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IRRIGATION SUITABILITY RATINGS AND OKRA PRODUCTIVITY OF SOME MID-BENUE TROUGH SOILS: A COMPARATIVE ANALYSIS

[1]Abagyeh, S. O. I., [2]Ibo, P. I. and [1]Idoga, S.
[1]Department of Soil Science, University of Agriculture Makurdi, Makurdi, Benue State
[2]Benue Agricultural and Rural Development Authority, Makurdi, Benue State
Corresponding Author's e-mail: abacks1959@gmail.com

ABSTRACT
A detailed soil survey using grid method was conducted to characterize and rate irrigation suitability of soils and relate it with okra productivity under surface irrigation. Two soil profiles were dug at each site and morphologically described. Soils sampled from identified profile horizons were analyzed. Parametric evaluation method using the soil characteristics was employed. A 4×4×4 factorial experiment was laid out in RCBD with 4 okra varieties. There were 4 irrigation frequencies and 4 locations as treatments, replicated three times. Data collected were subjected to ANOVA using GENSTAT 5 Release 4.24 with means, separated by Fishers Least Significant Difference. Mean fruit yields were used for comparative analysis. Water from adjoining rivers were sampled and analyzed. Soils ranged from shallow (50 cm) to very deep (200 cm), textures from sandy loam to clay loam surfaces with weak fine crumb to weak fine to medium crumb (DFP), granular (KRD, MRB) and coarse subangular blocky (TRF) subsurfaces. Water infiltration ranged from 0.45 to 2.40 $cmhr^{-1}$, hydraulic conductivity (1.06 to 23.34 x10-4 $cmsec^{-1}$) pH (5.51-6.15), EC (0.12-0.18 dsm^{-1}), Organic carbon (0.20-1.46 %) decreased with depth. Total nitrogen followed trends in organic carbon with available phosphorus ranging from 5.00 to 9.40 $mgkg^{-1}$, CEC (5.31-7.76 $cmolkg^{-1}$) and $CaCO_3$ (0 - 5 %) and were generally very low to medium. Okra varieties productivity index (Pi) did not agree with the soil irrigation suitability ratings of KRD soils. The moderately suitable (S2) class for Makurdi and Logo varieties conformed to the irrigation suitability rating of DFP soils. The highly suitable (S1) rating for $NH_4$7-4, Makurdi and Logo was in conformity with the highly suitable class of the MRB soils. The Pi (57.07 and 47.65) for Makurdi and Yandev Serial also conformed to the Si of TRF soils. Location and variety highly influenced okra fruit yields but irrigation frequency had no drastic effect on fruit yield of okra. All irrigation water parameters examined conformed to the irrigation water standard. The soils characteristics ranged from very low to low. Both the soils and water were suitable for surface (gravity) irrigation. Parametric evaluation method was therefore, effective in the study area.

Key Words: Parametric Evaluation, Irrigation Suitability Ratings (potentials), irrigation frequency, Okra and Productivity.

INTRODUCTION
The suitability of a given piece of land is its natural ability to support a specific purpose. This is strongly related to land qualities such as erosion resistance, water availability, and flood hazard that are not measurable (FAO, 1976). These qualities derived from land characteristics, such as slope angle and length, rainfall and soil texture that are measurable or estimable, and it is advantageous to use these later values to study land suitability. Different lands

however, respond differently to irrigation types while chemical, physical and biological properties may change significantly during a year particularly as demand increases on a groundwell and water table is lowered. Therefore, there is need to adapt the most suitable irrigation type for each soil for optimal productivity.

IAO (2014), evaluated land suitability for irrigation employing parametric evaluation system, using the soil characteristics (environmental factors, drainage properties, soil physical and chemical properties) of *Thiès Cuestain* Senegal. Irrigation farming pays far higher than its rain fed counterpart in terms of yield per hectare per year, thus enabling farmers to derive maximum benefits for their labour (Idoga and Egbe, 2012). Irrigation can be adopted as a solution to agricultural drought. It can be used only during the dry season or in a complementary mode during the rainy season when water stress occurs. However, irrigation, be it short or long term, is capital intensive in nature, and requires very high value crop with high payment capacity, nutritive value and popularity with wide marketability.

Okra (*Abelmoschus esculentus* L. Moench), one of the fruit vegetables grown in the Mid-Benue Valley is found in every market all over Africa (Schippers, 2000). West and Central Africa sub region account for more than 75 percent of okra produced in Africa with Nigeria as the largest producer (1.039 million tonnes) followed by Cote d'Ivoire, Ghana and other parts of the world. Okra contains carbohydrates, proteins and vitamins C in large quantities while its essential and non-essential amino acids are only comparable to those of soybeans (Adeboye and Oputa, 1996).

To ensure all year round crop production where temperature is not limiting, the alternative source of water is irrigation. The Benue River with its tributaries has sufficient water for total irrigation during the dry season and supplemental irrigation during dry spell. Unfortunately, only scanty irrigation activities by peasant farmers are conducted on the banks of the river during the lengthy dry season. The quality of irrigation water including underground water may be more significant to land suitability than soil quality, water issues are nevertheless frequently overlooked by most growers (James, 2010).

This research was therefore aimed to identify soils and water with high irrigation suitability potentials and to test actual soil performances using okra productivity index at different locations within the Mid- Benue Valley.

MATERIALS AND METHODS

The Study Area: The area comprised the Northbank of River K/Ala at Dogo (KRD=L1), Dura Flood plain (DFP= L2), Mu River Basin (MRB=L3) and the Teaching and Research Farm, University of Agriculture Makurdi (TRF=L4). The two sites lie between Latitude 7^0 23' and 07^0 44'N and Longitude 008^0 9'E and 009^0 12'E in the Nigerian Southern Guinea Savanna, a sub humid region. The region is globally characterized by declining agricultural productivity occasioned by weather based abnormalities owing to climate change which often culminate in decline rainfall (with subsequent prolonged dry season) besides other factors (Sidhu and Vatta, 2007).

Experiment 1

A detailed soil survey employing conventional grid method was conducted at the 4 locations covering an estimated area of 200 x 300 m in each of the four locations. The total area for the four locations was 240,000 m^2. The aim was to determine the irrigation suitability (potentials) of the soils using soil characteristics. Land and soil morphological parameters were carefully noted in the field. The sieved soil samples were subjected to laboratory analysis using the Manual of Selected Methods of Plants and Soil Analysis (IITA, 1979).

The parametric evaluation system of Sys *et al.* (1991) was applied, using the soil characteristics (Table1) to evaluate irrigation suitability of soils. These characteristics concern environmental factors, drainage properties as well as soil physical and chemical properties in Table 2. The land characteristics were rated and used to calculate the suitability (capability) index for irrigation

(Si = Ci) in Table 4 according to the formula:

$$CI = A\,X\,\frac{B}{100}\,X\,\frac{C}{100}\,X\,\frac{D}{100}\,X\,\frac{E}{100}\,X\,\frac{F}{100}$$

Where Ci = Capability index for irrigation. A = soil texture rating; B = soil depth rating; C = $CaCO_3$ status; D = electro-conductivity rating; E = drainage rating; F = slope rating.

Suitability classes were defined considering the value of the capability index in Table 3.The soil characteristics were then used according to different ratings specifying gravity (surface) irrigation.

Experiment 2

Experimental site: Field experiments were conducted between February and April of 2011 and in 2012 dry seasons in the four sites (KRD, DFP, MRB and TRF).

Experimental layout/design: A total land area of 200 m x 300 m (60,000 m^2) was marked out for the experiment in each of the site, KRD, DFP, MRB and TRF prior to this experiment based on the heterogeneity of the soils. At each site, a 4 × 4 × 4 factorial experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Treatments comprised 4 varieties of okra: NH47-4 (V1), Makurdi (V2), Logo (V3) and Yandev Serial (V4); 4 irrigation frequencies at 3 (F1), 5 (F2), 7 (F3) and 10day (F4) through flooding method.

Cultivation practices: Three plots spaced at 5 m were cleared and hoe was used to prepare each manually into 2 m x 2m beds. Planting was done on the 5th and 8th of February in 2011 and on the 9th and 12th of February in 2012. Three to four seeds were planted at 45cm inter-row and 50 cm intra-row spacing and thinned to two per stand at two weeks after planting, making 20 stands per bed (100,000 plants per hectare). The plots were saturated with water four days before planting to aid seed germination and plant establishment. NPK 15:15:15 was band applied at 20 g per stand (50 kgha^{-1}) at two weeks after first weeding. Second weeding proceeded at week 4 in KRD, DFP and MRB and week 5 in TRF. Aphids attacks were controlled by spraying Delthrin 10EC (1mgl^{-1})

Data Collection: The height of plant was taken weekly, plant canopy at week 5, 7 and week 9 using a metre ruler; the length and gird (circumference) of pod were measured with a thread loop and aliened along a ruler while fresh fruit yield per bed was taken at harvest using a weighing balance in gram and converted to tonnes per hectare. Two plant stands were uprooted in each bed and their fresh weights taken using a weighing balance. The plants were then dried to constant weights. The sum of each weight was divided by two to give the weight per plant. The beds were then irrigated at a flat rate of 0.20 m^3 (5 cm depth) per an irrigation to ensure uniform treatment for the different irrigation intervals and soil units as okra varieties' response to water stress varies. Final mean was calculated by summing up the means of similar treatments per frequency per variety and per location, then dividing it by the number of replications.

Analysis: The two year combined data (homogenized data) were subjected to analysis of variance using GENSTAT 5 Release 4.24 DE (GENSTAT, 2012) software and mean separated through Fishers Least Significant Difference.

Average fruit yields were given by adding mean okra fruit yields of irrigation frequencies from Location x Frequency x Variety Interactions and dividing by 4 (Table 5)

Soil productivity was given by dividing okra fruit yield of variety over expected optimal fruit yield of variety to get okra productivity index (Pi); then by multiplying the Pi by 100 to get percentage okra productivity:

Water sampling and analysis: In each of the chosen sites, one litre clean plastic water bottle was immersed inside the irrigation water supply source. The bottles were then properly labeled and immediately sent to the laboratory

$$\text{Okra productivity index (Pi)} = \frac{\text{Fruit yield of Variety}}{\text{Expected optimum Fruit Yiel of Variety}} \text{ - - - - - - - - i}$$

$$\text{Actual Soil Productivity} = \text{Percentage Okra Productivity} = \text{Pi X 100- - - - - - - - - - - ii}$$

for analysis. The temperature of irrigation water was obtained from mercury thermometer. Water pH was measured using a pH meter. Electrical conductivity of water was measured by the use of electrical conductivity metre. Stero-specific meters were used in the determination of Total dissolved solute (TDS) and total suspended solid (TSS) both in milligram per litre (mgl^{-1}). Trace elements were spectro-photometrically determined with DR-20 spectro-photometer.

RESULTS AND DISCUSSION

Soil Properties: The results of terrain and soil/water characteristics as contained in Table 1 showed that soils effective depths ranged from shallow (50cm) in TRFI, deep (95-110 cm) in TRF11 and FD to very deep (200 cm) in KRD and MRB pedons. Textures of lowland pedons; TRF11, DFP and MRB, were generally clay loam to clay whereas the upland pedons,TRF1 and KRD had sandy loam textures and exhibited higher sand contents than the lowlands pedons in all horizons. Structurally, soil development in the upper horizons (epipedons) of all pedons, were weak fine crumb with weak fine to medium, granular to coarse subangular blocky subsurfaces. The soils showed varying degrees of profile developments in the pedons from A-C to A-B-C. The depth to C horizon in upland TRF pedon was less compared to the KRD, DFP and MRB pedons. This agrees with Sawhney *et al.* (2000),'Soil physiographic relationship in southeastern sector of submontane tract of Punjab' and Singh and Mishra (1996) who attributed profile development between uplands and lowlands of 'Some typic soils of Gandak command area of Bihar, India' to the removal of soil particles from upper slope and their deposition in the lower slope. The lowlands, (DFP/MRB) had soil water infiltration from 0.45 to 0.70 $cmhr^{-1}$ with hydraulic conductivity from 1.06 $x10^{-4}$ to 7.26 $x10^{-4} cmsec^{-1}$, whereas the upland soils water infiltration ranged from 2.25 to 2.40 $cmhr^{-1}$ with hydraulic conductivity from 2.22 to 27.58 x $10^{-4} cmsec^{-1}$. This may be due to the dominance of the macropores in the sandstone derived soil which allows easier entry and percolation of water and air compared to the dominant micropores of the fine clayed alluvium derived soils that allows slow water/air entry and drainage (Salako, 1986). Generally, these physical parameters were lower in the lowland soils with slow to moderate permeability classes compared to the upland soils.

The soils had relatively higher pH values in the upper most horizons (5.45- 6.15) compared to lower horizons (5.48- 5.76). This may be attributed to nutrient cycling, primarily through root absorption of bases from lower horizons and their return to the surface through litter fall (Ezenwa and Barrera, 1985). All the soils recorded low values in their electrical conductivity (0.12-0.18 dSm^{-1}). The lowlands however had higher values (0.13-0.18 dSm^{-1}) compared to uplands (0.12- 0.14 dSm^{-1}). Most crops thrive well within this pH range and with the non saline nature of the soils; irrigation equipment may be very safe. The organic carbon content of the soil was higher in the surfaces (0.58-1.46 %) than in the subsurfaces (0.04-0.39 %) in all pedons and decreased with depth. Total nitrogen followed organic carbon trends. Ezenwa and Barrera (1985) attributed low organic carbon contents of Southern Guinea Savanna soils to occasional destruction of the leaf by wildfire. The soils were very low (5.00 $mgkg^{-1}$) to medium (9.40 $mgkg^{-1}$) in phosphorus content and decreased with depths in all soils. Mohan (2008), reported that the low values of phosphorus were due to low cation exchange capacity, clay content and soil reaction of less than 6.5. The soils were also low in CEC (3.37-10.21$cmolkg^{-1}$) with higher values in the lowland than the upland soil that may be attributed to the higher clay and organic matter contents of the lowland soils. Whereas $CaCO_3$ of lowlands soils ranged from 0–2 %, that of uplands ranged from 2-5 % in levels. The organic carbon, nitrogen and phosphorus levels could be improved with the incorporation of organic manures and mineral fertilizers and therefore not seriously limit crop production through irrigation.

Irrigation suitability evaluation of soils: The results as presented in table 3 showed that for the purpose of surface or gravity irrigation, the soil mapping unit KRD1 was classified as highly suitable (S1) as the soil had no limitation(s) to substantially reduce its productivity. The soil covered 12.5 percent, indicating that only 1.5 hectares of the landmass under study was highly suitable for the purpose. KRD11 soils had well drained status due to the pedon's textures of sandy loam from sandstones parent material as the major impediment for surface irrigation.

A good proportion, about 12 hectares (50 percent) of the landmass including DFP1, DFP11, MRB1 and MRB11 were highly suitable (S1) for the purpose of gravity or surface irrigation. Even the slow water infiltration rate of 0.45cm/hr at DFP as result of its imperfect drainage and 0.75cm/hr at MRB due to its moderate drainage could not substantially limit the soils suitability for surface irrigation. The sandy loam texture in the epipedon of TRF11 with sandy clay loam to clay subsurfaces have resulted in imperfect drainage, thus limited the soil's suitability for irrigation to marginally suitable subclass (S3). The land covers 12.5 percent, accounting for only 1.5 hectares of the research lands. Whereas, the shallow depth, relatively steep slope and well drained conditions have limited irrigation suitability of the TRF1 soil into the marginally suitable (S3dsw) subclass. This land covered 1.5 hectares, representing 12.5 percent of the surveyed lands.

Incorporation of organic matter into these soils will not only improve the soil textures but also adjust their structures.

Irrigation Suitability of Water: Although the quality and quantity of irrigation water are critical to the successful production of crops, these issues are frequently overlooked by most growers (James, 2010). Irrigation water had mean temperatures at 30 ^{0}C, implying that the temperatures were adequate for irrigated okra production. Improved and serial okra varieties performed better during the dry season irrigation with high temperatures (Jamala *et al*., 2011). According to James (2010) pH limit for irrigation water ranged from slightly acid (6.8) to moderately acid (5.2) while pH of 6.0 to 7.0 is considered most desirable for irrigation water (Bander *et al*., 2014). Result of water analysis (Table 4) showed that irrigation water were slightly (pH 6.5) to moderately (pH 5.5) acid; salinity between 0.01 to 05 dSm^{-1}. The low salinity and ECW of water may be due to the low concentrations of total dissolved salt content in the water (Rowe and Abdel-Magid, 1995).

Alkalinity and bicarbonate are of most significant concerns in irrigation among the water parameters. The most common cations of interest in water are calcium (Ca^{2+}), magnesium (Mg^{2+}) and sodium (Na^{+}). Low concentrations of Ca^{2+} (1.23-1.75), Mg^{2+} (0.41-56) and Na^{+} with 0.40 mgl^{-1} in MRB as the highest concentration were recorded in irrigation waters. The concentration of specifically Na^{+} falls within the less than 3.0 mgl^{-1} safe limit for irrigation water (James, 2010) with SAR value within 0.30 to 0.42; SAR of less than 4 is the excellent class for irrigation water (Ayers and Westcot, 1987) and therefore very safe for irrigation. Ca and Mg combined concentration in water is referred to as water hardness and can be used as indicator of alkalinity. Hard water, with a high concentration of Ca and Mg should be checked for high alkalinity. Hardness in water is a potential problem since the Ca and Mg can combine with HCO_3 to form insoluble calcium and magnesium carbonate salts. These salts can impact media pH and reduce the amount of sodium available to a plant

The most common anions are bicarbonate (HCO_3^-), chloride (Cl^-) and sulphate (SO_4-). Bicarbonate (HCO_3^-) concentrations ranged from 1.50 at to 2.75mgl^{-1}. These concentrations were however, less than 5mgl^{-1} (short term) and 10 mgl^{-1} (long term), the upper limits for irrigation water (Rowe and Abdel-Magid, 1995).The bicarbonate ion in soil solution cannot therefore harm the mineral nutrition of the plant through its effects on the uptake and metabolism (James, 2010). Hence, the rivers are highly suitable for irrigation. Calcite buildup due to excessive HCO_3^- concentration can reduce flow rate through orifices or emitters. This can, however, be corrected by injecting acidic materials into the system.

However, where salt problem occurs, drainage, leaching, and changes to more salt tolerant crops are used to avoid long-term salinity buildup but other cultural practices (more frequent irrigation, land grading, and methods of seedling and timing of fertilization) may be needed to deal with possible short-term or temporary increases in salinity which may be equally detrimental to crop yield.

After sodium, chlorine and boron are of most concern. According to Mass (1984), chlorine is essential to crops in very low amounts but it is the most common form of toxicity in irrigation water because it is not adsorbed or held back by soils as it moves with the soil-water. Chlorine values in irrigation water ranged from 0.85 to 1.25 mgl^{-1}, thus, conforming to the optimal concentration of 9.50 for short and 5.0 mgl^{-1} for long term irrigations (Rowe and Abdel-Magid, 1995) and therefore, very safe for irrigation purposes. Low values of Cl_2^- in these waters may be due to their association with basalt rocks that occurred along side with the rivers. Boron (B) concentrations in the irrigation waters fall within the range of 0.30 to 0.45 mgl^{-1} against the (Rowe and Abdel-Magid, 1995). Standard values of 0.75mgl^{-1} for long term and 2.00mgl^{-1} for short term irrigation uses. B concentration of more than 2.00 mgl^{-1} affect plant metabolism. As a rule of thumb, irrigation water supplies do not need to be checked for trace elements unless there is some reason to suspect toxicity

Total suspended solids were relatively low and ranged from 8.00 to 13.00 mgl^{-1}. However, very high concentrations of suspended organic as well as inorganic sediments cause problem in irrigation systems through clogging of gates, sprinklers heads and drippers. They can cause damage to pumps if screens are not used to exclude them. More commonly, sediments tend to fill canals and ditches and cause costly dredging and maintenance problems. Sediments also tend to reduce further the infiltration rate of soils.

Response of Okra varieties to water stress and location: Interaction between location x irrigation frequency x variety (Table 5) showed that irrigation frequencies had no drastic effect on all the okra varieties however, highly significant differences were recorded across locations. For the $NH_4$7-4 okra variety, the 3day irrigation frequency yielded significantly higher fruit yields of 4.21, 8.53 and 9.16 t/ha at KRD, DFP and MRB respectively while the 7day irrigation interval fruit yield of 7.40 t/ha stand out at TRF. Thus, indicating that $NH_4$7-4 performs better under low water stress except where root penetration was interrupted by plinthite at shallow depth as in TRF. These conditions result to stunted crop growth and subsequent poor yield (Litz, 1997).On the other hand, Makurdi variety and Yandev serial followed similar trend as irrigation interval at 7day gave significantly higher fruit yields of 2.82, 3.95 5.85 and 3.38 t/ha and 3.40, 8.41, 6.40 and 3.95 t/ha at KRD, DFP, MRB and TRF.

On average, V1 produced the highest fruit yield of 8.40 t/ha at MRB and the lowest fruit yield of 3.71 t/ha at KRD. This was followed by V4 with the highest yield of 8.08 t/ha at DFP and lowest yield of 3.36 t/ha at KRD. The superior performances of these cultivars may be due to the cultivars genotype as well as the more favorable conditions of their soils (clay loam soils which had low soil water infiltration (0.45-0.75$cmhr^{-1}$) but high water retention (27.46-27.93 %) status. These were followed by the fruit yield of 5.37 t/ha at Mu by V3 in the third position with its lowest yield of 2.81 t/ha at KRD. The overall lowest fruit yield was recorded by V2 with its highest yield of 5.59 t/ha at Mu with the lowest fruit yield (2.69 t/ha) at KRD. The last two okra varieties are low yielding cultivars planted on sandy loam soils with high soil water infiltration (2.25-2.40 $cmhr^{-1}$) but low water retention (19.41-19.66). Therefore, the performances of these species may be a function of their genotypes. The fruit yields of these varieties is in conformity with the findings of ADC (2010), that ‘okra fruit yield varies depending on varieties and a grower is expected to harvest between 5 to 8 tonnes per hectare of fiber free okra fruits on the average with 40 by 50 cm spacing’.

Comparative Analysis of Potentials and Actual Soil (Okra) Productivity: Comparative analysis of actual soil productivity based on the percentage fruit yield of okra varieties with soil irrigation suitability (potentials) as presented in Table 6 showed that on average, okra yield vary from 2.69 to 5.59 t/ha in Makurdi and Logo (low yielding cultivars) and 3.36 to 8.39 t/ha in $NH_4$7-4 and Yandev Serial (high yielding cultivars) with a 45 by 50 cm spacing at tender and fiber free stage. This is in conformity with the report of ADC (2010), that 'okra fruit yield varies from 3 to 8 t/ha depending on varieties. A grower is expected to harvest between 5 to 8 t/h on average of fiber free fruits with 40 by 50 cm spacing'. To ensure uniformity in all treatments, a flat water rate of 0.2m^3 was supplied at irrigation. However, as shown earlier, irrigation frequency has no drastic effect on the yields of okra fruits (Table 5)

Dogo location (KRD) had productivity index (Pi) of 44.17 and 41.58, rated as currently not suitable (N1) for NH47-4 (V1) and Logo (V3) okra varieties; 48.12 and 52.33, rated as marginally suitable (S3) for Makurdi (V2) and Yandev Serial (V4) against the soil irrigation suitability index (Pi) of 85.50, rated as highly suitable (SI) for KRD1 and 64.13, moderately suitable (S2) for KRD11. The wide gaps between the Pi and Si among the KRD soils are indicators of high risk of irrigating such soils under surface irrigation and should be avoided. Dura location (DFP) had productivity index of 100 and 89.17 and was rated as highly suitable (S1) for NH47-4 and Yandev Serial while the 68.87 and 73.93 was rated as moderately suitable (S2) for Makurdi and Logo okra varieties. The highly suitable sub-class for NH47-4 and Yandev Serial is in agreement with the irrigation suitability of DFP. From Table 6, the actual productivity values for V1, V2 and V3 showed that the soils of location MRB1 and 11 were highly suitable (S1) for the okra varieties. The only exception is V4 (Yandev Serial) where Pi was 73.69 indicating moderate suitability as against the highly suitability potential of the soils. Even then, the close ranges between the actual and potential suitability of the Mu location. This positive correlation could be due to the soils favorable characteristics of texture, depth, slope and drainage.

The soils of TRF were however not as good for irrigation and also for okra production. The actual Pi was quite low indicating marginal suitability (S3) just like their irrigation suitability potentials (Si). The major limitations of the soils are their relatively steep slope, coarse texture, shallow depth and therefore high water infiltration but less ability to hold water. Nevertheless, okra had productivity index 80.48 rated as highly suitable (S1) for NH47-4; 66.48, rated as moderately suitable (S2) for Logo, therefore, these varieties may be the best options for the TRF soils under the surface irrigation

Varietal Land Distribution: In specific terms, 50 %, that is, 12 hectares of the total landmass under study was highly suitable to NH_47-4; 25 %, 6 hectares was moderately suitable and 25%, about 6 hectares land was currently not suitable under flood method of irrigation. Makurdi variety had 25% (6 hectares) of the landmass that was highly suitable and 25%, 6 hectares that was moderately suitable for surface irrigation while the remaining 50%, about 12 hectares of the study area was only marginally suitable for the variety of okra production.

For the Logo variety, 25%, that is 6 hectare of the landmass was highly irrigable; 50%, that is, 12 hectares was moderately suitable while the 25%, 6 hectare was marginally suitable for surface irrigation. Whereas, 50% (12 hectares) of the total land studied was highly suitable for the cultivation of Yandev Serial under surface irrigation; 25% (6 hectares) was moderately suitable and the rest (25%, that is 6 hectares) of the studied land not currently suitable for this purpose.

CONCLUSIONANDRECOMMENDATION

Conclusion: The study revealed that the soils under investigation are limited by both physical and chemical characteristics, location and vari-

Table 1: Terrain, Soil/Water Characteristics Used in Irrigation Suitability Assessment

Pedon	Unit	KRD		DFP		MRB		TRF	
Xtics	**No**	**1**	**11**	**1**	**11**	**1**	**11**	**1**	**11**
A.Texture	class	CL	SL	CL	CL	CL	CL	SL	SL
B.Soil Depth	cm	200	200	105	115	200	200	50	95
C.$CaCO_3$	%	0-2	0-2	2-5	2-5	2-5	2-5	0-2	2-5
D.EC	dSm^{-1}	0.14	0.13	0.17	0.19	0.21	0.18	0.12	0.16
E.Drainage	class	Wd	Wd	Id	Id	Md	Md	Wd	Id
F.Slope	%	2-4	2-4	0-2	0-2	0-2	0-2	2-4	0-3
SWI	$cmhr^{-1}$	2.25	2.25	0.45	0.45	0.75	0.75	2.40	1.50
Hydraulic Conductivity	$x\ 10^{-4}$ $cmsec^{-1}$	18.83		6.40		7.26		18.38	8.83
WHC	%	19.41		27.66		27.93		19.41	24.50
Structure	-	1fcr-1f-mg		1f-mcr-sgf-mg		1fcr-1f-mcr		1f-ccr-2f-csbk	1f-mcr-3fcsbk
pH	Water	5.71		5.55		5.63		5.76	5.54
Av. P	$mgkg^{-1}$	8.55		1.75		9.39		1.07	1.32
OC	%	0.46		1.46		1.22		013	0.45
*Temperature	^oC	30.00		30.10		30.20		30.20	
pH*	H_2O	6.50		6.50		6.00		5.50	
*Salinity	dms^{-1}	0.05		0.10		0.10		0.06	
*TSS	mgl^{-1}	9.00		13.00		12.00		8.0	
*Boron	mgl^{-1}	0.35		0.25		0.30		0.45	
*NO_3^-	mgl^{-1}	0.003		0.002		0.001		0.002	
*HCO_3^-	mgl^{-1}	1.50		2.50		2.75		1.80	
*CO_3^{2-}	Mgl^{-1}	1.60		2.71		3.50		2.03	
*Cl^-	mgl^{-1}	0.85		1.00		0.90		1.25	
*SAR	-	0.312		0.415		0.357		0.295	
*ESP	%	11.59		13.71		12.94		11.30	

Key: Sites = KRD1/11-Dogo, DFP1/11-Dura, MRB1/11-Mu, TRF/11-Teaching and Research.

Xtics– Soil Characteristics = SWI- Soil water infiltration, WHC – Water holding capacity; **Texture** = CL-Clay loam and SL-Sandy loam. **Drainage** = Id –imperfectly drained, Md-Moderately drained and Wd-Well drained. *** = Water parameters:** TSS-Total suspended solids

Table 2: Selected Physico-Chemical Properties of Representative Pedons in Mid-Benue Trough

← Pedons →		Particle size distribution			Texture	Structure	Ksat	pH		O.C	N	P	CEC	EC
Horizon	Depth	sand	Silt	Clay				H_2O	KCl					
TRF I	(cm)	← % →			Class		$(cmsec^{-1})$ x10^4			← % →		$mgkg^{-1}$	$cmolkg^{-1}$	dSm^{-1}
Ap	0-21	71.7	17.8	10.4	SL	1f-ccr	12.71	5.56	4.77	0.16	0.029	1.55	4.45	0.12
A	21-31	81.4	10.5	8.1	SL	2f-csbk	19.09	6.15	4.80	0.06	0.022	0.95	4.54	0.12
Bw	31-50	77.4	9.2	13.0	SL	3f-csbk	23.34	5.56	4.52	0.18	0.035	0.72	6.02	0.13
Mean		**76.9**	**12.5**	**10.5**	**SL**		**18.38**	**5.76**	**4.70**	**0.13**	**0.029**	**1.07**	**5.31**	**0.12**
TRF II														
Ap	0-20	65.9	19.1	15.0	SL	1f-mcrr	11.88	5.60	4.70	0.45	0.041	1.60	5.44	0.15
AB	20-29	61.9	17.9	20.2	SCL	2f-mcr	12.73	5.45	4.76	0.45	0.043	1.48	6.51	0.17
Bvt_1	29-39	54.7	15.6	29.7	SCL	2f-csbk	8.49	5.56	4.48	0.39	0.028	0.89	5.86	0.17
Bvt_2	39-95	42.4	14.0	43.6	C	3f-csbk	2.22	5.54	4.65	0.28	0.027	1.32	6.66	0.16
Mean		**56.2**	**16.7**	**27.1**	**SCL**		**8.83**	**5.54**	**4.65**	**0.39**	**0.034**	**1.32**	**6.12**	**0.17**
KRD														
Ap	0-22	40.4	31.4	28.2	CL	1fcr	3.18	5.82	4.69	0.74	0.135	28.14	6.53	0.14
AB	22–64	62.4	21.6	16.0	SL	1fcr	19.09	5.55	4.27	0.76	0.041	1.78	5.87	0.14
Bt	64-133	72.4	17.5	10.0	SL	1f-mg	19.09	5.72	4.06	0.09	0.033	1.39	4.64	0.15
C	133-200	71.1	17.8	9.1	SL	1f-mg	27.58	5.76	4.35	0.24	0.018	2.88	6.81	0.13
Mean		**71.2**	**22.1**	**12**	**SL**		**18.83**	**5.71**	**4.34**	**0.46**	**0.056**	**8.55**	**6.53**	**0.14**

DFP														
Ap	0-18	24.2	46.4	29.2	CL	1fcr	3.71	5.48	4.30	1.46	0.132	0.132	9.40	0.16
A_g	18-46	26.1	47.2	26.4	L	1fcr	4.19	5.54	4.20	0.58	0.049	0.049	7.97	0.21
C1	46-77	36.1	42.3	21.4	L	1f-cr	7.85	5.66	4.00	0.04	0.035	0.035	6.16	0.13
C2	77-105	46.2	38.0	15.3	L	1f-mcr	9.85	5.51	4.15	0.06	0.018	0.018	6.60	0.13
Mean		**33.2**	**43.5**	**23.1**	**L**		**6.40**	**5.55**	**4.13**	**0.54**	**0.059**	**0.059**	**7.53**	**0.16**
MRB														
Ap	0-27	34.2	37.4	28.2	CL	1fcr	1.06	5.69	4.20	1.22	0.191	31.92	12.13	0.17
AB_t	27-83	24.6	36.1	39.1	CL	1fcr	1.59	5.64	4.07	1.11	0.063	2.22	6.11	0.18
B_t	83-125	18.3	20.0	61.5	C	1f-mcr	1.07	5.48	4.10	0.82	0.051	4.15	7.05	0.15
BC_t	125-152	47.4	24.2	28.2	SCL	sg-fgr	2.12	5.64	4.16	0.32	0.031	5.97	5.99	0.17
2C1	152-174	62.2	22.3	15.2	SL	sgf-m	14.93	5.75	4.30	0.30	0.015	7.24	5.42	0.15
2C2	174-200	66.0	22.0	11.7	SL	sgf-m	23.34	5.56	4.41	0.20	0.022	4.85	8.70	0.16
Mean		**42.8**	**27.2**	**29.8**	**SCL**		**7.26**	**5.63**	**4.21**	**0.49**	**0.063**	**9.39**	**7.57**	**0.17**

Key: Apart from TRF pedons, there was close similarity between pedons of the same site (KRD I and II, DEP I and II and MRB I and II.

Table 3: Suitability Index for Irrigation Capability Indices (Ci)/Classes

Capability Index	Class	Defintion	Symbol
60-80	I	Highly suitable	S1
45-60	II	Moderately suitable	S2
30-45	III	Marginally suitable	S3
<30	IV	Currently not suitable	N1
	V	Permanently not suitable	N2

Key: **Pedons = KRD1/11, DFP1/11, MRB1/11 and TRF1/11; Xtics** –Terrain and Soil Characteristics

Table 4: Soil Irrigation Suitability Classes for irrigation capability indices for Surface or Gravity Irrigation.

Pedon	**Code**		**KRD**		**DFP**		**MRB**		**TRF**	
Characteristics	**Symbol**	**Unit**	**1**	**11**	**1**	**11**	**1**	**11**	**1**	**11**
A.Texture	t	Class	100	75	100	100	100	100	75	75
B.Soil Depth	e	cm	100	100	100	100	100	100	80	90
C.$CaCO_3$	c	%	90	90	100	100	100	100	90	90
D.EC	k	dSm^{-1}	100	100	100	100	100	100	100	100
E.Drainage	w	Class	100	100	100	100	100	100	100	80
F.Slope	S	%	95	95	100	100	100	100	95	95
Suitability/Capability Index	**Si/Ci**		85.5	64.1	76.0	76.0	56.5	56.5	54.0	46.2
Suitability Class	**SC**		S1	S2	S1	S1	S1	S1	S3	S3
limiting factors	**Limiting factors**			t					es	w

Key: **Pedons = KRD1/11, DFP1/11, MRB1/11 and TRF1/11; Xtics** –Terrain and Soil Characteristics.

ety had highly significantly influenced the yield of okra fruits while irrigation frequency had no drastic effect on the yield of okra fruits.

The study also revealed that parametric method of soil irrigation suitability evaluation with okra is effective in the study area.

Recommendation: It is therefore recommended that routine soil health monitoring with field trials using varieties of crops should be sustained to achieve ''National Food Security''.

Table 5: Averages of Mean Okra Fruit Yields from L x F x V Interactions in Study Sites

SITE	IF	V_1	V_2	V_3	V_4
	1	4.21	2.79	2.88	3.73
	2	3.62	2.61	3.04	3.06
KRD	3	3.62	2.82	2.74	3.40
	4	3.36	2.56	2.56	3.25
	AV.	**3.71**	**2.69**	**2.80**	**3.36**
	1	8.53	3.94	4.10	8.15
	2	7.08	3.55	3.95	7.96
DFP	3	7.42	3.95	3.90	8.41
	4	6.93	3.94	3.91	7.79
	AV.	**7.49**	**3.85**	**3.96**	**8.08**
	1	9.16	5.79	5.60	6.37
	2	8.97	5.38	5.56	6.29
MRB	3	8.27	5.85	5.04	6.40
	4	7.19	5.34	5.27	5.68
	AV.	**8.39**	**5.59**	**5.37**	**6.19**
	1	7.32	3.40	4.01	3.91
	2	6.35	3.04	3.16	3.90
TRF	3	7.40	3.38	3.70	3.95
	4	5.98	2.94	3.39	3.63
	AV.	**6.76**	**3.19**	**3.56**	**3.85**
LSD					**0.732**

Key: Site = KRD1/11-Dogo, DFP1/11-Dura, MRB1/11-Mu, TRF/11-Teaching and Research;

IF = Irrigation frequency; OV = Okra varieties; V_1- NH47-4, V_2- Makurdi, V_3- Logo and V_4- Yandev Serial

Table 6: Soil Irrigation Suitability (Potential) and Actual Soil Productivity for the Mid-Benue Trough Under Surface/Gravity Irrigation

Soil Irrigation Suitability (Potential)					Okra Productivity (Actual)				
Pedon	**Si**	**C**	**D**	**S**	**OV**	**FY**	**Pi x 100**	**D**	**S**
KRD1	85.50	1	Highly Suitable	S1	V_1	**3.71**	44.17	CNS	N1
					V_2	2.69	48.12	Marginally Suitable	S3
					V_3	2.81	52.33	Marginally Suitable	S3
KRD11	64.13	11	Moderately Suitable	S2	V_4	3.36	40.00	CNS	N1
DFP1	100.00	1	Highly Suitable	S1	V_1	7.49	88.93.	Highly Suitable	**S1**
					V_2	3.85	68.87	Moderately Suitable	S2
					V_3	3.97	73.93	Moderately Suitable	S2
DFP11	100.00	1	Highly Suitable	S1	V_4	8.08	96.19	Highly Suitable	**S1**
MRB1	100.00	1	Highly Suitable	S1	V_1	8.40	100	Highly Suitable	**S1**
					V_2	5.59	100	Highly Suitable	**S1**
					V_3	5.37	96.06	Highly Suitable	**S1**
MRB11	100.00	1	Highly Suitable	S1	V_4	6.19	73.69	Moderately Suitable	S2
TRF1	54.00	111	Marginally Suitable	S3	V_1	6.76	80.48	Moderately Suitable	S2
					V_2	3.19	57.07	Marginally Suitable	**S3**
					V_3	3.57	66.48	Moderately Suitable	S2
TRF11	46.17	111	Marginally Suitable	S3	V_4	3.85	45.83	Marginally Suitable	**S3**

Key:**Pedon** = KRD1/11, DFP1/11, MRB1/1, TRF/11;**Soil Irrigation Suitability (Potential)** = Si-Suitability Index, C-Class, D-Definition and S –Symbol; **Okra Productivity**(**Actual**) = OV- Okra varieties :V_1- NH47-4, V_2- Makurdi, V_3- Logo and V_4- Yandev Serial; FY- Fruit yield, Pi- Productivity Index and CNS-Currently not suitable

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