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Computation of Water-Stress Ratio in Western Nigeria

An increasing world population exerts a continually growing demand on usable freshwater resources. Access to water plays a key role in development; it supports human life in direct consumption, agricultural uses and industrial activities. Time and drudgery involved to access safe drinking water resulted to loss of human resources and capital, thus affecting nearly every household life. This paper focuses on the determination of water-stressed ratio using Integrated Water Measurement Tool (IWMT). Structured simple time analysis and Adjusted composite index approaches were employed to compute (IWMT) values in all the sampled areas. Variables such as access to safe water coverage, water availability and use of water were considered. IWMT values from the two approaches show that Ese-Odo is the most water-scarce region with least IWMT values of 14.1 (Adjusted composite index: ACI) and highest value of 2.6 minsl^{-1} (Structured simple time analysis: SSA), while Owo, Ondo-West and Ose local government areas experience fair distribution of protected water supply with IWMT values of 1.05 minsl^{-1}, 20.8; 1.00 minsl^{-1}, 17.2; and 0.55 minsl^{-1}, 16.9 respectively. The results obtained indicate that constructive investments in water and sanitation would reduce proportion of household income spent in sourcing for safe drinking water, prevention of water-related diseases and in turn improves productivity. However, this paper concludes that top-down technical approach must be balanced with a bottom-up mechanism in order to derive realistic systems to prevent persistent water scarcity, shortage and to draw realistic adaption measures..

***Keywords**: IWMT, index, water stress, safe water, access, water-scarce, uses, household, ACI, SSA, ratio*

1. Introduction

During the last few years, water has become an increasingly important issue in industrialized and developing nations. In order to attain the Millennium Development Goals of halving the population of people without access to safe water by 2015, integrated water management approaches are required (IWMT). In monitoring the achievement of portable water at the local level, appropriate indicators are However this situation is very complex to explain in a simple language, therefore an index has been found to be a feasible way to express such complex condition (Steven *et al.*, 2002). The Water Poverty Index (WPI) was identified as the possible indicator for monitoring progress at the local level as it puts access to water in a wider water-related context (Sullivan 2000, 2002). The index has been designed to identify and evaluate poverty in relation to water resource availability (Steven *et al.*, 2002). Water shortages may relate to the inadequate ability of society to access the small volumes of water needed for drinking and domestic purposes. In most cases in developing world where they are water-stressed, women and children particularly girls spend most of their productive time trekking long distances sourcing for water. Public health systems are over-burdened by diarrhoeal diseases- the UN says that at any time; half the hospital beds in the developing world are occupied by patients suffering from diarrhoea and other water related ailments. (UNDP, 2004).

In analysing the reasons for water problems, it is important to recognise that water scarcity can be considered in two ways. First order scarcity is the shortage of water itself, while second order scarcity is that resulting from lack of social adaptive capacity. The poor lack social adaptive capacity and this suggests that this aspect of development in the water sector is most pertinent to poverty alleviation (Sullivan *et al.*, 2001).

Having technically evaluated water constraint globally, mostly in developing nations, this research study is designed and developed to test, validate and calibrate existing water-stressed model by applying Integrated Water Measurement Tool (IWMT). Adjusted Composite Index (ACI) and Structured Simple Time Analysis (SSA) are integrated components of IWMT model. These components are very flexible and allow incorporation of many water variables. IWMT model will be established to run all the data obtained in all eighteen local government areas in Ondo-State, Nigeria.

2. Materials and Methods.

2.1 Study Area

Ondo State is made up of 18 Local Government Areas is located in the South-western Zone of Nigeria. The state lies between longitudes 4”30” and 6” East of the Greenwich Meridian, 5″ 45″ and 8″ 15″ North of the Equator. This means that the state lies entirely in the tropics. Ondo State is bounded in the North by Ekiti/Kogi States; in the East by Edo State; in the West by Oyo and Ogun States, and in the South by the Atlantic Ocean. **Land Area:** 14,788.723 Square Kilometres (km^2). **Population:** 3,441,024 comprising 1,761,263 Males and 1,679,761 Females.

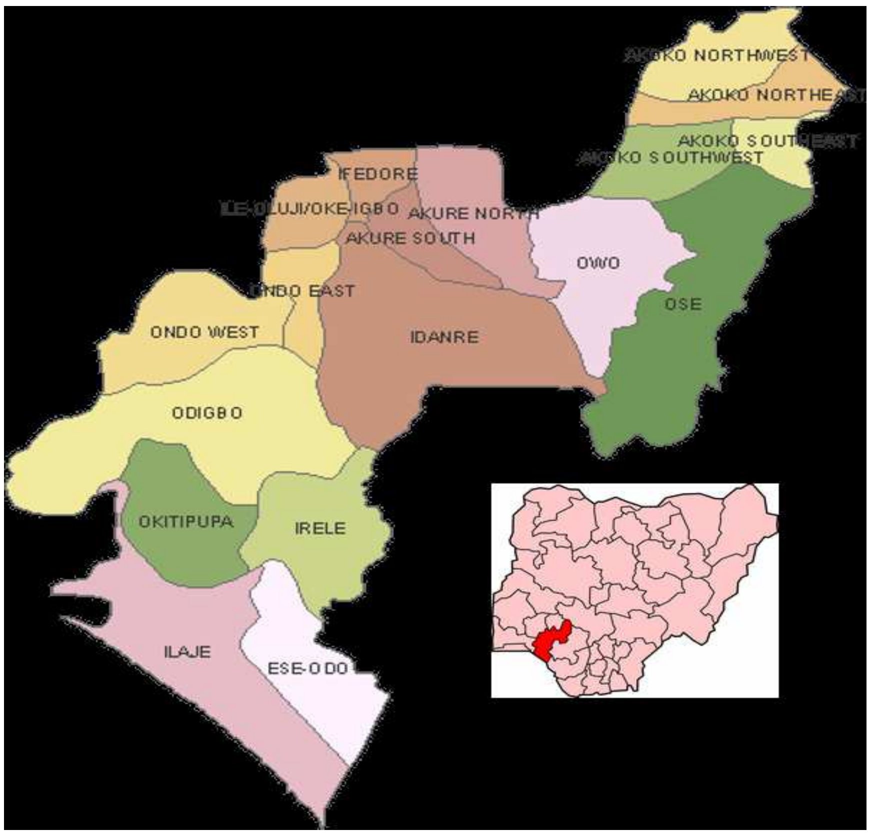

Figure 1. Map of Ondo State showing investigation locations.

2.2.1 The Composite Index Approach

In this approach, the index was constructed from a series of variables which captured the essence of what is being measured using national scale (Rodiya, 2007). A simple relationship was constructed for computing WPI taking into consideration all the key variables as follows:

$$SWPI = W_a A + W_s S + W_t (100 - T) \quad (1)$$

Where A is the adjusted water availability (%). The value of A should recognize the seasonal variability of water availability), S is the population with access to safe water and sanitation (%) and T is the index to represent time and effort taken to collect water for the household and WPI is the water poverty index. For the purpose of this study, (T) was modified to take account of gender and child labour issues as follows: (100-T). Since A, S, T are all defined to be between 1 and 100; W_s, W_t is 0.25 by weight and W_a is given 0.5. Therefore,

$$W_a + W_s + W_t = 1.0 \quad (2)$$

The relationship in equation (1) is finally modified as follows:

$$SWPI = \frac{1}{3}[W_a A + W_s S + W_t (100 - T)] \quad (3)$$

where W_a, W_s and W_t are the weight given to A, S and T respectively.

2.2.2. Adjusted Composite Index

Equation (3) above does not have capacity to contain all the veritable water variables. The relationship is further adjusted as follows:

$$IWMT = \frac{1}{3}[W_a A + 0.53C + W_s S + O.9D + W_t (100 - T)] \quad (4)$$

Where *C and D* are the adjusted water variables for the developing nations.These range between (0-1.0) depending on the water situation of such community.

2.2.3. Simple Time Analysis Approach

WPI is constructed using bottom-up approach considering variables such as total time taken in collecting water including queuing time, volume of water collected in each trip. For the household with pipe borne water, the volume and time taken to collect water per head is assumed to be the same across the members of the household. Using time-analysis approach, the index is determined as follows:

$$SWPI = \frac{T}{V} (\min/l) \quad (5)$$

where T is the total time (in minutes) spent per person in a day to collect water, while V is the volume of water collected in litres. In addition, the expression in equation (5) does not take in consideration of the time spent to travel to and fro for an individual to source/gather water. The time considered is the total time spent for queuing processes. Based on this discovery, equation (5) is adjusted as follows:

$$SSA = 1.86C\frac{T}{V}(\min/l) \quad (6)$$

Where C is the correcting factor that is used to address the total time taken to gather water; this factor is almost *unity*.

Based on a reconnaissance survey of eighteen local government areas in Ondo-State, ten most water-stressed communities in each of the local government areas were randomly selected for sampling purposes. 180 questionnaires were randomly administered to 18 households in each of the 100 sampled communities in all the local government areas. Data were obtained, tested and validated using the relationship in equation 3, 4, 5 and 6. Overall results were compared to draw conclusive resolutions.

3. Results and discussions

3.1 Computational analysis of Integrated Water Measurement Tool (IWMT) using Adjusted Composite Index (ACI) and Structural Simple Time Analysis (SSA).

Data were collected from 100 most water-stressed in all the local government areas in Ondo-State, WPI values were calculated using composite index and simple time analysis approaches. The summary of the dataset, showing means of total volume of water collected (T_V), total time spent to collect water (T_T) and Local Government Areas (LGA), is presented in Tables 1 and 2.

The Tables showed that Ese-Odo local government has the highest value of IWMT (2.2 $mins l^{-1}$), while Ondo-West has the least value of 0.8 $mins l^{-1}$ during the wet season as presented in Table 1. It was also found that Ese-Odo local government still recorded highest IWMT value of 2.6 $mins l^{-1}$, while Ose local government has the lowest IWMT value of 0.9 $mins l^{-1}$ during the dry season as presented in Table 2. This simple analysis showed that Ese-Odo local government is the most water-stressed region in Ondo State followed by Ilaje, while water stress was considered to be least at Ondo-West and Ose local government during wet and drying seasons respectively. During the consultation process, it was discovered that the dwellers derived their drinking water from a variety of sources such as; direct withdrawal from pond, streams and river, traditional wells of up to 1.5-2.0 m diameter with local construction, modern wells that are usually filled with concrete in order to prevent outside contamination and seepage flow and reticulated solar-powered boreholes of cleaner and high quality water. However, the presence of Owena multipurpose dam reduced the water-stress condition of Ondo-West, Ondo- East and Akure South local government. In addition, Awara dam serves Akoko N-E and some part of Akoko N-W, while Ose dam serves Owo and Ose local government areas as presented in Table 3. Aquifer in this region discharges sufficient amount of water which improves the yield of an average borehole in the above-named local government areas. Most of the faulty boreholes happened as a result of mishandling by dwellers, minor electrical and mechanical problems which could be easily corrected by community project management team.

Table 1. WPI and IWMT values for all the local government areas in Ondo-State in wet season.

S/N	L.G.A	T_T (min)	T_V (liters)	WPI	IWMT
1.	Akoko N-E	110	200	0.55	1.0
2.	Akoko N-W	130	200	0.65	1.2
3.	Akoko S-E	140	200	0.70	1.3
4.	Akoko S-W	110	200	0.55	1.0
5.	Akure-North	102	200	0.51	0.9
6.	Akure-South	105	200	0.53	1.0
7.	Ese-Odo	240	200	1.20	2.2
8.	Ifedore	130	200	0.65	1.2
9	Ifelodun	130	200	0.65	1.2
10.	Ilaje	226	200	1.13	2.1
11.	Ileoluji/Okegbo	130	200	0.65	1.2
12.	Irele	200	200	1.00	1.9
13.	Odigbo	180	200	0.90	1.7
14.	Okitipupa	150	200	0.75	1.4
15.	Ondo-East	125	200	0.63	1.2
16	Ondo-West	89	200	0.44	0.8
17	Ose	90	200	0.45	0.8
18.	Owo	100	200	0.50	0.9

Source: Field data,2011

Table 2. WPI and IWMT values for all the local government areas in Ondo-State in dry season.

S/N	L.G.A	T_T (min)	T_V (liters)	WPI	IWMT
1.	Akoko N-E	120	200	0.60	1.1
2.	Akoko N-W	140	200	0.70	1.3
3.	Akoko S-E	135	200	0.68	1.3
4.	Akoko S-W	130	200	0.65	1.2
5.	Akure-North	130	200	0.65	1.2
6.	Akure-South	120	200	0.60	1.1
7.	Ese-Odo	273	200	1.40	2.6
8.	Ifedore	152	200	0.76	1.4

9	Ifelodun	150	200	0.75	1.4
10.	Ilaje	240	200	1.20	2.2
11.	Ileoluji/Okegbo	152	200	0.76	1.4
12.	Irele	216	200	1.08	2.0
13.	Odigbo	190	200	0.95	1.8
14.	Okitipupa	165	200	0.83	1.5
15.	Ondo-East	145	200	0.73	1.4
16	Ondo-West	106	200	0.53	1.0
17.	Ose	100	200	0.50	0.9
18.	Owo	110	200	0.55	1.0

Source: Field data,2011

Table 3. Source of functional safe drinking water in Ondo-State

S/N	L.G.A	No of solar-powered Boreholes	No of hand pump Boreholes	No of modern grouted wells	No of dams
1.	Akoko N-E	8	32	24	1
2.	Akoko N-W	9	26	22	-
3.	Akoko S-E	7	23	20	-
4.	Akoko S-W	10	33	25	-
5.	Akure-North	12	37	44	-
6.	Akure-South	10	30	40	-
7.	Ese-Odo	4	14	9	-
8.	Ifedore	8	23	21	-
9	Ifelodun	10	20	20	-
10.	Ilaje	5	20	14	
11.	Ileoluji/Okegbo	9	24	21	-
12.	Irele	6	22	17	-
13.	Odigbo	7	23	21	-
14.	Okitipupa	8	22	23	-
15.	Ondo-East	9	30	23	-
16	Ondo-West	10	35	28	1
17.	Ose	11	32	27	1
18.	Owo	12	34	30	-

Source: Field data, 2011

Water from pond, stream, river, sea and traditional well is generally considered unsafe for drinking. Due to the presence of abundant salty seawater at Ese-Odo, Irele and Odigbo local government areas, development of surface and underground water becomes a problem. Despite the huge financial resource expended on provision of portable water at Ese-Odo and Irele local government areas, majority of the boreholes were not functioning and most of the functional ones are not very good for drinking as shown in Table 6. Finding also reveals that seepage of salty seawater into boreholes has contaminated most of the boreholes in the region and becomes highly unsafe for drinking. Thus, in turn make the development of underground water to be highly difficult and expensive. Converting seawater to safe drinking water either by desalination or any other processes has not been developed in this part of the world and this makes the exploitation of surface water impossible.

3.2. Computation of IWMT and WPI using Adjusted Composite Index approach

Tables 4 and 5 show the computed WPI values for wet and dry season using composite index approach.

Table 4. WPI and IWMT values for all local government areas in Ondo-State during wet season

S/N	L.G.A	Water Availability (%) Weight: 0.5	Access to Water (%) Weight: 0.25	T_{Index}	Index to time spent (100-T) Weight: 0.25	WPI	IWMT
1.	Akoko N-E	59.6	56.1	30.0	70.0	15.9	22.1
2.	Akoko N-W	28.7	53.2	35.0	65.0	14.6	20.3
3.	Akoko S-E	40.3	51.0	50.2	49.8	15.0	20.9
4.	Akoko S-W	45.9	49.8	56.1	43.9	15.5	21.5
5.	Akure-North	50.1	58.1	29.3	70.7	19.1	26.5
6.	Akure-South	57.8	63.2	28.6	71.4	20.9	29.1
7.	Ese-Odo	74.6	6.0	93.6	6.4	13.5	18.8
8.	Ifedore	33.2	50.1	49.9	50.1	13.9	19.3
9	Ifelodun	40.4	49.3	57.3	42.7	14.4	20.0
10.	Ilaje	71.8	10.0	91.6	8.4	13.5	18.8
11.	Ileoluji/ Okegbo	60.2	39.8	75.0	25.0	15.4	21.4
12.	Irele	68.2	14.0	86.7	13.3	13.6	18.9
13.	Odigbo	67.9	16.0	80.1	19.9	14.3	19.9
14.	Okitipupa	65.5	18.0	75.3	24.7	14.5	20.2
15.	Ondo-East	43.4	55.2	36.7	63.3	17.1	23.8
16	Ondo-West	59.6	60.3	29.0	71.0	20.9	29.1
17.	Ose	50.2	68.3	25.0	75.0	20.3	28.2
18.	Owo	48.1	55.1	26.2	73.8	19.6	27.2

Source: Field data,2011

Table 5. WPI and IWMT values for all local government areas in Ondo-State during dry season

S/N	L.G.A	Water Availability (%) Weight: 0.5	Access to Water (%) Weight: 0.25	T_{Index}	Index to time spent (100-T) Weight: 0.25	WPI	IWMT
1.	Akoko N-E	30.3	52.1	40.5	59.5	14.4	20.0
2.	Akoko N-W	25.1	49.6	46.9	53.1	12.7	17.7
3.	Akoko S-E	24.0	49.8	46.4	53.6	12.6	17.5
4.	Akoko S-W	22.6	42.3	50.1	49.9	14.5	20.2
5.	Akure-North	41.6	50.1	44.6	55.4	15.7	21.8
6.	Akure-South	32.6	60.0	35.4	64.6	15.8	21.9
7.	Ese-Odo	55.1	5.3	94.6	5.4	10.1	14.0
8.	Ifedore	29.6	48.2	48.9	51.1	13.2	18.3
9	Ifelodun	26.1	40.3	56.7	43.3	11.3	15.7
10.	Ilaje	50.3	10.2	82.4	17.6	10.7	16.3
11.	Ileoluji/Okegbo	45.6	33.2	65.9	34.1	13.2	18.3
12.	Irele	49.3	20.8	78.6	21.4	11.7	16.3
13.	Odigbo	37.2	30.6	68.9	31.1	11.3	15.7
14.	Okitipupa	45.3	30.1	69.6	30.4	12.6	17.5
15.	Ondo-East	40.3	51.6	42.0	58.0	15.9	22.1
16	Ondo-West	40.1	53.2	39.6	60.4	16.2	22.5
17.	Ose	40.1	60.2	35.2	64.8	17.1	23.8
18.	Owo	42.1	62.1	32.4	67.6	17.8	24.7

Source: Field data,2011

The comparison of WPI and IWMT in Table 4 and 5 showed that Akure-South and Ondo-West local government areas recorded highest WPI and IWMT values of 20.9 and 29.1 (index point) during the wet season. This indicator shows that the two local government areas experienced lowest degree of water stress. Ese-Odo and Ilaje local government areas recorded the lowest WPI and IWMT value of 13.5 and 18.8 (index point) each. The regions are heavily water-stressed. The values of WPI and IWMT obtained during the drying season period showed that Owo local government area has the highest value of 17.8 and 24.7 (index point), while Ese-Odo local government recorded the least value of 10.1and 14.0 (index point). This development showed that Ese-Odo local government and its environs are strongly water-stressed at both dry and wet seasons, while Ondo-West, Ose, Owo, Akoko

N-E, Akoko N-W, Akoko S-W, Akoko-South and Akure North are generally less water-stressed with fair access to safe drinking water at all season. The population of people that have no or poor access to safe drinking water was estimated for two concurrent years and the result in Table 6 showed that Ese-Odo was ranked to be the highest with 94.7% and 89.2%, while lowest values of 37.9% and 35.9% for the year 2007 and 2008 respectively. This also explains further the degree of water stress status at Ese-Odo local government area despite the financial commitment on the provision of portable water between year 2007 and 2008 by government at every level and some donor agencies. However, fairly accessibility of portable water at Owo local government area and its environs is not enough to satisfy the water demand of the dwellers and so more technical and financial commitment must be invested to improve the volume of safe drinking water and the percentage of dwellers that can access it. Analysed data in Table 9 showed that the percentage of people that had no access to freshwater reduced from 58.4% (2,613,584) to 54.8% (2,452,472) between the year 2007 and 2008 respectively. The reduction is strongly correlated to the investment in water and sanitation within the period of assessment.

Table 6: Ranking of Investment in Water and Sanitation in all the local government areas in Ondo-State

S/N	L.G.A	Investment (₦)	2007	Investment(₦)	2008
1.	Akoko N-E	80,333,245.16	8	89,769,240.23	9
2.	Akoko N-W	70,900,345.96	11	77,780,236.19	12
3.	Akoko S-E	63,567,176.00	15	65,467,105.19	18
4.	Akoko S-W	78,670,200.17	9	86,450,789.16	10
5.	Akure-North	88,540,070.33	7	99,765,129.26	8
6.	Akure-South	89,205,100.56	5	102,134,256.18	6
7.	Ese-Odo	**90,105,255.13**	4	**105,452,245.10**	4
8.	Ifedore	70,000,200.45	12	73,265,105.99	14
9	Ifelodun	68,900,245.12	14	73,451,243.86	13
10.	Ilaje	**89,205,070.12**	6	**106,126,243.23**	3
11.	Ileoluji/Okegbo	69,540,100.13	13	78,900,733.45	11
12.	Irele	59,240,100.43	17	70,106,345.67	15
13.	Odigbo	59,470,214.12	18	67,780,567.88	17
14.	Okitipupa	60,120,473.10	16	68,450,453.12	16
15.	Ondo-East	75,245,250.77	10	100,500,345.18	7
16	Ondo-West	98,000,582.22	1	124,578,217.24	1
17.	Ose	95,325,420.19	2	108,432,106.13	2
18.	Owo	93,216,110.10	3	103,221,103.25	5

Source: Data from the survey

Table 7: Ranking of population without access to safe water in all the local government areas in Ondo State

S/N	L.G.A	Population (%) (2007)	Population (%) (2008)	Ranking
1.	Akoko N-E	47.9	43.2	14
2.	Akoko N-W	50.4	47.3	10
3.	Akoko S-E	50.2	49.6	11
4.	Akoko S-W	57.7	53.3	8
5.	Akure-North	49.9	45.9	12
6.	Akure-South	40.0	36.3	16
7.	Ese-Odo	**94.7**	**89.2**	1
8.	Ifedore	51.8	49.1	9
9	Ifelodun	59.7	55.3	7
10.	Ilaje	**89.8**	**84.7**	2
11.	Ileoluji/Okegbo	66.8	66.2	6
12.	Irele	79.2	75.2	3
13.	Odigbo	69.4	65.1	5
14.	Okitipupa	69.9	65.3	4
15.	Ondo-East	48.4	40.8	13
16	Ondo-West	46.8	46.9	15
17.	Ose	39.8	36.2	17
18.	Owo	37.9	35.9	18

Source: Data from the survey,2011

Table 8 Estimated average total population without access to safe water in all the local government areas in Ondo-State

Year	Average total population (%)	Estimated population
2007	58.4	2,613,584.
2008	54.8	2,452,472

4. Conclusion

The study evaluated Integrated Water Management Tools (SWPI) and compared the results with Structural Water Poverty Index (SWPI). The results obtained from the two approaches indicated that Ese-Odo, Ilaje and Irele local government areas are the most water-stressed, while areas such as Ose, Owo, Ondo-West, and Ondo-East local government areas have fair access to portable water. Heuristic application of Integrated Water Management Tools (IWMT) to test the generated dataset provided flexible and strong decision-making strategies in such a way as to construct a holistic water management tool to address the problems of scarcity, and its relation to water access and use. SWPI, cannot link complex multidimensional aspects of water management together as a result of this, IWMT approach is always preferable. The results presented various approaches to test our standardized data sets are expected to enhance our understanding of the significant effects of water poverty to economy, human development, health and education. Many states and local government areas are moving towards a point where water resources are insufficient for agriculture, drinking and other domestic uses and to prevent the occurrence of ***virtual water,*** further researches are needed to be conducted regularly on water problems and proffer realistic and technical solution to enhance the supply of safe drinking water at reasonable distance in all strategic locations across communities and regions in developing countries.

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