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Full Length Research Paper

Irrigation suitability evaluation and crop yield – An example with *Amaranthus cruentus* in Southwestern Nigeria

Fasina, A. S.*, Awe, G. O. and Aruleba, J. O.

Department of Crops, Soil and Environmental Sciences, Faculty of Agricultural Sciences, University of Ado – Ekiti, Ekiti State, Nigeria.

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A detailed soil survey of 1.03 hectares of land within University of Ado Ekiti Teaching and Research Farm was carried out to evaluate the suitability of the soils for irrigation agriculture and to examine the influence of three different soil types, water and fertilizer rates on the yield of *Amaranthus cruentus.* All the soils evaluated were considered not suitable for gravity irrigation but soil A was considered highly suitable, soils B and C were considered moderately suitable for drip irrigation respectively. The results showed that soil types greatly influenced *Amaranthus* yield significantly (P<0.05). Soil A gave the highest total biomass yield (4597.9 kg/ha), followed by soil C (3152.2 kg/ha) and soil B (3111.1 kg/ha). Fertilizer regime based on soil test gave the highest biomass yield of 4051.6 kg/ha followed by the control with 3636.7 kg/ha and lastly the blanket with 3173.9 kg/ha. The study showed that watering the crop daily gave the highest biomass yield of 3703.1 kg/ha followed by once in two days with 3632 kg/ha and twice daily with 3527 kg/ha. This study confirmed that fertilizer recommendations based on soil test is necessary for determining the adequate level of nutrients that could replenish the soil as well as satisfy the need of the crop. The study suggests the use of drip irrigation rather than gravity irrigation in terms of water use.

Key words: Drip irrigation, gravity irrigation, *Amaranthus*, suitability evaluation, yield.

INTRODUCTION

In most of West Africa countries, Nigeria inclusive agricultural practices in West Africa are rainfall dependent. Water scarcity, the need for energy savings as well as the optimization of crop yield both in quality and quantity require that irrigation practices and systems available to achieve high level of performance and efficiency. Farmers involve in large scale farming have to take daily decisions on how they can allocate and meet the demands for water by crops. About 60 – 95% part of the physiological active plant is water (Adefisan et al., 2007). There exists a strong relationship between plants, soil and atmosphere, the linkage factor is water. The relationship can be summarized as follows: The plants need water for transpiration and transportation of minerals, the soil stores the water needed by the plants and the atmosphere provides the energy needed by the plant to withdraw the water from the soil while plants lose most of the water through transpiration back to the atmosphere. The cyclic relationship must be kept intact and flowing during the growing season in order to avoid uninterrupted growth of the plants. Therefore, water must be made readily available in the soil for the plants (Xinyou et al., 2003).

The primary aim of irrigation is to complement the water available from natural sources such as rainfall, dew, flood and ground water that seeps into root zone. It is needed in most parts of West Africa where there may be a prolonged drought period and mostly where water from natural sources is inadequate for effective crop germination and production (Fasina, 2008).

Total irrigation potential of Nigeria is about 3.14 million/hectares: 1.10 million hectares for public irrigation projects and 2.04 million hectares for fadama irrigation projects. Only about 4% of the cultivated land area in Nigeria is under irrigation. Estimated irrigated cropland varies from one source to the other but its total water

*Corresponding author. E-mail: sundayfash2002@yahoo.com.

Table1. Suitability index for the irrigation suitability indices (CI) Classes.

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

Source: Sys 1985

managed area is estimated to be a little over 950,000 ha. These yield about 10% of the national crop yield (Maurya et al., 1990).

Considering how large hectares of wetlands are wrongly used for crop production regardless of their irrigation suitability for dry season vegetable and swamp rice production in Nigeria, there is the need to evaluate such lands for irrigation agriculture. Many workers have used crop yield to confirm the suitability of soils for crop production (Fasina, 2005; Oluwatosin and Ogunkunle, 1991) . Attempts have been made to predict the yield of crops through studies on land evaluation at defined management levels (Ogunkunle and Beckett, 1987; Fasina, 2005).

An important aspect of land evaluation that needs to be investigated is how crop yield will respond on soils evaluated for irrigation agriculture.

The objective of this study therefore is to evaluate the irrigation suitability of some selected wetland soils within University of Ado – Ekiti teaching and research farm for irrigation agriculture and also see how *Amaranthus cruentus* crop yield will respond on such soils evaluated for irrigation.

MATERIALS AND METHODS

Environmental setting, soil survey and land evaluation procedure

The experiment was conducted at the University of Ado – Ekiti, Teaching and Research Farm, Ado – Ekiti in South Western Nigeria, West Africa. The area lies between latitude $7^{o}31^{1}$Nand 7^{o} 49^{1}E and covers an area of 1.03 Hectares. It has a humid tropical climate characterized by distinct dry and wet seasons with moderate mean annual rainfall of about 1367 mm. rainfall is seasonal with two peaks. Temperature in this area is almost uniform throughout the year with very little deviations from the mean annual temperature of 27^{o}C. February and March are the hottest months with mean temperature of 28^{o}C and 29^{o}C respectively.

The major soil types of the area were mapped using the rigid grid method following the guidelines of Soil Survey Staff, 2003. Three soil types were identified, profile pits were dug in each of the identified soil types and describe according to the soil survey manual (Soil Survey Staff 2003). Field descriptions and sample collections were made during the dry season to ensure freedom from ground water disturbance. Soil samples were analyzed following the guidelines of IITA (1979) for soil analysis.

The three soils identified were classified according to USDA Soil Taxonomy (Soil Survey Staff, 2003), FAO/UNESCO (2006) and Local Series (Smyth and Montgomery 1962). The land was evaluated for irrigation system employing land characteristic such as environmental factors, drainage properties, and soil physical and chemical properties. The data generated from the field for each Pedon was then used to calculate the suitability index for irrigation (Ci) using the equation below:

$$Ci = A \times B/100 \times C/100 \times D/100 \times E/100 \times F/100$$

Where Ci = Suitability index for irrigation
A = Soil texture rating
B = Soil Depth rating
C = $CaCO_3$ Status
D = Electrical Conductivity
E = Drainage rating
F = Slope rating

Suitability classes are defined considering the value of the suitability index as shown in
Table1.

Field trials

Field Trials were conducted on the three different soil types within an area of 1.03 hectares. Each soil type consists of 27 experimental plots. The size of each plot is 2.5m x 2.5m. A split-split plot experimental design was used for the experiment. The effect of different soil types, water rates and fertilizer rates were tested using *A. cruentus* as a test crop. The seeds were as follows:

W_1 – Twice a day (22 litres)
W_2 – Once a day (1l litres)
W_3 – Once in two days (11 litres)

Fertilizer rates
F_0 – Control (No fertilizer application)
F_1 – Blanket fertilizer recommendation
F_2 – Recommended fertilizer based on soil test

A. cruentus was raised in the nursery and transplanted at 3 weeks to each of the experimental sites. The various fertilizer recommendations; recommended rate – 67.2 kg/ha and Blanket – 336 kg/ha NPK was applied at 10 days after transplanting. An average fertilizer application for recommended rate was applied for blanket recommendation. Weeding was carried out at 15 and 25 days after transplanting. At harvest, the total biomass from each plot was weighed and recorded. Data was collected from each plot on fresh weight, root weight, fresh leaf weight and fresh stem weight.

Analysis of variance (ANOVA) was used for analyzing the yields of *A. cruentus* on each of the soil types and the treatment means compared using the Duncan Multiple Range Test (DMRT) at 0.05% level of significant.

Table 2. Physical and chemical properties of the experimental plots.

Soil Properties	Pedons		
	A	B	C
PH (H_2O) 1:2	5.40	5.20	4.50
Organic Carbon (%)	1.76	1.68	1.25
Total N (g/kg) `	0.04	0.41	0.31
Available P. (mg/kg)	4.22	4.15	2.35
Exchangeable bases (Cmol/kg)			
Ca	0.40	0.39	0.40
Mg	0.30	0.29	0.29
Na	0.09	0.09	0.09
K	0.08	0.08	0.09
Exchangeable acidity (Cmol/kg)	0.40	0.40	1.00
CEC (Cmol/kg)	1.27	1.25	1.87
Base saturation (%)	68.50	68.00	46.52
Electricity conductivity (mmh/cm^{-1})	0.89	0.87	0.86
$CaCO_3$ (%)	3.38	3.23	3.28
AWH (%)	35.30	36.82	34.95
Sand (%)	85.2	74.60	78.60
Silt (%)	11.4	23.40	19.40
Clay (%)	3.4	9.00	2.00
Textural class	LS	SL	LS

Table 3. Suitability index for irrigation.

Soil	Aggregate suitability rating		Class	Definition	Class	Definition
	GI	DR	GI		DR	
A	40.21	80.75	N1	currently not suitable	S1	highly suitable
B	33.86	68.85	N1	currently not suitable	S2	moderately suitable
C	43.32	73.10	N1	currently not suitable	S2	moderately suitable

Note: GI- Gravity irrigation; DR- Drip irrigation.

RESULTS AND DISCUSSION

Soil physical and chemical properties

The results of the chemical and physical properties of the experimental plots are as shown in Table 2.

Irrigation suitability evaluation

The suitability of the soils was assessed for irrigation following the method of Sys (1985). The assessment of soils for irrigation involves using properties that are permanent in nature that cannot be changed or modified without exorbitant cost. Such properties are known to constitute some kind of hindrance to irrigation crop production. Chemical properties that are usually considered (e.g. fertility) can be changed with minor improvement. The processing of the parametric evaluation system for gravity and drip irrigation using the Sys (1985) method gave the irrigation suitability results in Table 3 below.

From Table 3, all soils were considered not currently suitable for gravity irrigation while soil A was considered highly suitable for drip irrigation and soil B and C are considered moderately suitable for drip irrigation. The limiting factor for soil C that lowers the soil to S2 for drip irrigation is mainly due to the problem of soil drainage.

Soils A, B and C that were classified as currently not suitable for gravity irrigation is mainly due to soil texture (loamy sand and sandy loam) which were rated 55,55 and 75 respectively for the three different soils using the Sys (1985) method for irrigation suitability assessment. Soil texture is relevant to permeability, infiltration and water holding capacity of the soil. As we know water and plant nutrient losses may be greater than coarse textured soils so the timing and quantity of chemical and water applications is particularly critical on these soils. Surface irrigation requires heavier soils than drip irrigations.

The comparison of the two types of irrigation revealed that it would be more beneficial to irrigate by drip as the latter mode improves all the suitability to the irrigation

Table 4. Influence of soil types, water and fertilizer rates on yield (kg/ha) and yield components of *Amaranthus cruetus* in Ado Ekiti, Southwestern, Nigeria in kg/ha.

A. Water rate	Total biomass	Fwt	Rwt	FLwt	FSwt
Once daily (11 liters)	3703.1a	835.56a	438.00a	448.00a	497.19a
Once in 2 days (11 litres)	3632.0a	788.74a	341.93a	443.26a	469.93a
Twice daily (22 litres)	3527.0a	859.26a	404.15a	510.22a	533.93a
B. Fertilizer					
Recommended	4051.6a	783.40a	347.26a	518.52a	548.74a
No fertilizer	3636.7a	964.10a	435.56a	479.41a	513.19a
Blanket	3173.9a	736.0a	401.78a	403.96a	439.11a
C. Soil Type					
A	4597.9a	692.15b	175.41b	318.81b	306.37b
B	3111.1b	904.30a	466.96a	546.96a	602.67a
C	3153.2b	887.11a	542.22a	535.70a	592.50a

Means with the same letters are significantly difference at P(<0.05).
Key: Fwt: Fresh weight Rwt: Root weight; FLwt: Fresh Leave weight
FSwt: Fresh Stem weight

purpose (e.g. soil A). The drip irrigation is recommended for a sustainable use of this natural resource.

Influence of soil types, water and fertilizer regimes on yield components of *Amaranthus*.

The result of the influence of soil types, water and fertilizer rates on yield components of *Amaranthus* is shown in Table 4. There were significant differences in total biomass with reference to the different soil types (Table 4). Differences were also observed in total biomass for the different water and fertilizer rates though they were not statistically significant. The best total biomass was obtained under once daily water rate (3703.1 kg/ha), recommended fertilizer rate (4051.6 kg/ha) and soil type A (Oshun Series – about 4598 kg/ha). The reason for the highest biomass in the once daily water rate can be attributed to the fact that this quantity of water (11 litres) was adequate enough for *Amaranthus cruetus* to perform its daily physiological activities. This water rate (11 litres) was either not too much or too low to be able to influence good yield. The twice daily application may have resulted in nutrient leaching or erosion while the application of once in 2 days treatment may have resulted in low water supply to *Amaranthus*. This can also result in water deficit to the crop. The total biomass result obtained for the different water rates followed this trend of argument. The water applied will eventually affect the water content in the plant tissue that will later influence crop yield. This is true of most vegetables and that is why they are highly perishable (Olaniyi, 2004). Recommended fertilizer rate gave the highest total biomass of 4051.6kg/ha, which is significantly higher than 3636.7 kg/ha and 3173.9 kg/ha obtained from no fertilizer and blanket applications respectively. The reason for this trend is due to the fact that the recommended fertilizer rate considered the native nutrient in the soil before application that is, application of fertilizer was based on soil test while for blanket rate, the native nutrient in the soil not considered before application. This is the reason why even the control plot (no fertilizer treatment) performed better than the blanket (Table 4). This application of blanket regime may either cause nutrient imbalance or nutrient antagonism. The result obtained in this study on the influence of fertilizer application on *A. cruentus* agreed with the results obtained by previous workers (Fasina et al., 2007; Fasina and Ogunkunle, 1995) who all said that blanket fertilizer regimes would not give maximum yield of crop. From the above discussion, it is obvious that fertilizer application is best done after a soil test has been carried out to determine the native nutrient of the soil that reveals the nutrient status of the soil.

The three different soils are clearly characterized by different total biomass yield (Table 4). Soil A (Oshun Series) gave the highest biomass yield of about 4598 kg/ha, which is significantly higher than 3153.2 and 3111.1 kg/ha from soils C and B respectively. The various differences in the biomass yield as presented in Table 4 may be due to the differences observed in the native soil fertility nature of the soil (Table 2). From the soil analysis result in Table 2, it was observed that soil A has a low Nitrogen level (0.04 g/kg) when compared with soil B (0.41 g/kg) and soil C (0.31 g/ks). This low value of total N for soil A falls below the critical level of N (0.20 g/kg) recommended for vegetable production (FPDD, 1989) in Southwestern Nigeria. It is obvious that soil A will respond to and benefit from Nitrogen fertilizer application which eventually influences yield produced on it. Some previous workers (Fasina and Ogunkunle, 1995; Fasina et al., 2007; Onasanya and Ogunkunle, 2002) have all observed that fertilizer application and soil types can significantly influenced crop on the field. In a study carried out by Fasina 2005 to determine the influence of soil types and management on maize yield on some

Table 5. Irrigation suitability and crop yield rating

Gravity irrigation.			Drip irrigation					
Soils	Irrigation Class	Soil rating	Yield ton/ha	Yield rating	Irrigation class	Soil rating	Yield tons/ha	Yield Rating
A	N1	4	4.60a	1	S1	1	4.60a	1
B	N1	4	3.11c	3	S2	2	3.11c	3
C	N1	4	3.15b	3	S2	2	3.15b	3

Means with the same letters are not significantly different (P<0.05)

selected farms in Lagos State, Nigeria, it was observed that there was substantial variation in response to management by the different soil series in terms of maize yield. Differences in crop yield on farmers' field may largely depend on management, soil properties and land use history of the sites. This statement is in agreement with the observation made by Onasanya and Ogunkunle (2002). Fasina and Ogunkunle (1995) had earlier on suggested that land evaluation may not have much practical relevance in terms of crop yield prediction without reference to crop management level. The result of the yield components did not follow a particular pattern. No significant differences were obtained for fresh weight with reference to water and fertilizer rates.

However, significant (P<0.05) differences in root weight, fresh weight, fresh leaf weight and fresh stem weight were observed with reference to the different soil types (Table 4) . This is expected and probably may be due to the fact that the different soils have different soil properties and land use history that likely will have influenced the various results obtained. This result agreed with result obtained by earlier workers (Olufolaji and Tayo, 1989; Olufolaji, 1989).

Irrigation suitability rating and crop yield

In spite of the rating of the soils by the evaluation of Sys (1985) for irrigation suitability, it is useful to know whether the ratings of these soils by the evaluation method reflects farmers experience in terms of crop yield which in this case is *A. cruentus* . In other words, can we say that S1 soils by Sys (1985) system of rating for irrigation will give an S1 *Amarathus* yield on farmers plot?

The result of crop yield obtained in this study shows that the suitability classes of the soil for gravity and drip irrigation are clearly characterized by different crop yields (Table 5) from the various soils. Soil A under drip irrigation was classified as highly suitable (S1) for drip irrigation and also gave an S1 yield (4.6 tons/ha). Soils B and C under drip irrigation were classified as moderately suitable for drip irrigation and gave an

S3 yield rating. Soils A, B and C were considered to be currently not suitable (N1) for gravity irrigation and so they were rated 4.

However, soil A which rated 4 and not suitable for gravity irrigation gave an S1 yield rating. The reason for the lack of agreement between the irrigation suitability evaluation and crop yield may be attributed to the fact that the parameters employed in the evaluation of the soil for irrigation suitability evaluation are not the same with factors that determine crop production or yield of crop. While irrigation suitability evaluation considers mostly physical and land characteristics (soil depth, slope $caco_3$ electrical conductivity, drainage and soil texture). Factors that determine crop yield are mostly chemical properties of the soil (e.g. pH, organic matter, soil nutrients e.t.c.) when evaluating the land for irrigation suitability. The result obtained in this study agreed with the findings of Adeyanju and Fasina (2007) who concluded that there is need for critical study of the relevance of land qualities and characteristics and their range of values in land evaluation studies as presently being used in Nigeria.

This study shows clearly that crop yield prediction from irrigation suitability evaluation of drip irrigation may be preferable to gravity irrigation and may be reliable to some extent in predicting yield. The point that is clearly shown here also is the fact that land evaluation may not have much reference to crop management level.

Conclusion

The reliability of using land evaluation (irrigation suitability) as a basis for crop yield prediction was examined in Ado – Ekiti, Southwestern Nigeria using *A. cruentus* as a test crop from the result obtained, all the three soils evaluated were considered presently not suitable for gravity irrigation but soil A was considered highly suitable for drip irrigation while soil B and C were considered moderately suitable for drip irrigation. It is therefore better to irrigate these soils using drip irrigation. Soil types at series level significantly (P<0.05) influenced *Amaranthus* yield were obtained from the three different soil types. Soil A gave the highest total biomass yield (4597.9 kg/ha) followed by soil C (3152.2 kg/ha) and lastly soil B (3111.1 kg/ha). This study also concluded that fertilizer recommendations based on soil test is still the solid basis for determining the adequate level of nutrients that could replenish the soil as well as satisfy the need of the crop. The result of the water rate application confirmed that watering the field once daily gave the highest biomass yield (3703.1 kg/ha), followed by once in two days (3632 kg/ha) and lastly watering twice daily with 3327kg/ha. It is therefore advisable to water the crop once daily.

The results of the analysis of the water used at the project site for irrigating *Amaranthus* was found suitable for irrigation with respect to pH, total dissolved solids, bicarbonate levels. This study however concluded that land evaluation may not be practically relevant in terms of crop yield prediction without reference to the management practice.

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