



## **GIS-BASED IRRIGATION SUITABILITY EVALUATION OF LAPAI-AGAIE IRRIGATION SCHEME, NIGER STATE, NIGERIA**

**<sup>1</sup>Jankaro Larai S., <sup>1</sup>Odofin, A. J., <sup>1</sup>Lawal, B. A. and <sup>2</sup>Onuigbo, I. C.**

<sup>1</sup>Department of Soil Science and Land Management, Federal University of Technology,  
P.M.B. 65, Minna, Niger State, Nigeria.

<sup>2</sup>Department of Survey and Geo-Informatics, Federal University of Technology,  
Minna, Niger State, Nigeria.

**Corresponding Author's E-mail:** elijankaro@yahoo.com **Tel.:** 08065078196

### **ABSTRACT**

Irrigation is one of the most important inputs for an efficient and sustainable agricultural production. Many farmers are out of jobs during the dry season and prices of locally produced food are high as a result of food scarcity during this period. The objective of this study is to map potential irrigable areas based on soil physical properties. The overall soil suitability was estimated using the weightage of each factor (slope, soil pH, soil texture, Infiltration rate, Organic carbon, Effective soil depth, Available water capacity, Cation Exchange Capacity, sodium adsorption ratio, exchangeable sodium percentage and drainage) to obtain potential irrigable sites. The data were combined using a multi-criteria decision approach to select suitable sites for irrigation. Landsat imagery with 30m resolution was used for the overall land suitability classification. The overall land suitability shows that 59.0 % of the area have been classified highly suitable (S1) for irrigation and 32.0% are moderately suitable (S2) for surface irrigation while 9.0% has been classified as marginally suitable (S3). The limiting factor that lowered the soil to S2 is mainly the organic carbon of the soil. The study shows that GIS based suitability evaluation could ease the identification and mapping of suitable land for irrigation purpose. Important management information for the study area can be easily deduced from the land suitability maps for enhancing sustainable development of agriculture. It is hoped that the information generated from this study will serve as a means of readily identifying opportunities for farmers and investors to access and put the land into suitable use.

**Keywords:** Bakajeba, GIS, Irrigable sites, Suitability class, Soil properties.

### **INTRODUCTION**

In order to ensure food security, providing comprehensive, reliable and timely information on land suitability is very important, this is as reported by Tadele and Zewde (2021). However, food production via irrigated agriculture does not correspond to the current rapid population growth (Bagherzadeh and Paymard, 2015). Land evaluation is the assessment of land performance for specified purposes. Mohammed *et al.* (2017) was of the view that a piece of land without determination of its suitability has serious consequences, and inadequate information of the degree extent of its suitability constitute a setback the achievement of global security particularly in developing economies such as Nigeria.

Determining the suitability of land for irrigation requires thorough evaluation of soil properties. Most of the data related to irrigation management are complex, spatially variable and temporal in nature. The integration of irrigation data and their use in irrigation planning and management led to the introduction of Geographic Information Systems (GIS) and other technologies (Kjelds and Storm, 2014). Irrigation represents an alteration of the natural conditions of the landscape by extracting water from an available source, adding water to fields where there was none or little before, and introducing man-made structures and features to



extract, transfer and dispose of water (Vidya, 2013). Many irrigation projects, especially in the developing tropical regions, are embarked upon without any land capability assessment, resulting in avoidable and undesirable ecological consequences (Umweni and Ogunkunle, 2014).

Computer based systems and tools help the decision maker to manage irrigation system quickly and efficiently. Few computer-based tools/systems have become popular among the irrigation experts and authority. Soil properties vary from place to place. Hence, the knowledge of soil chemical and physical characteristics is a vital criterion for cropland suitability analysis and mapping (Getachew and Solomon, 2015). Many irrigation projects, especially in the developing tropical regions, are embarked upon without any land capability assessment, resulting in avoidable and undesirable ecological consequences (Umweni and Ogunkunle, 2014). The objective of this study is to map potential irrigable areas based on soil physical properties and slope of the study area. It is hoped that the information generated from this study will equip potential users with information that is essential for the sustainable management of the soil of the study area for sustainable agriculture and serve as a means of readily identifying opportunities for farmers and investors to access and put the land into suitable use.

## **MATERIALS AND METHODS**

### **The Study Area**

The study was conducted at Lapai-Agaie Irrigation scheme which lies on latitude 09° 13' 09.83 " N and longitude 06° 35' 87.9 " E near Bakajeba village along Paiko-Lapai road in Niger State. It is about 40 km from Minna. The area is located in a tropical climate which is characterised with two distinct seasons (Wet and Dry) annually. The rainy season starts from April to October with heavy rainfall between July and September. The annual amount of rainfall varies between 1,300 mm to 1,800 mm. The cold and dry harmattan winds usher in the dry season between November and February. The temperature become relatively high with a peak in dry season between 30° C and 41° C during the periods of December and April, while low temperatures of between 25° C and 30° C highest within the season occurring at mid-days between May and July. The study site is located in the southern part of Niger State which is characterised by gentle slopes and have the landscape of guinea savannah plain land.

### **Soil Sampling and Mapping**

The study was conducted at Bakajeba irrigation scheme, the size of the site surveyed for this research purpose was about 200 hectares. Soil identification and mapping was by rigid grid method of soil survey with the aid of soil auger. Traverses were cut at 100 m apart along a baseline and observation points were at 100 m apart along each traverse. Auger holes were made at each point down to a depth of 100 cm and soil was examined at each 20 cm incremental depth interval for the 100 m depth. Morphological properties were recorded at each point including soil texture, colour, consistence, vegetation, evidence of rock outcrop and so on. The points were further grouped on the basis of the recorded morphological features. The area was delineated into 3 mapping units and two profile pits were dug in each mapping unit. A total of six profile pits were dug to specification (2m x 1m x 1m) and described in the field according to FAO guidelines. Each of the profile pits was demarcated into different horizons and soil description was done. Soil samples were collected at each genetic horizon starting from the bottom to top of the profile pits for laboratory analysis.

### **Evaluation Parameters**

Effective soil depth was determined using a measuring tape to measure from the soil surface to the upper boundary of the limiting horizon of the profile pits. Drainage



characteristics were determined using Munsell Colour Charts. The basic infiltration rate was determined on the field using a double ring infiltrometer method. Core samples were used for determination of available water capacity, Soil texture was determined using Bouyoucos hydrometer method with sodium hexametaphosphate as dispersing agent. The textural classes of the soils were determined using soil textural triangle.

### Land Suitability Classification

To evaluate the land suitability for irrigation, parametric evaluation system was applied, using soil and land characteristics. These characteristics concern environmental factors, drainage properties, soil physical and chemical properties. The rating was selected for different qualities. The overall soil suitability was estimated using the weightage of each factor. The data generated from the field for each pedon was used to calculate the suitability index for irrigation using the equation below. Suitability classes were defined considering the value of suitability index. They were rated and used to calculate the overall suitability index  $S_i = W_{max} \times \sqrt{A/100 \times B/100 \times C/100 \times D/100}$

where;  $S_i$  = Suitability index,  $W_{max}$  = maximum rating value of the parameters, A, B, C...= rating values for other parameters.

The data were combined using a multi-criteria decision approach to select suitable sites for irrigation. Landsat imagery with 30m resolution was used. The imagery was subjected to digital image processing. The overall soil suitability was estimated using the weightage of each factor to obtain potential irrigable sites.

## RESULTS AND DISCUSSION

All the soils are deep (soil depth > 80cm). This is good enough and will allow good penetration of the roots of crops. The depth to a contrasting soil layer of sand and gravel can affect irrigation management decisions if the depth to this layer is less than 3 feet, the rooting depth and available water for plant is decreased (Table 1). Soils with less available water for plants require more frequent irrigation. All mapping units had sandy-loam soil texture. This could be attributed to similar parent materials and environment in which the soils were developed (Robert *et al.*, 2019).

**Table 1:** Physical properties of soils of the study site

Pedon	Soil texture	AWC (mmH <sub>2</sub> O m <sup>-1</sup> )	Infiltration rate (cm hr <sup>-1</sup> )	ESD %	Slope %	Drainage
MP1A	SL	138	8	80	4.6	MWD
MP1B	SL	126	2	82	5.2	well
drained						
MP2A	SL	135	7	100	5.0	well
drained						
MP2B	SL	129	4	126	3.6	well
drained						
MP3A	SL	125	5	100	4.3	well
drained						
MP3B	SL	132	6	110	4.9	well
drained						

SL: sandy loam, AWC: available water capacity, ESD: effective soil depth, MWD: moderately well drained



All soils were rated highly suitable (S1) for pH with suitability index of 100% (Table 2). pH is an important soil property that determine solubility and reaction of soil elements such as Al and Mn (John *et al.*, 2018). Infiltration rate was highly suitable in all mapping units. Organic carbon was rated moderately suitable (S2) at MP1 and highly suitable (S1) at MP2 and MP3. The soil organic carbon ranged from 2.14 to 8.57g kg<sup>-1</sup> and was low. Organic matter plays important role in soil by binding soil mineral particles and provide exchange sites for nutrients (Robert *et al.*, 2019).

**Table 2:** Chemical properties of soils of the study site

Pedon	Ph	Organic carbon (gkg <sup>-1</sup> )	CEC (cmolk <sup>-1</sup> )	ESP(%)
MP1A	6.55	4.38	31.2	2.42
MP1B	6.51	2.10	35.4	2.11
MP2A	6.71	2.98	20.0	3.54
MP2B	6.48	3.15	18.0	3.45
MP3A	6.20	2.45	35.4	3.07
MP3B	6.45	3.50	32.2	3.06

CEC: cation exchange capacity, ESP: exchangeable sodium percentage

Available water capacity (Table 3) was moderately suitable (S2) at MP1 and MP2 while MP3 was rated highly suitable (S1) with index value 85%. CEC was rated highly suitable (S1) at MP1 and MP3 while MP2 was moderately suitable (S2) with index of 75%. Exchangeable Sodium Percentage (ESP) was highly suitable in all soils of the mapping units. A large proportion of the soil were imperfectly drained were rated 100% for irrigation suitability. This is considered to be suitable for irrigation agriculture. With reference to slope, the soils were rated highly suitable for surface irrigation.

**Table 3:** Land suitability indices for irrigation of soils of the study site

Land quality	MP1	MP2	MP3
Texture	85(S1)	95(S1)	90(S1)
Ph	100(S1)	100(S1)	100(S1)
Infiltration rate	85(S1)	100(S1)	100(S1)
Available Water Capacity	75(S2)	80(S2)	85(S1)
Organic Carbon	65(S2)	85(S1)	75(S2)
Effective Soil Depth	85(S1)	100(S1)	100(S1)
Slope	95(S1)	85(S1)	65(S1)
Drainage	100(S1)	90(S1)	100(S1)
CEC	100(S1)	90(S1)	100(S1)
ESP	90(S1)	90(S1)	85(S1)
Aggregate class	S2s	S1	S2st

CEC: Cation Exchange Capacity, ESP: exchangeable sodium percentage

The overall suitability (Figure 1) shows that 59.0 % of the area have been classified highly suitable (S1) for irrigation and 32.0% are moderately suitable (S2) for surface irrigation while 9.0% has been classified as marginally suitable (S3).

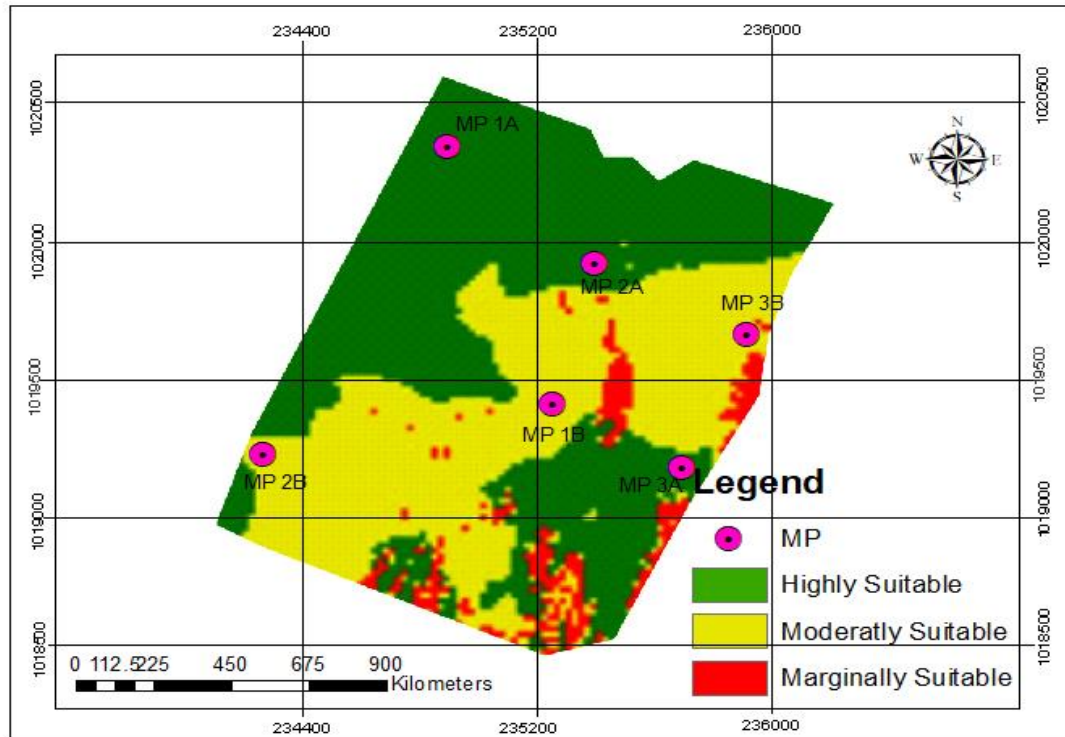


Figure 1: Land Suitability Map of the study area

## CONCLUSION AND RECOMMENDATIONS

In conclusion, the study shows that GIS based suitability evaluation could ease the identification and mapping of suitable land for irrigation purpose. Important management information for the study area can be easily deduced from the land suitability maps for enhancing development of agriculture in the country. The result revealed that a largest percentage (59%) of land in the study area is highly suitable for surface irrigation, 32% is moderately suitable area while 9% of the land is marginally suitable for irrigation. The limiting factor that lowered the soil to S3 is mainly the soil organic carbon of the soil. Special management of these areas through increased fertilizer and organic matter application may be required for accelerated recovery. Concerned investors should incorporate GIS-based multi-criteria decision-making analysis in selecting sites for irrigation, this will help to generate maximum returns from agricultural land and sustainable production.

## REFERENCES

- Bagherzadeh, A. and Paymard, P. (2015). Assessment of land capability for different irrigation systems by parametric and fuzzy approaches in the Mashhad Plain, northeast Iran. *Soil & Water Res.*, 10:90–98.
- Food and Agriculture Organization (2017). Food and Agriculture Organization 2017.FAOAQUASTAT <http://faostat.fao.org>.
- Getachew, A. T. and Solomon, B. A. (2015). Land Suitability analysis for Rice Production: A GIS Based Multi Criteria Decision Approach. *American Journal of Geographic Information System* p-ISSN: 2163-1131, 4(3): 95-104pp
- John, J. T., Balthazar, M. M., Johnson, M. S., Ernest, S. and Sibaway, B. M. (2018). Pedological Characterization and Classification of Some Typical soils in ThreeAgro-





- Ecological settings of South-Eastern Tanzania. *International Journal of Scientific and Engineering Research*, Volume 9. ISSN 2229-5918.
- Mohammed, T., Wapa J. M., Lawal, B. A. and Moammed, A. (2017). Suitability Assessment of some Soils for Cultivation of Maize (*Zea Mays*) Along a Toposequence in College of Agriculture, Mokwa Teaching and Research Farm, Niger State, Nigeria. *Abuja Journal of Agriculture and Environment (AJAE)*. Pp. 300 – 306
- Rabia, A. H. (2012). “A GIS based land suitability assessment for agricultural planning in Kilte Awulaelo district, Ethiopia,” The 4th International Congress of ECSSS, EUROSOIL “soil science for the benefit of mankind and environment”, Bari, Italy, pp. 1257, 2-6.
- Robert, E. O., Lawal, B. A. and Odojin, A. J. (2019). Geographic Information System (GIS)-Based Digital Mapping of Soil Properties for Arable Agriculture in Ike-Bunu, Kogi State. *Agricultural Society of Nigeria, Annual conference proceedings*, Pp. 62 – 65.
- Tadele, T. L. and Zewde, S. (2021). Land Suitability Analysis for Surface Irrigation in Humbo Worede, Wolaita Zone, Ethiopia. *EQA-International Journal of Environmental Quality*, 44: 32-43.
- Umwani, A. S. and Ogunkunle, A. O. (2014). Irrigation capability evaluation of Illushi floodplain, Edo State, Nigeria. *International Soil and Water Conservation Research*, 43(2):79- 87.
- Vidya, K., Sanjukta, C. and Avinanda, S. (2013). Assessment of Irrigation and Agriculture Potential Using Geospatial Techniques: A Case Study of “Bhima-Ujjani” Project. Symbiosis Institute of Computer Studies & Research, a Symbiosis International University, Pune, India bcd. Symbiosis Institute of Geo-Informatics, Symbiosis International University, Pune, India.