FUDMA Journal of Earth and Environmental Sciences (FUDJEES), Vol. 1, No. 2, 2024
Print ISSN: 1595-9686
EISSN: 1595-9708

SUGARCANE LAND USE AND WATER RESOURCES ASSESSMENT IN GAGARAWA LGA, JIGAWA STATE, NIGERIA

Tudunwada[1*] I. Y. and M. M. Maina[2]

[1]Centre for Atmospheric Research, National Space Research & Development Agency, Abuja
[2]Department of Agricultural and Environmental Engineering, Bayero University, Kano.

*Corresponding Author's email: iyakuba2@gmail.com, +2348035945174.

https://doi.org/10/33003/jees.2024.0102/02

ABSTRACT
The availability of water resources for sugarcane production in Gagarawa, Jigawa State, Nigeria, a potential area for large-scale sugarcane production, was assessed. Sugarcane (Saccharum officinarum L.), a tall perennial grass belonging to the grass family Gramineae, is a long-duration crop that produces enormous amounts of biomass. It is the major crop from which sugar is produced. With Nigeria's growing population, demand for sugar is rising, but production is low. Water resources are key to producing sugarcane. Many areas in northern Nigeria may be suitable for sugarcane, except for water availability. Remote sensing data from Landsat 7.0 and STRM 30m were used to analyse the physical land qualities. Annual rainfall (500mm) and evaporation (73.1 mm/day) were obtained from GIOVANNI & Power LARC. Infiltration and silt sedimentation were determined using soil infiltration test and siltation from runoff silt content (204mm/hr). Sugarcane water requirements and groundwater were determined using CropWat model 8. The analysis indicated that the land is perfect for rainfed and irrigated sugarcane cultivation, with an average annual rainfall of 500 mm. Sugarcane requires 2088 mm of water, resulting in a deficit of 1588 mm, which is to be supplemented by irrigation. Groundwater potential of 1239.4 mm was available but still indicates a deficit. Alternative sources to compensate for the deficit are River Hadejia and the field's construction of rainwater harvesting structures. The recommendation was to consider using surface and groundwater conservation in addition to the annual rainfall in the study area.

Keywords: Sugarcane, Water Resources, Remote Sensing and GIS

INTRODUCTION

Sugarcane (Saccharum officinarum L.), the tall perennial grass, a member of the grass family Gramineae, is the primary sugar crop from which sugar is produced. Its by-products are versatile in medicine, pharmacy, confectioneries and beverages, electricity and energy industries. Sugarcane is the raw material used for manufacturing sugar in Nigeria, accounting for about 61% of the total world sugar production (Wayagari *et al.*, 2003).

With a growing population, the demand for sugar and sugar products is expected to rise, but production seems to have stagnated for quite a while. The total refined sugar from production and import is about 720 thousand tonnes. Still, with the Nigerian population growing at 2.27%, the potential demand for refined sugar will rise to 1.6B tonnes by 2020, creating a deficit of over 1.5B tonnes. Public and private investment in the sugar sector is very low. Much of the large-scale production of sugarcane is being carried out by the two government-controlled estates, Bacita in Kwara State and Numan in Adamawa State, both of which are now undergoing a transformation from public to private ownership and are out of production (Nmadu *et al.*, 2013). Thus, it is imperative to encourage small and medium-scale production. Common problems militating against increased sugarcane production in Nigeria are capital, organised market, biotic and abiotic stresses, land fragmentation, high transportation and production costs, water, low-capacity building, lack of sugarcane growers and technologist associations, macro- and micro-environmental issues, lack of legal frameworks and lack of national and regional networking groups (Wada *et al.*, 2017).

Land use suitability assessment for crops, according to Singha and Swain (2016), is an assessment of an area to determine how proper it is for a particular use of the land for a given crop in a specific location. It requires low-cost but highly reliable data. A perfect source of such data is remotely sensed data. A combination of the spatial analysis function of a Geographic Information System (GIS) makes land suitability assessment objective, scientific and accurate by revealing spatiotemporal variation of land quality and a proper understanding of the mechanism and process of regional environmental changes induced by economic and human activities (Tashayo et al., 2020). The need to expand sugarcane cultivation, protect land resources, manage policy, and improve productivity and sustainability is assured with the integration of remote sensing and GIS for efficient and relatively cheaper data collection and analysis.

Ahmad *et al.* (2021) assessed the suitability of land for sugarcane production in Mokwa LGA, Nigeria, using the Digital Elevation Model and climatic data and discovered sugarcane influencing factors to be slope, rainfall, and temperature. Jamil *et al.* (2018) used ten site-specific criteria (rainfall, texture, drainage, soil depth, slope, distance to major road, distance to nearest sugar mill, erosion hazard, risk of flooding and pH). They applied a weighted multicriteria evaluation technique in a GIS environment to evaluate land suitability for sugarcane cultivation in Bijnor district, India. Similarly, Chen *et al. (2023)* employed an analytic hierarchy process to assess sugarcane cultivation suitability based on the requirements of sugarcane growth and development on climate, terrain, and other environmental conditions, as well as the influence of natural disasters in Guangxi Province, China. Inman-Bamber & Smith (2005) studied the water relations in sugarcane and response to water deficits to assess where knowledge of sugarcane water relations must be strengthened for progress to be made in irrigation management as well as genetic improvement and general management response to climate as well as plant and soil resources. Oliveira *et al.* (2022) assessed the impacts of sugarcane expansion on water availability in a river basin in southeastern Brazil, revealing a reduction in streamflow with sugarcane expansion.

Many areas in northern Nigeria may be suitable for sugarcane, except for water availability. This paper aims to assess the availability of water resources in the study area for profitable and sustainable sugarcane farming, promote its cultivation across the country, boost the sugar industry, fetch foreign revenue through sugar and other by-products export, and improve land productivity.

MATERIALS & METHODS

Study Area

Gagarawa is a local government area north of Jigawa State, Nigeria. Its headquarters are in the town of Gagarawa. It has an area of 654 km² and a population of 80,394 per the 2006 census. The postal code of the area is 732. Its geographical coordinates are 12° 24' 33" North, 9° 31' 39" East. It falls under the Sudano-Sahelian floodplain wetland and comprises ponds and seasonally flooded lands replenished by the annual flooding of River Hadejia, which is located in the shaded portion (Figure 1).

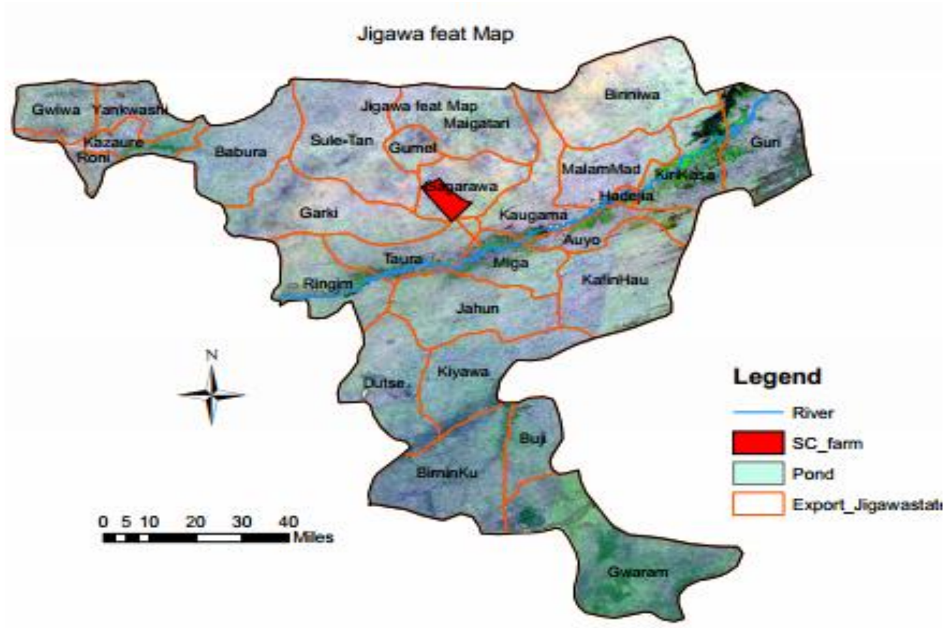

Figure 1: Map of Jigawa State Showing the Study Area

Satellite and ancillary data

Remote sensing data from Landsat 7.0 and STRM 30m (path 188, row 52 from USGS Global Visualization Viewer, GloVis of 2015) were used for the GIS analyses (elevation, pour point and flow accumulation) using ArcGIS 10.3. Annual rainfall and evaporation were obtained from archived climatic data (NASA GIOVANNI & power arc). GIOVANNI is an acronym for the Geospatial Interactive Online Visualization and Analysis Infrastructure. It is a Web-based application developed by the Goddard Earth Sciences Data and Information Services Center (GES DISC) that provides a simple and intuitive way to visualise, analyse, and access vast amounts of Earth science remote sensing data (https://giovanni.gsfc.nasa.gov/giovanni/). In contrast, Power Arc provides solar and meteorological data sets from NASA research to support renewable energy, building energy efficiency and agricultural needs (https://power.larc.nasa.gov/). CROPWAT 8, a decision support tool developed by the FAO's Land and Water Development Division, was used to determine sugarcane water requirements based on soil, climate, crop data, and groundwater (Jamshid, 2003). Infiltration and silt sedimentation were determined with an infiltrometer and siltation from runoff silt content tests, as described by Herrero et al. (2015).

RESULTS AND DISCUSSIONS

Rainfall

Gagarawa LGA has an average rainfall of 500 mm (fig. 2). For sugarcane, a total rain of 1500 to 2500 mm evenly distributed over the growing season of the area is adequate in the months of vegetative growth, followed by a dry period for ripening (FAO, 2021). During the active growth, rainfall encourages rapid cane growth, elongation and internode formation. However, during the ripening period, high rainfall is not desirable because it leads to poor juice quality, which encourages vegetative growth and the formation of water shoots and increases in tissue moisture.

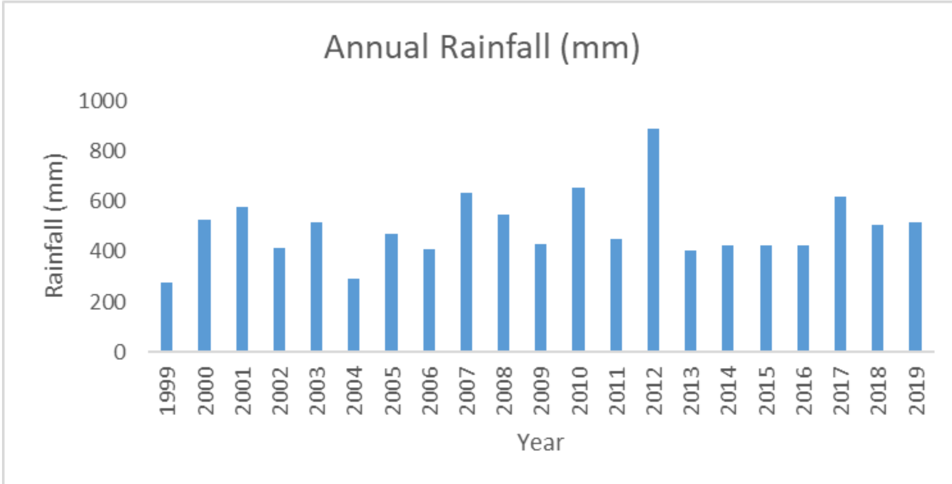

Figure 2: Average Annual rainfall of Gagarawa LGA from 1999-2019
Source: PowerLarc, 01 July 2020

Sugarcane can be grown in the area under fully irrigated farming and supplemental. irrigation during the short rainy season to be able to meet up with the water adequately Requirement of sugarcane. This will give a high-quality yield. The average yield of cane Stalk is 60–70 tonnes per hectare per year with proper cultural management, and it could be Higher even up to 150 tons per hectare per season (FAO 2019). Since the average annual rainfall of Gagarawa is about 500 mm, sugarcane needs about 2088 mm of water to mature. Therefore, a deficit of about 1588 mm must be from alternative sources (surface and/or groundwater sources). Rainfall is a significant input for CropWat.

Evapotranspiration

Evaporation occurs when liquid water is converted to water vapour and removed from the evaporating surface. Evaporation and transpiration co-occur, and there is no easy way of distinguishing between the two processes (FAO, 2019). Evapotranspiration is essential in evaluating soil water deficit and water use efficiency, especially in locations with irregularly distributed precipitation (da Costa et *al*., 2022). It is a significant input for determining sugarcane water needs in the area.

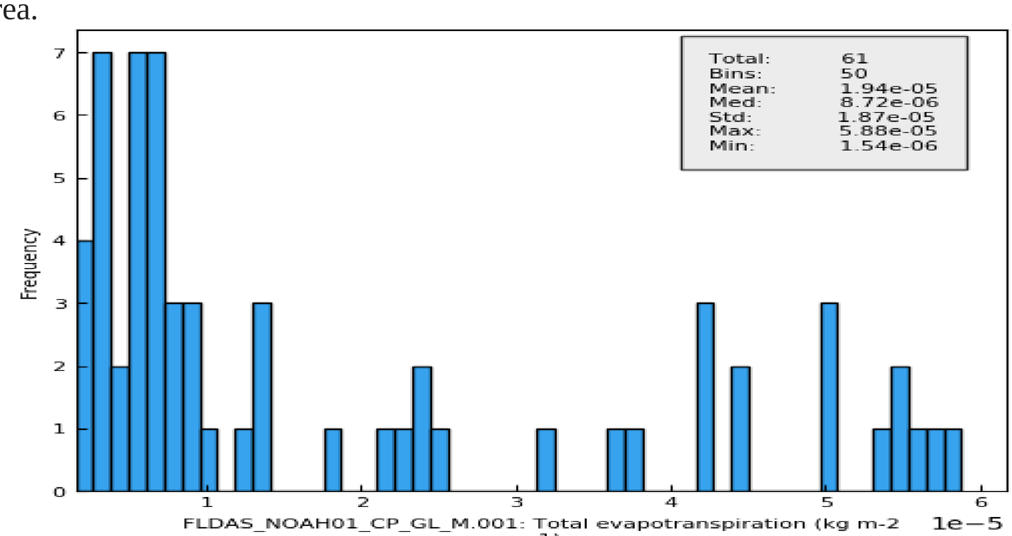

Figure 3: Total Monthly Evapotranspiration: Region 9.528E, 12.409N
Source: NASA GIOVANNI 01/012020

FUDMA Journal of Earth and Environmental Sciences (FUDJEES), Vol. 1, No. 2, 2024
Print ISSN: 1595-9686
EISSN: 1595-9708

Groundwater

A total water depth of 1239.4 mm was available from groundwater in the study area (Figures 3 & 4). This was determined using CropWat (Jamshid, 2003). Despite the potential abundance of groundwater sources in the area, there is still the need to secure additional sources for sustainable sugarcane production. The next alternative is to consider conveying water from the nearby River Hadejia and constructing a rainwater harvesting structure on the field to impound water in a surface reservoir. This amount will significantly affect the water availability for irrigation, as well as recharging the shallow aquifers for abstraction when the need Arises.

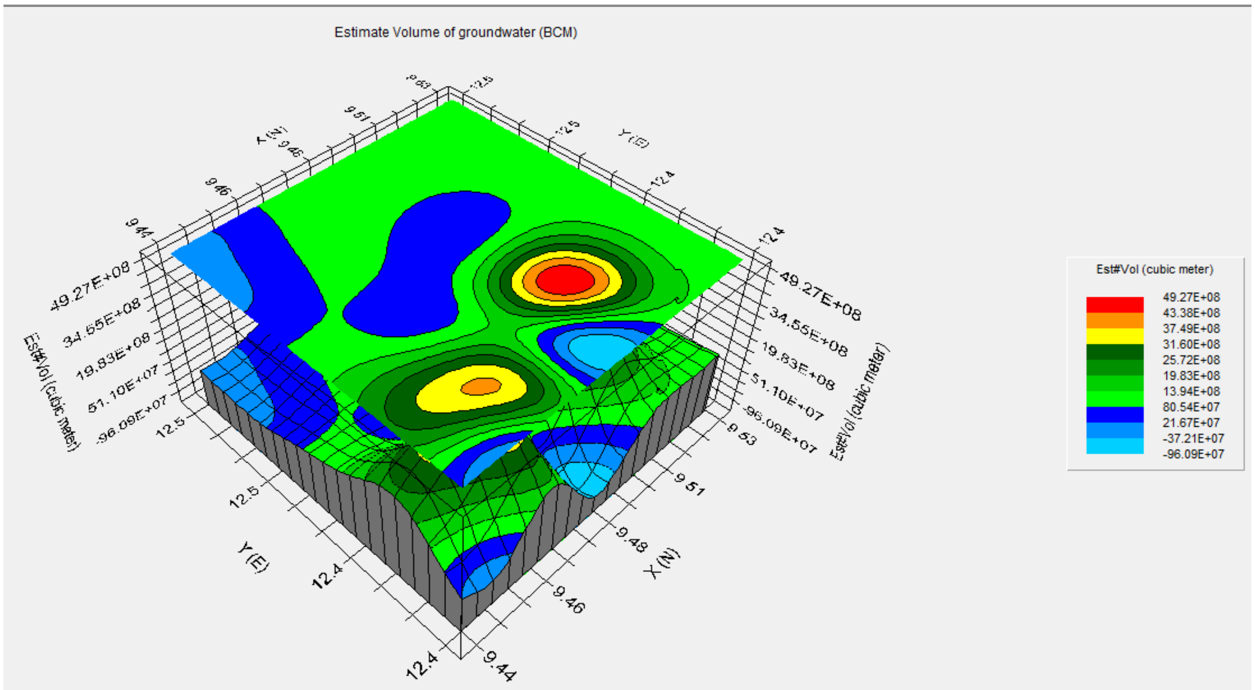

Figure 4: Estimated Volume of Groundwater in the Study Area

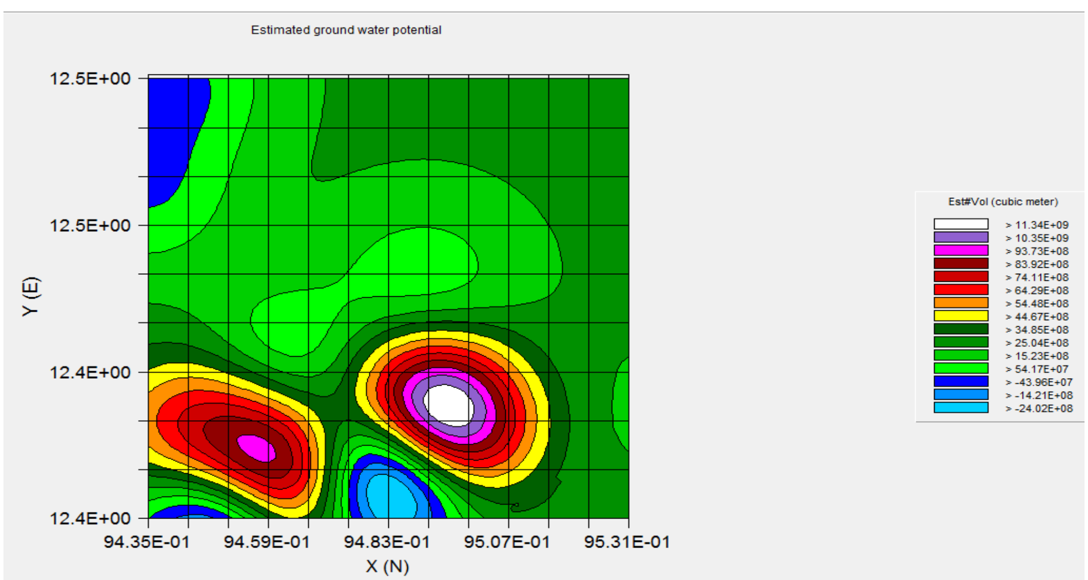

Figure 5: Estimated Groundwater Potential in the Study Area

Surface Water

Currently, there was no surface water holding structure around the study area. However, given the region's size, there is potential for developing a sizable surface water harvesting structure that can serve as both groundwater recharges and a surface reservoir to supplement rainfall in the irrigated sugarcane farms. The lowest elevation point in Figure 6 could serve as a potential reservoir for this purpose. Figures 7 & 8 further support the potential of this location as a reservoir in the study area.

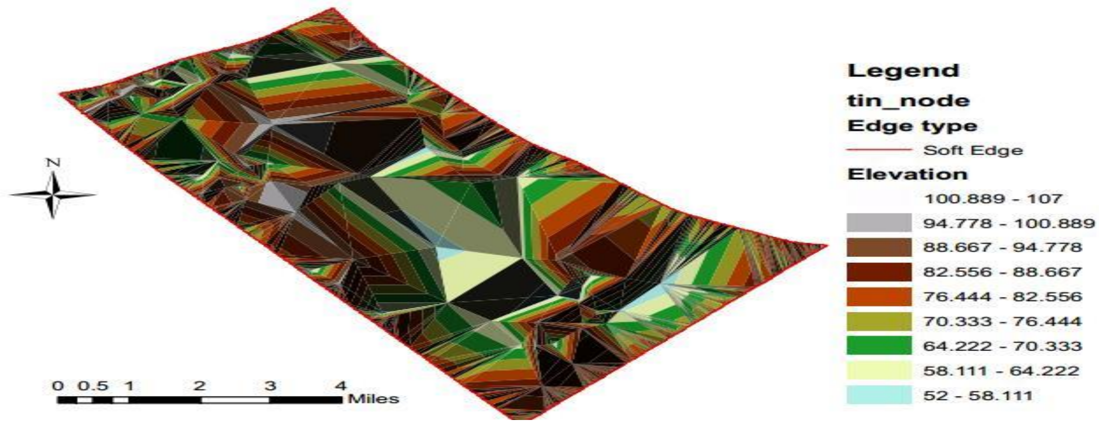

Figure 6: Surface Elevation of the Study Area

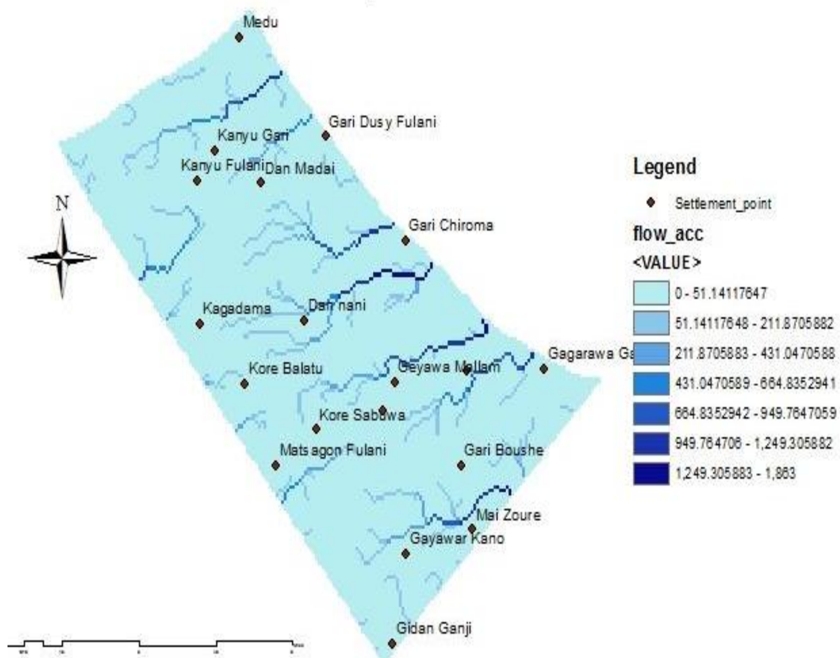

Figure 7: Flow Accumulation Map of the Study Area

FUDMA Journal of Earth and Environmental Sciences (FUDJEES), Vol. 1, No. 2, 2024
Print ISSN: 1595-9686
EISSN: 1595-9708

Figure 8: Pour Points Map of the Study Area

Alternative sources of water supply (conveying water from R. Hadejia)

Lifting water from the River Hadejia area to the farm area through the shortest distance will cover about 17 km and up to 19 km. To reduce the energy cost of pumping, a gravity flow will be enhanced by constructing a conveyance channel at a divergent angle along the direction of the flow path of the river. It will take longer than the perpendicular distance from the river. This will cover from 17 to 19 km (figure 10). The pipeline will be buffered at 5m on each side. The profile (figure 9) shows that pipes can be laid to ease water flow under low pressure with gravity since the farm level is lower than the intake point.

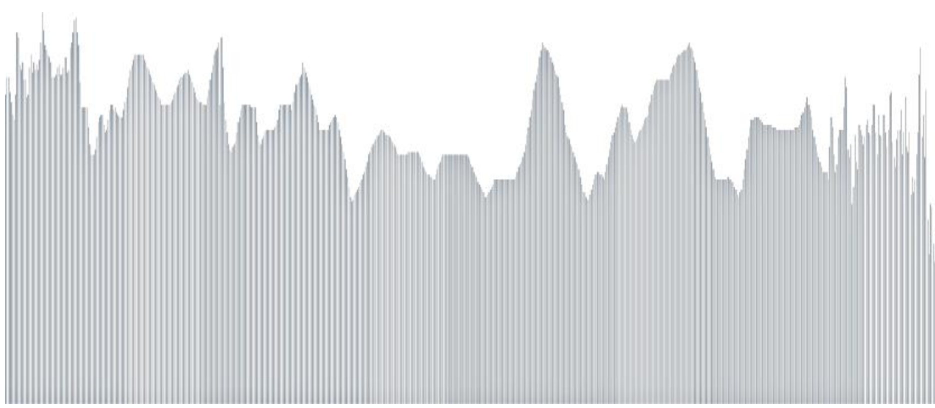

Figure 9: Isometric View of the terrain from River Hadejia to the Study Area

FUDMA Journal of Earth and Environmental Sciences (FUDJEES), Vol. 1, No. 2, 2024
Print ISSN: 1595-9686
EISSN: 1595-9708

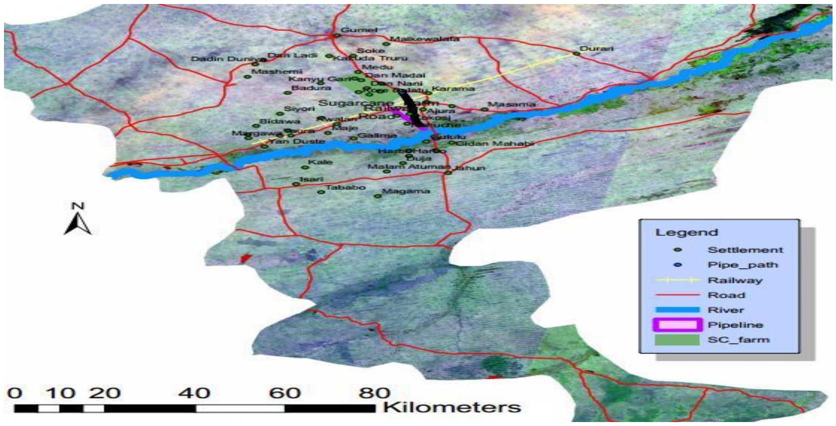

Figure 10: Proposed Conveyance Pipes From R. Hadejia to the Study Area

Infiltration and Silt Sedimentation Test

The infiltration and silt sedimentation test showed that the soils of the study area are perfect for water movement along the soil–plan continuum (204mm/hr) and can sustain rainfed and irrigated sugarcane cultivation (Hamlin, 2015).

CONCLUSION AND RECOMMENDATIONS

With a growing population, the demand for sugar and sugar products is rising in Nigeria, but production seems very low. Many areas in northern Nigeria are suitable for sugarcane production, but the main challenge is water availability. The study area was ideal for sugarcane cultivation based on climate, water availability, and soil physical properties. Alternative water sources were also identified, including conveying water from the River Hadejia and establishing a water harvesting structure (earth dams). The conveyance method and possible routing paths were also determined.

Nigeria has the potential for extensive and intensive sugarcane production. It is recommended that the government overcome the challenges outlined in this study. The challenges discovered and the remedies proposed in this study area could be applied in similar regions to boost sugarcane production, develop the sugar industry, and diversify farmers' productivity and income. Past research in sugarcane water relations has been piecemeal, especially in Nigeria. It is imperative to expand research in this area.

REFERENCES

Ahmad, A.H., Jibrin, A., Usman, I., Ya'u, S.L., Yelwa, S.A. & Ibrahim U.A. (2021). Land Suitability Assessment for Sugarcane Production in Mokwa Local Government Area, Niger State, Nigeria. *Nigerian Journal of Scientific Research,* 20(2): 2021; March –April; abu.edu.ng; ISSN-0794-0319.

Chen, S., Huichun Y., Chaojia, N., H. W. & Jingjing, W. (2023). Research on the Assessment Method of Sugarcane Cultivation Suitability in Guangxi Province, China, Based on Multi-Source Data. *Agriculture* 2023, *13*(5), 988**;** https://doi.org/10.3390/agriculture13050988

Da Costa F. M., dos Santos, S., Lyra, M.A., & Layra, G.B. *et al.* (2022) Actual Evapotranspiration for Sugarcane Based on Bowen Ratio-Energy Balance and Soil Water Balance Models with Optimized Crop Coefficients. *Water Resour Manage* **36**, 4557–4574 (2022).

FAO (2019). Land and Water, Sugarcane. *Food & Agricultural Organization of the United Nations Report, 2019.*

FAO (2021). Water Relations and Water Management of Sugarcane. *Food & Agricultural Organization of the United Nations Report, 2021*.

Hamlin, M. S. (2015). Measuring Soil Infiltration Rates in Cultivated Land: A Case Study of Ifakara, Tanzania. *Master's Thesis Physical Geography and Quaternary Geology, 30 Credits. Department of Physical Geography. Stolkholm University.* NKA 123 2015**.**

Herrero, A. Céline B., Camenen, B. (2015). Laboratory Analysis on Silt Infiltration into a Gravel Bed. *36th IAHR World Congress, Jun 2015, Delft - La Haye, Netherlands*. 9. ffhal-01362691.

Inman-Bamber, N.G. and Smith, D.M. (2005). Water Relations in Sugarcane and Response to Water Deficits. *Field Crops Research*. Volume 92, Issues 2–3, 14 June 2005, Pages 185-202

Jamil, M. Ahmed, R. and Sajjad, H. (2018). Land Suitability Assessment for Sugarcane Cultivation in Bijnor District, India Using Geographic Information System and Fuzzy Analytical Hierarchy Process. *Geo Journal* Vol. 83, No. 3 (2018), pp. 595-611. Published By Springer.

Jamshid, Y. (2003). The Integration of Satellite Images, GIS & CropWat Model to Investigate Water Balance in an Irrigated Area: A Case Study of Salmas & Tassoj Plain, Iran. *M.Sc. Thesis, ITC, Enschede, Netherlands.*

Nmadu, J.N., Akindele, O. and Ibrahim, F. (2013) Prospects of Sugar Production and Imports: Meeting the Sugar Demand of Nigeria by Year 2020. *Russian Journal of Agricultural and Socio-Economic Sciences.* February 201314(2):15-25.

Oliveira, K.D., Tomasella, J., Caram, R., Falck, A.S. and Sanchez, I.D. (2022). Impacts of Sugarcane Expansion on Water Availability in a River Basin in Southeastern Brazil. *CATENA*, Volume 216, Part B, September 2022, 106437.

Singha, C. & Swain, K.C. (2016). Land Suitability Evaluation Criteria for Agricultural Crop Selection: A Review. *Agricultural Reviews*, 37(2): 125-132. Retrieved from www.arccjournals.com/journal/agriculturalreviews/R-1588

Tashayo, B., Honarbakhsh, A., Akbari, M. & Eftekhari, M. (2020). Land Suitability Assessment for Maize Farming Using a GIS-AHP Method for a Semi-Arid Region of Iran. *Journal of the Saudi Society of Agricultural Sciences*, 19: 332-338. doi: https://doi.org/10.1016/j.jssas.2020.03.003.

Wada, A. C., Abo-Elwafa, A., Salaudeen M. T., Bello L. Y. and Kwon-Ndung E. H. (2017). Sugarcane Production Problems in Nigeria and Some Northern African Countries. *Direct Research Journals* Vol.5 (3), pp. 141-160, March 2017 ISSN 2354-4147.

Wayagari, J.W., Ayoola,.G.B., Imolehin, E.D. and Misari, S.M.(2003): Economic Evaluation of Chewing Sugarcane Production in the Central Zone of Nigeria. *Sugar Tech-,* vol. 5 (1 and 2): 81-84.