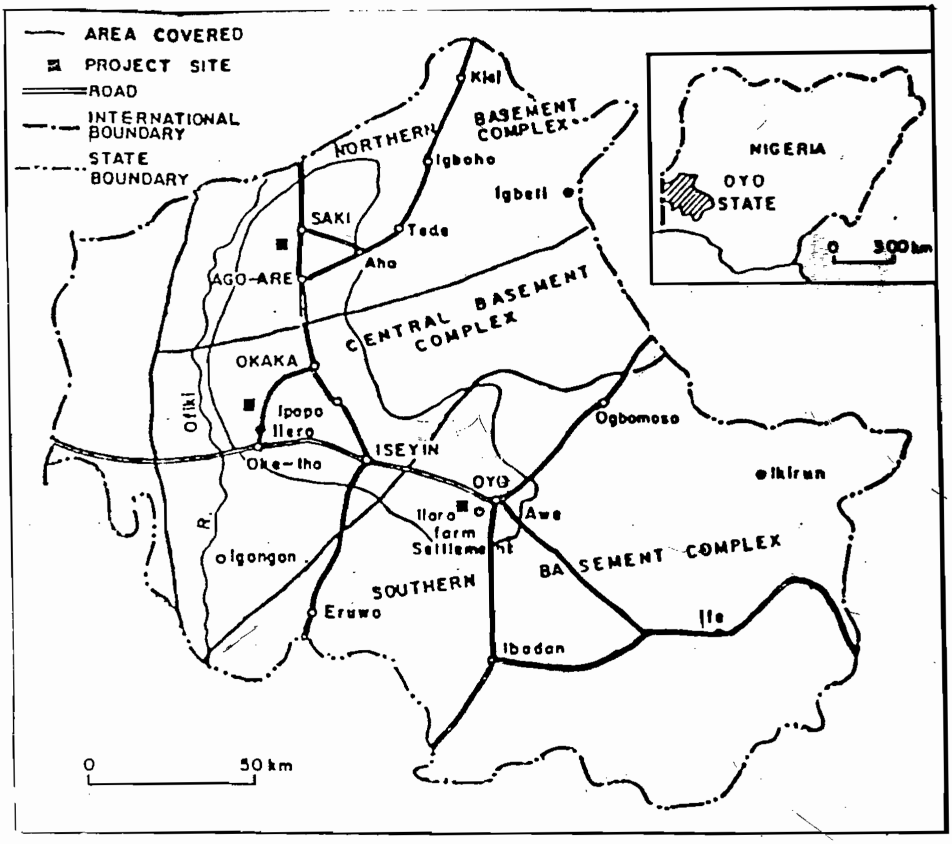

Fig.1: Location map of the Study area

Table 1. Land Super Qualities, Qualities, Subqualities and Characteristics Used in ONLES

Land Super Qualities

Climate	C
Soil	S

Land Qualities

Insolation availability	(i)	Workability	(k)
Moisture availability	(w)	Soil degradation	(d)
Oxygen availability	(b)	Rootability	(r)
Nutrient availability	(f)	Ability for farm layout	(y)
Nutrient retention	(n)	Drought hazard	(t)
Erosion hazard	(e)	Storm hazard	(s)

Land Subqualities

Rainy season climatic constraints

we	Excessive rainfall.
wh	High air humidity as related to the occurrence of pests and diseases.
tg	Unfavourable length of growing season.
ir	Low radiation (sunshine, light intensity).
td	General drought hazard and apparently consistent occurrence of drought periods.
st	High incidence of storm hazard.
ac	accessibility problems.
ew	water (sheet) erosion hazard.
wl	flood hazard
km	mechanized land preparation problems
kw	soil workability problems
te	drought stress because of shallow rooting caused by iron pan formation.
og	shallow ground water level.
od	poor soil drainage and aeration conditions.
ow	water logging problems

Non seasonal specific constraints

dc	high chemical soil degradation
dp	high physical soil degradation
nr	low nutrient retention capacity
na	low general nutrient reserves
fc	copper deficiency
fd	iron deficiency
fm	manganese deficiency
fz	zinc deficiency
fi	magnesium deficiency
fk	potassium deficiency
fp	phosphorus deficiency
fn	nitrogen deficiency
fh	acidic soil
yx	hinderance of machinery

because of permanent features like rock outcrops and stoniness.

rp limited rooting depths due to iron pan.

rr limited rootability within rooting depth as related to abrupt textural change, high bulk density, firm consistency.

Land Characteristics

Characteristics of Climate
- Sunshine hour
- Day length
- Rainfall during raining season (amount, intensity and timing interval)
- Storm incidence
- Evaporisation (actual and potential)
- Humidity (length)
- Length of August break
- Wind speed.

Characteristics of Land Forms:

- Slope angle
- Slope length
- Drainage density
- Rock hinderances, outcrops and boulders
- Micro relief
- Positions in landscape.

Characteristics of Soil:

- Soil drainage class
- Stoniness and gravel content
- Texture
- Effective soil depth
- Cementation and pans
- Available water holding capacity
- Bulk density
- Infiltration rate
- Soil erodibility
- CEC
- Total exchange bases
- Base saturation
- Nitrogen contents
- Available phosphorus
- Exchangeable potassium
- Organic matter contents
- Carbon/Nitrogen ratio
- Weatherable minerals
- Clay mineralogy
- Extractable micronutrients
- Structural stability.

Concept of Land Qualities and Characteristics

Super Quality

The success of any land use system is controlled mainly by climate and soil. Thus a super quality is that which acts in a distinct manner in its influence on the suitability of an area for any Land Use Type (LUT). The critical values of the super quality is such that might adversely or favourably affect the use. Examples are climate and soil. The importance of super quality is reflected in the rating of characteristics which ranges between 20 and 100 (Table 2).

Land Quality

This is the state of variables of

land use system, which can be limiting factors, influencing the behaviour of the land use system. Examples are moisture availability, erosion hazard, rootability etc. The relative importance of land quality to super land quality is reflected in the rating whereby very severe to no-limitations have a range of 60-100 (Table 2).

Sub-Quality

A sub-quality is the practical consequence of land quality. They are those complex attributes of land that have known effect upon crops or kinds of land use under consideration. Examples are: excessive rainfall, low radiation, high incidence of storm hazard, flood hazard etc.

Land Characteristics

Land characteristics are measurable properties of the physical environment directly related to land use, which can be used to distinguish between land units of differing suitabilities and are used in describing sub-qualities.

Examples are sunshine hour, wind speed, slope angle, erodibility, effective soil depth etc.

Relevant land qualities, subqualities and characteristics are to be picked for a given land use or crop out of the numerous presented by this system. The number of land characteristics to be considered has to be reduced to a strict minimum to avoid repetition of related characteristics in the formula which may lead to the depression of the land index.

The most limiting quality and /or characteristic determines the final suitability class. Land super qualities are formed by the combination of land qualities. Land qualities are formed by the combination of subqualities which inturn are formed by the combination of land characteristics. However, subqualities are not actually used in evaluation but are only meant to indicate broad constraints. Each land super quality has a singe capital letter code. Each land quality has a single small letter code. The sub-qualities have two letter codes, the first of which is the same as that of land quality. All the qualities considered come under two major super qualities (ie. climate and soil).

Land Use Type (LUT)

Land Use Type (LUT) is a specific sub-division of major kind of land use serving as the subject of land evaluation and is defined as precisely as possible in terms of produce and management. This LUT is defined by a crop and purchased input level.

The management level depends on purchased inputs. It can be expressed in terms of money spent per hectare per year. The actual expenditure depends on the constraints/limitations which are overcome by purchased inputs.
The input levels used in this system

are given in Table 3. Management also involves sociological, economical, political and personal conditions in which crop production takes place, but LUT as it is used in this system does not include details of levels of management. Often differences in management result in wide variation in crop yield.

Table 2: Limitation Levels and their Rating

Symbol	Intensity of Limitation	Land characteristic rating Most Important	Less important
0	None	95 - 100	95 - 100
1	Slight	85 - 95	90 - 95
2	Moderate	60 - 85	85 - 90
3	Severe	20 - 60	60 - 85
4	Very Severe	< 20	< 60

Table 3: Input Levels used in ONLES

Input Level	Cost of Production	Remarks
Very low	Very low, ₦100 ha per year	Little or no input. The farmer is traditional and peasant with no access to purchased input. He uses hoe and cutlass only. Labour is self and family.
Low	Low to moderate. ₦100 - ₦55 per ha per year.	This is small shoulder with some access to extension services; he buys some fertilizer and seed every year. He hires labour during the peak period.
Moderate	Medium. ₦500 - ₦1000 per has per year	These are target farmers who follow the recommendation of the extension workers on inputs and management as possible. They hire tractor to till the land, they apply herbicide at times.
High	> Medium to High. ₦1000 per ha per year.	These are the commercial farmers, government farms who try to optimize inputs in an economic way. The farmer has a very high management level.

Limitation and Suitability classes

The final suitability classes are described in terms of degree of limitation of the super qualities (i.e. climate and soil constraints). There are five limitation classes on relative limitation scale. The ratings selected for different limitation levels are given in Table 2.

The combination of the suitability indices for all the land qualities considered produce the suitability classes. The combination of the climate and soil indices then give six final suitability classes (i.e. Si, S2, S3, S4, NS1 and NS2) (Table 4). This enables the land user to know, at least, for the final suitability classes whether the climate is limiting or the soil or both.

Table 4: Final suitability classes in terms of climatic/ soil limitations and expected yield class

Suitability Class	Climatic Limitation Class	Soil Limitation Class	Expected yield class % of the reference yield
S1	none (0)	none (0) to slight (1)	> 75%
S2	none (0) to slight (1)	slight (1) to moderate (2)	50 - 75%
S3	moderate severe (2)	none (0) to slight (1) to moderate (2)	40 - 50%
S4	moderate (3) to severe	slight (1) to moderate (2)	30 - 40%
NS1	moderate (2) to severe (3)	moderate (2) to severe (3)	25 - 30%
NS2	severe (3) to very severe (4)	severe (3) to very severe (4)	< 25%

Execution of the System:

To use this system, the procedures are as follows:

1. Data from soil surveys and other related surveys must be available. Where such surveys have not been conducted, the exercise should be carried out to generate relevant data needed for land evaluation study.
2. Land Use (e.g. crop) of interest (specifying the input levels) in the survey area is selected and defined.
3. Sub qualities with the greatest influence on the performance of the selected crops are established. To assist in the selected, the land characteristics influencing each sub quality are described.
4. Land characteristics that are relevant to each sub quality must be measured. This is usually done during land resources survey. Hence, the purpose of the evaluation must be well defined so as to know those land characteristics to be measured during the field survey.
5. The relationships between land condition and yield or performance of a given land use type are used to rate the land characteristics as they occur in a map unit. Literature, both international and local may be consulted to actually determine the class limits of the land characteristics. Usually, the rating is qualitative. They have been subdivided into a few numbered categories, e.g. high = 0, medium = 1, and low = 2. For many characteristics there are several rating options presented in order of priority.
6. There is the possibility of change in rating due to input level per characteristic. Therefore provision should be made for this. First, rating under 'actual' performance should be determined. For example, in rating for potassium, if the lowest potassium level in the top 20cm is less than 2cmol/kg^{-1} soil which is the critical level of the most arable crops in South Western Nigeria (Agboola Obigbesan, 1974, Agboola and Ayodele 1987), then it is rated 20 on the limitation scale (Table 2). Thus the 'actual' rating is 20. If high input level is being considered then we move horizontally along the limitation scale to change the rating to say 85 ('potential'). Usually the rating is higher than the 'actual' because of the improvement due to inputs.
7. For each rating however, the appropriate input level, climate and or soil constraint classes that influence the selected crop must be determined. For each land characteristic, there is a table of classes of constraints such as the one in Table 5. This table shows the rating under the appropriate input level and specified land use type (crop). The combination of these rating give the suitability

class.

TESTING THE SYSTEM

Testing is an essential process in the development of land evaluation system. It is basically a continuous exercise which involves the use of fresh information from the field to make the system better. This exercise has to continue as long as the system is introduced to an environment different from where the original system was developed.

ONLES was calibrated in three locations in this agro-ecological zone. The locations are at Ilora (representing the Southern part of the zone), Ilero (Central part), and Shaki (Norther part). Each location fails within some of the sampled blocks of Mudorch *et al* 1976). In these sampled blocks a detailed soil survey was conducted and soil was mapped at the series level. Calibration was based on maize grain yields. In each location, sampled farms were randomly selected to represent major soil series in the area. Data were collected as shown in Table 6. This set of data was used to determine the input level of each farmer following the criteria in Table 3. Maize grain yield was collected at ten spots from an area of 30m x 60m on each farm for two years.

The suitability classes obtained were then ranked. The maize grain yield obtained were also ranked and rank correlation coefficient (Ostle and Mesing, 1981).

The reliability of the suitability classes were further tested by comparing the yield index computed from the evaluation classes using standard yield values of the on-farm adaptive research (OFR) of Western Nigeria with the recommended yield index (Sys, 1985). Yield index is given by the formula:

$$\text{Yield Index} = \frac{\text{Actual Yield}}{\text{Standard Yield}} \times 100$$

RESULTS AND DISCUSSION

For 'actual' suitability, there was no significant correlation (r = 0.34, r = 0.41 in 1988 and 1989 respectively) between suitability classes and maize grain yield (Table 7). This result is not unexpected because by including land characteristic 'f' (nutrient availability) in the criteria for evaluation, the input level of the land users was not taken into consideration. Whereas, all the farmers involved in this calibration study applied fertilizer to offset the limitation 'f'. Hence the lack of significant correlation would have been recorded if the farmers had not applied fertilizer to remove limitation 'f'. Therefore, this system under 'actual' suitability will be useful to rate farmland under low input level.

Table 5 **Land Requirement for Rain fed Maize**

Land Characteristics (class) (index)	S1 100 - 95	S2 95 - 75	S3 75 - 55	S4 55 - 35	NS1 35 - 25	NS2 0 - 25
Topography (t)						
a) slope %	0 - 2	2 - 4	4 - 8	8 - 16	16 - 20	> 20
b) slope %	0 - 4	4 - 8	8 - 16	> 16	any	
Moisture availability (w)						
Total rainfall during the growing season	800 - 1200	700 - 800	600 - 700	500 - 600	< 500	any
Oxygen availability (O) drainage	good	moderate	imperfect/ rapid	poor/very excessive	poor but drainable	poor but not drainable
Nutrient availability 0 - 20cm (f)						
Total N%	> 0.15	0.08 - 0.15	0.04 - 0.02	0.02 - 0.01	< 0.01	any
Avail. P (ppm)	> 22	13 - 22	6 - 13	3 - 6	< 3	any
Extr. K (Cmol kg^{-1} Soil)	> 0.5	0.2 - 0.5	0.01 - 0.2	0.05 - 0.1	< 0.05	any
Mn (ppm)	> 20	15 - 20	12 - 15	5 - 12	< 5	any
Zn (ppm)	> 15	12 - 15	8 - 15	3 - 8	< 3	any
Cu (ppm)	> 10	4 - 10	1 - 4	0.04 - 1	< 0.4	any
Nutrient retention capacity (n)						
(c) ECEC (Cmol kg^{-1} Soil	> 15	7 - 15	3 - 7	2 - 3	< 2	any
(d) ECEC (Cmol kg^{-1} Clay	> 24	16 - 24	16	any	any	any
Base saturation						
c) (%)	> 80	50 - 80	20 - 50	< 35	any	any
d) (%)	> 70	50 - 70	35 - 50	< 35	any	any

Organic matter						
c) (%)	> 3	1 - 3	0.4 - 1	< 0.4	any	any
Physical soil characteristics (s)						
Texture/structure	C - 60s, Cl SC, SCL,L	SL, Lf5, LS	LeS, fS	Cm, C5	S	S
a) Gravel (%)	< 15	15 - 60	60 - 75	75 - 90	> 90	any
b) Gravel (%)	< 40	40 - 80	80 - 90	> 90	any	any
d) Gravel (%)	< 20	20 - 95	75 - 80	> 80	any	any
Soil depth (cm)	> 90	50 - 90	30 - 50	20 - 30	< 20	any
Bulk density (g/cm^3)	< 1.0	1.0 - 1.21	1.22 - 1.63	1.63 - 2	> 2	any

KEY:

a = mechanized	C - 60s = Clay, blocky structure	CS = Coarse Sand
b = not mechanized	CL = Clay loam	LCS = Loamy coarse sand
c = AP or A horizon	SC = Sandy Clay	fs = Fine sand
d = B or sub horizon	SCL = Sandy clay loam	SL = Sand loam
	S = Sand	LfS = Loamy fine sand
	L = Loam	Cm = Massive clay

Table 6 **Agronomic practices of the selected farms**

Farm Location	Soil Series	Maize variety planted	Plant (per ha)	Weeding	Fertilizer rate kg/ha	Fertilizer type	Planting Date 1988	1989	Yields tons/ha 1988	1989
Ilora	Ibadan	TARS-Y	55,558	One hand weeding at 4 weeks after planting	250kg/ha	NPK 15-15-15	30/4/88	28/4/88	2.4	2.6
	Egbeda	TZRS-Y	55,558	One hand weeding at 4 weeks after planting	300kg/ha	NPK 15-15-15 urea, single superphosphate	9/7/88	26/6/89	2.8	2.6
	Shante	TZRS-W	55,556	Pre-emergence herbicide at planting	350kg/ha	NPK 15-15-15 Urea	21/5/88	27/5/89	2.7	2.6
	Fashola	TZRS-W	55,556	One hand weeding at 4 weeks after planting	50kg/ha	NPK 15-15-15	31/5/88	29/5/89	0.8	1.0
Ilero	Shepe-teri	TZRS-Y	55,556	One hand weeding at 4 weeks after planting	250kg/ha	NPK 15-15-15 Urea	7/5/88	4/6/89	2.3	2.4
	Woro	TZRS-W	55,556	One hand weeding at 4 weeks after planting	250kg/ha	NPK 15-15-15 Urea	7/5/88	11/5/89	2.5	2.7
	Igboho	TZRS-W	55,556	One hand weeding at 4 weeks after planting	200kg/ha	NPK 15-15-15 Single superphosphate	6/5/88	26/5/89	2.2	2.4

	Temi-dire	TZRS-W	'55,556	One hand weeding 4 weeks after planting	at 200kg/ha	NPK 15-15-15	6/5/88	26/5/89	2.2	2.4
Saki	Titiale	TZERS-Y	53,556	Pre-emergence plus one supplemental hand weeding	350kg/ha	Urea, NPK 15-15-15	4/5/88	5/5/89	1.3	1.5
	Owutu	TZRS-W	53,556	Pre-emergence herbicide plus one supplemental hand weeding	350kg/ha	NPK 15-15-15, Urea	30/5/88	28/5/89	2.3	2.8

Table 7: **Rank Correlation between the Suitability and Maize Grain Yield**

Suitability Class	r - values	
	1988	1989
a) When all the characteristics 'f' was included in criteria for evaluation (i.e. 'actual' suitability class)	0.39ns	0.41ns
b) When characteristics 'f' was not included in the criteria for evaluation (i.e. potential suitability)	0.70**	0.70**

ns = not significant
** = P 0.01

However, for 'potential' suitability, i.e. when limitation 'f' was not included in the criteria for evaluation on the assumption of medium to high input level by the farmers, there was a highly significant positive correlation between the suitability classes and the yield of maize ($r = 0.70$; $p \leq 0.01$ in 1988 and 1989 respectively Table 7). This result shows that the rating of the farmland without taking the input levels of the farmers into consideration actually rated the farmland for maize production wrongly. We therefore submit that land limitation 'f' is an effective one and should only be used with due regards to the input level of the farmers.

Furthermore, Table 8 shows the comparative values between the land class and yield class. The result revealed that under 'actual' suitability rating, only farmland occupying Fashola series which is in land class S3 gave a corresponding yield class in both years. This is because the farmer who cropped the land operated under low input level.

Under 'potential' suitability rating, all the farmlands except the one occupying Fashola series gave the corresponding crop yield class. For example farmland on Egbeda series which is rated as S1 gave a corresponding yield class (S1) in both years. The case of Fashola farmland is a confirmation of the importance of input level.

Table 8: Comparison of suitability classes and yield classes

Soil Name of	Land Suitability Classes		Optimum Yield		Obtained Yield (1988)		Obtained Yield (1989)	
the Farmlands	Actual	Potential	Recommended Index	Recommended Class	Index	Class	Index	Class
Shante	S3	S2	50 - 75	S2	77	S1	66	S2
Egbeda	S2	S1	75	S1	80	S1	78	S1
Ibadan	S3	S2	50 - 75	S2	57	S2	68	S2
Fashola	S3	S3	40 - 50	S3	37	NS	43	S3
Shepeteri	NS1	S3	40 - 50	S3	66	S2	71	S2
Woro	S2	S1	75	S1	74	S2	77	S1
Temidire	NS1	S3	40 - 50	S3	54	S2	51	S2
Igboho	S3	S1	75	S1	68	S2	78	S1
Titiale	NS1	S3	40 - 50	S3	52	S2	60	S2
Owutu	S3	S2	50 - 75	S2	51	S2	70	S2

ADVANTAGES OF THE SYSTEM

1. The system is comprehensive in its approach. It is a culmination of a large amount of research and data gathering on the requirement of selected crops and the land factor affecting the suitability.
2. It is crop specific making it simpler to define land use requirement.
3. The system estimates yields at different input levels thus

quantifying the suitability classes, whereas, in most of the existing land evaluation systems, the end result is usually qualitative.
4. It is able to identify the most limiting constraints to a crop in any agro-ecoplogical zone.

DISADVANTAGES OF THE SYSTEM

1. It is a system that is based on mono-cropping system, whereas majority of the farmers in this zone practice mixed cropping.
2. With so many subqualities and characteristics to choose from, one has to be very careful not to produce wrong rating class through excessive weighing of relatively less relevant criteria. There is a danger that an inexperienced soil surveyor could get lost in the computation of the suitability class.

CONCLUSION

The study has demonstrated that the ONLES system actually works. It is very good for recognizing the limitations of land use types. The ability to predict yield potentials under specified input level is a strong advantage. However, like any other land evaluation system, it has operational weaknesses. One hopes that as the systerm is introduced into other zones, more useful information will be fed into it to make it very relevant and useful to the Nigerian environment. An improvement on this to include multiple cropping systems will be a significant contribution. Further research along this line is therefore advocated.

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