

SUSTAINABLE WATER MANAGEMENT SYSTEM FOR CROP PRODUCTION IN NIGERIA
PLANTAIN, CITRUS, PINEAPPLE AND TOMATO AS CASE STUDIES

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ABSTRACT

Four candidate crops namely citrus, plantain, pineapple, tomato were selected for this study. Twenty seven year rainfall data were obtained from NIHORT, Ibadan. Growth stage of the crops citrus, 1977 - 1985; plantain, 1993 - 1994; pineapple, 1995 - 1996; and tomato, 2007 - 2008 were determined. Land mass (km²) of twelve cities such as Port Harcourt, Kano, Sokoto, Jos, Abuja, Bida, Markurdi, Eket, Warri, Enugu, Calabar, and Ibadan were assessed through the internet. Positions of each city were obtained from the Nigeria Institute of Meteorology (NIMET). Three months rainfall data of the twelve cities were retrieved from NIMET. Monthly maximum and minimum temperatures were collated. Reference evapotranspiration, crop coefficient and crop water needs were calculated. Predicted and potential amount of rainfall water available for harvest were evaluated. Rainfall harvesting structure was installed and tested. Results obtained showed that about 15m³ of water was harvested at Ibadan between August and December, 2008. Eket with land area of 175, 477km² and monthly rainfall of 452.5mm positioned on latitude 4°57'N and Longitude 8°20'E exhibit the highest rainfall water harvesting potentials at 1.728 x 10⁶m³ in three months. Analysis of the crops water need indicated 124.27mm, 358.15mm, 385.05mm, and 7,634.35mm per growth season for tomato, pineapple, plantain and citrus respectively using the generated model from the rainfall-water harvest of NIHORT, Ibadan, $Y = 5.75X + 198$, where X = rainfall (mm), and Y = rainfall water harvested in litres.

INTRODUCTION The population of Nigeria according to the recent census is well over 148million. The natural resources in terms of land coverage are about 92,000km³. Less than 2% of this land mass is put into irrigation based horticultural crop production. Unfortunately, food production trend does not correspond to the population growth of Nigeria which is put at about 3.5%. It is therefore expedient that, to ameliorate poverty alleviation and stabilize food security, management of our natural resources cannot be politicized or under-estimated. The unique position of water in the world predicated researchers to look for sustainable alternative to conventional water resources, especially in the enhancement of subsistence farming (Andres, 1995; Gioda et al., 1993) as it affects resource poor rural families. FAO (2003) reported that among the 93 developing countries surveyed, 10 are already using more than 40% of their renewable water resources for irrigation. Presently, current global water withdrawals for irrigation was estimated at 2,500km³/yr (FAO, 2003), where as with the current world population put at 6 billion, the required quantity of water to meet this population is about 6000km³. This observation leaves a deficit of 3,500km³ of water that is needed to meet the expected target. Rainwater harvesting therefore becomes an indispensable alternative to provide for the shortfall while also recharging the groundwater. Unfortunately, out

of one hundred and ninety countries of the world, thirty of them had no record of functional renewable water resources data with Nigeria ranked as the worst affected (FAO, 2003). The alarming rate of the world population growth rate estimated at 6.5 billion in 2006, 7 billion in 2010, 8 billion in 2025 and 10 12 billion with the most expected increase occurring in developing countries (Lal, 2006) calls for SWM to cope with these challenges. In addition, the increasing demand for water resources of 300km³yr⁻¹ in 1900, 3,400km³yr⁻¹ in 2000 coupled with the estimated population affected by water scarcity of 130million in 1990, 436 million in 1995 and projected to be 800 million and 3,950 million in 2025 and 2050 respectively (Lal, 2006), concerted research efforts must be put in place for provision of water to cope with the demands. Sustainable water management system that will address all the raised issues must therefore be water resources conserving, socially supportive, commercially competitive and environmentally sound (Gold, 2007). Natural resources abound in Nigeria. These include lands, rivers, underground water, rainfall and sunshine hours coupled with solid minerals. However, the life wire of this seemingly limitless resource is water because life becomes difficult and uncomfortable without it. Generally, management of resources should be more of challenges than availability in sufficient quantity to Nigeria. This predicates on the fact that

management of land, human and other natural resources is a major problem stirring the economy of the country. Various water management system as a natural resources has been developed to increase food production in the country. These include construction of irrigation system like sprinkler, flood, basin and surface measures. Notwithstanding these inventions, food production constitutes the major challenges facing the government of Nigeria. These water management systems however collapsed either due to poor maintenance or inadequate knowledge of the farm families in handling them when broken down. A low-cost sustainable water management system through rain harvesting for horticultural crops especially in plantain, citrus, tomato and pineapple. Rain water harvesting system consists of three main components which include the functional roof, which is designed to capture rain that falls on the roof, the storage device for storing of water captured through the roof gutter and the distribution adjoints made of plastic pipes for easy of haulage. Rain water harvesting could be described as resource poor farmers friendly because of the inability of the poor to afford the capital intensive and technically complex traditional water supply system widely promoted by governments and agencies worldwide (John and Erik, 1999; Lee and Visscher, 1990; John, 2000). Rainwater harvesting was used by the National Horticultural Research Institute,

Ibadan to develop 0.5ha of juvenile citrus trees (Afolayan et al., 2008). However, crops such as tomato, pineapple, citrus and plantain were discussed. Rainwater harvesting agriculture (RHA) according to Fengrui et al., 2000 was first developed by scientists in Gansu province over a decade ago. It is considered an integrated system for water management on rainfall land in semi-arid areas. However, its success requires integration with other agricultural technologies and management practices. Rainwater harvesting is adaptable to a wide variety of crops such as plantain, citrus, tomato and pineapple etc. The importance of plantain to human nutrition predicated on its nutrients value abundant in the leaves. These include boron, manganese, calcium and magnesium. Hence, irrigation becomes unique and indispensable when considering plantain nutrition balance (Chandler, 1995). Tomato is a major source of vitamins and mineral with over 20 chemical composition (Rai and Yadav, 2005) and is being exploited as a promoter of gastric secretion and blood purifier (Kallo and Bhutani, 1993). Tomato is also used in cancer of the mouth and sore mouth. Recent studies even revealed that tomato protects against cancer of the digestive tract and prostate (Rai and Yadav, 2005). Pineapple performs best between 24° and 27° with annual rainfall of 1200–1500mm and potential yield estimated at 40–75t/ha (Romain, 2001). The vegetative part constitute good fodder

for animals while the leavers contain a very resistant fibre used for making clothing and cordage (Romain, 2001). Citrus consisting a wide array of species namely sweet orange, lemon, grapefruit, lime, mandarin, has worldwide production at 85 million tons. The aim of this study is the development of alternative sustainable water management different from the conventional management system through surface or undergroundwater for the production of horticultural crops mainly plantain, citrus, pineapple and tomato.

MATERIALS AND METHODS

Four high priority, horticultural crops namely PT, PA, TO, and CT were isolated and selected for this study. The growth stages of the crops with effect from direct seeding till first day of harvesting were determined as follows: PT 1993 1994, PA 1995 1996, TO 2007 2008, CT 1977 1985. Twenty seven years rainfall data were obtained from the Meteorological station of HIHORT, Ibadan. Effective rainfall was calculated using Crop Wat 4 Windos version 4.3 developed by Martin et al; 2003. Reference crop evapotranspiration (mm/day) (ET_0) was calculated from the model of Blanney-Criddle $ET_0 = p (0.46T_{mean} + 8)$, P mean daily percentage of annual daytime hours,

$$T_{mean} = \frac{T_{max} + T_{min}}{2}$$

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T_{mean} = mean daily temperature ($^{\circ}C$), T_{max} = the ratio of the sum of all T_{max} values during the month to the number of days of the month, T_{min} = ratio of the sum of all min. value during the month to the number of days of the month. The crop water needs (Etc) was determined using $ET_{crop} = ET_0 \times K_c$ where K_c is crop factor based on crop growth stages. Land mass (km^2) of twelve selected cities consisting of KNO, SOK, JOS, ABJ, BID, MAK, EKT, WAR, PHT, ENG, CAL, and IBD were assessed through the internet. Position of each city reference to Latitude ($^{\circ}N$) and Longitude ($^{\circ}E$) were obtained from the Nigeria Institute of Meteorology (NIMET). Three months continuous rainfall pattern of the cities were retrieved from NIMET. Mean values of monthly maximum and minimum temperatures were determined. Rainfall harvesting structure was constructed based on $28m^2$ surface area and 7.5m gutter length at 0.7m head loss. Rainfall data for the computation of the amount of water harvested was obtained from Agro-Met garden of NIHORT, Ibadan.

RESULT AND DISCUSSIONS

Total growth stages of the four crops are shown as follows: Citrus exhibited the highest growth stages with the following breakdowns, initial growth stages 337days crop development stages 609 days, mid season 731 days, late season

maturity stages 1461 days; plantain records 62, 93 and 185 days as initial crop development, mid-season and late season growth stages, pineapple maintain 52, 76, 31 and 154 days for initial, crop development, mid season and late season growth stages and tomato being the crop with the least growth stages records 31, 93, 30 and 154 late season s growth stages respectively. This trend tallies with the physiological stages of the different crops especially where moisture is not limiting. Table 1 present the 3 months rainfall pattern of the selected cities in Nigeria. ENG with the land area of 8.027km^2 and Latitude $6^{\circ}28'N$ recorded the highest amount of rainfall in July followed by KNO and MKD, the least. Rainfall data of August however deviates from the July pattern. This is expected in view of the conventional 2 week rainfall break experienced in Nigeria known as August dry spell. However, WAR (13110km^2 and Latitude $6^{\circ}4'N$) had the highest rainfall at 684.2mm and SOK ($32,000\text{km}^2$, Latitude $13^{\circ}01'N$ the least (130.2mm). Similarly, ENG maintained its lead followed by IBD ($27,000\text{km}^2$) and Latitude $26'N$) at 428.5mm and 401.1mm respectively. Table 2 explains the pattern of rain days in these cities within 3 months of rainfall. In all the months, rainfall appeared fairly uniformly distributed with

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rain days for JOS, the highest; 7 days for MAK, the least. Similar trends characterized the months of August and September, 2008 Although, conventionally, horticultural crops could be adequately propagated in all the cities with the exception of MAK that recorded less the recommended in September at 83mm. Table 3 shows the predicted and potential amount of rainfall water available for harvest in the selected cities. In July, EKT appeared the city with the highest potential at $1727.82 \times 10^6\text{m}^3$ and CAL, the least.

This observation holds because rainfall amount is directly proportional to the land mass, assuming harvesting roof structures are constant. Records for the month of August shows a similar trend. Generally, the potential in the quantity of water available for harvest suggest that horticultural crop production is economically buoyant in all the cities with high degree of success if rainfall data is properly assessed and utilized. Average crop water needs (mm/day) for are 2.43, 72.99; 0.78, 23.34; 0.73, 21; and 0.66, 19.83mm respectively. CT has the highest crop water need followed by PT. This is expected because the growth stages differ accordingly. Fig. 1 and 2 show the processes of rainfall harvester design. The design takes into consideration storage capacity of the reservoir. However, the development is subject to improvement so as to standardize the surface area across Nigeria agro-ecologies.

CONCLUSION

Over dependence of Nigeria on oil has relegated horticultural crop production to the background. However, with imminent collapse in oil industry due to the activities of the militants, it is essential for the country to invest in water resources management that is rainfall driven. Experts should be assembled to study the weather pattern and foods production trend in the country. Reliable data is very scanty on the recharge capacity of our underground and surface water.

Even then, fortune is required to harvest these forms of water for domestic and horticultural activities due to high capital involvement in acquiring water machines, purification systems and connection pipes. Rainwater therefore, can be harvested from all the building and piped for domestic activities. Farm rainfall harvester could be constructed across the agro-ecologies of Nigeria and networked through irrigation facilities for food production.

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Total *Table 1: Rainfall pattern and Temperature profile of some cities in Nigeria for 3 months with respective mass.*

<i>Cities</i>	<i>T_{max} (°C)</i>	<i>T_{min} (°C)</i>	<i>July</i>	<i>Rainfall (mm) August</i>	<i>Sept.</i>	<i>Land mass (Km²)</i>
Kano	35	25	371.7	274.9	134.9	20,760
Sokoto	35	25	152.2	130.2	-	22,000
Jos	26	23	272.2	307.8	157.4	26,899
Abuja	35	25	183.0	370.9	195.0	7,315
Bida	35	25	305.6	252.1	-	74,244
Makurdi	30	25	109.3	280.2	83.0	30,955
Eket	30	25	275.7	684.2	397.5	175,477
Warri	30	25	501.9	635.4	420.5	131,110
Porthacourt	30	25	285.1	289.2	375.5	17,400
Enugu	30	25	222.3	338.4	300.2	8,022
Calabar	30	25	510.2	597.7	217.9	604
Ibadan	30	25	221.4	250.3	401.1	27,000

TABLE 2: Rain Days Pattern, Latitude ($^{\circ}N$), Longitude ($^{\circ}E$) and ET_0 value of some cities in Nigeria for 3 months.

Cities	<u>Rain day</u>			Latitude ($^{\circ}N$)	Longitude ($^{\circ}E$)	Evapotranspiration (ET_0) (mm)		
	JULY	AUG	SEPT			JULY	AUG	SEPT
Ibadan	18	18	7	$12^{\circ}21'$	$8^{\circ}32'$	6.10	6.40	6.94
Okoto	8	16	-	$13^{\circ}01'$	$5^{\circ}16'$	6.10	6.50	-
Osogbo	26	26	15	$9^{\circ}52'$	$8^{\circ}54'$	5.40	5.20	5.50
Lagos	12	21	17	$9^{\circ}37'$	$6^{\circ}12'$	6.10	5.50	6.40
Abuja	22	25	-	$9^{\circ}05'$	$6^{\circ}01'$	6.10	6.40	-
Enugu	7	19	9	$7^{\circ}42'$	$8^{\circ}35'$	5.80	5.70	7.07
Kaduna	23	27	24	$4^{\circ}57'$	$8^{\circ}35'$	5.80	5.50	5.71
Warri	23	20	25	$5^{\circ}31'$	$5^{\circ}44'$	5.80	5.52	6/04
Niger	19	25	19	$6^{\circ}28'$	$7^{\circ}33'$	5.80	5.87	5.85
Port Harcourt	17	25	19	$4^{\circ}57'$	$7^{\circ}01'$	5.80	5.50	5.50
Alabar	22	27	22	$4^{\circ}57'$	$8^{\circ}20'$	5.80	6.10	6.10
Adani	23	21	24	$7^{\circ}26'$	$3^{\circ}54'$	5.80	6.04	5.72

Source NIMET Quarterly Weather Review, 2008 and WAMEX Symposium, 1987

TABLE 3: 3 Months Rainfall Amount (mm) and potential for water harvest in some selected cities of Nigeria (July-September, 2008)

Cities	Rainfall amount (mm)			Predicted water amount (litres) for harvest at $28m^2$ roof surface			Potential water amount (m^3) for harvest		
	July	Aug	Sept	July	Aug	Sept	July	Aug	Sept
Ibadan	221.4	250.3	401.1	1471.05	1637.23	2504.33	312.49	241.36	386.78
Okoto	371.7	274.9	134.9	2335.28	1778.68	973.68	274.79	203.82	100.02
Osogbo	152.2	130.2	-	1073.15	946.65	-	173.94	148.80	-
Lagos	272.2	307.8	157.4	1763.15	1967.85	1103.05	261.50	295.59	151.16
Abuja	183.0	370.0	195	1250.25	2330.68	1319.25	47.81	96.90	50.94
Enugu	305.6	252.1	-	1955.2	1647.58	-	810.32	688.46	-
Kaduna	109.3	280.2	83.0	826.48	1809.15	675.25	120.83	309.77	91.76
Port Harcourt	275.7	684.2	397.5	1783.28	4132.15	2483.63	1727.82	4287.9	2,491.15
Warri	501.9	635.4	428.5	3,078.75	4049.55	2661.88	235.01	297.53	200.65
Niger	285.1	389.2	375.5	1837.33	2435.9	2357.13	177.17	241.86	233.35
Adani	222.3	338.4	300.2	1476.23	2143.8	1924.15	63.69	96.95	86.01
Alabar	510	597.3	217.9	3,131.65	3632.48	1450.93	11.01	12.88	4.70