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Philipa O. Idogho, Olotu Yahaya

Determination of Water Sensitivity Index in Estako-West and Esan Central, Nigeria

As world population and industrial-agricultural outputs have increased, the use of water has accelerated. This development leads to extreme difficulty to provide sufficient safe drinking water in Etasko-West and Esan Central. Water sensitivity was measured in six major towns in Etasko-West and Esan Central. Water Measuring Indicators such as Water Poverty Index-Real Time (WPI_r), Water Factor Value (WFV) and Access-Demand Factor (γ) were applied to generate water sensitivity iterations. The outputs of these iterations show that Irrua *has the fairest water supply and distribution with WPI_r, WFA and γ index value of 0.22; 0.77 and 0.76, while Auchi and Ewu experience acute water shortage with the following index values: WPI_r-0.43, 0.39; WFV-0.06, 0.16; and γ-0.64, 0.6 respectively. Results of One-Sample Test and Paired Sample Statistics show that the proportion of monthly income spent on portable water is significant at 0.95 confidence interval in all towns, except Auchi. Comparative analysis indicates strong relationship (R^2=0.667) between the resources spent in procuring clean water and accessibility-demand ratio in the region. Private sector participation recorded highest investment value of 62% on water sector; government and corporate organization recorded 23% and 15% respectively. Since private sector determines the progresses of water sector, this accounts for the exorbitant tariff of 1, 500 N per m^3 in this region. It is deduced that the most significant problems faced with water accessibility-affordability are transportation, finance and power supply with computed constraint index value of 47%, 40% and 13% respectively. Finally, Etasko-West and Esan Central are highly water-stressed. Government, corporate organization and private investors need to establish technically-based measures to ensure perfect accessibility and affordability of this scarce utility.*

Keywords: *Water, Accessibility, Sensitivity, WPI_r, Estako-West, Esan Central*

1. Introduction

"Water is Life" is a notion which is accepted without exception. It is one commodity without which life cannot exist on this earth – not only because it is essential for the actual living process but also because it is necessary for supporting man's material activities, which lead to his material development (Hassanali, 2005). Vast quantities of water exist on the earth. Research shows that oceans cover an area of about 360 million cubic km, which is equivalent to almost 71% of the earth's surface; in addition water is present in lakes, rivers and streams, underground and in the atmosphere. However of the total quantity available, which amounts to over 1,300 million cubic km, only 35 to 40 million cubic km is freshwaters (Hassanali, 2005). With increasing human population and consequent increasing human activities, coupled with decreasing natural resources, the need for water for survival has taken added dimensions in the recent years. Progressive pollution of freshwater supplies by accelerated human activity has made an already critical problem, even more acute (Olotu et al., 2009).

In the last 50 years, the world's urban population has increased fourfold, and now closes to 50% of the world's population lives in urban centers. But while urban populations grew rapidly, expansion of water supply services did not. Spending on water supply has not kept pace with growth, and there are dramatic differences in infrastructure expenditure between cities in low and high income countries. As a result, it is estimated that between 30% and 60% of the urban population in most nations is not being adequately served. (Basu, 2001).The poor are more likely to use inadequate or contaminated sources such as unprotected wells or surface water; to rely on time-consuming methods of water collection, such as stand posts or hand pumps; and to be forced to pay high prices for informally-vended water. Having noticed the degree of water-stress in most of our communities at Estako West and Esan Central, combating this problem, techniques and integrated models are expected to be developed, tested with veritable output to ensuring economic and optimum usage in order to reduce the extent of water scarcity, improve water supply and even distribution.

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2. Materials and methods

2.1. The Study Area

Etsako West and Esan Central are the two most water-stressed regions in Edo State, Nigeria. Both local government areas were created in 1991. The regions cover areas of 943.47 km^2 and 266.3 km^2; with their headquarters situated at Auchi and Irrua respectively. The dwellers in these areas are predominantly farmers, traders and civil/public servants. Auchi is densely populated due to the influx of people in and out of the place as a result of its strong commercial and educational links. In addition, Edo State has approximately between latitude 05°

44′N and 07° 34′N of the Equator and between latitude 06°04′E and 06°43′E. It is bounded in the South by Delta state in the West by Ondo State; in the North by Kogi State and in the East by Anambra state (Benin city, 1999). According to the 2006 national census, Etsako West has a total population of 127,718 comprises of 65,312 Male and 62,406 Female while Esan Central has a total population of 105,242 comprises of 53,017 Male and 52,225 Female. However, the two regions have almost the same soil type which is generally the reddish yellow land with two distinct seasons; wet and dry seasons. Figure 1 shows area view of the settlement in the regions under consideration.

Figure 1. Area view of the region. Source: MTN-Nigeria,2012

Data for this research study were primarily sourced. Obtained findings were technically compared with some of the studies from other authors. A total of 200 questionnaires were randomly distributed to some respondents across the selected towns and villages in the region.

2.1.1 Water Poverty Index -Real Time Approach

Computing Water Poverty Index using real time analysis is the most convenient method. However, this technique cannot be used to capture a wide-range of water resources data. Based on this, the expression in equation (1) below could only be applied to estimate water index on a confined range of data generation; and the output would be subjected to validation (Olotu et al., 2009).

$$WPI_R = 0.98\frac{T}{V} \quad (1)$$

Where: WPI_R means Water Poverty Index Real Time Approach; T is the time taken to access water, while V is the Volume of water that can be accessed.

2.1.2. Water Factor Value: Using area Composite Approach

This approach is more flexible and applicable than Real Time mechanism. It comprises all the components that determine the degree of water scarcity in any given region. Variations of each of these components is location-area dependent. The expression in equation (2) shows the relationship of the components:

$$WFV = \frac{R + E + U + C + A}{5} \tag{2}$$

Where: WFV means Water Factor Value, R is the water resources in the area; E is the environmental composition of the location; U is the use to which water resource is applied either for domestic, agriculture, industrial or recreation; C and A mean Capacity to manage water resource and degree of water Accessibility to the teeming population respectively.

Equation (2) is structurally modified as follows:

$$WFV_c = 0.2(R + E + U + C + A)\alpha \tag{3}$$

Where α is the accessibility factor for portable water. However the value of α varies from region to region as it is shown in the Table 1.

2.1.3. Index of Volume-Water Access and Volume of Water Demand

Water accessibility ratio for all the selected areas was determined using the expression in equation

$$\gamma = \alpha \frac{VWA}{VWD} \tag{4}$$

Where γ is the index of volume of water access to volume of water demand; VWA and VWD stand for volume of water accessible and volume of water demanded at a given time respectively. In most areas, the modification value α is between (0.85-1.00).

2.2. Data analysis

Generated data were subjected to mathematical-based iteration using the derived expressions in 1, 2, 3 and 4 respectively. Statistical analysis such as One-sample statistics, paired sample correlation and paired sample test were applied to analyze the outputs of generated data. Calibration curves series such as linear, power and polynomial were used to produce water demand-access curves.

4.1. Results and discussion

4.1. Water Demand-Access Calibration Curves

The calibration curves are shown in figure (1) to (6) respectively. The curves show the relationship between average volume of water needed (VWD) and volume that could be accessed and supplied (VWA). Ewu has the least values of **R^2=0.017; 0.004; and 0.004**. This indicates that there no relationship in water demand and supply at Ewu. The dwellers in this area primarily depend on rainwater and water hawkers. Findings also revealed that the area lacks the capacity to harvest large quantity of rainwater which could sustain them water during the dry season. In addition, the water hawkers usually fail to meet the demand due to reasons such as distance, road networking system and the price of the utility. Auchi and Aviele have better water distribution than Ewu. There are a good number of water vendors (Water tankers) in Auchi and its environs that distribute water to the subscribers, also some corporate bodies and private individuals invested in the provision of portable water in the area. Boreholes are drilled in strategic positions in Auchi and this spreads to Jattu and Aviele. Irru has fair distribution of safe drinking water. People in this area source for water through rain harvest, surface and underground water. The outputs of the research carried out shown that the aquifer in this region discharges appreciable quantity of water; this has resulted into a number of boreholes in the region. Most of these boreholes do not dry during the dry season, in Auchi, Aviele, Jattu, Ewu and Ugbalo boreholes are not very feasible. Most of them dry up during the dry drying season indicating that they are directly recharged by rainwater.

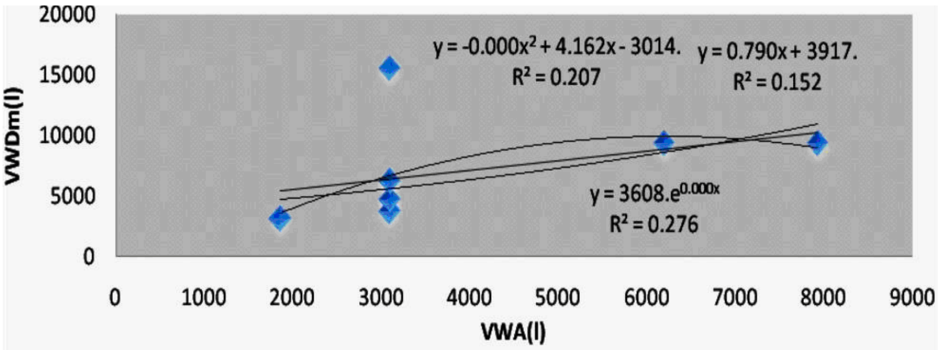

Figure 1. Water demand-supply caliobration curve at Auchi.

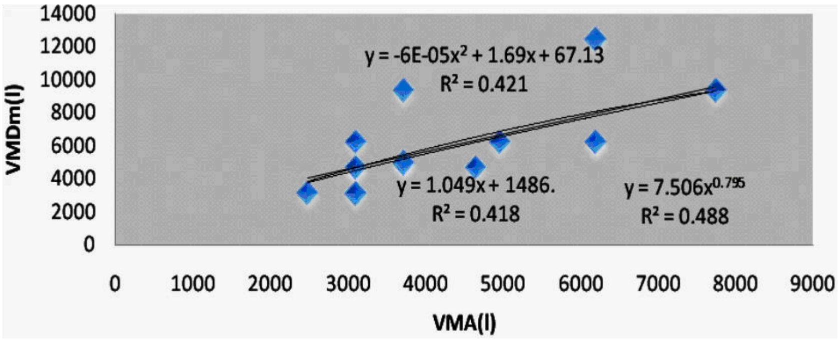

Figure 2. Water demand-supply calibration curve at Irrua.

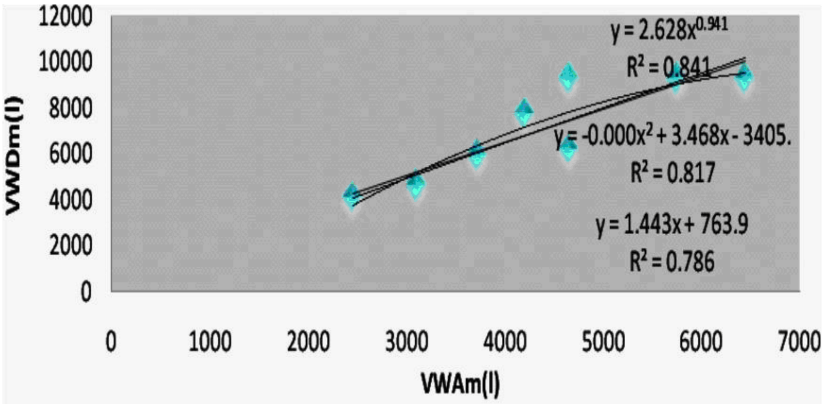

Figure 3. Water demand-supply calibration curve at Jattu.

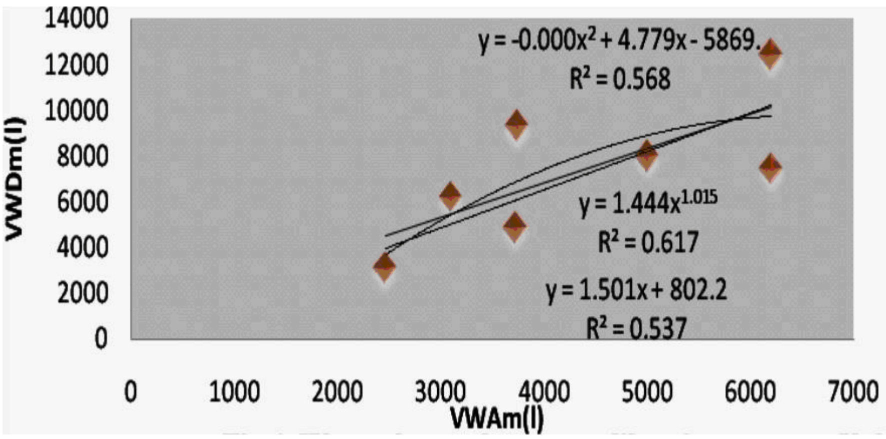

Figure 4. Water demand-access calibration curve at Ugbalo.

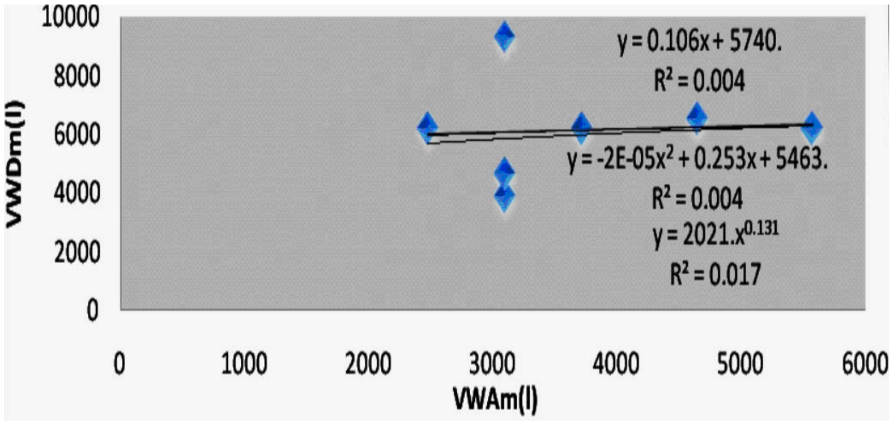

Figure 5. Water demand-supply calibration curve at Ewu.

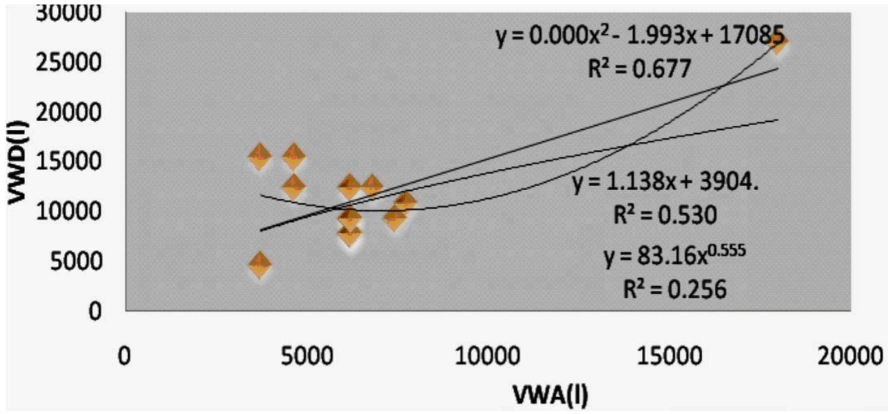

Figure 6. Water demand-access calibration curve at Aviele.

4.2. Water Monitoring Tools

Monitoring water supply and demand requires formulation of sensitive physics-based deterministic models (Olotu etal., 2008). Water resources variable such as capacity, environment, resources and access were applied to derived *Water Factor Value (WFA)* in equation [2] and [3]. Effective water accessibility and distribution using ***WFA*** tool ranges between [0.00-1.00]. The outputs of water resource iterations in all the towns shown that Irrua has the highest value of 0.76 and lowest value of 0.06 at Auchi. This observation shows that Irrua has the highest degree of water supply and distribution, while Auchi has the least water distribution coverage. *Water Poverty Index-Real Time Approach (WPI_r)* does not accommodate all above listed variables. The only parameters applied to derive the model are ***volume (litres), time (minutes) and correcting factor (C).***

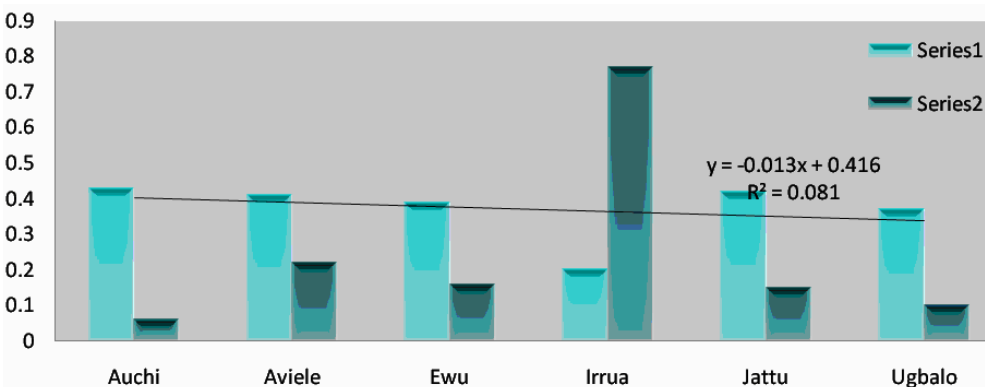

Figure 8. Descriptive chart of WPIr and WFV

As a result of limited derivation variables, WPI_r approach could not be used to monitor water resources progresses for a long period and also in populated zones. Auchi has the highest value of 0.43, while Irru has the least value of 0.20. The tool uses bottom-up measuring approach. Increase in WPI_r values correlate to the degree of water stress, scarcity and distribution. This shows that Auchi still has lowest degree of water distribution, while Irru enjoys strongest degree of water accessibility.

5. Conclusion

Estako-West and Esan Central are highly sensitive to deficit in supply and distribution of safe drinking water. These regions are moving towards a situation that could be described as ***permanent shortage of water utility (PSWU)***. Despite huge resource being sent on water resource at Auchi, this could still not ensure even and adequate supply. Aviele and Ewu experienced very acute water shortage, while Irrua and Ugbalo have very fair distribution of portable water at relative price. Private sector involvement has become an important aspect of the region's water related activities in providing access to portable water at very high rate, while the governments at every level are generally unable to generate and sustain the huge investments as well as required technical skills. Corporate organization participation on provision of safe drinking water in all the places visited is a voluntary scheme to assist the dwellers of these regions; ***management*** and ***maintenance*** of such water project is weak because tariff is not usually charged and this always reduces the life span of the project. Water Measuring Indicators such $\boldsymbol{WPI_r}$, ***WFV*** and $\boldsymbol{\gamma}$ produced realistic results which could be used to monitor water demand, supply and distribution for short-long time duration and also draw holistic measures against water shortage, scarcity and uneven distribution.

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Addresses:

- Dr. Philipa O. Idogho, The Rector, Auchi Polytechnic, Auchi, Edo state, Nigeria, philipaidogho@yahoo.com
- Olotu Yahaya, Department of Agricultural Engineering, Auchi Polytechnic, Auchi, Nigeria, realyahaya@yahoo.com

Corresponding author: philipaidogho@yahoo.com_realyahaya@yahoo.com