

Application of the Water Vulnerability Index in Oke-Ogun Area of Oyo State, Nigeria

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Abstract

Access to water is influenced by many biophysical and socio-demographical contexts which can trigger vulnerability or modify adaptive capacity of local communities due to a greater dependence on water resources that are climate sensitive for livelihood supports. The study provides a method of assessing vulnerability to water scarcity by applying the Water Vulnerability Index (WVI) for three case study communities (Iseyin, Okeho and Shaki) in Oke-Ogun region, Nigeria. Data were captured through household survey in the case study communities alongside with a document review. Frequencies of responses to study variables were categorised to form the sub-components of WVI such as access, resources, capacity, and environment. Results indicate that within the study region, there are significant variances in the WVI of each community depending on land and water-related livelihoods and in relation to different socio-demographic characteristics. The critical areas with less WVI are the informal neighbourhoods where residents are predominantly agrarian, pointing to the fact that households living in most biophysically vulnerable places are mostly affected by water scarcity and are in need of critical interventions for adaptation.

Key words: Water access, water scarcity, water vulnerability index, Oke-Ogun

Introduction

Climate change impacts water systems with its variability and vulnerability in human systems (Adeniji, 2008). Growing demand for water in Africa is exceeding available water resources as a result of population pressure and settlements' spatial expansion, poor water infrastructure development and resource degradation in the continent (Romero, 2007; UNDP, 2006). Water supply shortages impact human health, livelihoods with increasing poverty in the sub-Saharan Africa in particular where most populations are already vulnerable to other climate stress (Adger, 2006; Boko *et al.*, 2007).

In the Intergovernmental Panel on Climate Change (IPCC) reports, some terms are often used interchangeably to explain water-related vulnerability in the context of climate change. These include: impact potentials, resilience, sensitivity, adaptivity, adaptive capacity and coping mechanism (IPCC 2001; IPCC, 2007). Vulnerability is the degree to which a system is susceptible to, or unable to cope with the adverse effects of climate change, including climate variability and extremes (IPCC, 2001). Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity (CCKN, 2001; IPCC, 2007). According to UNEP (2002), vulnerability in this context can be defined as: 'the interface between exposure to the physical threats to human well-being and the capacity of people and communities to cope with those threats. Threats may arise from a combination of social and physical processes. Human vulnerability thus integrates many environmental concerns'.

Many agencies and individuals have contributed to the development of assessment techniques for vulnerability to climate change and its impact on water regime (e.g. Sullivan *et al.*, 2002; Sullivan *et al.*, 2003; Sullivan, 2010; Sullivan and Meigh, 2005). The use of indicators and indices is widespread in both the water sector and in economic policy. Example of such tools in macro-economic management is the use of the Retail Price Index (RPI). Numerous indicators of water quality and water stress measurement index include: Water Poverty Index (WPI) by Sullivan *et al.* (2003), Development Index (HDI) by the United Nations Development Programme, Climate Vulnerability Index (CVI) and Water Stress Index (WSI) (See table 1).

Table 1: Water resources indicators, applicable scales and data requirements

Indicator/ Index	Reference	Spatial Scale	Required Data
Access to drinking water and sanitation services	WHO, 2000	Country	percentage of population with access to drinking water percentage of population with access to sanitation services
Water Stress Indicator	Falkenmark, 1989	Country	total annual renewable water resources population
Dry season flow by river basin	WRI, 2000	river basin	time-series of surface runoff (monthly data) population
Basic Human Needs Index	Gleick, 1996	Country	domestic water use per capita
Indicator of water scarcity	OECD, 2001	country, region	annual freshwater abstractions total renewable water resources
Indicator of water scarcity	Heap et al., 1998	country, region	annual freshwater abstractions desalinated water resources internal renewable water resources external renewable water resources ratio of the ERWR that can be used
Water availability index	Meigh et al., 1999	Region	time-series of surface runoff (monthly) time-series of groundwater resources (monthly) water demands of domestic, agricultural and industrial sector
Vulnerability of Water Systems	Gleick, 1990	watershed	storage volume (of dams) total renewable water resources consumptive use proportion of hydroelectricity to total electricity groundwater withdrawals groundwater resources time-series of surface runoff
Water Resources Vulnerability Index (WRVI)	Raskin, 1997	Country	annual water withdrawals total renewable water resources GDP per capita national reservoir storage volume time-series of precipitation percentage of external water resources
Indicator of Relative Water Scarcity	Seckler et al., 1998	Country	water withdrawals in 1990 water withdrawals in 2025
Index of Watershed Indicators (IWI)	EPA, 2002	Watershed	15 condition and vulnerability indicators
Water Poverty Index	Sullivan et al., 2003	Country/Region	Access, capacity, resources, use and environment of water resources

Source: As indicated in the references column

A need to aggregate many components to determine the water-related vulnerability of a population was first advocated by Sullivan et al.

(2003). Vulnerability assessment is basically done by aggregation of data from many sources (DWC, 2006; Sullivan and Meigh, 2007; World Bank, 2009), some of which may be difficult to determine and measure across a country. Despite this limitation, DWC (2006) categorised different cases of techniques for determining vulnerability to water variability: Global vulnerability and critical regions to climate change – water stress; Sectoral vulnerability to climate change – food security; Geographic vulnerability – small islands, low coastal area and megacities; Developmental vulnerability – Millennium Development Goals.

Based on earlier work on water vulnerability (Sullivan et al. 2006, 2008; Knoesen 2009) and attempts to develop an index application, so that it can incorporate information relevant to local municipalities and the enterprises and households that they represent in South Africa, Sullivan (2010) identified two dimensions of water vulnerability study: *supply-driven vulnerability (vulnerability of water systems)* and *demand-driven vulnerability (vulnerability of water users)*. Some other studies have shown the use indicators to explain dimensions and degree of vulnerability on different scales (Adejuwon, 2008; Sullivan, 2001; Sullivan *et al.*, 2002; Sullivan and Meigh, 2005). At the community level, vulnerability assessment of small islands indicated that some geographical areas have multiple stress and are impacted by climate vulnerability index due to increasing population often concentrated into the risk areas, rather than because of major shifts in total rainfall amount (DWC, 2006).

Contextually, the Nigeria's First National Communication (FNC) (2003) identified the nation's natural ecosystems, agricultural ecosystems and water resources including coastal and marine ecosystems, as highly vulnerable to climate change impacts. Furthermore since the adoption of the communication, vulnerability assessment and adaptation mapping with focus on some pilot projects have been carried out in the country. For instance, project report on Building Nigeria's Response to Climate Change (BNRCC) - a four year project (2007-2011), funded by the Canadian International Development Agency (CIDA) and the General Circulation Models (GCM) downscaled to local stations by the Climate Study Analysis Group (CSAG) have shown that the coastal regions are predicted to warm less than the interior regions, due to the cooling effect of the Atlantic Ocean.

Also, temperature increase is predicted to occur in the northeast, in the Sahel region of Nigeria. The warmer climate in the arid northeast would

decrease the atmospheric humidity, and thereby reduce the chance of cloud formation and rainfall. Projections over the rainforest and the guinea savannah in Nigeria indicated earlier onset dates of rainfall and later cessation dates, with increase of about two weeks in the rainy season. On the other hand, the models predict a shorter rainfall season over the Sudan savannah, suggesting a decrease of more than one week (Abiodun et al., 2011). At the national level, these predictions are laudable but have the tendency of missing the demographic and biophysical factors that may be specific to some local communities and which have significant contribution to vulnerability assessment and adaptation mapping of such localities. There is therefore a need for vulnerability assessment at the micro level of human population - local community, where the impacts are felt directly by the people and the findings may influence local policy making since most often, regional or national policy may not integrate some local specifications such as demographical, biophysical and environmental factors.

This paper therefore aims at applying Water Vulnerability Index (WVI) methodology to show aggregates of social and biophysical factors (access, resource, capacity, environment and use) that contribute to population vulnerability as relates to water shortages using a case study of three communities (Iseyin, Okeho and Shaki) in Oke-Ogun region, Nigeria. This is because; one way to do the vulnerability assessment is the use of index which incorporates specific demographic characteristics in providing information on immediate impacts on households and local communities and their adaptive capacity.

Methodology

The study area

Oke-Ogun region is located between latitudes $7^{\circ}39'N$ and $9^{\circ}10'N$ and longitudes $2^{\circ}40'E$ and $4^{\circ}20'E$ in Oyo State, Nigeria, West Africa (Figure 1). The region is characterized by the wooded savannah of southwest Nigeria which in recent times is experiencing ecosystem degradation with impacts on water footprint (Akinbami *et al.*, 2003; Fasona *et al.*, 2011). Mean temperature during the wet season is $28^{\circ}C$ and $35^{\circ}C$ during the dry seasons. Annual mean rainfall ranges between 1200 mm and 1600 mm. Observed impacts of the rainfall pattern include short days/months of rain in the wet season, double peak rainfall periods with interlude of a little

Data types and sources

This study drew inspiration for index methodological approach related to water resource assessment such as the Water Poverty Index (WPI), Human Development Index (HDI), Climate Vulnerability Index (CVI) and Water Stress Index (WSI) (Sullivan *et al.*, 2003). While some methods of index (e.g. WSI, HDI) are mostly applied to national assessment (Sen, 1999); the WPI and WVI focus more on local scales (Sullivan and Meigh, 2003; Sullivan *et al.*, 2003). This paper adopted the equation elements that were used for WPI by Sullivan *et al.* (2003) which was also adopted by Adeniji (2010). The WVI was designed as a composite, interdisciplinary tool, linking indicators of water and human welfare to indicate the degree to which water scarcity impacts on human populations. The five key components are combined using the following mathematical expression:

$$WVI = \frac{\sum_{i=1}^N w_i X_i}{\sum_{i=1}^N w_i} \quad \dots (1)$$

This can be re-written as:

$$WVI = \frac{w_r R + w_a A + w_c C + w_u U + w_e E}{w_r + w_a + w_c + w_u + w_e} \quad \dots (2)$$

(Source: Sullivan *et al.* 2003; Adeniji, 2010)

Where w the weighted average of the five components: Resources (R), Access (A), Capacity (C), Use (U), and Environment (E). Each component is first standardized so that it falls in the range 0 to 100; thus the resulting WVI value is also between 0 and 100. The highest value, 100, is taken to be the best situation (or the lowest possible level of water vulnerability), while 0 is the worst.

Data were sourced via household survey of 397 respondents which were selected through a multistage systematic sampling technique across three local communities (i.e. Iseyin, Okeho and Shaki) in Oke-Ogun region. Participating households were selected from informal and formal neighbourhoods. The former are found in the agrarian communities, with population mostly engaged in land related livelihoods and are mostly occupied by extended families. The latter are planned with services, layout with building approval and land zoning procedure, owned by single

families who are mostly engaged in non primary production. The selection of two different neighbourhoods was intended to examine spatial differences within the same communities in relation to all components of WVI. The survey questionnaire was aimed to capture demographic and livelihood issues, coping capacity, housing characteristic, water resource, use and access. This study did not capture geospatial component of WVI as supposed by the CVI that was done by Sullivan *et al* (2003) because relevant data such as degree of isolation from other water resources, rate of erosion and deforestation and degree of land conversion from natural vegetation and other relevant information from the national ecosystem census for the selected communities were not available.

Data analysis

Details of indicators used to determine the acceptable bench marks are provided in the appendix. Responses to each question relating to the sub-components were standardized for easy summarization. Responses from household survey's questionnaire were coded and entered into a Statistical Package for Social Sciences (SPSS 16th edition)) programme for descriptive analysis provided the frequencies and percentages. Study variables were then categorized and recoded into binary format using an acceptable benchmark for household water access (UN-Habitat, 2003, WHO, 2000). The percentages of the responses within the "acceptable" line were combined to generate subcomponents of the WVI. Equality of ranking (Kruskal-Wallis with Chi Square)) was done to determine the significance differences in the observed WVI of the case study communities.

Results and Discussion

The analysis of the WVI in the Oke-Ogun region indicates a spatial variation within the sub-components of the WVI. The desirable benchmark for the study communities shows that the indicators of each sub-components of the WVI are not the same – indicating spatial difference across the study region (Table 1). It is also observed from the analysis of the subcomponents of WVI and their contributing indicators that type of neighbourhood has a significant contribution to the vulnerability of the selected communities (Table 2).

Table 1: Measuring the community water vulnerability index in Oke-Ogun

Local Communities		Informal neighbourhoods			Formal neighbourhoods		
Sub-components	Indicators	Iseyin N=65	Okeho N=56	Shaki N=104	Iseyin N=60	Okeho N=48	Shaki N=64
Resource (R)	Water quality	65.1	75.9	63.8	76.4	78.0	62.5
	Water reliability	42.9	21.2	45.0	53.1	16.7	36.5
	Protection of water sources	86.2	83.9	91.3	83.3	87.5	90.6
Access (A)	Access to water (type)	35.0	29.0	55.2	72.1	65.2	50.0
	Access to sanitation facilities	18.5	25.0	32.7	36.7	29.2	37.5
	Access to bathroom facilities	46.8	52.4	72.2	62.1	80.0	74.2
	Percentage of water carried by women	65.1	66.7	61.3	53.6	56.8	52.7
	Time spent in water collection	18.8	21.8	20.8	68.5	65.9	67.9
	Time spent in water collection	14.1	23.6	22.4	85.7	81.8	94.6
	Proximity of water point	-	-	-	-	-	-
Capacity (C)	Affordability of water						
	Household monthly income	30.8	46.4	36.9	36.7	52.1	46.0
	Education level of h/hold head		42.8	73.5	81.7	75.2	68.7
	Occurrence of water related illness	63.5	67.9	53.8	35.0	61.7	50.0
	Access to information on GEC	27.7	73.6	80.9	93.1	88.9	90.2
Environment (E)	Membership of CSO (social networking)	33.3	40.5	41.7	31.3	55.0	45.7
	Waste disposal methods	6.2	7.1	13.5	9.8	5.0	14.6
	Human population living space based on average household size	84.6	87.3	78.2	78.2	95.0	91.7
	Human population density based on room density	25.0	30.4	45.2	35.7	78.0	72.9
	Building structural condition	46.2	69.2	66.3	61.3	85.0	93.8
Use (U)	Percentage of household living in risk zones	23.1	30.4	27.9	27.1	43.1	52.1
	Quantity of water (litre) per person per day	22.2	28.6	34.5	29.4	30.4	22.2

Note:

The analysis is based on the "acceptable or desirable" (based on frequencies percentages). Values represent the percentiles of the frequency (f/100) of each sub components which were derived from the variables in the questionnaire.

The lowest WVI value both within the components and within the weighted average indicates the most critical zone (most vulnerable) which needs urgent policy intervention.

Table 2: Aggregates of subcomponents of WVI for neighbourhood types in Oke-Ogun

Local Communities		Informal neighbourhoods	Formal neighbourhoods
Indicators	Sub components	Total N=225	Total N=172
Resource (R)	Water quality	0.673	0.717
	Water reliability	0.383	0.356
	Protection of water sources	0.880	0.872
Access (A)	Access to water (type)	0.397	0.630
	Access to sanitation facilities	0.267	0.349
	Access to bathroom facilities	0.571	0.715
	Percentage of water carried by women	0.643	0.542
	Time spent in water collection	0.205	0.675
	Proximity of water point	0.224	0.878
Capacity (C)	Household's head monthly income	0.375	0.444
	Education level of household head	0.561	0.753
	Occurrence of water related illness	0.495	0.480
	Access to climate information	0.780	0.909
	Membership of social networks	0.397	0.449
Environment (E)	Waste disposal methods	0.980	0.163
	Human population	0.782	0.948
	Population density (room density)	0.357	0.760
	Building structural condition	0.613	0.878
	Percentage of household living in risky zones	0.271	0.512
Use (U)	Quantity of water per person per day	0.294	0.297

Note: Formal neighbourhood are those which have been planned by local authorities and have some degree of service provision while informal are the indigenous areas and others which are been developed spontaneously without spatial planning.

The result of Chi-Square ranking of the obtained value for each component of WVI based on weighted averages shows that there are variances in the vulnerability level across neighbourhoods and across the selected communities in the study region (Table 3). Specifically, residents in the informal areas of Iseyin have the highest WVI value of 0.4193.

Table 3: Ranking of WVI components in descending order for communities in Oke-Ogun region

Sub components of CVI	Informal neighbourhoods			Formal neighbourhoods		
	Iseyin N=65	Okeho N=56	Shaki N=104	Iseyin N=60	Okeho N=48	Shaki N=64
Resource (R)	0.6473 ³	0.6033 ⁶	0.6670 ²	0.7093 ¹	0.6073 ⁵	0.6320 ⁴
Access (A)	0.3305 ⁶	0.3642 ⁵	0.4410 ⁴	0.6312 ²	0.6315 ¹	0.6282 ³
Capacity (C)	0.4148 ⁶	0.5424 ⁵	0.5736 ³	0.5556 ⁴	0.6658 ¹	0.6012 ²
Environment (E)	0.4818 ⁵	0.5766 ⁴	0.4622 ⁶	0.7022 ¹	0.650 ³	0.6906 ²
Use (U)	0.2210 ⁶	0.2860 ⁴	0.3450 ²	0.3040 ³	0.2220 ⁵	.3510 ¹
CVI Weighted Averages	0.4192 ⁶	0.4745 ⁵	0.4978 ⁴	0.5805 ²	0.5553 ³	0.5806 ¹

Note to numbers in superscript: (6) - the most vulnerable and (1) - the less vulnerable.

In the overall assessment, the most critical areas are the informal neighbourhoods (Figure 2), which indicates that the spatial dimension and pattern of settlement have an impact on the vulnerability of the residents. Communities and neighbourhoods with access to other social services such as education and with improved social status which were found in the formal neighbourhoods indicate a more resilient capacity for water vulnerability. For instance, the formal neighbourhood in Shaki in particular has the highest WVI value (i.e. the area is less vulnerable), is more populated but has a higher order of community services. The observed characteristics and functionality of Shaki as a nodal town also provide a likelihood of the community building up more capital for adaptive capacity.

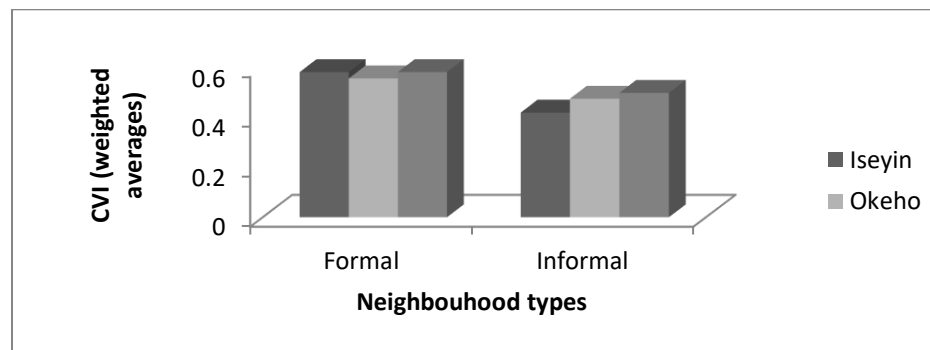


Figure 2: Water Vulnerability Index (CVI) in the selected communities based on equality of ranking

The analysis also identifies the contributions of each component to the overall WVI of the selected communities. The dominant components with the highest level of acceptability are in this order: environment, resource, and capacity. Components with less contribution value are “use and access” which have the lowest percentages especially in informal neighborhoods (Figure 3). This means that availability of physical water resources in a locality may not result in certainty of improved water use and water access because of other factors that are related to water development. This result is similar to the conclusion of the Human Development Report (HDR-UNDP, 2006) that water scarcity is not about physical scarcity but more of poverty and governance to translate water resources to improved access and efficient usage. The result of the analysis is presented in pentagonal shapes which were overlaid on the location map of the case study communities (Figure 4).

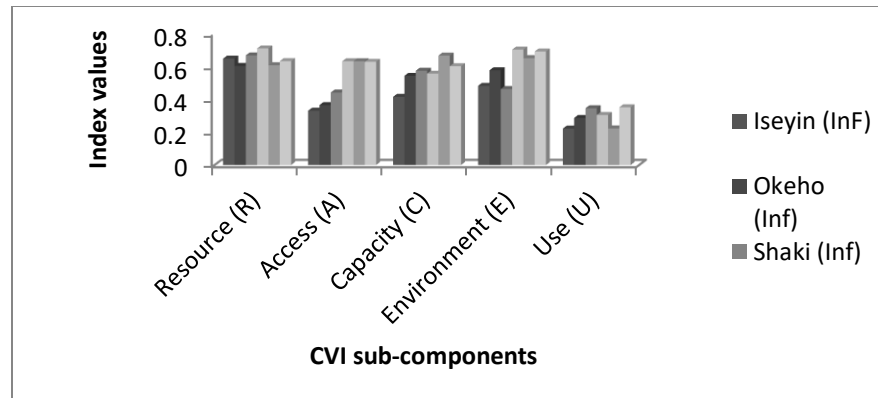


Figure 3: WVI sub-components values for the case study communities
 Note: F (Formal neighbourhood), Inf (Informal neighbourhood)

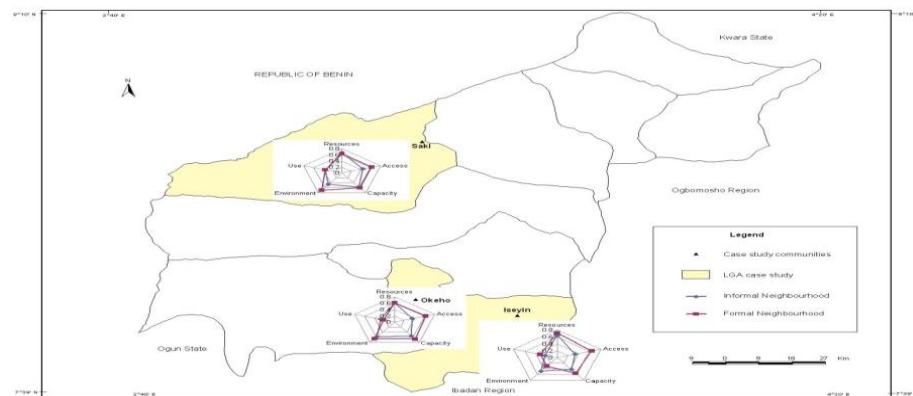


Figure 4: A Pentagram of the components of the CVI for the case study communities

Conclusion

Application of the WVI in Oke-Ogun region indicates that population vulnerability in relation to water supply shortages varies across a study area depending on neighbourhood types, demographic composition, access to water, capacity to cope and other biophysical factors (indicators under capacity and access sub-components). It is also evident from this study that water access and use are the most critical components of WVI in the informal neighbourhoods that are already marginalized from development and, social services are the most critical areas for policy

intervention. In the context of the changing climate and desertification in the sub humid environment where Oke-Ogun is located in Nigeria, addressing social deprivations and other environmental stress outcomes could provide pathways to improve water access and it is therefore, a key determinant in reducing water-related vulnerability.

From the overall application of the WVI and estimates obtained in this study, implications for policy intervention in the sub-humid environment in Nigeria include: Provision of mini water schemes aimed at improving water access and water use of the population. Water vulnerability is not directly as a result of physical absence of water resource, or other environmental capitals but that of the inability of the communities to translate the available water resources into real access and use. It is necessary to note the importance of investment in building adaptive capacity of local communities through improved livelihood and access to other social services. This is because the result of the component analysis also shows that higher capacity values were obtained in the area with which access to education services and climate-related information are available. It is imperative that water policy in Nigeria should be downscaled to take care of local variations and specification which always suffer from generalization models in national policy interventions. The observed pattern of water-related vulnerability in the study area shows that populations living in the informal neighbourhoods who are already deprived and vulnerable to some other socio-environmental stressors are worse off.

In conclusion, developing national research, monitoring and assessment capacity, including training in vulnerability assessment with institutional supports in data collection, analysis and integration of research and policy are critical. Participatory, interactive, and, in particular, implementation oriented studies are to be carried out in all marginalized communities across Nigeria to provide contextual vulnerability assessment and to effectively deal with the degree of risks and adaptation assets that might be available in the local settings. The development of adaptation strategies requires multidisciplinary approaches that meet the demands of specific local and regional climate decision-making.

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References

- Adejuwon, J.O. (2008). Vulnerability in Nigeria: A national-level assessment. In Leary N. et al. (Eds.), *Climate Change and Vulnerability*, Earthscan, London, pp. 198 – 203.
- Adeniji, G. (2010). Women's Coping Strategies with Water Variability and Vulnerability in Oyo North Region, Nigeria (*Ph.D thesis*), *University of Ado-Ekiti, Nigeria*, p. 299.
- Adeniji, G. (2008). Water governance system in the face of environmental change: The sustainable criteria for urban water management in Nigeria. *Environ-Link*, 2(1), 16 – 24.
- Adeniji-Oloukoi, G., U. Bob and V. Moodley (2013). Households' coping strategies to address water shortages related to climate variability in Oke-Ogun, Nigeria. *Environmental Development*, 5, 23-38.
- Abiodun, B.J., A.T. Salami and M. Tadross (2011). *Developing climate change scenarios, Biophysical impacts and adaptation strategies in Nigeria*. A final report submitted to Nigerian Environmental Study/Action Team (NEST) as part of the Building Nigeria Response to Climate Change (BNRCC) Project.
- Adger, W.N. (2006). Vulnerability. *Global Environmental Change*, 16, 268 – 281.
- Akinbami, J.F.K., A.T. Salami and W.O. Siyanbola (2003). An integrated strategy for sustainable forest-energy-environment interactions in Nigeria. *Journal of Environmental Management* 69, 115–128.
- Boko, M., I. Nyong, A. Niang, C. Vogel, C., Githeko, A., Medany, M., Osman-Elasha, B. R. Tabo and P. Yanda (2007). *Africa: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)*, in: Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J.

- Van der Linden and C.E. Hanson (Eds.), Cambridge University Press, Cambridge UK, pp. 433 – 467.
- DWC (2006). *Climate changes the water rules: How water managers cope with today's climate variability and tomorrow's climate change*. The Netherlands: Dialogue on Water and Climate.
- CCKN, (2001). *Vulnerability and adaptation to climate change: Concepts, issues, assessment methods*. CCKN Foundation Paper, www.cckn.net.
- FNC (2003). *First National Communication on Climate Change*. Federal Government of Nigeria, Abuja.
- Fasona, M., M. Tadross, B. Abiodun and A. Omojola (2011). Land systems response to water footprint in the wooded savannah of Nigeria. In: Salami, A.T. and O.I. Orimoogunje (Eds.), *Environmental Research and Challenges of Sustainable Development in Nigeria*. Obafemi Awolowo University Press, Ile-Ife, pp. 499– 523.
- IPCC (2001). *Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change. Part 1, 2 and 3, Synthesis report and Policy makers Summaries*. Cambridge University press, Cambridge, UK.
- IPCC (2007). *Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, Pachauri, R.K and Reisinger, A. (Eds.)]. IPCC, Geneva, Switzerland, 104 pp.
- Romero, A. (2007). *Perceptions of vulnerability of water supplies and water users in the Upper Orange Basin, South Africa*. MSc dissertation, Oxford University Centre for the Environment, Oxford, UK.
- Sen, A. (1999). Mortality as an indicator of economic success and failure. *Discussion Paper 66*, London: School of Economics and Political Science.
- Sullivan, C. A. (2010). Quantifying water vulnerability: a multi-dimensional approach. *Stoch Environ Res Risk Assess*, DOI 10.1007/s00477-010-0426-8.
- Sullivan, C.A. (2001). The potential for calculating meaningful water poverty index. *Water International*, **26**, 471-480.
- Sullivan, C.A. and A.M. Meigh (2003). The water poverty index: Development and application at the country scale. *Natural Resources Forum*, **27**, 189-199.
- Sullivan, C. and J. Meigh (2005). Targeting attention on local vulnerability using an integrated index approach: the example of the climate vulnerability index. *Water Science and Technology* **51**(5), 69-78.

- Sullivan, C.A. and J.R. Meigh (2007). Integration of the biophysical and social sciences using an indicator approach: addressing water problems at different scales. *Journal of Water Resources Management*, **21**, 111-128.
- Sullivan, C.A., J.R. Meigh and T. Fediw (2002). Developing and testing the Water Poverty Index (WPI). *Phase 1 Final Report*. Wallingford, United Kingdom: Department for International Development, Centre for Ecology and Hydrology.
- Sullivan, C.A., A.M. Meigh, T. Giacomello, P. Fediw, P. Lawrence, M. Samad, S. Mlote, C. Hutton, J.A. Allan, R.E. Schulze, D.J.M. Dlamini, W. Cosgrove, J. Delli Priscoli, I. Smout, J. Cobbing, R. Callow, C. Hunt, A. Hussain, M.C. Acreman, J. King, S. Malomo, E.L. Tate, D. O'Regan, S. Milner and I. Steyl (2003). The water poverty index: development and application at the community scale. *Natural Resources Forum*, **27**, 189-199.
- United Nations Development Programme (UNDP) (2006). Human Development Report - *Beyond scarcity: power, poverty and the global water crisis*. Palgrave Macmillan, New York. Available: hdr.undp.org/en/media/HDR06-complete.pdf; Accessed February 10, 2007.
- United Nations Environment Programme (UNEP) (2002). *Global environment outlook 3: past, present and future perspectives (GEO-3)*. Earthscan Publications, London
- UN-Habitat (2003). *Guide to monitoring Target 11: Improving the Lives of 100 Million Slum Dwellers*, UN-HABITAT, Nairobi.
- Wikipedia (2013). "Indicators and Indices for decision making in water resources management. (accessed June16, 2013).
- World Bank (2009). *Water and climate change: understanding the risks and making climate-smart investment decisions*. World Bank, 52911, authors: Alavian V, Qaddumi, H.M., Dickson, E., Diez, S.M., Danilenko, A.V., Hirji, R.F., Puz, G., Pizarro, C., Jacobsen, M., Blankespoor, B., Sept 2009.

Appendix

Bench marks for determining the water vulnerability index in Oke-Ogun region, Nigeria

S/N	Key Dimension Indicators	Subcomponents	Value label	Remarks
1	Resources (R)	Number of hydrological techniques		Data not available**
		Water Quality	Potable sources = 1 non potable = 0	protected well, spring, boreholes and taps are potable (UN-Habitat, 2003)
		Water reliability	yes = 1 No = 0	The water is available from the source all through the year
		Protection of water sources	Yes = 1 No = 0	The supply source is protected or covered by a concrete slab, a wooden / metal door
2	Access (A)	Access to water	Portable = 1 Others = 0	Located close to residence and could be accessed without physical barrier
		Access to sanitation	Acceptable = 1 Non acceptable = 0	Direct private connection to public sewer or septic tank, pour flush / Water closet, pit latrine (private or shared, not public), and VIP are acceptable (UN-Habitat, 2003)
		Percentage of water carried by women	Females as water carriers = 1 Others = 0	Household survey indicate that water collection is mostly done by female household members
		Time spent in water collection	At most 60 minutes = 1 Above 60 minutes = 0	Improved accessibility to water should be within a kilometre and not more than 60 minutes (UN-Habitat, 2003). Time for collection is sum of waiting time and time to cover the actual distance to and fro the water source (WHO and UN-Habitat, 2003)
		Proximity of water point (distance)	At most a kilometre = 1 Above 1 kilometre = 0	*** Most residents of the study area do not pay for water services except for ceremonies/parties when large volume is required. Water should not take an undue proportion of the household income, i.e. less than 10% (UN-Habitat, 2003).
3	Capacity (C)	Affordability		
		Household income	At least #15,000 per month = 1 Below #15,000 per month = 0	#15,000 is equivalent of 2(USD) per day. A monthly income of this amount indicates a relative poverty level. This amount also falls within the minimum wage of the FGN
		Educational level of household head	At least post primary school = 1 At most primary school = 0	The study takes the Universal Basic Education (UBE) standard of at least primary or the Junior secondary school certificate as minimum literacy level
		Illness to water supply	Infected with water related diseases = 1 No infection = 0	Based on the percentages of household with reported infection of water related sickness during the survey
		Percentages of household living in informal housing	Informal housing = 0 Formal housing = 1	Informal and or illegal housing are owing to any combination of the following: low standard of services or infrastructures; breaches of land zoning; lack of planning and building permits; or the irregular nature of the land subdivision.
		Percentage of annual budgetary allocation to water-related development		No available data at the LGAs or the community level. The state government has a budgetary allocation of 2 to 3 percent (WCOS, 2008)

S/n	Key Dimension Indicators	Subcomponents	Value label	Remark
4	Use (U)	Quantity of water per capita per day	At least 25 LPD = 1 Below 25 LPD = 0	Sufficient quantity is with availability of at least 20 litres /person/day (UN-Habitat, 2003)
5	Environment	Wastedisposal methods Human population Density Building condition Percentages of households reporting erosion on their land Percentage of household living in risk zones	Acceptable = 1 Not acceptable = 0 Acceptable = 1 Unacceptable = 0 Good = 1 Bad = 0 Acceptable / non risk zone = 1 Housing around risk zone	Definition was confirmed via FGD and Environmental Health Officer. 60 persons per kilometre is the indicator estimated by the National Population Commission , FGN, based on an average of two persons per habitable room Based on respondents' judgement, confirmed via FGD No available data Vulnerable and risk zones include, around geological hazardous areas like floodplains; garbage mountains; high-industrial pollution areas;
6	Geospatial	Neighbourhood types	Formal = 1 Informal = 0	Household living within a layout/planned neighbourhood and or with formal title deeds both to land and residence, with documentation that can be used as proof of secure tenure status (UN-Habitat, 2003)

Source: Author's Fieldwork (2008)