# Agricultural Water Management for Rice Production: A Comprehensive Analysis

**Ohaji Evans Chukwudi Paulinus (B.Eng, M.Eng, PhD),**
Civil Engineering Department,
University of Agriculture and Environmental Sciences (UAES),
Umuagwo, Imo State-Nigeria
evans.ohaji@uaes.edu.ng

**Mahmud Hussaini (HND, B.Sc. PGD, M.Eng)**
Civil Engineering Department, Federal Polytechnic,
Bali, Taraba State

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***Abstract***

*The identified problem revolves around establishing the water requirements for rice seeding, growth, and maturity in hot climatic conditions. This study reviews the net water requirement for rice growth or production under various climatic conditions in the Cross River Basin. It was observed that the water requirement from seeding to harvest varies from location to location, maintaining a FAO range, as postulated by Brouwer et al., 1986, ultimately falling between 450mm to 700mm for hot weather.The methodology used for investigating the Net Irrigation Water Requirements for rice growth to maturity involves the application of New_Clim Location and CropWater software. These tools were utilized to compute Reference Evapotranspiration (ETo) and Crop Water Requirements (CWR) for the net irrigation water requirements of rice, respectively. The data were obtained from meteorological stations within the Cross River Basin. In rainfed conditions, no water stress is practically observed throughout the entire crop cycle, affirming that no irrigation system is needed in such a specific climate. This study uses data generated through New_LocClim as input into CropWat, which, among other factors, determines the net water requirement for rice growth and production. Consequently, the results obtained from the use of the CropWat model in determining rice water requirements for Obudu, Nkari, Ikom, and Ijegu-Yala were 633.7 mm, 397.9 mm, 303.0 mm, and 548.4 mm, respectively. The water requirement of only two locations, Obudu and Ijegu-Yala, fell within the FAO-suggested range of 450 mm to 700 mm (Brouwer et al., 1986) for hot climates, while Nkari and Ikom LGAs did not comply with Brower et al., 1986 postulation due to their location in a relatively less hot climate.*

***Keywords:*** *Keywords: Rice water requirements, Hot climatic conditions, Net Irrigation Water Requirements, CropWat model, New_Clim Location, Crop Water Requirements (CWR)*

**1. Introduction:**

Rice cultivation, a water-intensive practice, necessitates efficient water management for optimal yields. This section reviews multiple studies focusing on water distribution, crop performance, and overall agricultural productivity. Satellite data analyses by Sakthivadivel et al. (1999), Mandavia (1998), Thiruvengadachari and Sakthivadivel (1997), and Shanan (1992) contribute insights into water management practices. Efficient water management practices are crucial for rice cultivation. The section emphasizes the flooded fields in bunded rice cultivation, highlighting the global water scarcity context. On average, 1,432 liters of water are needed to produce 1 kg of rice. The study focuses on the Cross River watershed, spanning latitudes 4.8°N to 6.85°N and longitudes 7.84°E to 9.84°E. Bounded by the lower Benue basin to the north, the Anambra-Imo basin to the west, the Niger Delta basin to the southwest, and the United Republic of Cameroon to the east, it includes parts of Akwa-Ibom and Cross River states in southeastern Nigeria. Encompassing 28,620.33 $km^2$, the main drainage systems include the Cross, Great, and Little Kwas, Calabar, AkpaYafe, Kwa Ibo, and Imo rivers. With a tropical rainy climate, the Cross River basin experiences high rainfall (ranging from 1250mm to 4000mm per annum), elevated temperatures (22.8°C to 30.8°C), and high relative humidity. Groundwater resources vary, with coastal plain aquifers composed of sands, clay, and gravel, featuring a near-surface water table. Artesian flow strength fluctuates with the tide, and in the north of the coastal plain, the water table is up to 50m below the surface. The study applies the methodology to the cultivation of rice, a typical hot climate crop, within dam locations such as Obudu, Ikom, Ijegu-Yala, and Nkari. The first three dams are in Cross River state, and Nkari Dam is in Akwa-Ibom state, with a combined estimated population of 9.1 million people. The coordinates of the study areas are as follows:

2. **Study Area and Locations**

Four LGAs were selected for the study, namely Obudu, Ikom, Ijegu-Yala and Nkari as depicted in the Map in Figure 1.

**Table-1: Research Locations & Dry Weather Periods**

| S/N | LGA | Latitude | Longitude | Lowest Height of Instrument | State | Dry Period | |
|---|---|---|---|---|---|---|---|
| | | | | | | Start | End |
| 1 | Obudu | 9.172 | 6.62 | 70 | Cross River | 25 Oct | 25April |
| 2 | Ikom | 5.962 | 8.72 | 70 | Cross River | 28Nov | 15 March |
| 3 | Ijegu-Yala | 6.850 | 8.76 | 97 | Cross River | 22Nov | 28 March |
| 4 | Nkari | 7.75 | 5.39 | 70 | Akwa-ibom | 8 Nov | 14 March |

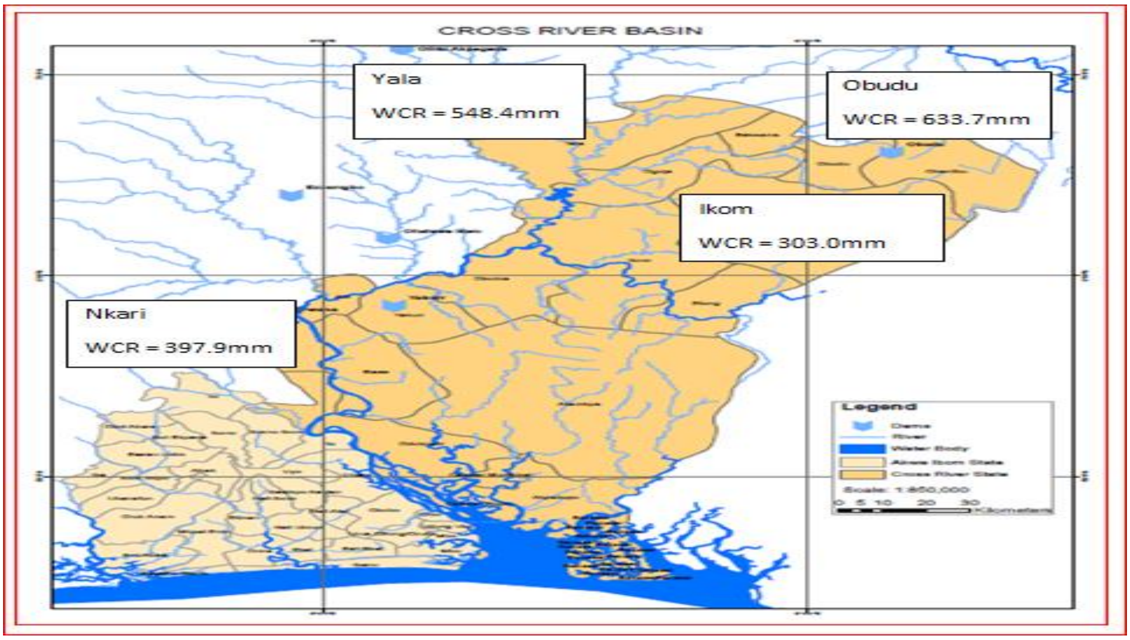


**Figure 1: Showing study area**

## 3. Methods:

The article details the use of CROPWAT 8.0 for Windows, a FAO decision support tool, for calculating Crop Water Requirements (CWR). New_LocClim, a tool for spatial interpolation of agroclimatic data, is also discussed. Representative soil characteristics, such as total available soil moisture, rain infiltration rate, and puddle cracking critical depletion, are outlined.

## 4. Analysis and Results:

This section presents the determination of irrigation water requirements for specific locations (Obudu, Nkari, Ikom, Ijegu-Yala) based on climatic and crop data. Tables and figures illustrate the correlation between software-generated and observed precipitation. The Chi-square contingency test demonstrates a significant link between water management and crop productivity.

### 4.1 Discussion:

The analysis of irrigation water requirements highlights location-specific disparities, with Obudu and Ijegu-Yala aligning with FAO recommendations for hot climates. Conversely, Nkari and Ikom deviate due to their less hot climate. The Chi-square contingency test results emphasize a substantial association between effective water management and enhanced crop productivity.

## Table-2: Obudu Crop Water Requirement

Crop Water Requirements

ETo station: Obudu
Rain station: Obudu
Crop: Obudu Rice
Planting date: 25/11

| Month | Decade | Stage | Kc | ETc | ETc | Eff rain | Irr. Req. |
|---|---|---|---|---|---|---|---|
| | | | coeff | mm/day | mm/dec | mm/dec | mm/dec |
| Oct | 3 | Nurs | 1.20 | 0.34 | 2.0 | 10.6 | 0.0 |
| Nov | 1 | Nurs/LPr | 1.12 | 1.96 | 19.6 | 1.3 | 69.1 |
| Nov | 2 | Nurs/LPr | 1.06 | 3.05 | 30.5 | 0.0 | 120.5 |
| Nov | 3 | Init | 1.09 | 3.10 | 31.0 | 0.0 | 90.3 |
| Dec | 1 | Init | 1.10 | 3.13 | 31.3 | 0.1 | 31.2 |
| Dec | 2 | Deve | 1.09 | 3.10 | 31.0 | 0.0 | 31.0 |
| Dec | 3 | Deve | 1.05 | 3.00 | 33.0 | 0.1 | 32.9 |
| Jan | 1 | Deve | 1.00 | 2.90 | 29.0 | 0.2 | 28.8 |
| Jan | 2 | Mid | 0.97 | 2.84 | 28.4 | 0.3 | 28.0 |
| Jan | 3 | Mid | 0.97 | 3.03 | 33.3 | 0.8 | 32.5 |
| Feb | 1 | Mid | 0.97 | 3.22 | 32.2 | 1.3 | 30.9 |
| Feb | 2 | Mid | 0.97 | 3.42 | 34.2 | 1.7 | 32.4 |
| Feb | 3 | Late | 0.98 | 3.54 | 28.3 | 2.4 | 25.9 |
| Mar | 1 | Late | 0.99 | 3.64 | 36.4 | 2.0 | 34.4 |
| Mar | 2 | Late | 0.99 | 3.71 | 37.1 | 2.1 | 35.0 |
| Mar | 3 | Late | 0.99 | 3.63 | 14.5 | 2.7 | 10.7 |
| | | | | | **451.8** | **25.8** | **633.7** |

**Table-3: Ikom Cropwater Requirement**

Crop Water Requirements

ETo station: Ikom | Crop: Rice

Rain station: Ikom | Planting date: 28/11

| Month | Decade | Stage | Kc | ETc | ETc | Eff rain | Irr. Req. |
|---|---|---|---|---|---|---|---|
| | | | coeff | mm/day | mm/dec | mm/dec | mm/dec |
| Nov | 1 | LandPrep | 1.05 | 2.61 | 7.8 | 10.5 | 58.8 |
| Nov | 2 | LandPrep | 1.05 | 2.64 | 26.4 | 24.8 | 1.6 |
| Nov | 3 | Init | 1.06 | 2.68 | 26.8 | 19.6 | 97.0 |
| Dec | 1 | Init | 1.10 | 2.76 | 27.6 | 13.6 | 14.0 |
| Dec | 2 | Deve | 1.10 | 2.75 | 27.5 | 7.1 | 20.4 |
| Dec | 3 | Deve | 1.06 | 2.66 | 29.3 | 6.7 | 22.6 |
| Jan | 1 | Deve | 1.00 | 2.55 | 25.5 | 5.5 | 20.1 |
| Jan | 2 | Mid | 0.96 | 2.45 | 24.5 | 3.6 | 20.9 |
| Jan | 3 | Mid | 0.95 | 2.58 | 28.3 | 8.2 | 20.2 |
| Feb | 1 | Mid | 0.95 | 2.72 | 27.2 | 12.5 | 14.7 |
| Feb | 2 | Mid | 0.95 | 2.86 | 28.6 | 15.8 | 12.8 |
| Feb | 3 | Late | 0.96 | 2.89 | 23.1 | 23.6 | 0.0 |
| Mar | 1 | Late | 0.97 | 2.93 | 29.3 | 33.1 | 0.0 |
| Mar | 2 | Late | 0.97 | 2.94 | 29.4 | 41.1 | 0.0 |
| Mar | 3 | Late | 0.97 | 2.90 | 20.3 | 27.6 | 0.0 |
| | | | | | 381.7 | 253.3 | 303.0 |

**Tabe-4: Ijegu-Yala Cropwater Requirement**

Crop Water Requirements

ETo station: Ijegu Yala | Crop: Rice

Rain station: Ijegu Yala | Planting date: 22/11

| Month | Decade | Stage | Kc | ETc | ETc | Eff rain | Irr. Req. |
|---|---|---|---|---|---|---|---|
| | | | coeff | mm/day | mm/dec | mm/dec | mm/dec |
| Nov | 1 | LandPrep | 1.05 | 2.93 | 26.4 | 24.3 | 91.0 |
| Nov | 2 | LandPrep | 1.05 | 2.92 | 29.2 | 14.6 | 104.6 |
| Nov | 3 | Init | 1.09 | 3.06 | 30.6 | 11.1 | 75.3 |
| Dec | 1 | Init | 1.10 | 3.08 | 30.8 | 7.4 | 23.4 |
| Dec | 2 | Deve | 1.08 | 3.04 | 30.4 | 2.4 | 28.0 |
| Dec | 3 | Deve | 1.04 | 2.95 | 32.5 | 3.0 | 29.5 |
| Jan | 1 | Deve | 1.00 | 2.87 | 28.7 | 4.0 | 24.6 |
| Jan | 2 | Mid | 0.98 | 2.85 | 28.5 | 3.9 | 24.5 |
| Jan | 3 | Mid | 0.98 | 3.03 | 33.3 | 4.8 | 28.5 |
| Feb | 1 | Mid | 0.98 | 3.21 | 32.1 | 4.9 | 27.2 |
| Feb | 2 | Late | 0.98 | 3.40 | 34.0 | 5.2 | 28.8 |
| Feb | 3 | Late | 0.99 | 3.48 | 27.8 | 9.3 | 18.5 |
| Mar | 1 | Late | 0.99 | 3.54 | 35.4 | 13.4 | 21.9 |
| Mar | 2 | Late | 0.99 | 3.59 | 35.9 | 16.9 | 19.0 |
| Mar | 3 | Late | 0.99 | 3.50 | 3.5 | 2.0 | 3.5 |
| | | | | | **439.0** | **127.4** | **548.4** |

**Tabe-5: Nkari Cropwater Requirement**

Crop Water Requirements

ETo station: Nkari | Crop: Rice

Rain station: Nkari | Planting date: 08/11

| Month | Decade | Stage | Kc | ETc | ETc | Eff rain | Irr. Req. |
|---|---|---|---|---|---|---|---|
| | | | coeff | mm/day | mm/dec | mm/dec | mm/dec |
| Oct | 2 | LandPrep | 1.05 | 2.77 | 5.5 | 7.3 | 56.5 |
| Oct | 3 | LandPrep | 1.05 | 2.80 | 30.8 | 28.6 | 2.2 |
| Nov | 1 | Init | 1.06 | 2.87 | 28.7 | 19.2 | 98.8 |
| Nov | 2 | Init | 1.10 | 2.99 | 29.9 | 11.1 | 18.8 |
| Nov | 3 | Deve | 1.10 | 2.98 | 29.8 | 9.9 | 19.9 |
| Dec | 1 | Deve | 1.06 | 2.88 | 28.8 | 9.3 | 19.6 |
| Dec | 2 | Deve | 1.02 | 2.77 | 27.7 | 7.2 | 20.4 |
| Dec | 3 | Mid | 0.98 | 2.68 | 29.5 | 5.7 | 23.8 |
| Jan | 1 | Mid | 0.97 | 2.69 | 26.9 | 3.0 | 23.8 |
| Jan | 2 | Mid | 0.97 | 2.71 | 27.1 | 0.9 | 26.2 |
| Jan | 3 | Mid | 0.97 | 2.87 | 31.6 | 4.1 | 27.5 |
| Feb | 1 | Late | 0.98 | 3.06 | 30.6 | 7.1 | 23.5 |
| Feb | 2 | Late | 0.99 | 3.25 | 32.5 | 9.3 | 23.3 |
| Feb | 3 | Late | 0.99 | 3.34 | 26.7 | 15.1 | 11.7 |
| Mar | 1 | Late | 0.99 | 3.43 | 24.0 | 15.5 | 1.9 |
| | | | | | **410.1** | **153.1** | **397.9** |

4.2. **Model Validation:**

Observed and simulated data correlation coefficients (0.95 to 1.0) validate the accuracy of the models and methodologies presented. The validation underscores the reliability of advanced technologies and satellite data in optimizing water use for rice cultivation.

### 4.3 Data Verification on Precipitation

***Table-6: Climate of Obudu LGA and CropWat Input Data***

| **Months** | Precipitation (Software) | Precipitation (Observed) |
|---|---|---|
| January | 1.3 | 2.63 |
| February | 5.4 | 6.04 |
| March | 11.8 | 24.68 |
| April | 60.9 | 74.89 |
| May | 135.8 | 143.58 |
| June | 174.5 | 175.85 |
| July | 206.6 | 219.66 |
| August | 271.8 | 257.88 |
| September | 239.8 | 268.98 |
| October | 100 | 118.2 |
| November | 1.2 | 8.22 |
| December | 0.1 | 2.71 |
| Mean | 100.77 | 108.58 |

**The data in table 6 were verified for reliability and figure 2 indicates an excellent relationship.**

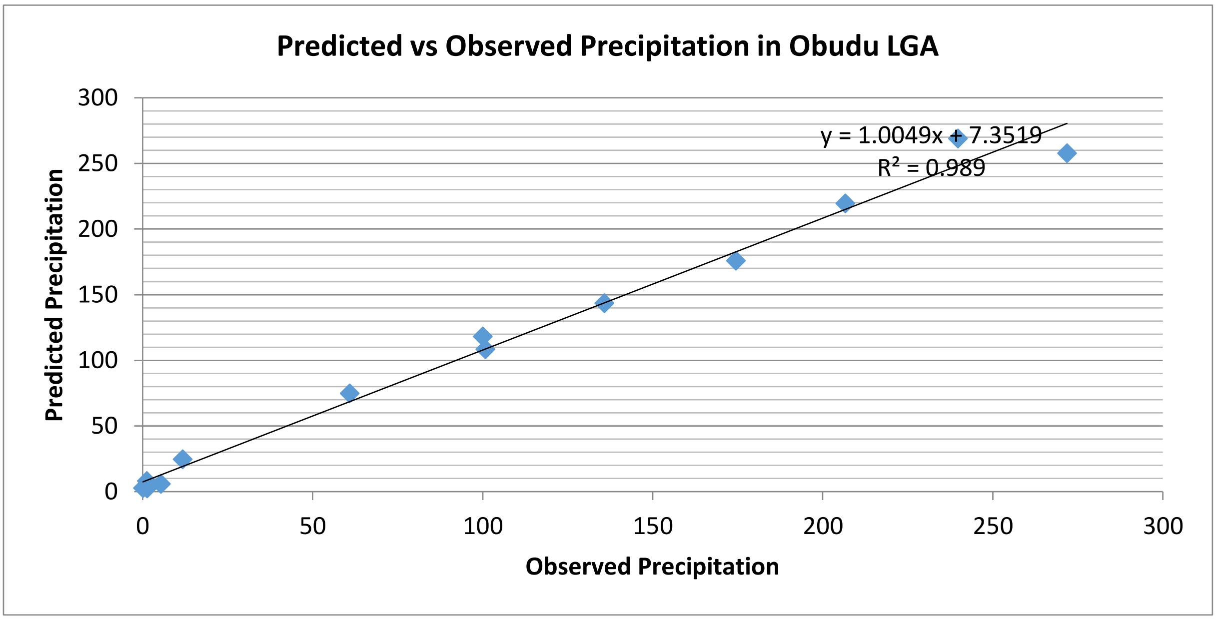


Figure 2: Data verification on Precipitation

### 5.1 Conclusion and Recommendations:

In conclusion, the study on Agricultural Water Management for Rice Production in the Cross River Basin provides valuable insights into the net water requirements for rice cultivation in hot climatic conditions. The comprehensive analysis utilized advanced technologies, satellite data, and precise irrigation scheduling to determine the irrigation water needs for specific locations within the Cross River Basin. The study reveals location-specific disparities in the water requirements for rice cultivation, with Obudu and Ijegu-Yala aligning with the FAO recommendations for hot climates, while Nkari and Ikom deviate due to their less hot climate. The Chi-square contingency test results highlight a significant association between effective water management and enhanced crop productivity.

### 5.2 Recommendations:

a) Tailored Water Management Strategies: Implement location-specific water management strategies based on the study's findings. Tailoring irrigation practices to the specific climatic conditions of each location can optimize water use and improve crop productivity.

b) Awareness and Education: Disseminate the study's results to farmers, agricultural extension services, and policymakers. Promote awareness about the importance of adopting efficient water management practices for rice cultivation, especially in regions with distinct climatic variations.

c) Research Expansion: Encourage further research to explore additional factors influencing rice water requirements, such as soil characteristics and agronomic practices. Continuous investigation and adaptation of models to local conditions can enhance the precision of water management recommendations.

d) Policy Integration: Advocate for the integration of the study's findings into agricultural policies at both regional and national levels. Incorporating scientifically validated water management practices into policies can contribute to sustainable agricultural development.

e) Collaborative Efforts: Foster collaboration between academia, government agencies, and agricultural stakeholders. Collaborative efforts can facilitate the implementation of research findings, promote knowledge exchange, and enhance the overall effectiveness of water management strategies in rice cultivation.

f) By implementing these recommendations, stakeholders can contribute to the sustainability of rice production in the Cross River Basin, ensuring optimal yields while addressing the challenges posed by water scarcity and climate variability.

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