Impact of Effective Rainfall on Crop and Irrigation Water Requirements of FARO-59 Rice in Edo State, Nigeria

Edith Oyati Nwabuogo [1], Akinbile Christopher Oluwakunmi [2], Ibrahim Rasheed [1], Olotu Yahaya [1], Audu Lukman Muhammed [1]

[1] *Auchi Polytechnic*
Along Benin-Okene Road, P. M. B. 13, Auchi, Edo State, Nigeria

[2] *The Federal University of Technology, Akure*
P. M. B. 704, Akure, Ondo State, Nigeria

DOI: 10.22178/pos.124-80

LCC Subject Category: T1-995

Received 25.10.2025
Accepted 28.11.2025
Published online 30.11.2025

Corresponding Author:
Ibrahim Rasheed

Abstract. Efficient planning of irrigation systems, especially in rainfed rice cultivation, depends on accurate estimates of effective rainfall and crop water requirements. This study evaluated the effective rainfall, crop water requirements, and irrigation requirements of FARO-59 rice cultivated on two contrasting soils—loamy sand (Auchi) and silty loam (Agbede) in Edo State—using four CROPWAT estimation methods for effective rainfall (fixed percentage, empirical formula, United States Department of Agriculture, and Food and Agriculture Organization of the United Nations) implemented in CROPWAT 8.0. The characterisation of soil samples revealed significant differences between the reference locations, with higher total available moisture (153 mm/m), lower infiltration rate (17 mm/day), and deeper rooting depth (24.3cm) recorded for silt loam soil at Agbede compared with loamy sand soil at Auchi. The effective rainfall varied significantly among the methods, with FP and EF (488.30 mm and 482.70 mm, respectively) the highest, while USDA estimated the lowest (383.40 mm). Across all methods and locations, the crop water requirements were similar, ranging from 316.30 to 317.30 mm, indicating that the seasonal rainfall distribution adequately supported the crop water demand of FARO-59 rice. A minimal or zero irrigation water requirement for most methods was estimated, except for a slight increase in supplemental irrigation need (12.20 mm) estimated by FAO. This study revealed that the choice of method significantly affects the estimation of effective rainfall with little or no influence on the crop water requirements of FARO-59 rice under intense rainfall conditions in Edo State, Nigeria. The results of this study provide a helpful baseline for optimising FARO-59 water-use efficiency and a valuable guide for informed irrigation scheduling in similar agroecological zones.

Keywords: FARO-59; crop coefficient; wilting point; CLIMWAT 2.0; CROPWAT 8.0.

INTRODUCTION

Due to population growth, competition for food production is increasing alarmingly, necessitating a practical approach to managing water, especially for rice cultivation [1, 2]. Rice is one of the most crucial staple grains worldwide, providing nutritional value to half of the global population [3]. However, rice cultivation is characterised by high water requirements, with most of the cultivation period requiring substantial water [4]. Optimising irrigation strategies requires understanding variations in rice water requirements; this will be useful in dynamic climates where fluctuations in humidity, temperature, and rainfall drastically affect crop yields.

The total water required by crops to grow well in the field is called crop water requirement and is expressed as ETc. It accounts for the total amount of water released by plant bodies and the soil surface. Across the different growth stages of rice, such as germination, tillering, flowering, and ripening, water requirements differ [5]. The periods of peak water demand are critical for stem and grain development and typically coincide with the tillering, jointing, and booting stages. In contrast, a reduction in water level may occur at maturity [6]. Inadequate water supply during these stages can severely affect rice yield; approximately 165 mm is required during the tillering stage, and about 170 mm during the heading stage [7]. About 4,000–6,000 m^3/ha of water is needed annually for rice production; this depends on factors such as soil type, local climate, management practices, and cultivar selection [8].

Over the past three decades, researchers have developed several advanced and novel methods for irrigation scheduling. Despite these advances, farmers worldwide have shown low acceptance of these methods because they lack access to weather data and soil parameters and have limited technical know-how. Farmers are confused about how to make the right decision and do not understand how to find deep solutions to the complexity associated with different scheduling techniques [9]. Also, the failure of researchers to understand farmers' constraints and the contexts in which they operate is another challenge [10]. The primary occupations of the people living in Edo State, Nigeria, are the cultivation of vegetables, paddy and other crops. Paddies are the most cultivated crop in this district; rice production has been their primary source of food and economic survival. The erratic rainfall pattern and scarcity of irrigation facilities and water have seriously affected rice cultivation in this region, thereby affecting rice production, income generation, and overall life.

Therefore, adopting innovations and improvements in rice cultivation to address water scarcity is crucial to achieving optimal yields. The accessibility to data on effective rainfall, crop and irrigation water requirements of upland rice on a regional scale (Etsako West, Edo State) is scarce and lacking; hence, this study investigated the effects of different effective rainfall methods for estimating the crop and irrigation water needs of FARO-59 rice in Auchi and Agbede, Edo State, Nigeria; this will be a helpful guide for the efficient use of water through irrigation systems and for improving the yield of FARO-59 upland rice in the region in a sustainable manner.

METHODS

Study area. The administrative headquarters of Etsako-West Local Government Area of Edo State is Auchi, about 130 km from Benin City. Geographically, it is situated between latitude 05° 40' 42″N and longitude 06° 23' 41″E and latitude 05° 43' 18″N and longitude 06° 26' 61″E of the Greenwich meridian [11]. Auchi has an average temperature range of 28–32 °C. The region experiences rainfall between April and October; the rainfall pattern is bimodal, with the first peak in May-June, a late peak in September-October, and a brief dry spell in August. The mean annual rainfall ranges from 180 mm to 200 mm. Longitude (06016.3E, 06018.7E) and latitude (06052.2N, 06055.4N) represent the location of Agbede in Edo State. Surface runoff from streams and rivers in the neighbouring communities of Auchi, Warake, Ewu, Ewora, Jagbe, and Idoa creates the Agbede wetlands [12]. Agbede experiences a short dry season and a long wet season, with typical rainforest vegetation. The wet season in Agbede lasted 7 months, usually from April to October of each year, with heavy rainfall between July (462 mm) and August (359 mm). The relative humidity ranges between 75% and 90% during the wet season. The dry season spans five months, with a reduction in precipitation (from 99.8 to 22.3 mm). Agbede experiences a mean annual temperature of 25-33 °C, which is high during the driest period of the season [13].

CROPWAT 8.0. According to FAO, CROPWAT 8.0 is a decision-support system developed for various purposes, including the estimation of reference evapotranspiration (ET0), consumptive water use, and the net and gross irrigation water requirements of other crops.

Study data. Average monthly rainfall, maximum and minimum temperature, relative humidity, sunshine hours, and wind speed are the climate data used in the study. They were sourced from historical data in CLIMWAT 2.0 for use in CROPWAT 8.0. The researchers used soil data collected from the reference locations for analysis and interpretation in CROPWAT, and they selected the FARO-59 upland rice variety for the study.

Estimation of Rereference evapotranspiration (ET_0). Reference evapotranspiration (ET_0) was determined using climate parameters such as relative humidity, precipitation, reference evaporation, solar radiation, wind speed, and air temperature (minimum and maximum). These meteorological parameters provided the input data for the estimation of the FAO Penman Monteith Method (Equation 1), which was subsequently programmed for the computation of reference evapotranspiration (ET_0) by the CROPWAT 8.0 interface:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \; (mmday^{-1}) \quad (1)$$

According to [14] and as presented in equations 1, 2, ad 3, reference evapotranspiration ($mmday^{-1}$) is represented by ET_0; Net radiation at the crop surface ($MJm^{-2}day^{-1}$) is represented with R_n; soil-heat-flux density ($MJ\,m^{-2}\,day^{-1}$) is taken as zero in daily ET calculations because its magnitude is negligible at that time scale and is represented with G; mean daily air temperature recorded 2m above ground (°C) is represented with T; wind speed at the same height (ms^{-1}) is represented with U_2; the saturation and actual vapour pressures (kPa) are represeted with e_s and e_a, respectively; vapour pressure was derived from the difference between ($e_s - e_a$) in kPa; Δ is the slope of the saturation-vapour-pressure curve with respect to temperature ($kPa°C^{-1}$); and the psychrometric constant is represented with γ ($kPa°C^{-1}$).

$$ET_c \text{ (Crop water requirements)} = ET_0 \times K_c \times A \text{ (mm/day)} \quad (2)$$

where ET_c is the crop coefficient, ET_0 is the reference evapotranspiration, K_c is the crop factor or coefficient, and A is the planting area. The crop factor for rice was selected in accordance with FAO recommendations.

$$IWR_{rice} = ETc_{rice} - Eff_{rainfall} \quad (3)$$

where IWR_{rice} is the irrigation water requirement of rice; ET_c is the crop water requirement; $Eff_{rainfall}$ is the effective rainfall.

$$TAM = (FC - WP) \times D \quad (4)$$

where TAM in the soil for the crop during the growing season (mm/m), WP = wilting point (θwp), D = current rooting depth of the crop (m) while readily available moisture (RAM) (in mm) is calculated as:

$$RAM = TAM \times P \quad (5)$$

where P is the depletion fraction, mm/m.

Data Analysis. In this study, the water-can sprinkler irrigation method for FARO-59 rice was adopted as a small-scale irrigation system in Auchi and Agbede towns and used as a reference for investigating the impact of effective rainfall on crop and irrigation water requirements using CROPWAT 8.0. In this study, the researchers adopted the following procedures and assumptions:

1) The researchers selected the FARO-59 upland rice variety and a common planting date (17 April 2025) for both Auchi (loamy sand) and Agbede (silty loam soil).

2) Soil types of the selected areas (Auchi and Agbede towns) for each scheme were used.

3) Following FAO recommendations, the researchers adopted crop coefficients (Kc) of 1.05 for the initial stage, 1.20 for the mid-season stage, and 0.60 for the late-season stage of rice cultivation.

4) Critical depletion fraction from initial to mid-season was (0.45) and harvest (0.50).

5) Yield response factors at the initial stage (0.20), development stage (0.80), mid-season (0.60), and late stage (0.20) were adopted [15, 16].

6) To compare the results, the researchers estimated the effects of four built-in effective rainfall methods in CROPWAT 8.0 (fixed percentage, empirical formula, USDA, and FAO) on the crop water and irrigation requirements of FARO-59 rice, as illustrated by the stepwise approach in Figure 1.

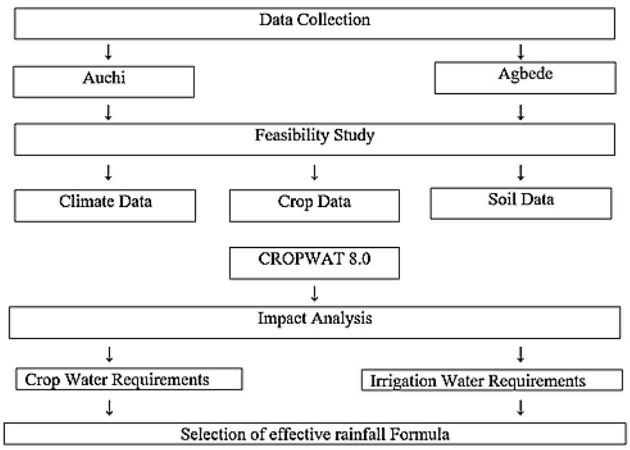

Figure 1 – Summary of the chart for experimental procedure

Plate 1 – Initial growth stage of rice

Plate 2 – Developmental growth stage of rice

Plate 3 – Mid-season growth stage of rice

Plate 4 – Late-season growth stage of rice

RESULTS AND DISCUSSION

Climate Data. Historical or reference meteorological data, including maximum and minimum temperatures (°C), relative humidity (%), wind speed (m/s), rainfall (mm), and sunshine duration (hours), were downloaded from CLIMWAT 2.0 for the CROPWAT 8.0 interface.

Crop Data. When assessing reference evapotranspiration from the field, the researchers considered the crop type and variety, development stage, critical depletion fraction, yield response factor, and crop height. As stated earlier, they based the crop coefficient (Kc) values on FAO recommendations for rice production [15]. Using this information, the researchers established the crop data.

Soil Data. One of the crucial modules for input in CROPWAT 8.0 is soil data, including parameters such as total available water (TAW), maximum infiltration rate, maximum rooting depth, initial soil moisture depletion, and initial available soil moisture. Auchi is located in the northern parts of Edo State, and the predominant soil groups in this district are loamy sand (LS), sandy loam (SL), and sandy soil (S), which contain about 82-90% sand. In this study, the soil texture at Auchi is loamy sand, with 82–84% sand. Poor nitrogen levels and soil fertility are characteristics of the experimental plot, due to its poor nutrient and water retention capacity. A higher proportion of silt (62–65%) and improved soil fertility are estimated for the silty loam of Agbede compared to the loamy sand of Auchi soil. The experimental plot dimensions at the two locations were 10 x 10 m, with a 1 x 1 m allowance for treatment size. Twenty-five stands of FARO-59 rice were planted in the plot, with 1 m x 1 m alleyways separating the treatments and replicates. The researchers used a spacing of 20 cm × 20 cm for planting upland rice [17], and they present the estimated values for the contrasting soil parameters in Table 1.

Table 1 – Estimated soil parameters for Auchi and Agbede soil

Soil parameters	Loamy sand (Auchi)	Silty loam (Agbede)
Total available moisture (mm/m)	96.0	153.0
Maximum Infiltration rate (mm/day)	30.0	17.0
Maximum rooting	21.0	24.3

Soil parameters	Loamy sand (Auchi)	Silty loam (Agbede)
depth (cm)		
Initial soil moisture depletion (%TAM)	0.0	0.0
Initial available soil moisture (mm/m)	96.0	153.0

Trends of Effective Rainfall for FARO-59 Rice for the Planting Period. In Table 2, the effective rainfall estimates for FARO-59 rice showed variations across the four methods, reflecting differences in estimation techniques, whereas the reference locations (Auchi and Agbede) yielded identical values. The highest total effective rainfall (488.30 mm and 482.70 mm) was estimated for the fixed percentage (FP) and empirical formula (EF) methods, suggesting that both approaches contribute more rainfall to the crop water supply. In contrast, the USDA estimated the lowest total seasonal effective rainfall (383.40 mm), indicating a more conservative assessment of rainfall availability. An intermediate value (421.90 mm) was calculated by FAO, indicating that the estimated outcome lies between the high FP/EF values and the low USDA values. Generally, rainfall increased from the initial to the late growth stages. The selected effective rainfall methods significantly influenced the computed values, whereas differences in soil texture between Auchi and Agbede had no significant effect under the given conditions.

Table 2 – Effective rainfall values for FARO-59 rice for Auchi (loamy sand) and Agbede (silty loam)

DAYS	GS	FP (AU)	FP (AG)	EF (AU)	EF (AG)	USDA (AU)	USDA (AG)	FAO (AU)	FAO (AG)
Apr2	Ini	17.50	17.50	18.00	18.00	16.20	16.20	14.30	14.30
Apr3	Ini	45.10	45.10	46.20	46.20	41.30	41.30	37.10	37.10
May1	Dev	44.90	44.90	46.00	46.00	41.30	41.30	36.90	36.90
May2	Dev	46.20	46.20	47.10	47.10	42.20	42.20	38.20	38.20
May3	Dev	53.00	53.00	53.00	53.00	44.80	44.80	45.00	45.00
Jun1	Mid	59.40	59.40	58.70	58.70	47.90	47.90	51.40	51.40
Jun2	Mid	65.20	65.20	63.70	63.70	50.50	50.50	57.20	57.20
Jun3	Late	75.40	75.40	72.70	72.70	51.60	51.60	67.40	67.40
Jul1	Late	81.60	81.60	77.40	77.40	47.70	47.70	74.40	74.40
	TOTAL	488.30	488.30	482.70	482.70	383.40	383.40	421.90	421.90

Notes: GS (growth stage), FP (Fixed percentage), EF (Empirical formula), USDA (United States Department of Agriculture), FAO (Food and Agriculture Organisation of the United Nations), AU (Auchi), AG (Agbede)

Crop Water Requirements of FARO-59 Rice for Loamy Sand and Silty Loam Soil. Table 3 presents the crop water requirement (CWR) for FARO-59 rice at the reference locations. The researchers obtained similar values across the four methods used to estimate effective rainfall (FP, EF, USDA, and FAO), with no variation in the calculated results. They consistently recorded higher CWR in the loamy sand soil of Auchi than in the silty loam soil of Agbede because the loamy sand has a lower water-holding capacity. From the initial to mid-season stage, CWR increased, then declined toward maturity. The values of 317.30 mm (Auchi) and 316.30 mm (Agbede) were recorded as total CWR, suggesting minor differences for the reference locations considered. Table 3 reveals that soil texture slightly influenced CWR, whereas the choice of effective rainfall method did not significantly affect CWR under the given conditions.

Table 3 – Crop water requirements values for FARO-59 rice for Auchi (loamy sand) and Agbede (silty loam)

DAYS	GS	FP (AU)	FP (AG)	EF (AU)	EF (AG)	USDA (AU)	USDA (AG)	FAO (AU)	FAO (AG)
Apr2	Ini	16.90	16.90	16.90	16.90	16.90	16.90	16.90	16.90
Apr3	Ini	41.70	41.60	41.70	41.60	41.70	41.60	41.70	41.60
May1	Dev	41.40	41.40	41.40	41.40	41.40	41.40	41.40	41.40
May2	Dev	41.40	41.30	41.40	41.30	41.40	41.30	41.40	41.30
May3	Dev	44.60	44.50	44.60	44.50	44.60	44.50	44.60	44.50

DAYS	GS	FP (AU)	FP (AG)	EF (AU)	EF (AG)	USDA (AU)	USDA (AG)	FAO (AU)	FAO (AG)
Jun1	Mid	39.60	39.50	39.60	39.50	39.60	39.50	39.60	39.50
Jun2	Mid	38.30	38.10	38.30	38.10	38.30	38.10	38.30	38.10
Jun3	Late	34.10	33.90	34.10	33.90	34.10	33.90	34.10	33.90
Jul1	Late	19.30	19.10	19.30	19.10	19.30	19.10	19.30	19.10
	TOTAL	317.30	316.30	317.30	316.30	317.30	316.30	317.30	316.30

Notes: GS (growth stage), FP (Fixed percentage), EF (Empirical formula), USDA (United States Department of Agriculture), FAO (Food and Agriculture Organisation of the United Nations), AU (Auchi), AG (Agbede)

Irrigation Water Requirements of FARO-59 Rice for Loamy Sand and Silty Loam Soil. Minimal irrigation water requirements (IWR) for FARO-f59 rice across all methods were recorded (Table 4), indicating effective rainfall during the growth stage. Throughout the planting period at both locations, zero irrigation was estimated for FARO-59 rice using the Fixed Percentage (FP) and Empirical Formula (EF) methods, indicating that rainfall supply fully met the water needs of FARO-59 rice. A negligible irrigation requirement of 0.50 mm (Auchi) and 0.40 mm (Agbede) was estimated by the USDA. In contrast, the FAO method yielded the highest IWR value (12.20 mm), especially during the early stage of development. These differences suggested that, despite sufficient rainfall, the FAO reported a more conservative method for estimating effective rainfall, resulting in slightly higher requirements for supplemental irrigation systems. Also, the loamy sand of Auchi and the silty loam of Agbede consistently yielded identical IWR values across methods. Across all methods, the results suggest that cultivation of FARO-59 rice can be practised under the reference climatic conditions, with little to no irrigation required in a well-distributed rainfall pattern.

Table 4 – Irrigation water requirements of FARO-59 rice for Auchi (loamy sand) and Agbede (Silty loam)

DAYS	GS	FP (AU)	FP (AG)	EF (AU)	EF (AG)	USDA (AU)	USDA (AG)	FAO (AU)	FAO (AG)
Apr2	Ini	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr3	Ini	0.00	0.00	0.00	0.00	0.40	0.30	4.50	4.50
May1	Dev	0.00	0.00	0.00	0.00	0.10	0.10	4.50	4.50
May2	Dev	0.00	0.00	0.00	0.00	0.00	0.00	3.20	3.20
May3	Dev	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun1	Mid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun2	Mid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun3	Late	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul1	Late	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL	0.00	0.00	0.00	0.00	0.50	0.40	12.20	12.20

Notes: GS (growth stage), FP (Fixed percentage), EF (Empirical formula), USDA (United States Department of Agriculture), FAO (Food and Agriculture Organisation of the United Nations), AU (Auchi), AG (Agbede)./

CONCLUSIONS

Despite differences in total available moisture, rooting depth, and infiltration rates across the contrasting soils considered in this study, identical seasonal crop water requirements were observed across locations, suggesting that soil textural classification has little effect under the prevailing rainfall conditions. Substantial variations among methods were observed in rainfall adequacy, but rainfall met crop water needs, resulting in little or no irrigation for most methods. These findings highlighted the importance of choosing an appropriate, effective rainfall method for accurate water management planning and the relevance of using CROPWAT to support irrigation decisions in rainfed rice systems. This study provides a helpful guide for improving water use efficiency and sustainable upland rice production in Edo State and similar agroecological zones. Future research should focus on field validation and assessment of irrigation needs, as well as on the cultivation of FARO-59 rice under dry-season conditions.

Acknowledgements

The Tertiary Education Trust Fund (TetFund - Nigeria) under the Institutional-Based Research Scheme (IBR) and the approval of Auchi Polytechnic, Auchi, Edo State, Nigeria, is hereby acknowledged for providing the needed funds for the execution of this study.

Conflict of interest

The authors declare no conflict of interest that may be attributed to any information reported in this study.

REFERENCES

1. Bwire, D., Saito, H., Sidle, R. C., & Nishiwaki, J. (2024). Water Management and Hydrological Characteristics of Paddy-Rice Fields under Alternate Wetting and Drying Irrigation Practice as Climate Smart Practice: A Review. *Agronomy, 14*(7), 1421. doi: 10.3390/agronomy14071421
2. Jaibumrung, K., Nilsalab, P., Gheewala, S. H., & Musikavong, C. (2023). Ecological footprint, water scarcity footprint, and benefit-to-cost ratio analysis for sustainable rice production in Thailand. *Sustainable Production and Consumption, 39*, 79–92. doi: 10.1016/j.spc.2023.04.019
3. FAO. (2022). The State of Agricultural Commodity Markets 2022. In *FAO eBooks*. doi: 10.4060/cc0471en
4. Darzi-Naftchali, A., & Karandish, F. (2017). Adapting rice production to climate change for sustainable blue water consumption: an economic and virtual water analysis. *Theoretical and Applied Climatology, 135*(1–2), 1–12. doi: 10.1007/s00704-017-2355-7
5. Rezaee, L., Davatgar, N., Moosavi, A. A., & Sepaskhah, A. R. (2023). Implications of spatial variability of soil physical attributes in delineating Site-Specific irrigation management zones for rice crop. *Journal of Soil Science and Plant Nutrition, 23*(4), 6596–6611. doi: 10.1007/s42729-023-01513-y
6. Ahmad, M. J., & Choi, K. (2021). Climate-Induced perspective variations in irrigation schedules and design water requirements for the Rice–Wheat system. *Agronomy, 11*(10), 2006. doi: 10.3390/agronomy11102006
7. Luo, W., Chen, M., Kang, Y., Li, W., Li, D., Cui, Y., Khan, S., & Luo, Y. (2021). Analysis of crop water requirements and irrigation demands for rice: Implications for increasing effective rainfall. *Agricultural Water Management, 260*, 107285. doi: 10.1016/j.agwat.2021.107285
8. Hashemi, S., Darzi-Naftchali, A., Karandish, F., Ritzema, H., & Solaimani, K. (2024). Enhancing agricultural sustainability with water and crop management strategies in modern irrigation and drainage networks. *Agricultural Water Management, 305*, 109110. doi: 10.1016/j.agwat.2024.109110
9. Stirzaker, R. J., Stevens, J. B., Annandale, J. G., & Steyn, J. M. (2009). Stages in adopting a wetting front detector. *Irrigation and Drainage, 59*(4), 367–376. doi: 10.1002/ird.472
10. Vanclay, F. (2004). Social Principles for Agricultural Extension to Assist in the Promotion of Natural Resource Management. *Australian Journal of Experimental Agriculture, 44*(3), 213–222. doi: 10.1071/ea02139
11. Olatunde, M. B., Olatunde, F. O., & Oriakhi, H. E. (2022). Street guide mapping of Auchi, Edo state, Nigeria. *Studia Universitatis Babeș-Bolyai Engineering*, 136–148. doi: 10.24193/subbeng.2022.1.13
12. Olomukoro, J., Ajayi, S., Osibanjo, O., Alabaster, J., Lioyd, R., Cude, C., Ehaise, F., Anyasi, C., Emere, M., Nasiru, C., Essien-Ibok, M., Akpan, A., Udo, M., Chude, L., Umoh, I., Asuquo, I., Fagbote, E., Olanipekun, E., Uyi, H., & Dimari, G. (2015). Investigation of the water quality of two rivers in Agbede –Wetlands in Southern Nigeria. *Global NEST Journal, 17*(3), 451–462. doi: 10.30955/gnj.001420

13. Ozegin, K. O., Ataman, J. O., & Okolie, E. C. (2017). Prospecting for metallic mineral deposits using integrated electromagnetic and electrical resistivity tomography in Agbede, Edo State, Nigeria. *Scientia Africana, 16*(2), 269–281.

14. Oyedokun, J. O., Omobowale, M. O., & Raphael, O. D. (2023). Determination of crop growth specific coefficients and water requirement of okra (Abelmoschus esculentus) under greenhouse conditions in Ibadan, Nigeria. *Journal of Applied Sciences and Environmental Management, 27* (12).

15. Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (1998). Crop Evapotranspiration-Guidelines For Computing Crop Water Requirements-FAO Irrigation And Drainage Paper 56. *FAO.*

16. Akinbile, C. O., Ogundipe, A., & Davids, R. O. (2020). Crop water requirements, biomass and grain yields estimation for upland rice using CROPWAT, AQUACROP and CERES simulation models. *Agricultural Engineering International: The CIGR e-journal, 22*(2), 1–20.

17. Akinbile, C. O., Eze, R. C., Ewulo, B. S., & Abolude, A. T. (2023b). Assessing the combined effects of biochar concentrations and different fertiliser applications on physicochemical properties of a sandy loamy soil. *Ife Journal of Science, 25*(1), 045–057. doi: 10.4314/ijs.v25i1.6