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ORIGINAL RESEARCH ARTICLE

DETERMINATION OF WATER PRODUCTIVITY OF CASSAVA IN IBADAN, SOUTH WESTERN NIGERIA

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ABSTRACT

The response of yields to the actual water (effective rainfall) used by cassava, was the main area of study of this project. A twenty data point (20 years) was processed using CROPWAT 8.0 model using fixed percentage (80%) method, the model was used to run the 20 years daily rainfall data collected from NIMET (Nigeria Meteorological Agency) Oyo State from 1994 to 2013 (20 years) while the cassava yield was collected from FAOSTAT website. The rainfall pattern for the annual period of cultivation for cassava was determined through the planting and dates of the crop. The results of the annual water productivity values show that there was a very low water productivity of 0.9kg/m^3 in 2012 while 2013 recorded the highest water productivity of 2.2 kg/m^3. The early planting of cassava after rainfall started in the month of March which contributed to the high yield recorded in 2010, 2011 and 2013. The poor performance of cassava in 2012 could be due to the following; the variety used, the soil type, the plant's age at harvest, and the rainfall intensity and distribution during that particular year. The trend of the results was used to determine the alternative cost of water if the farm would be fully irrigated. It was gathered that 7000 litres of untreated water would be supplied to any farthest location at ₦ 12,000. Therefore, the cost was determined based on the yield and the water used annually.

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1.0 Introduction

Cassava *(Manihot esculenta)* is extensively cultivated as an annual crop in tropical and subtropical regions for its edible starchy tuberous root, a major source of carbohydrates. Cassava is the third largest source of food carbohydrates in the tropics, after rice and maize, (FAO, 1995).

Cassava is a major staple food in the developing world, providing a basic diet for over half a billion people. It is one of the most drought-tolerant crops, capable of growing on marginal soils. Nigeria is the world's largest producer of cassava, while Thailand is the largest exporter of dried cassava. Cassava is important source of food in the tropics. The cassava plant gives the third highest yield of carbohydrates per cultivated area among crop plants, after sugarcane and sugar beets. It plays a particularly important role in agriculture in developing countries, especially in sub-Saharan Africa, because it does well on poor soils and with low rainfall.

Water is the most common liquid on our planet, essential to all life forms and it is also important for crop need. The need of water is increasing sharply throughout the world which is one of the most burning issues of current time. Fresh water resources are depleting due to global climatic changes, rash use of surface water, and misuse of ground water and fast increasing industrial pollution. World need for food and crop demand is increasing day by day because of rapid increase in population. (Bastiaanssen *et al*., 2000).

As competition for increasingly scarce water resources intensifies, irrigation is under growing pressure to produce “more crops from fewer drops” and to reduce its negative environmental impacts, including soil salinization and nitrate contamination of drinking water. Greater use of water-saving precision technologies, such as drip and micro-irrigation, will make an important contribution to sustainable intensification.

Irrigation water requirements are particularly abundant in the works under several surfaces, crop water requirements, crop yield and evapotranspiration as influenced by water accessibility, crop water modeling and irrigation scheduling techniques. Then this consistent data and evapo-transpiration (ETo) through CROPWAT model can be utilized to estimate the contribution of rainfall towards crop water requirement to determine that how much irrigation is required to enhance the productivity. CROPWAT is one of the models extensively used in the field of water management throughout the world. It is an application software used for irrigation planning and management. It facilitates the estimation of the crop evapotranspiration, irrigation schedule, crop water requirement and yield reduction under varying weather conditions (FAO, 2000). Rainfall determines the potential of any region in term of crops to be produced, farming system to be adopted, the nature and sequence of farming operations to be followed and to achieve higher agricultural productivity. The objectives of this study were therefore to estimate the effective rainfall using CROPWAT 8.0 model, evaluate the crop water productivity of cassava on annual basis

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for the period of twenty (20) years and calculate the cost of alternative water used for cassava production for the entire period of twenty years on annual basis.

Among the models, CROPWAT has been the most widely used for estimation of evapotranspiration and crop water requirement. Since there are few weather stations in the study areas, data required for the Penman-Monteith method has normally been extrapolated from representative weather stations nearby. The weather data available for this study will be processed using CROPWAT to estimate evapotranspiration and crop water requirement.

2.0 Materials and Methods

The study was carried out using Ibadan (Nigeria) as a case study area. Ibadan lies approximately between latitude $7^{0}39^{l}$ N and longitude 3^{0} 90^{l} E of Nigeria and altitude 238m above the sea level (Google earth). The area lies within the southwest savannah zone of Nigeria. The average length of the dry season is about 121-151 days (October to March) during which little or no precipitation occurs. Means daily air temperatures (minimum and maximum) range between 23.6^{0}C and 33.2^{0}C. The wind speed ranges from 50.3 km/day in December to 735 km/day in April, with a north eastern to south western wind direction dominating from November through April. The soil is a medium loam, which has developed on deeply weathered Pre-Cambrian Basement Complex rocks but overlain by Aeolian drift of varying thickness (Ogunwole, 2000).

2.1 Climatic Data

The climatic data used for this work were obtained from the data files of Ibadan over a period of Twenty years (1994-2013) from the Nigerian Meteorological Agency (NIMET) and was imputed into CROPWAT-8.0 for windows. The weather data are being generated from the automatic weather station of the agency (NIMET), which relatively records accurate climatic data of its environments.

2.2 Cassava Yield Data

The cassava yield data used for this study for the period of twenty years (1994-2013) was obtained from Food and Agriculture Organization Statistics (FAOSTAT, 2015). The data was calculated per hectare on annual basis.

2.3 Determination of Reference Crop Evapotranspiration

The Reference Evapotranspiration (ETo) represents the potential evaporation of a well-watered grass crop. The water needs of other crops are directly linked to this climate parameter (Mohammed, 2009).

In order to calculate reference evapotranspiration (ETo), the respective climate data should be collected from the nearest and the most representative meteorological stations. Several institutes and agencies may keep climatic records such as the Irrigation Department, the

Meteorological Service or nearby Agricultural Research Stations and may provide information on climatic stations inside or in its vicinity (Allen *et al.*, 1998).
For this work, the data have been obtained from both the automatic weather station of NIMET and FAOSTAT. Daily climatic data of the year 1994-2013 were used. The climatic data used is rainfall data and the second data used was the cassava yield data.

Although several methods exist to determine ETo, the Penman-Monteith Method has been recommended as the appropriate combination method with the climatic data; temperature, sunshine, humidity, windspeed, (FAO, 1998).

The FAO Penman-Monteith method to estimate ETo is expressed as;

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

Where:
ETO = Reference evapotranspiration (mm day^{-1})
Rn = Net radiation at the crop surface (MJ m^{-2} day^{-1})
G = Soil heat flux density (MJ m^{-2} day^{-1})
T = Mean daily air temperature at 2 m height (°C)
μ_2 = Wind speed at 2 m height (ms-1)
e_s = Saturation vapour pressure (kPa)
e_a = Actual vapour pressure (kPa)
Δ = Slope vapour pressure curve (kPa $°C^{-1}$)
γ = Psychrometric constant (kPa $°C^{-1}$)

For this project, The United States Department of Agriculture, Soil Conservation Service method on CROPWAT-8 was used to determine the effective rainfall on monthly basis which accumulated to annual effective rainfall. The USDA, SCS method for calculation of effective rainfall is described in a FAO publication (Dastane, 1978). The method is implemented in models for planning and management of irrigation as the CROPWAT model, where the USDA, SCS method is the default method for calculation of effective rainfall among other four methods (Marica, 2013).

2.4 Determination of Cassava Crop Water Productivity

Water Productivity is more directly linked to overall ambitions in water-scarce or water-costly situations than in systems which are supplied with plentiful, low value water. WP is most meaningful as an indicator as water resources become increasingly scarce. Assessment may be required for the whole system or parts of it, defined in time and space with the formula below,

$$WP = \frac{Agricultural \quad produce}{water \quad used \quad or \quad consumed} \quad (2)$$

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In this project, the annual agricultural yield or benefit of cassava was obtained from the FAOSTAT for the period of twenty years (1994-2013) on yearly basis and the rainfall data obtained from NIMET was processed to determine the amount of water required by the plant at that particular period of time or Water Used or Consumed. With the equation 2 above, the annual water productivity was calculated for the specified period of time. Due to the water productivity calculated, it was easy to predict the amount of water that will be needed in the cassava production annually.

2.5 Cost of Water Applied

Economics of water contributes towards improved allocations of water and the costs of water used and also the full social benefits of the goods and services that water provides.
In this study, the cost of the quantity of water used was determined by considering the cost of water supply by the water tankers from the Oyo State Water Corporation, Eleyele, Ibadan. It was discovered that the price for which the water is delivered depends on the distance. Therefore, for the farthest location supply of 7,000 litres of untreated water, the cooperation charges ₦12,000. With this knowledge, the quantity of water used annually from 1994 to 2013 was calculated annually. This also helps to predict and have the foreknowledge of the amount of money to be spent on irrigation or supply of water if the cassava production is on the large scale, particularly for exportation.

3.0 Results and Discussion

Table1 below shows the rainfall pattern based on the planting and harvesting dates of cassava for the period of 20 years. From the rainfall pattern it was seen that it took nine (9) months for the cassava to germinate, some were assumed planted early while some were planted late based on the daily rainfall data obtained.
Figures1, 2 and 3 below shows effective rainfall versus cassava yield; water productivity and cost of alternative water for irrigation respectively.

Table 1: Rainfall pattern during cassava cultivation period

Year	Mar (mm)	Apr (mm)	May (mm)	June (mm)	July (mm)	Aug (mm)	Sept (mm)	Oct (mm)	Nov (mm)	Dec (mm)	Jan (mm)	Total Rainfall (mm)
1994	-	88.9	301.2	63.6	164.0	67.0	211.5	246.6	19.5	0.0	-	1,162.3
1995	127.8	81.3	146.7	129.9	220.7	260.1	139.3	213.1	20.2	-	-	1,339.1
1996	-	122.1	188.3	231.4	116.9	161.4	226.5	84.9	0.0	0.4	-	1,131.9
1997	-	141.9	104.7	154.1	63.6	98.8	151.7	170.5	1.6	9.0	-	895.9
1998	-	126.9	198.5	259.5	114.2	177.3	80.3	263.4	0.0	0.0	-	1,220.1
1999	-	-	189.8	226.9	230.3	162.7	149.5	154.9	24.4	0.0	19.0	1,157.5
2000	-	-	112.6	104.0	149.8	183.6	241.0	144.2	19.6	0.0	18.8	973.6
2001	-	-	145.9	194.2	93.5	52.1	229.1	63.0	1.9	0.2	1.0	780.9
2002	-	79.4	116.6	189.3	180.3	168.9	62.6	254.4	74.1	0.0	-	1,125.6
2003	-	101.0	129.4	203.7	205.7	107.6	283.8	153.8	39.9	0.0	-	1,224.9
2004	-	55.0	181.4	223.6	100.6	136.5	142.0	228.5	0.7	0.0	-	1,068.3
2005	-	123.0	111.1	165.2	152.4	92.5	352.7	160.6	3.7	0.0	-	1,161.2
2006	-	67.1	107.6	167.1	98.8	104.9	148.8	188.0	256.1	4.9	-	1,143.3
2007	-	65.9	176.6	229.4	133.3	356.6	178.4	168.8	71.5	10.8	-	1,391.3
2008	-	98.7	64.9	204.3	283.5	161.9	199.7	92.9	0.0	24.7	-	1,130.6
2009	-	104.4	130.8	146.7	229.4	74.3	111.5	117.8	2.1	0.0	-	917.0
2010	131.6	70.8	204.4	167.4	107.1	205.7	256.5	240.5	101.4	-	-	1,485.4
2011	38.6	36.2	68.6	143.3	140.5	308.1	244.6	163.6	0.6	-	-	1,144.1
2012	38.4	214.6	221.1	145.5	87.7	104.4	190.3	182.5	15.7	-	-	1,200.2
2013	37.3	67.2	105.2	124.5	126.4	10.6	128.5	163.7	29.8	-	-	793.2

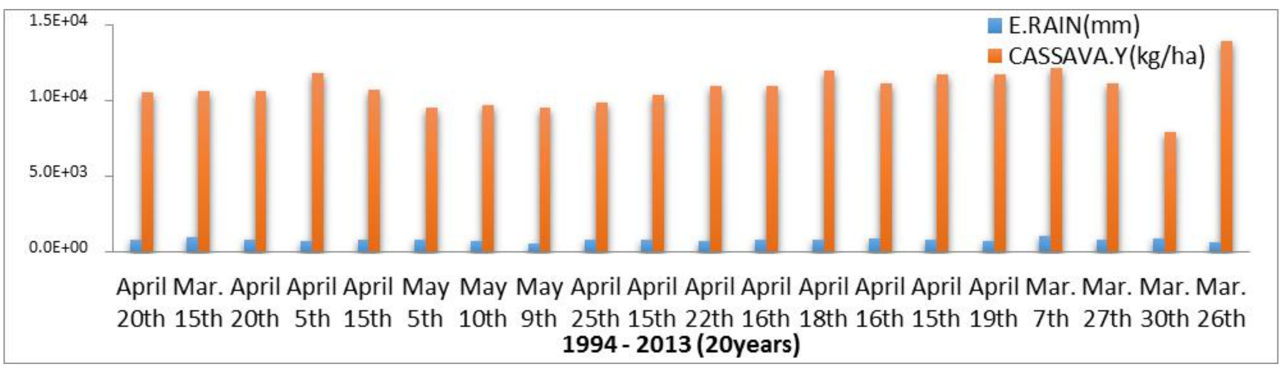

Figure 1: Effective rainfall versus cassava yield.

3.1 Water Productivity

The figure 2 below shows the trend of water productivity across the years (1994 - 2013).

Total rainfall values was computed from the weather station for a period of twenty (20) years in order to estimate the amount of rainfall that was recorded on yearly basis. Also to know the trend of rainfall that was recorded for 20 years. Effective rainfall was computed from CROPWAT 8.0 using fixed percentage (80%) method. From the data collected, maximum rainfall was recorded in the 17th year (March 7 – November 12) with a value of

1485.4mm, while the minimum value was recorded in the 8th year (May 10 – January 10) with a value of 780.9mm. Effective rainfall was computed in order to know the amount of water in terms of rainfall that is available for the crop (cassava). The maximum and minimum values for effective rainfall were 1037.1mm and 577.8mm respectively.

Table 2: Water productivity table between 1994-2013 (20 Years)

Year	Planting Date	Harvesting Date	Total Rainfall (mm)	Effective Rainfall (mm)	Cassava Yield (Kg/Ha)	Effective Rainfall (mm^3/Ha)	Effective Rainfall (m^3)	Water Prod. (Kg/m^3)
1994	April 20th	Dec. 23rd	1162.3	777.4	10592.8	7774000	7774	1.362593
1995	Mar. 15th	Nov. 17th	1339.1	949.6	10667.1	9496000	9496	1.123326
1996	April 20th	Dec. 22nd	1131.9	808.5	10664.6	8085000	8085	1.31906
1997	April 5th	Dec. 10th	895.9	702.6	11881.8	7026000	7026	1.691119
1998	April 15th	Dec. 20th	1220.1	829.2	10746.1	8292000	8292	1.29596
1999	May 5th	Jan. 10th	1157.5	814.6	9599.8	8146000	8146	1.178468
2000	May 10th	Jan. 17th	973.6	718.8	9700	7188000	7188	1.349471
2001	May 9th	Jan. 10th	780.9	577.8	9601.2	5778000	5778	1.661682
2002	April 25th	Dec. 27th	1125.6	819.8	9901.3	8198000	8198	1.20777
2003	April 15th	Dec. 20th	1224.9	858.4	10402.3	8584000	8584	1.211824
2004	April 22th	Dec. 28th	1068.3	769	11001.1	7690000	7690	1.430572
2005	April 16th	Dec. 21th	1161.2	789	10990.2	7890000	7890	1.392928
2006	April 18th	Dec. 27th	1143.3	842.2	12000.3	8422000	8422	1.424875
2007	April 16th	Dec. 17th	1391.3	921	11202.6	9210000	9210	1.216352
2008	April 15th	Dec. 20th	1130.6	790.8	11800.4	7908000	7908	1.49221
2009	April 19th	Dec. 11th	917	702.6	11767.9	7026000	7026	1.674907
2010	March 7th	Nov. 12th	1485.4	1037.1	12215.5	10371000	10371	1.177852
2011	March 27th	Nov. 30th	1144.1	776.8	11210.8	7768000	7768	1.443203
2012	March 30th	Nov. 27th	1200.2	870.7	7958.5	8707000	8707	0.914035
2013	March 26th	Nov. 30th	793.2	644.8	13947.4	6448000	6448	2.163058

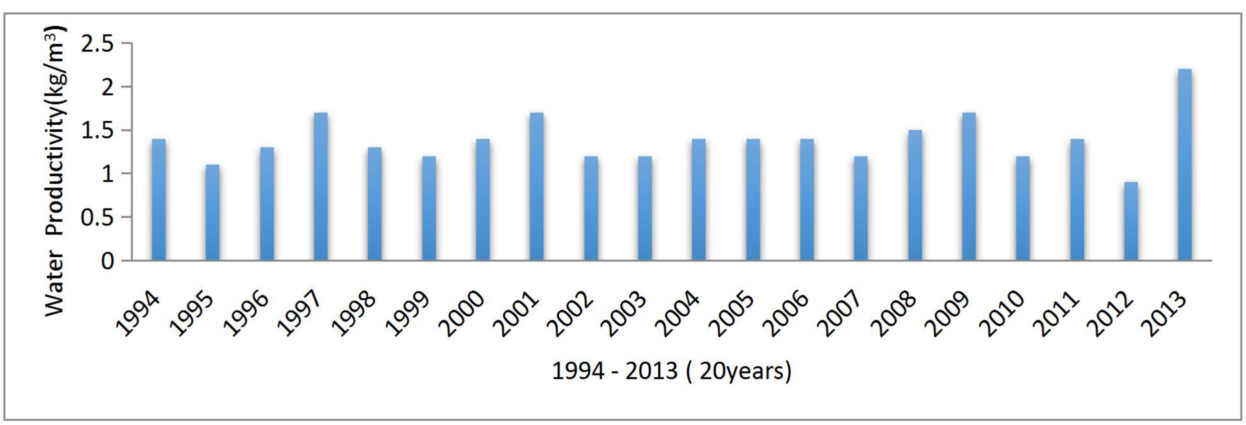

Figure 2: Water productivity

3.2 Cost of Alternative Water

Table 3: Annual water cost

Year	Cassava Yield (Kg/Ha)	Effective Rainfall (m^3)	Effective Rainfall (litre)	Cost of water Used (₦)
1994	10592.8	7774	7774000	13324636
1995	10667.1	9496	9496000	16276144
1996	10664.6	8085	8085000	13857690
1997	11881.8	7026	7026000	12042564
1998	10746.1	8292	8292000	14212488
1999	9599.8	8146	8146000	13962244
2000	9700.0	7188	7188000	12320232
2001	9601.2	5778	5778000	9903492
2002	9901.3	8198	8198000	14051372
2003	10402.3	8584	8584000	14712976
2004	11001.1	7690	7690000	13180660
2005	10990.2	7890	7890000	13523460
2006	12000.3	8422	8422000	14435308
2007	11202.6	9210	9210000	15785940
2008	11800.4	7908	7908000	13554312
2009	11767.9	7026	7026000	12042564
2010	12215.5	10371	10371000	17775894
2011	11210.8	7768	7768000	13314352
2012	7958.5	8707	8707000	14923798
2013	13947.4	6448	6448000	11051872

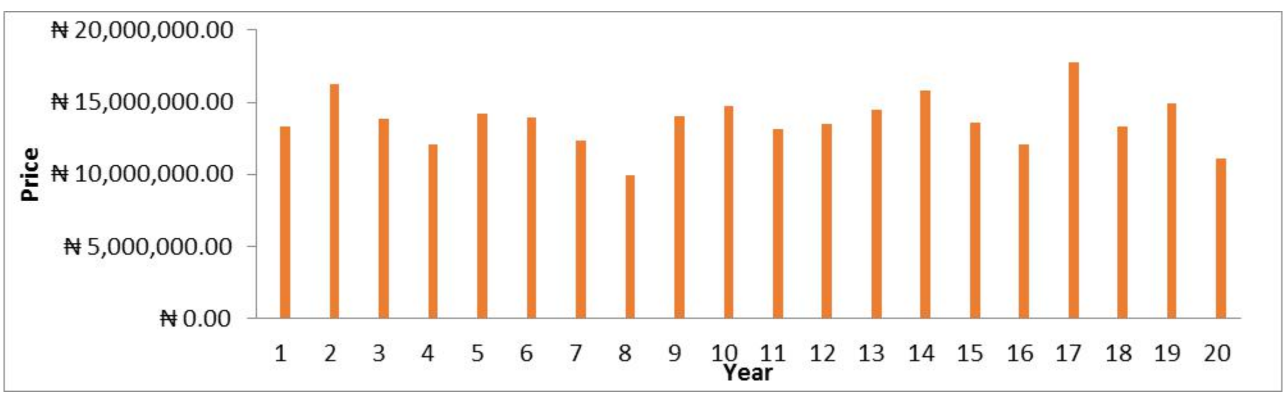

Figure 3: Cost of water

The maximum yield of cassava in kg/ha was recorded to be 13,947.40 as at the 20th year (2013) which was planted on the 26th of March and harvested on the 30th of November, with an effective rainfall of 644.8mm. Based on the trend of data collected, it shows that the maximum yield was recorded when we observed low rainfall which can be linked to the cost of water that can be used in replacement for effective rainfall (irrigation).

From the figure above, the cost of water used in replace of rainfall on yearly basis (i.e. 1994 – 2013). The maximum cost of water used was observed on year 17 (2010) with the maximum price of 17,775,894. The minimum cost of water used was observed on year 8 (2001) with the minimum price of 9,903,492.

These costs are important to determine so that it could be valued along with the main cost of cassava like in the determination of virtual water. This is applicable mostly in countries like Israel where water is very scarce. When cassava is produced, the value of the cost of water used for the production is added to the selling price in case of export. Similar thing should be employed here so as to attach value to our water. Planting early in the rainy season will generally produce the highest yields as shown in Table 2. All the cassava planted early in the month of march in the 1995, 2010, 2011 and 2013 had a better yield compare to others except in some few occasions and this was due to the fact that the plants have adequate soil moisture during the most critical part of their growth cycle.

However, research has shown that yields can vary according to the variety used, the soil type, the plant's age at harvest, and the rainfall intensity and distribution during any particular year. One or more of the aforementioned factors could be responsible for the low yield in 2012.

4.0 Conclusion and Recommendation

Based on the yield shown above, effective rainfall and water productivity observed to be maximum in the 20th year (2013), the cost of water was calculated to be ₦11,051,872 in which the costs is low compare to other years. This amount can be used to purchase water need for cultivation of cassava in dry season when irrigation is needed in order to obtain maximum yield. The cost of water used can also be used to calculate the concept of virtual water.

It is strongly recommended that other parameters like sunshine hour, temperature etc, should also be put into consideration in determining the water productivity for the production of cassava as this will shed more light on the crop yield to water use relationship. Since the effective rainfall was determined using Cropwat 8.0 model, it is advised to use other models rainfall data for this study.

It is as well recommended that federal government parastatals and research institutes should be willing to assist in researches by their willingness to release data and useful materials to assist in further research works.

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