EVALUATION OF THE POTENTIAL OF SOILS AROUND OYI RIVER, TAKETE-ISAO, NIGERIA FOR IRRIGATION

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Abstract— **Irrigation is important for round year production of food to guarantee food security of the increasing population. The potential of three soil units (YA, YB and YC) around Oyi River in Takete-Isao, Nigeria was evaluated for surface, sprinkler and drip irrigation systems using the parametric approach of irrigation suitability evaliuation. Soil unit YA has suitability index of 46.17, 54.66 and 64.13 with suitability class ratings of S3 (marginally suitable) and S2 (moderately suitable) for the three irrigation systems respectively. YB was 38.30 and rated N1- currently not suitable for surface irrigation while YC is rated moderately suitable with suitability index of 63.18 and 76.00 for sprinkler and drip irrigation systems respectively. Post-harvest residue management, land tillage across slope and construction of contour bunds, incorporation of organic manure, maintenance of vegetative cover and cultivation of cover crops were recommended.**

Keywords— **irrigation, suitability, evaluation, drip, sprinkler, surface**

I. INTRODUCTION

There is growing concern over food security in Africa and especially sub-Saharan Africa [1]. Productivity is declining in rain-fed agriculture globally [2]. To double food production over the next two decades, water has been considered as the most important component for the transformation of low productive rain-fed agriculture into most effective and efficient irrigated agriculture [2, 3].

Irrigation is viewed as a key factor in progress towards achieving food security in Africa. However, while nearly 40% of the world's agricultural production comes from irrigated land [4], only 4 per cent (6 million ha) of the sub-Saharan African total cultivated area is irrigated [5].

Food crops production in Nigeria comes mainly from rain-fed smallholder agriculture, therefore rainfall is one of the most important factor in food supply. The dependence on rain by most of small holder farmers largely contributed to low-output and inability to meet the food supply of the fast growing population [6]. The high dependency on rain-fed farming and erratic rainfall require alternative ways of improving agricultural production in Sub-Saharan African region [6].

Today food production via irrigated agriculture does not correspond to the current rapid population growth. Soil salinity and contamination in addition to the excessive urban development are also the main factors that affect the state of food production by irrigated agriculture [7]. In Nigeria irrigation technology is low. The total irrigation potential of Nigeria is about 3.14 million hectare, 1.10 million hectares for public irrigation projects and 2.04 million hectares for fadama irrigation projects [8]. Only about four percent of the cultivated land area in Nigeria is under irrigation. Estimated irrigated cropland varies from one source to the other but its total water managed area is estimated to be a little over 950,000 ha. These yield about 10% of the national crop yield [8].

According to [9], the irrigation of more land is necessity for world food security. To develop a sustainable irrigation system, it is required to know the limitations and potentials of the land [10]. It is a prerequisite that the suitability of soils be assessed for irrigation before such a project is undertaken. Global food security and stability depends on the management of the natural resources such as river basins. The efficient management of river basins has been identified as solution to problems of agricultural productivity [11] in that most of the soils are productive and can support cultivation of crops all year round [11, 12] therefore the evaluation of suitability of soils at the basin of Oyi river along Itakete Isao-Isanlu, Nigeria for sprinkler, surface and drip irrigation systems was considered.

II. MATERIALS AND METHODS

2.1 Description of the study area

The study was carried at Warshull Integrated Farms Limited which covered an area of 80 hectares on 08°10'21"N and 05°29'41"E at the basin of Oyi River along Itakete-Isao/Isanlu road, Yagba East Local Government, Kogi State, Nigeria.

The area has climate typical of humid tropics with rainfall that spans the month of April to November with the peak in June to September. The dry season extends from December to March. The mean annual rainfall is 1337.55mm, mean annual temperature is 33°C and mean annual relative humidity is 70%.

The vegetation of the area is dominated by tall grasses, trees and shrubs. Farming activities in the area is predominantly on subsistence bases in which farmers cultivate yam, cassava, rice, sesame, beniseed, cowpea, maize and vegetables.

2.2 Field work
The soil units within the area were identified using the rigid grid method following the guidelines of Soil Survey Staff [13]. The soil units were identified and delineated with texture and colour. Three soil units were identified and labeled YA, YB and YC. Soil profiles were dug in areas where soil units are identified. The profiles were described and soil samples collected for laboratory analysis. The effective soil depth, drainage and slope were measured directly at the field following the method of FAO [14].

2.3 Laboratory analysis

The electrical conductivity EC was determined using (1:2.5 ratio of soil : water) suspension. The texture of the soil was determined by the hydrometer method [15]. $CaCo_3$, pH, organic carbon (%), total nitrogen (%) available P (ppm) exchangeable bases (Cmol/kg) exchangeable acidity (Cmol/kg) were determined following the International Institute for Tropical Agriculture guidelines [16]. The effective cation exchange capacity, base saturation and exchange sodium percentage were calculated.

2.4 Irrigation suitability procedure

To evaluate the land suitability for irrigation, the parametric evaluation system of Sys [17, 18] were applied using soil and land characteristics

These characteristic include environmental factors, drainage properties, soil physical and chemical properties. They were rated and used to calculate the capability index for irrigation Ci according to the formula:

$$Ci = A \times \frac{B}{100} \times \frac{C}{100} \times \frac{D}{100} \times \frac{E}{100} \times \frac{F}{100}$$

Where Ci = suitability index for irrigation
A= Rating of soil texture   B=Rating of soil depth   C= Rating of $CaCo_3$ status
D = Electrical Conductivity   E = Drainage rating
       F = Slope rating

Table 1 : Suitability Index for Irrigation Suitability Indices Ci classes

Capability Index	Class	Definition	Symbol
>80	I	Highly suitable	S_1
60-80	II	Moderately suitable	S_2
45-60	III	Marginally suitable	S_3
30-45	IV	Currently not suitable	N_1
<30	V	Permanently not	N_2

Source: Sys [17]

Table 2: Rating of soil depth for irrigation

Soil depth [cm]	Rating for surface Irrigation	Rating for sprinkler Irrigation	Rating for drip Irrigation
< 20	25	30	35
20-50	60	65	70
50-80	80	85	90
80-100	90	95	100
>100	100	100	100

Table 3: Rating of CaCO3 for irrigation

CaCO3 [%]	Rating for surface Irrigation	Rating for sprinkler Irrigation	Rating for drip Irrigation
< 0.3	90	90	90
0.3-10	95	95	95
10-25	100	100	95
25-50	90	90	80
>50	80	80	70

Table 4: Rating of salinity for irrigation

EC [ds m–1]	Rating for surface Irrigation		Rating for sprinkler Irrigation		Rating for drip Irrigation	
	C, SiC, SiCL, S, SC Textures	Other Textures	C, SiC, SiCL, S, SC textures	Other Textures	C, SiC, SiCL, S, SC textures	Other Textures
< 4	100	100	100	100	100	100
4-8	90	95	95	95	95	95
8-16	80	50	85	50	85	50
16-30	70	30	75	35	75	35
>30	60	20	65	20	65	25

C – clay; SiC – silty clay; SiCL – silty clay loam; S – sand; SC – sandy clay

Table 5: Rating of drainage classes for irrigation

Drainage Classes	Rating for surface Irrigation		Rating for sprinkler Irrigation		Rating for drip Irrigation	
	C, SiC, SiCL, S, SC Textures	Other Textures	C, SiC, SiCL, S, SC Textures	Other Textures	C, SiC, SiCL, S, SC textures	Other Textures
Well Drained	100	100	100	100	100	100
Moderately Drained	80	90	90	95	100	100
Imperfectly Drained	70	80	75	85	80	90
Poorly Drained	60	65	65	70	70	80
Very Poorly Drained	40	65	45	65	50	65
Drainage Status Not Known	70	80	70	80	70	80

C – clay; SiC – silty clay; SiCL – silty clay loam; S – sand; SC – sandy clay

Table 6: Rating of slope for irrigation

Slope classes [%]	Rating for surface Irrigation		Rating for sprinkler Irrigation		Rating for drip Irrigation	
	non-terraced	Terraced	non-terraced	terraced	non-terraced	terraced
0-1	100	100	100	100	100	100
1-3	95	95	100	100	100	100
3-5	90	95	95	100	100	100
5-8	80	90	85	95	90	100
8-16	70	80	75	85	80	90
16-30	50	65	55	70	60	75
>30	30	45	35	50	40	55

Table 7: Rating of Textural Classes for Irrigation

Tex	Rating for Surface Irrigation					Rating for Sprinkler Irrigation					Rating for Drip Irrigation				
	Fine gravel (%)			Coarse gravel (%)		Fine gravel (%)			Coarse gravel (%)		Fine gravel (%)			Coarse gravel (%)	
	< 15	15-40	40-75	15-40	40-75	< 15	15-40	40-75	15-40	40-75	< 15	15-40	40-75	15-40	40-75
CL	100	90	80	80	50	100	90	80	80	50	100	90	80	80	50
SiL	100	90	80	80	50	100	90	80	80	50	100	90	80	80	50
SCL	95	85	75	75	45	95	85	75	75	45	95	85	75	75	45
L	90	80	70	70	45	90	80	70	70	45	90	80	70	70	45
SiL	90	80	70	70	45	90	80	70	70	45	90	80	70	70	45
Si	90	80	70	70	45	90	80	70	70	45	90	80	70	70	45
SiC	85	95	80	80	40	85	95	80	80	40	85	95	80	80	40
C	85	95	80	80	40	85	95	80	80	40	85	95	80	80	40
SC	80	90	75	75	35	95	90	80	75	35	95	90	85	80	35
SL	75	65	60	60	35	90	75	70	70	35	95	85	80	75	35
LS	55	50	45	45	25	70	65	50	55	30	85	75	55	60	35
S	30	25	25	25	25	50	45	40	30	30	70	65	50	35	35

III. RESULTS AND DISCUSION

3.1 Physico-chemical properties of the soils

The laboratory analysis results of the soils surface (0-40cm depth) of the three soil units identified are presented in Table 8.

The soils were moderately sandy to highly sandy with percentage sand range of 49-75%. Soil unit YA is sandy clay loam, YB is Loam and YC is sandy loam textured. The sandy loam and loamy sand texture indicates that there has been some degree of removal of fine soil particles by surface runoff and it implies that there is potential for the soil to be eroded and leached of nutrients if left open for a long period of time. It also indicates the well to moderately drained condition of the soils. The effective soil depth was 56cm as a result of hard pan at soil unit YA while it was 63cm and 102cm at units YC and YD as result of water table. The high water table at the dry period of the year (Januray) indicates that the soils units have high potential for irrigation agricultural production.

The pH of the soils ranged from 5.42 to 6.10. The pH values are rated [19] strongly acidic to slightly acidic, deficiency of nutrient in the soil units is not likely and response to fertilizer/soil amendment will be high.

The organic matter content ranged from 2.50 to 4.90%. These values are considered to be moderate and adequate for crop production. Organic matter is very important to soil fertility and nutrient availability.

The total Nitrogen values range of 3.30 to 6.01g/kg are high. The values are above the range of 2 g/kg of soil recommended by Federal Ministry of Agriculture for an ideal Nigerian soil [20]. It followed that same trend with organic matter; the use of leguminous crops in the cropping will help to maintain nitrogen level of the soils.

The available phosphorus values 22.19 to 35.44 ppm are high and above the critical levels. The values are optimum for crop production.

The calcium (Ca) is the most abundant among the cations (bases), the values recorded (2.31-3.53cmol/kg) are low. Magnesium (Mg) content (1.07-1.8cmol/kg) is moderate, potassium (K) (0.71-1.10cmol/kg) is high and sodium (Na) (0.39-0.67cmol/kg) is moderate [21]. There are no serious intensive crop production activities in the farm soil and most of the land area is under cover, therefore there has not been serious depletion of nutrients. There will be need for improved fertility management scheme to prevent the decline of these nutrients because they are easily depleted under intensive cultivation, improve their levels in the soils and availability to cultivated crops.

Table 8: Physico-chemical properties of the soil units

Soil properties	Soil units		
	YA	YB	YC
pH(H2O)	6.10	5.60	5.42
OM	%	2.50	3.60	4.90
TN	g/kg	3.30	4.18	6.01
AP	Ppm	22.19	35.44	28.60
Ca^{2+}	Cmol/kg	3.53	2.31	2.70
Mg^{2+}	Cmol/kg	1.07	1.18	1.13
K^+	Cmol/kg	1.09	0.72	1.10
Na^+	Cmol/kg	0.56	0.58	0.53
EA	Cmol/kg	0.39	0.59	0.67
ECEC	Cmol/kg	6.64	5.38	6.13
BS	%	94.13	89.03	89.07
$CaCO_3$	%	4.64	3.06	3.45
AWH	%	29.10	41.32	38.45
EC	mmh/cm^{-1}	0.79	0.92	0.82
Sand		63	49	75
Silt	%	16	31	06
Clay	%	21	20	19
Texture		SCL	L	SL
Drainage		Moderately drained	Moderately drained	Well drained
Slope	%	3.1	4.7	2.72
Other observations		Fe-mn concretion, effective depth 56cm	Water table at 63cm	Water table at 102cm

OM=organic matter, TN=total nitrogen, AP=available phosphorus, Ca=calcium, Mg=magnesium, K=potassium, Na=sodium, EA=exchangeable acidity, BS=percentage base saturation, SL=sandy loam, SCL=sandy clay loam, L=Loam

The effective cation exchange capacities are moderate. The values ranged from 5.38 to 6.64 cmol/kg of soil at the surface. This value is low but typical of most Nigeria soils [22]. This indicates that the soils have low plant nutrient reserves therefore soil management efforts should be geared towards improving nutrient reserves of the soil.

The percentage base saturation value is high. The values are higher than 70% and it indicates that the soils high cation concentration in the exchange complex and implies that there is no threat of soil acidity to crop production in the area.

Soil unit YA has iron and manganese concretions, this could harden irreversibly if the soil is exposed for a long time to form hardpan and rendered the soil uncultivable.

3.2 Irrigation suitability evaluation

The three soil units of the study area were evaluated for surface, sprinkler and drip irrigation systems. The suitability index values and class ratings are presented in table 9.

In the evaluation of soils for surface irrigation, soil unit YA and YC are have suitability index values (Ci) of 46.17 and

48.74 respectively and they are rated into suitability class S3- marginally suitable. Soil unit YC has Ci of 38.30 and was rated currently not suitable, this implies that the soils require some management measures to make it suitable for surface irrigation.

The evaluation for sprinkler irrigation showed an improvement in ratings of soil unit YB and YC than the surface irrigation. Soil unit YB and YC are rated S3- marginally suitable and S2- moderately suitable with ci values of 45.64 and 63.18 respectively.

In the evaluation for drip irrigation system, soil units YA and YC are rated S2- moderately suitable with ci of 64.13 and 76.00 respectively. YB is S3- marginally suitable with ci of 53.87 respectively.

All the soil units are placed in classes lower than S1- highly suitable as a result of texture, soil depth and slope ratings. These properties conditioned the soils to be rated below S1.

Texture is an important soil property to irrigation in that, it determines to a large extent permeability, infiltration and water holding capacity of soils [11]. The soils of the study area are coarse textured therefore water and nutrient losses will be high.

Soil depth influences irrigation management decisions. It determines rooting depth and available soil water which in turns determine the frequency of irrigation. Soil depth was critical at YA and YB.

Slope relates to runoff, soil drainage, erosion, use of machinery and choice of crops. The slope percentages recorded in all the soil units are not ideal for surface irrigation system. This reflected in the lower suitability class rating of soil units for surface irrigation.

Table 9: Suitability index values (Ci) and suitability classes of the irrigation methods

Mapping unit	Surface irrigation		Sprinkler irrigation		Drip irrigation	
	Ci	Suitability classes	Ci	Suitability classes	Ci	Suitability classes
YA	46.17	S3	54.66	S3	64.13	S2
YB	38.30	N1	45.64	S3	53.87	S3
YC	48.74	S3	63.18	S2	76.00	S2

S2- Moderately suitable   S3- Marginally suitable   N1- Currently not suitable

IV. CONCLUSION AND RECOMMENDATION

The soils of the study area are marginal in terms of fertility and require soil management measures to maintain and raise the fertility status of the soil units. Soil units YA and YC are the most suitable for irrigation. Sprinkler irrigation system is most suitable for soil unit YC and drip irrigation system is the suitable for soil unit YA and YC.

Post-harvest residue management, land tillage across slope and construction of contour bunds, incorporation of organic manure, maintenance of vegetative cover and cultivation of cover crops are therefore recommended.

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