Journal of Research in Forestry, Wildlife & Environment Vol. 13(2) June, 2021
E-mail: jrfwe2019@gmail.com; jfewr@yahoo.com
http://www.ajol.info/index.php/jrfwe
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ISBN: 2141 – 1778
Musa et al., 2021

EVALUATION OF DIFFERENT IRRIGATION METHODS IN CHANCHAGA IRRIGATION SCHEME, NORTH CENTRAL NIGERIA

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ABSTRACT

This study was aimed at evaluating different methods of irrigation based on parametric evaluation method for Chanchaga irrigation scheme, Nigeria. Soil samples were collected at various rooting depths of 0-15 cm, 15-40 cm and 40-75 cm, the collected samples were analysed for physical properties. Various suitability classes were generated for surface, sprinkler and drip irrigation methods using the capability index. The results revealed that the use of drip irrigation system for soil depths of 0-15 cm and 15 -40 cm within the study area were found to be suitable and not suitable for deep rooted areas of 40-75 cm. The sprinkler irrigation method was found to be suitable for study locations 3 and 4 at depths of 15-40 cm. At depths 40-75 cm, drip irrigation method was found suitable for locations 1, 2 and 5 while locations 3 and 4 supports the use of sprinkler irrigation method. It is therefore concluded that the sprinkler and drip irrigation methods are both highly favoured for irrigation purpose in the Chanchaga irrigation scheme.

Keywords: Capability, Index, Irrigation, Soil, Suitability, Water

INTRODUCTION

Irrigation plays a vital role in the increase of crop yields (Jovzi *et al*. 2012; Albaji *et al*. 2012). The parametric evaluation method is a technique that is based on the characteristic's morphology, physical and chemical properties of the soil (Dawson and Hillier, 2010; Ma *et al*., 2015). Properties considered include slope, drainage properties, soil texture and soil depth. The suitability classification process of land is the grouping of specific areas of land in terms of their suitability for a defined use (Albaji and Alboshokeh, 2017; Everest *et al*. (2020). The land qualities which includes soil erosion resistance, soil water availability and flood hazards are strongly linked to land suitability (Bagherzadeh and Paymard, 2015) which in themselves are unlimited qualities. Considering these qualities which are derived from land characteristics such as rainfall and soil texture, slope angle and length, which is beneficial in using them in concluding indicators in the land suitability for irrigation purposes. In a study of Albaji *et al*., (2010) conducted in the plains Dosalegh, Iran, the evaluation of different types of irrigation techniques revealed that for improved land productivity the drip and sprinkler irrigation methods were more effective and efficient than that of surface irrigation (Bagherzadeh & Paymard, 2015). However, soil texture, salinity, and slope were the main limiting factor in using either surface or sprinkler irrigation methods in this area, while the calcium carbonate content, soil texture and salinity were the main limiting factors in using drip irrigation methods were (Albaji *et al*. 2015). The study carried out by Albaji and Hemadi (2012) in the Dasht Bozorg Plain of Iran showed that by adopting sprinkle irrigation method instead of drip and surface irrigation, the arability of 1611.6 ha (52.5%) on the plain improved. In addition, by applying drip irrigation method instead of sprinkle or surface irrigation methods, the land suitability of 802.4ha (26.2%) on the same plain was improved. Comparisons of the different types of irrigation systems revealed that sprinkle and drip irrigation methods were more effective and efficient than surface irrigation for improving land productivity (Albaji *et al*. 2014). Brou and Woldegiorgis (2010) in their study where they performed a land suitability evaluation for two types of irrigation which are surface and drip irrigation systems in the Kilte Awulaelo District of Tigray region, Ethiopia using the parametric evaluation. The results showed that a larger amount of the land (30,100 ha – 71.8%) can be classified as more suitable for drip irrigation than surface irrigation.

Suitable irrigation method is essential for selecting a good irrigation farming to attain structured water use and to reduce land and water degradation for better nutrient and pesticide control in crop production (Davis *et al*. 2013). However, the practice of irrigation has the prospective to make a major impact on the land and water quality during comprehensive use. The intensive use of water in particular alters the distribution of water throughout the environment and powers the transportation of pollutants (such as nutrients pesticides), compaction, erosion, salinization and waterlogging etc (Ray *et al.* 2017). Soil and water compatibility are very important under irrigation, where soil acts as a sponge to take up and retain water giving room for infiltration and percolation (Iqbal *et al*. 2020). If the soil is not compacted, the irrigation water applied may perhaps have an adverse effect on both the chemical and physical properties of the soil (Blanco-Canqui *et al*. 2015). The basic understanding of soil, water and plant will help farmers during irrigation to efficiently manage their crops, soil irrigation systems and water supplies for optimal crop yield. Furthermore, a good soil management and timely application of irrigation water may result in prevention of land degradation.

This study is therefore aimed at evaluating the effects of different irrigation methods in Chanchaga irrigation scheme, Niger State, using the parametric approach and to determine the capability index and suitability classes for the Irrigation methods

MATERIALS AND METHODS

Study Area

Chanchaga irrigation scheme is situated within Chanchaga Local Government area of Niger State, Nigeria. The irrigation scheme lies within the guinea savannah ecological zone of Nigeria on latitude 9^0 41’ 00” N and longitude 6^0 38’ 00” N. The scheme is located at the bank of River Chanchaga thus supporting an all year-round farming operation. The rainy season farming operation starts mostly from April and ends November. While the dry season starts mostly from November ending to late March of the following year (Chukwu and Musa, 2008). The average temperature and rainfall period within the study area is 27.5^{o}C and 1229 mm respectively (Musa *et al*. 2012). The study area is basically loamy and sandy soil which are averagely-well drained in nature. The common types of crops grown within the irrigation includes: Rice, Spinach, Potato, Okra, Maize and Sorghum. Figure 1 shows the map of the River Chanchaga in blue extracted from the maps of Chanchaga Local government area of Niger State, Nigeria while Figure 2 presents the 3D map of the area.

A. Soil sampling and analysis

The soil samples were randomly collected from five different locations on the irrigation scheme. The coordinates of where the soil samples were collected are presented in Table 1.

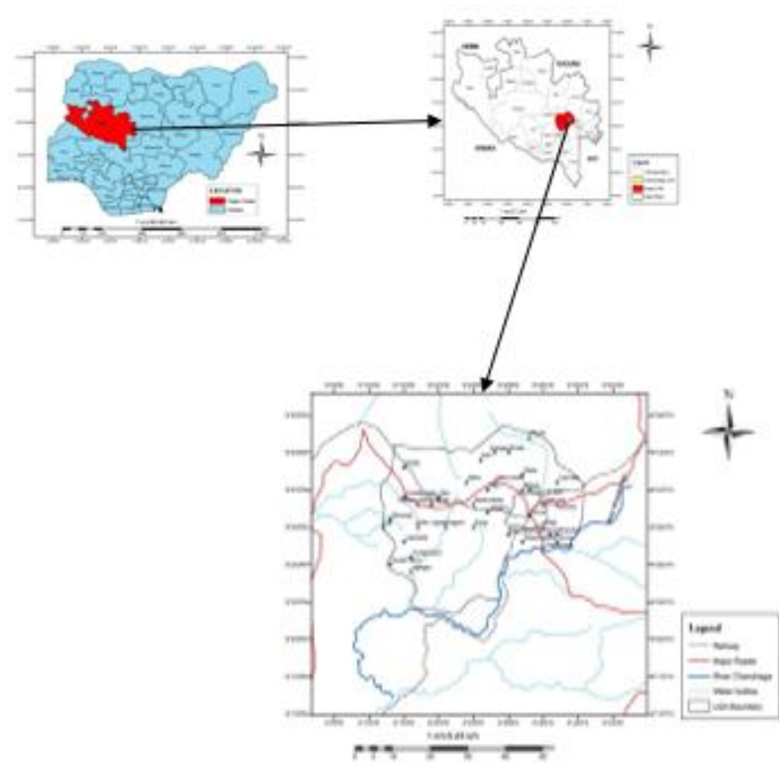

Figure 1: Chanchaga Irrigation Scheme showing River Chanchaga

Figure 2. 3D view of the irrigation scheme using Google earth 2019

Table 1. Soil Sampling points on the irrigation scheme

Sample points	Longitude coordinates	Latitude coordinates
A	$9^0$32'01" N	$6^0$34'33" E
B	$9^0$32'12" N	$6^0$34'33" E
C	$9^0$32'11" N	$6^0$34'36" E
D	$9^0$32'14" N	$6^0$34'35" E
E	$9^0$32'17" N	$6^0$34'36" E

Soil sampling was collected depths of 0-15 cm, 15-40 cm and 40-75 cm using a soil auger for each of the study location. Thus, a total number of fifteen soil samples were collected. Each of the soil sample collected were kept in a carefully labelled polythene bag and kept in a cooling box to maintain the soil temperature from the field. This is in accordance to the works of Musa *et al*., (2012); and Musa *et al.* (2017). The soil samples collected were taken to the laboratory for drying and analysis within twenty-four hours (Albaji *et al*. 2008).

The proportional distribution of the soil were as follows; coarse sand (2.0–0.2 mm), medium sand (0.2–0.1 mm), fine sand (0.1–0.05 mm), coarse silt (0.05–0.02 mm), fine silt (0.02–0.002 mm), and clay (<0.002 mm) was calculated successively and the soil texture was classified using the USDA Soil Textural Classification System.

B. Capability and Suitability Indices

The quality and quantity of water in agricultural systems of arid and semi- arid areas of the world are of great essence. Thus, the trend to water application to farm lands for irrigation purposes to meet agricultural demands is of great importance. The parameters considered were assigned values for each factor. Thus, (Ci) which is the capability index for irrigation was developed as presented in equation 1 below according to Albaji*et al*. (2015) and Ma *et al*. (2015).

$$ci = A \; x \; \frac{B}{100} \; x \; \frac{C}{100} \; x \; \frac{D}{100} \; x \; \frac{E}{100} \; x \; \frac{F}{100} \quad .1$$

where A, B, C, D, E, and F are soil texture rating, soil depth rating, calcium carbonate content rating, electrical conductivity rating, drainage rating and slope rating, respectively. Table 2 presents the irrigation capability indices (Ci) classes and its suitability.

Table 2. Suitability classes for the irrigation capability indices (Ci) classes.

Capability index	Definition	Symbol
> 80	Highly suitable	S1
60 - 80	Moderately suitable	S2
45 - 59	Marginally suitable	S3
30 - 44	Currently not suitable	N1
< 29	Permanently not suitable	N2

The factors considered to determine the suitability index for irrigation of the soils within the study area includes soil texture, soil depth, calcium carbonates status, electrical conductivity of soil solution, drainage properties and slope.

RESULTS

The textural classification of the soils within the study area is presented in Table 3 below. The table presents that the quantity of fine gravel in the soil samples at soil depths of less than 15 cm which were observed to be relatively 100 % clay while for soil samples at 15 – 40 cm depth was 90% clay and for soil samples at 40 – 75 cm depth had 80% clay content. This is similar to the findings of Chukwu and Musa (2008) and Abaji *et al*. (2015). The rating of the soil depths with respect to irrigation method is present in Table 4 while the class of drainage systems under the various types of the irrigation systems is presented in Table 6. The slope rating of the study area is presented in Table 7 which indicates the terraced and non-terraced sections of the study under the various irrigation methods.

Table 3. Textural classes rating for surface irrigation

Textural class	Fine gravel	(%)		Coarse gravel	(%)
	<15	**15-40**	**40-75**	**15-40**	**40-75**
CL	100	90	80	80	50
SIL	100	90	80	80	50
SCL	95	85	75	75	45
L	90	80	70	70	45
SIL	90	80	70	70	45
SI	90	80	70	70	45
SIC	85	95	80	80	40
C	85	95	80	80	40
SC	80	90	75	75	35
SL	75	65	60	60	35
LS	55	50	45	45	25
S	30	25	25	25	25

CL: Clay Loam. SiL: Silty Loam. SCL: Sandy Clay Loam. L: Loam. SiL: Silty Loam. Si: Silty. SiC: Silty Clay. C: Clay. SC: Sandy Clay. SL: Sandy Loam. LS: Loamy Sand S: Sandy.

Table 4: Rating of textural classes for drip irrigation

Textural class	Fine gravel	(%)		Coarse gravel	(%)
	<15	**15-40**	**40-75**	**15-40**	**40-75**
CL	100	90	80	80	50
SIL	100	90	80	80	50
SCL	95	85	75	75	45
L	90	80	70	70	45
SIL	90	80	70	70	45
SI	90	80	70	70	45
SIC	85	95	80	80	40
C	85	95	80	80	40
SC	95	90	85	80	35
SL	95	85	80	75	35
LS	85	75	55	60	35
S	70	65	50	35	35

Table 5: Soil depth rating 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 6. Rating for drainage classes

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 7. Slope rating 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

The land capability index (CI) and Suitability Classes (SC) were developed for each location at different depths with respect to the various type of irrigation method considered are presented in the Tables 8 to 10. Table 11 presents the summary of the CI and SI for the various soils within the study area to the various irrigation systems

Table 8. CI values and SC for surface irrigation at different depths

Location	15(cm)	suitability classes	40(cm)	suitability classes	75(cm)	suitability classes
1	14.43	N2	30.01	N1	36.93	N1
2	14.43	N2	30.01	N1	36.94	N1
3	17.31	N2	36.94	N1	43.09	N1
4	17.31	N2	36.93	N1	43.10	N1
5	14.43	N2	30.01	N1	36.94	N1

Table 9. CI and SC values for sprinkler irrigation at different depths

Location	15(cm)	suitability classes	40(cm)	suitability classes	75(cm)	suitability classes
1	23.08	N2	41.68	N1	50.87	S3
2	23.09	N2	41.68	N1	50.87	S3
3	23.09	N2	44.50	N1	50.87	S3
4	23.09	N2	44.50	N1	50.87	S3
5	23.09	N2	41.68	N1	50.87	S3

Table 10. CI and SC values for drip irrigation at different depths

Location	15(cm)	suitability classes	40(cm)	suitability classes	75(cm)	suitability classes
1	26.60	N2	47.68	S3	57.60	S3
2	26.60	N2	47.60	S3	57.60	S3
3	25.20	N2	44.80	N1	50.40	S3
4	25.20	N2	44.80	N1	50.40	S3
5	26.60	N2	47.60	S3	57.60	S3

Table 11: The Most suitable soil locations for surface, sprinkler and drip irrigation systems by notation to CI for different irrigation systems

Location	Soil depth	The Maximum capability index for irrigation (CI)	Suitability classes	The most suitable irrigation systems	Limiting factors
A	0-15cm	26.6	N2	Drip	$CaCo_3$ and drainage
	15-40cm	47.68	S3	Drip	$CaCo_3$ and drainage
	40-75cm	57.60	S3	Drip	$CaCo_3$ and drainage
B	0-15cm	26.60	N2	Drip	$CaCo_3$ and drainage
	15-40cm	47.60	S3	Drip	$CaCo_3$ and drainage
	40-75cm	57.60	S3	Drip	$CaCo_3$ and drainage
C	0-15cm	25.20	N2	Drip	Soil texture, $CaCo_3$ and drainage
	15-40cm	44.80	N1	Drip	Soil texture, $CaCo_3$ and drainage
	40-75cm	50.40	S3	Drip	Soil texture, $CaCo_3$ and drainage
D	0-15cm	25.20	N2	Drip	Soil texture, $CaCo_3$ and drainage
	15-40cm	44.80	N1	Drip	Soil texture, $CaCo_3$ and drainage
	40-75cm	50.40	S3	Drip	Soil texture, $CaCo_3$ and drainage
E	0-15cm	26.60	N2	Drip	$CaCo_3$, salinity and alkalinity
	15-40cm	47.60	N1	Drip	$CaCo_3$, salinity and alkalinity
	40-75cm	57.60	S3	Drip	$CaCo_3$ and drainage

DISCUSSION

The surface irrigation systems have been applied over time within the study area for the various types of crops grown to meet the demand of water by crops. The major crops grown in this area with irrigation water are rice, maize, and guinea corn, in addition to fruits such as melons, watermelons, and vegetables such as tomatoes, pepper, leafy vegetables and cucumbers. There are limited instances of sprinkle and drip irrigation on large area farms in the study area. A gradual reduction in the clay content in the various soil samples collected at varying depths was observed which implies that more water will be required to sustain crop growths in the study area. The percent of the soil texture was observed to reduce with increase in depth.

The rate at which irrigation water is applied to the various farm sections using the three irrigation methods specified in the study. It was observed that the rating for surface irrigation method was lower compared to the sprinkler and drip irrigation method. This implies that much water is used in surface irrigation system when compared to the other two. The drip irrigation system maximizes the rate of delivery of water to the farm lands as it applies water directly to the root zones of the crops. The findings here is in conformity with the works of Albaji *et al*. (2015).

The slope of the farmlands was observed not to be even in the study area. Thus, having its effect on the amount of delivered to some sections of the land especially in the case of surface irrigation system. This informed the terracing of some sections of the farmland within the study area. This is in accordance with the works of Albaji *et al*. (2010b).

The CI for drip irrigation system within the study area of locations 1, 2, 3, 4 and 5 at the depth of 15cm were classified as permanently not suitable. The CI at locations 1, 2 and 5 at 15-40cm were classified as marginally suitable while the CI at location 3 and 4 at 15-40cm were currently classified as not suitable for irrigation practice. This is agreement to the findings of Behzad *et al*., (2010), Albaji and Hemadi (2011) and Sarkar *et al*. (2014). The CI at location 1, 2, 3, 4 and 5 at 40-75cm were all classified as being marginally suitable.

CONCLUSION

Several parameters were used for the analysis of the field data in order to compare the suitability of different irrigation systems. The analysed parameters included soil and land characteristics. From the results obtained, it was concluded that the sprinkler and drip irrigation systems are more suitable than surface irrigation method for most of the study area. This change in irrigation management practices would imply the availability of larger initial capitals to farmers (different credit conditions, for example) as well as a different storage and market organizations. The shift from surface irrigation to high-tech irrigation technologies, e.g. sprinkler and drip irrigation systems, therefore, offers significant water-saving potential which should be supported by the various agencies. It is therefore recommended that sprinkler and drip irrigation methods are highly sustainable for use in the study area.

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