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# Geospatial Assessment of Crop Water Requirement for Yield Optimization of Oil Palm in South West Nigeria

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## ABSTRACT

Oil palm is a very important crop because of many products that are generated from it, which can boost the economy of Nigeria and create job opportunities for teeming Nigerian youths. The crop is being cultivated, although not maximum capacity, in many areas of the country. The major factors considered in oil palm cultivation are soil type and climate especially temperature and rainfall. This study assessed the crop water requirements for yield optimization of oil palm in Southwest Nigeria. The study showed that the greater percentage of the Southwest Nigeria is suitable for the crop's cultivation. However, the crop water requirements of oil palm increase northwards from the humid forest zone to the Sahel savannah zone of the study area. Moisture is available for oil palm's utilization in the savannah region but not in abundant quantity as in the southern humid forest zone. Irrigation requirements increase from humid forest agro ecological zone to the Sahel savannah zone. The study therefore suggests that yield optimization could be achieved through complementing the rainfall with irrigation water.

**Keywords:**

Crop water requirement, irrigation, yield optimization, agro ecological zones

## I. INTRODUCTION

The oil palm, *Elaeis guineensis* is a perennial crop that is traced to the tropical rain forest of West Africa (Olagunju, 2008). Its spread reached South America and then to Asia in the 16th and 19th century respectively. Palm oil is edible plant oil derived from its fruits. Palm oil is one of the few vegetable oils that contains relatively high content of saturated fats, thus it is semi-solid at room temperature. The oil is widely used as cooking oil and is very important in food industries as well as soap and personal care industries. Oil palm is a perennial crop which starts to yield about 3 to 4 years after planting and its average economic lifetime of about 25 years. Although higher yield could be obtained from a well-managed plantation, its average peak yield is within the range of 25-28 ton/ha (Gurmit, 1999).

The natural habitat of oil palm is riverine forests or freshwater swamps. However, it has adapted to diverse ecological zones in the tropical belt (long. 15°N – 15°S), from savannah to rainforest and highlands (< 1500 m) although it is widely grown on lowlands. The crop grows on most tropical soils with adequate water supply. Slightly acidic soils with pH 4 – 6 and slopes of < 20° are suitable. The crop can withstand annual rainfall between 650 and 4500 mm with 2-4 months of dry period although the ideal rainfall is 2000 – 2500 mm/year without any dry season. The suitable temperatures for oil palm is a mean maximum temperature of 28 – 34°C and mean minimum temperature of 21 – 24°C. Oil palm requires full sunlight for maximum photosynthesis and sunshine hours should exceed 5 h/day or 1825 h/year provided the high sunshine hours are not accompanied by drought, high water vapour pressure deficit (> 1.8 kPa) and/or extreme temperatures (> 38°C) while the solar radiation should be at least 12 MJ/m<sup>2</sup>/day (Janick and Paull, 2008). In addition, fertilizer demands are moderate compared to other industrial crops and are mainly for compensating the nutrients harvested in the fruit bunches.

While Nigeria has the capability of being the leading producer of palm oil globally, this is no longer the situation as the country is far behind Malaysia and Indonesia who have emerged as major producers of palm oil (FAO, 1986). This decline cannot be divorced from the discovery of crude oil and neglect suffered by the agricultural sector thereafter. Kei *et al* (1997) observed that the success of the Oil palm sector in Malaysia is built on sustainable plantation management together and adoption of modern processing technologies.

Many youths are disinterested in farming because of this neglect, seemingly the unprofitable nature of the sector because of lack of adequate information and modern knowledge - based agricultural practices such as advanced information about crop water requirement (CWR). Since climate has

a great effect on the sustainability of the all crops including oil palm, knowledge of climate-suitability is very important before investing in its cultivation. However, many farmers embark on oil palm cultivation without the knowledge of the climatic requirements of the crops they intend to cultivate. Understanding climate-suitability and crop water requirement of oil palm cultivation in the south western part of Nigeria could go a long way in stimulating intense investment in its cultivation and higher yield resulting from adequate irrigation water management. This will in turn boost the economic situation of the rural and urban population (CBN/ NISER, 1992) and create more jobs along the value chain of palm oil processing.

This study therefore aimed to determine the climate-suitability of the study area and crop water requirement (CRW) for oil palm cultivation with the view of expanding potential cultivable areas and determining irrigation requirements using geoinformatics and Food and Agriculture Organization's Penman-Monteith method embedded in CROPWAT 8.0 software.

### Aim and Objective

The aim of this study is to evaluate the water availability for optimal yield with respect to crop water requirement of oil palm in Southwest Nigeria.

The specific objectives are:

1. To analyze the degree of climate-suitability of the study area for oil palm cultivation;
2. To analyze the variation in the water available with respect to the crop water required for optimal yield in the study area; and
3. To generate suitability map and irrigation map for optimal yield of oil palm.

### Significance of the Study

The result of this study will enable policy makers in the area of agriculture and youth empowerment to look into how oil palm cultivation could help improve the nation's economy and create jobs for our teeming youth population. It will also enable water resources managers allocate more water to cater for the deficit in crop water requirement for oil palm cultivation across the region. The study will also contribute to knowledge in the area of crop management and provide a framework for food security and irrigation management.

## II. METHODOLOGY

### Description of the Study Area

The study area lies between latitude 5°49' and 9°12'N of the equator and longitude 3°15' and 6°03'E of the

Greenwich Meridian and located in the Southwest zone of Nigeria (Figure 1). It is divided into six states namely – Ekiti, Lagos, Ogun, Ondo, Osun and Oyo. The study area has three main agroecological zones (Figure 2) that

support oil palm production – Humid Forest, Derived Savannah and Southern Guinea Savannah being situated in the tropical belt of longitude 15°N – 15°S (Janick and Paull, 2008).

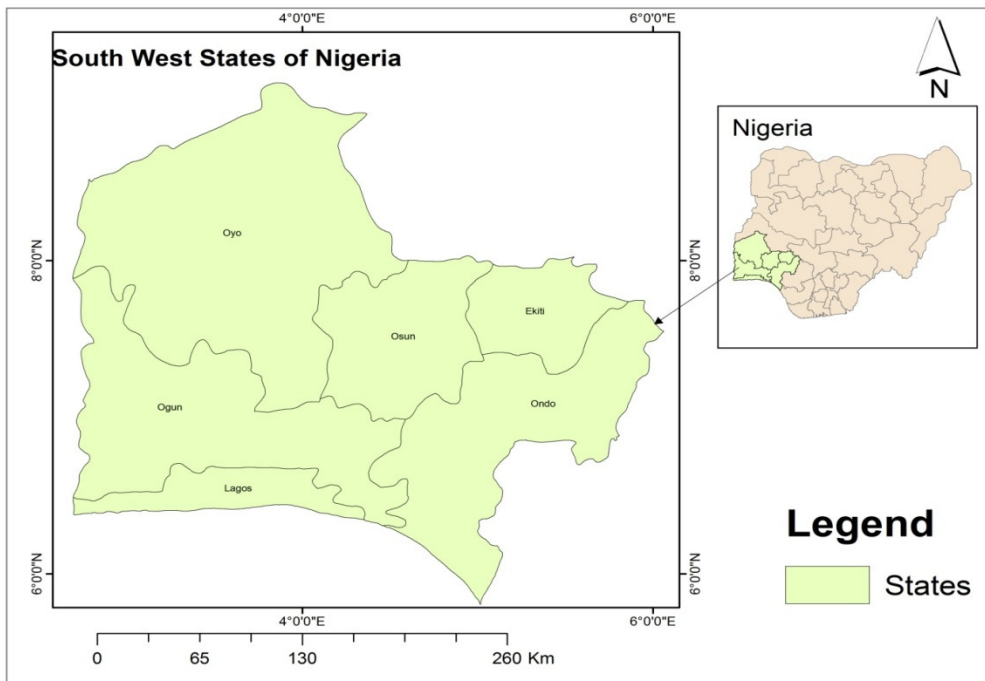


Figure 1: Southwest Nigeria showing the six states

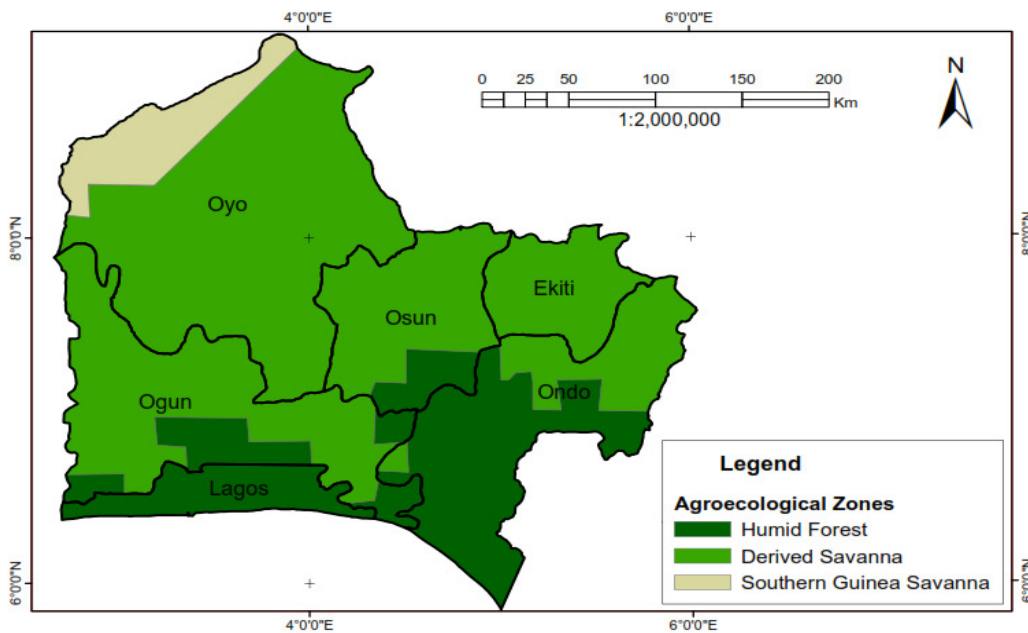


Figure 2: The agro ecological zones in Southwest Nigeria

## Climate Suitability Analysis of the Study Area for Oil Palm Cultivation

To determine the climate suitability of the study area for oil palm cultivation, climatic data of mean annual rainfall, mean minimum temperature and mean maximum temperature obtained from the fixed weather stations were interpolated and rasterized using ArcGIS 10.0 software. The results of the climatic data were reclassified to exclude unsuitable regions using the following criterion: Mean annual rainfall (650 – 4500 mm), mean minimum temperature (21 – 24°C), mean maximum temperature (28 – 34°C), average sunshine hours (> 5 h/day), and solar radiation ( $\geq 12$  MJ/m<sup>2</sup>/day). Overlay analysis was carried out to determine climate suitable areas.

### Crop Water Requirement (CRW) and Irrigation Requirement (IR) Analyses

Determination of Crop Water Requirement (CWR) for oil palm was achieved using Penman-Monteith method of the CROPWAT 8.0 software taking into consideration, the reference evapotranspiration ( $ET_o$ ), soil type, field capacity, permanent wilting point and effective root zone of the crops. The CROPWAT model calculated the CWR by solving the following equations:

$$CWR_i = \sum_{t=0}^T (Kc_i * ET_o - P_{eff}) \quad (1)$$

Where  $Kc_i$  is the crop coefficient of the given crop  $i$  during the growth stage which ranges between  $t$  and  $T$ , and  $P_{eff}$  is the effective rainfall while  $ET_o$  is the reference crop evapotranspiration (in mm/day) which is defined by the equation below:

$$ET_o = \frac{0.408 \Delta (R_n - G) + \gamma \frac{900}{T + 273} U_2 (e_s - e_a)}{\Delta + \gamma (1 + 0.34 U_2)} \quad (2)$$

Where:  $ET_o$  = reference evapotranspiration [mm day<sup>-1</sup>];  $R_n$  = net radiation at the crop surface [MJ m<sup>-2</sup> day<sup>-1</sup>];  $G$  = soil heat flux density [MJ m<sup>-2</sup> day<sup>-1</sup>];  $T$  = mean daily air temperature at 2 m height [°C];  $U_2$  = wind speed at 2 m height [ms<sup>-1</sup>];  $e_s$  = saturation vapour pressure [kPa];  $e_a$  = actual vapour pressure [kPa];  $e_s - e_a$  = saturation vapour pressure deficit [kPa];  $\Delta$  = slope vapour pressure curve [kPa °C<sup>-1</sup>] and  $\gamma$  = psychrometric constant [kPa °C<sup>-1</sup>].

Irrigation requirement will compensate for the moisture deficit of the oil palm water requirement during the growth stages for optimal performance of the crop in terms of yield. Irrigation requirement was estimated by the software considering the initial soil moisture and the crop water requirement and effective rainfall.

### III. RESULTS AND DISCUSSION

Net radiation at the crop surface ( $R_n$ ) and Reference evapotranspiration ( $ET_o$ ) were estimated by CROPWAT 8.0 model and the result for Ibadan station is shown in Table 1 as an example. The  $ET_o$  ranges between 2.92 and 4.49 mm/day while the average value is 3.78 mm/day while the net radiation flux  $R_n$  ranges between 13.7 and 19.1 MJ/m<sup>2</sup>/day and the average value is 16.8 MJ/m<sup>2</sup>/day. It is observed that the reference evapotranspiration increases from January up till February before the onset of rainfall in March and then decreases downward till August due to increase in precipitation.

**Table 1: Meteorological Data of Ibadan, Oyo State for estimating  $R_n$  and  $ET_o$**

Month	Min Temp	Max Temp	Precipitation	Humidity	Wind	Sun	Rad	$ET_o$
	°C	°C	mm	%	m/s	hours	MJ/m <sup>2</sup> /day	mm/day
January	21.1	32.8	4	65	1.20	6.3	17.3	4.04
February	21.7	33.9	23	62	1.20	6.8	19	4.49
March	22.8	33.9	83	67	1.00	6.3	19.1	4.46
April	22.8	32.8	150	68	0.80	6	18.7	4.23
May	22.2	31.7	156	73	0.80	6.1	18.3	4.04
June	21.7	29.4	182	76	0.80	5.3	16.7	3.59
July	21.1	27.8	173	79	0.50	3.5	14.2	2.98
August	20.5	27.2	147	79	0.80	2.9	13.7	2.92
September	21.7	28.9	183	76	0.80	3.5	14.7	3.18
October	22.2	30	179	73	0.80	5.5	17.1	3.64
November	21.7	31.7	29	70	1.00	6.6	17.9	3.91
December	20.5	32.8	7	67	1.00	6.7	17.4	3.86
Average	21.67	31.08	109.67	71.25	0.89	5.46	17.01	3.78

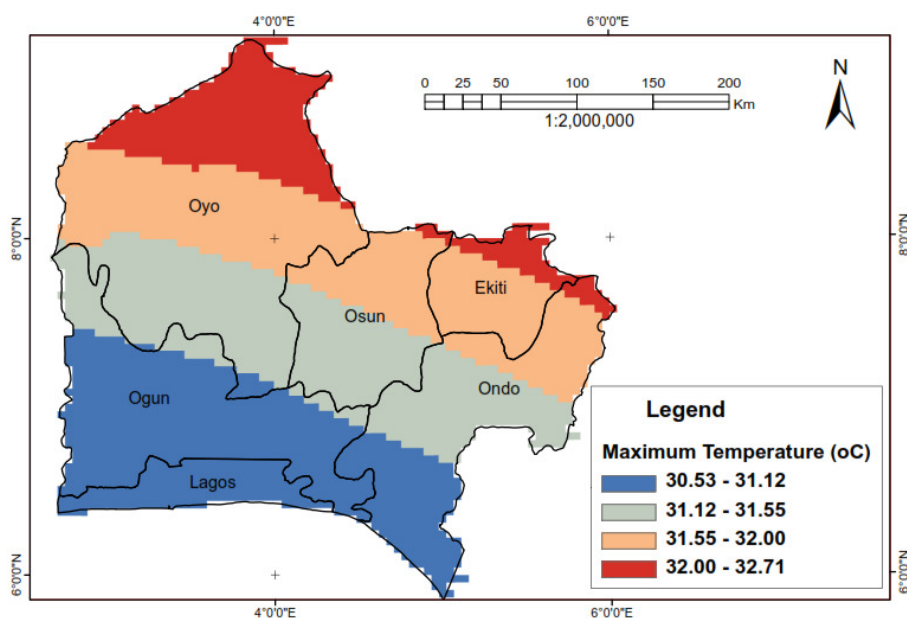
The crop water requirements of (CWR) for oil palm in different climatic zones surrounding the Southwestern Nigeria are shown in Table 2. The values range from 1138.6 m<sup>3</sup>/ha in Station 4 that is located in the humid forest (HF) agroecological zone to 1571.9 m<sup>3</sup>/ha in Station 3, that is within Derived savannah (DS). The

spatial variation in CWR of oil palm across the six Southwestern states is shown in Figure 5. It is observed that the crop water requirements increase northwards from the Humid Forest zone to the Derived Savannah zone and they correspond to the temperature variations as presented in Figures 3 and 4.

**Table 2: Crop Water Required (CWR), Effective Rainfall (ER) and Irrigation Requirements (IR) for 5 Weather Stations**

No	Station	State	Agroecological Zone	CRW (m <sup>3</sup> /ha)	ER (m <sup>3</sup> /ha)	IR (m <sup>3</sup> /ha)
1	Ibadan	Oyo	DS	1234.1	987.6	426
2	Ikeja	Lagos	HF	1143	1046.6	361.2
3	Ilorin	Kwara	DS	1571.9	895.2	743.8
4	Benin-city	Edo	HF	1138.6	1240.8	259.7
5	Lokoja	Kogi	DS+SGS	1329.9	891.7	571.8

HF=Humid Forest; DS=Derived Savannah; SGS=Southern Guinea Savannah



**Figure 3: Average maximum temperature in Southwest Nigeria**

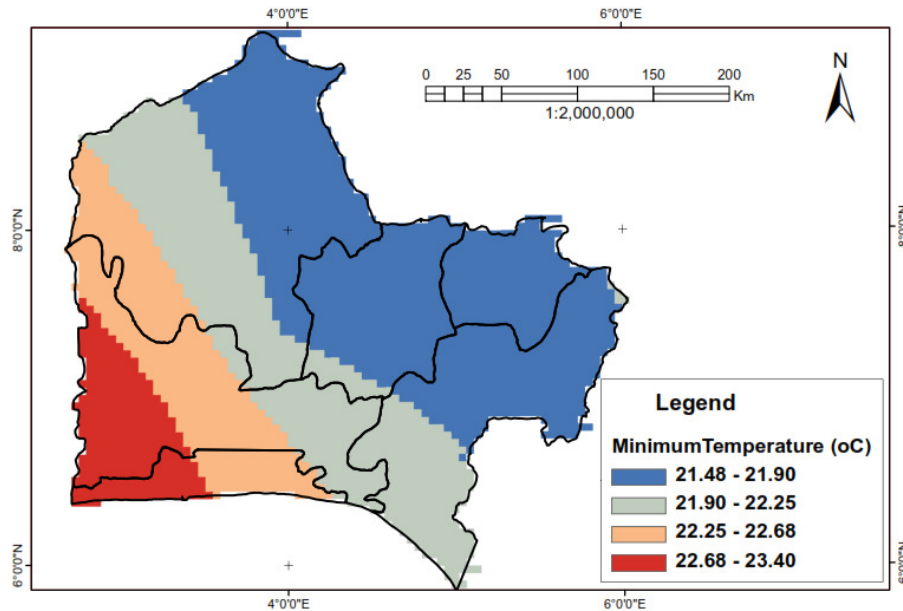


Figure 4: Average minimum temperature in Southwest Nigeria

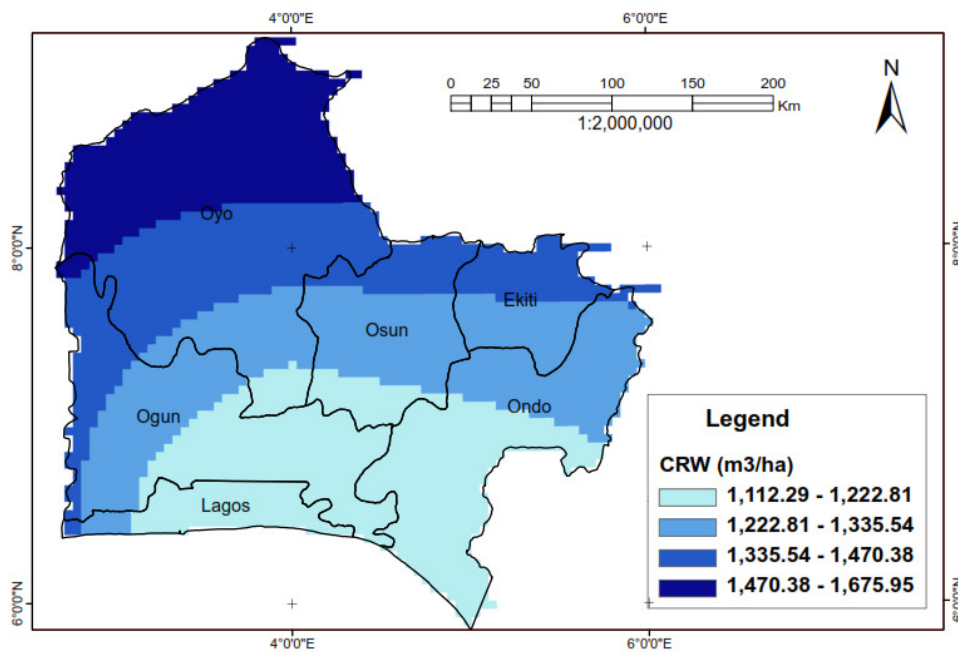


Figure 5: Spatial Distribution of CWR (m<sup>3</sup>/ha) for oil palm cultivation across the Southwest Nigeria

Similarly, the effective rainfall (ER) which is the actual amount of moisture available for the crop in different climatic zones of the study area is shown in Figure 6. The values range from 1,223.76 m<sup>3</sup>/ha in Humid Forest agroecological zone to 820.39 m<sup>3</sup>/ha in the Derived

Savannah zone. From the result, it shows that available moisture for oil palm's utilization in the Derived Savannah region is far less than moisture present in the Humid forest region of the study area.

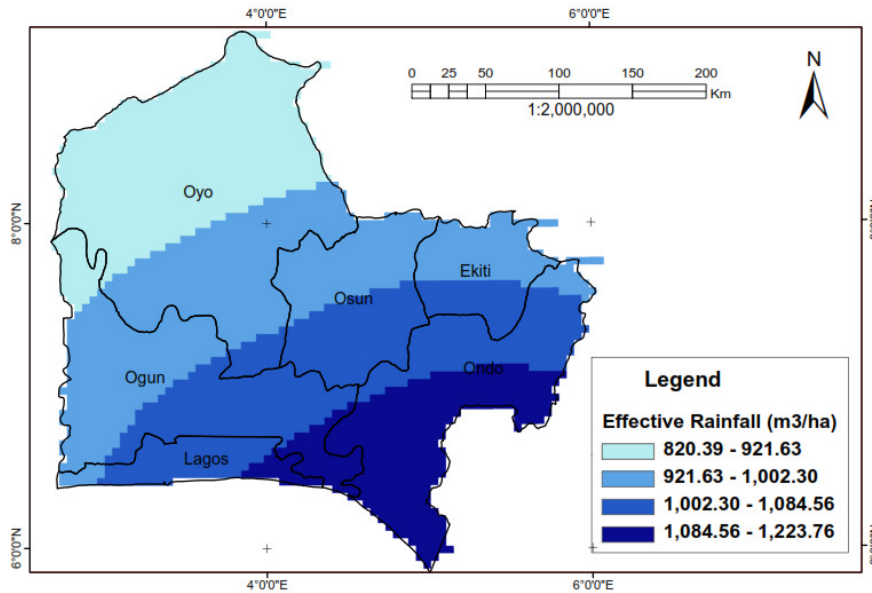


Figure 6: Effective Rainfall in Southwest Nigeria

The irrigation requirement (IR) which is the amount of moisture that is expected to be supplied from irrigation system to replenish the moisture loss through evapotranspiration in order to sustain the growth of the crop in different climatic zones is also shown in Table 2. The values range from 361.2 m<sup>3</sup>/ha in Station 2 that is

located in the humid forest agroecological zone to 426 m<sup>3</sup>/ha in Station 1 that is located in the Derived Savannah. The higher value of 743.8 m<sup>3</sup>/ha represents Southern Guinea Savannah belt where Ilorin (Station 3) falls within. Figure 7 shows the spatial variation in IR of oil palm across the study area.

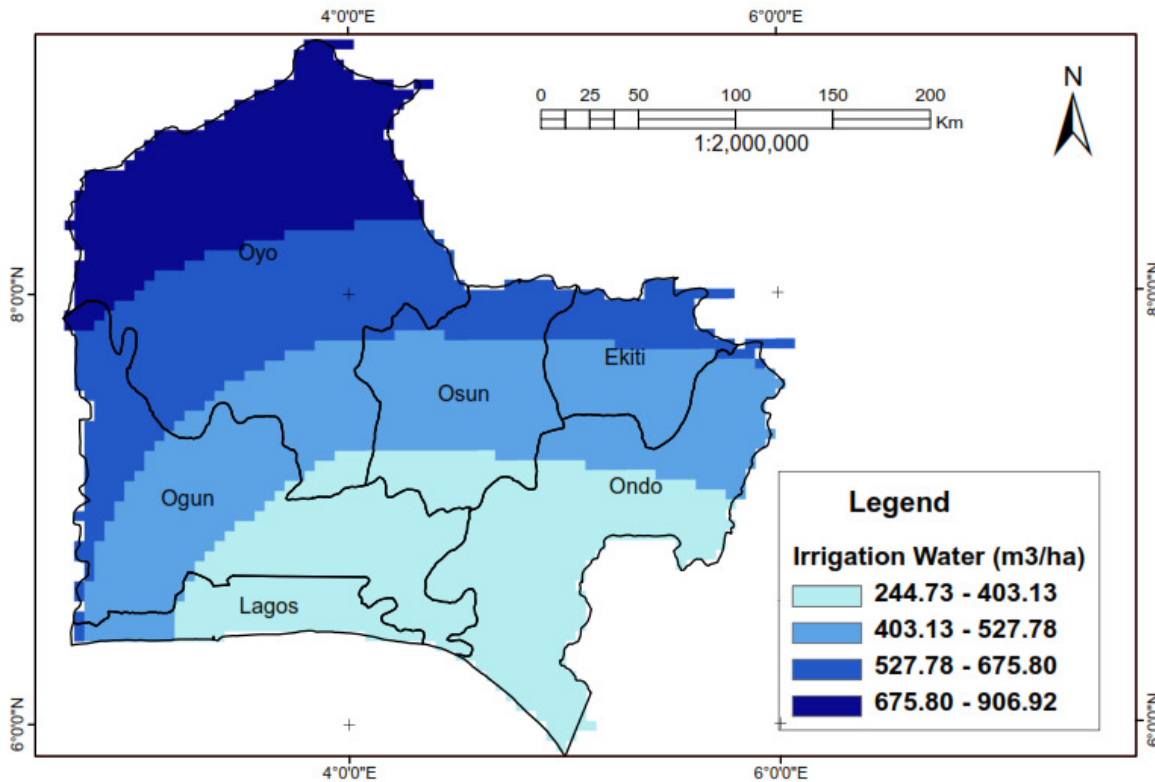


Figure 7: Irrigation Requirement (IR) for oil palm cultivation in Southwest Nigeria

#### IV CONCLUSION

Crop water requirements of oil palm increase northwards from the humid forest zone to the Sahel savannah zone. Moisture is available for oil palm's utilization in the savannah region but not in abundant quantity as in the southern humid forest zone. Irrigation requirements increase from humid forest agroecological zone to the Sahel savannah zone. Since many crops grown in the savannah agroecological zone of Nigeria is supported through irrigation, oil palm cultivation in commercial scale can easily be extended to the savannah regions with provision of adequate irrigation water.

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