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PRIORITIZATION OF ADAPTATION STRATEGIES FOR WATER SUPPLY AND DEMAND UNDER CLIMATE CHANGE AND ITS VARIABILITY IN ABUJA, NIGERIA

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ABSTRACT

Climate change and its impact has become a global and prime event of the 21st century. Its effects on almost all spheres of human existence are worrisome and the low awareness and complete disregard for its causes, impacts and adaptation strategies call for an urgent solution. One of its effects is a sharp variability in available water resources for human use. Created in 1976 and with a current population of over 1.6 million, Abuja, Nigeria's capital city has a growing water supply deficit; occasioned by several factors including climate change. To mitigate the deficiency occasioned by climate change, this study has considered some adaptation strategies and prioritized them. A survey was conducted with the use of a structured questionnaire and hydro-metrological data was also gathered from various relevant agencies. By applying the Analytical Hierarchy Process as a Multicriteria Decision method in the comparison of suitable adaptation strategies, the manager's strategy of sourcing for an additional water resources had the highest priority vector of 0.4348 while the professional strategy of raising awareness to enhance consumer behavioural change was next with a vector of 0.3097. These two methods are thus recommended to mitigate against the effect of climate change on the water supply deficit in Abuja, Nigeria. The use of water saving devices ranked lowest and thus should be considered as the least attractive option.

Keywords: Climate Change, Prioritization, Adaptation strategies, Water Deficit

INTRODUCTION

Globally, climate change and variability resulting from increasing temperatures has led to rapid glacial melt, floods, droughts, and variability in the timing, location and amount of precipitation (Blackshear *et al*., 2011). Similarly, climate change has brought about water-stress due to reduction in freshwater availability thereby affecting water supplies as water catchment areas will get less precipitation (Boko, *et al*., 2007). Hence, changes in precipitation regimes will bring about reductions in river flows and falling in groundwater tables (Satterthwaite *et al*., 2007). According to Loftus *et al* (2011), flows into rivers, lakes and reservoirs as well as groundwater will be reduced and the sustainability of water supply is directly threatened by droughts due to reduction in stream-flow and inflows into reservoirs, lakes and groundwater. Also, drought indirectly impacts water supply through the increased occurrence of wildfires (Howe *et al*, 2005). Furthermore, the seasonality of water supply levels may change, particularly in regions where spring snowmelt is the main source of water. In Peru for example, freshwater availability at the coast, where over half of the population is concentrated, has seen a reduction of 12% over a period of 35 years (Bates *et al*., 2008).

According to Karmalkar *et al* (2010), Nigeria's mean annual temperature average has increased by 0.8^{o}C between 1960 and 2006, at an average rate of 0.18^{o}C per decade while precipitation shows a statistically decreasing trend of 3.5 mm per month (1.8%) per decade in the same period. Furthermore, Ayanshola, *et.al* (2015) revealed that reduction in water availability in Abuja, Nigeria is occasioned by increase in temperatures and decrease in rainfall trends.

Further to this as reported by Ayanshola, *et.al* (2015), is the influx of people into the city. The water sector has therefore been so much stressed that the water supply source, Lower Usman Dam had to be augmented by the Gurara Inter-basin Water Transfer Project.

Considering the vulnerability of the developing countries such as Nigeria, adaptation to the various impacts of climate change and urbanization becomes a crucial option to be considered Ozor and Nnaji 2010). This paper therefore focuses on prioritization of the adaptation strategies for water supply and demand under climate change and urbanization for the Nigerian Federal Capital Territory, Abuja. Two major strategies proposed to be adapted in order to meet the future water demand deficit of the FCT include the 'Managers Strategy' which is a business as usual approach that only seeks for more sources of water supply to meet the water demand of both the present and projected population. And the 'Professionals Strategy' which is basically a demand-focused moderation approach. It mainly seeks to control the current demand as well as future population.

For water resources and management sustainability in the FCT, five criteria for comparison were established. These are Social acceptability, environmental justification, technological applicability, time-efficiency and economic feasibility.

MATERIALS AND METHOD

The Study Area

Abuja has over the years witnessed an obvious influx of people with a population of about 1.6 million in year 2000 and a growth rate of between 20-30% (NPC, 2006). It is located in the North Central Geopolitical Zone of Nigeria and bounded in the North by Kaduna State, on the West by Niger State, on the East and South by Nassarawa and Kogi states respectively (Fig. 1). Available information from the FCT Water Board indicates that there are four operating dams with a combined capacity of 890 million m^3 that services the FCT (FCT Water Board, 2010; Ali, 2012).

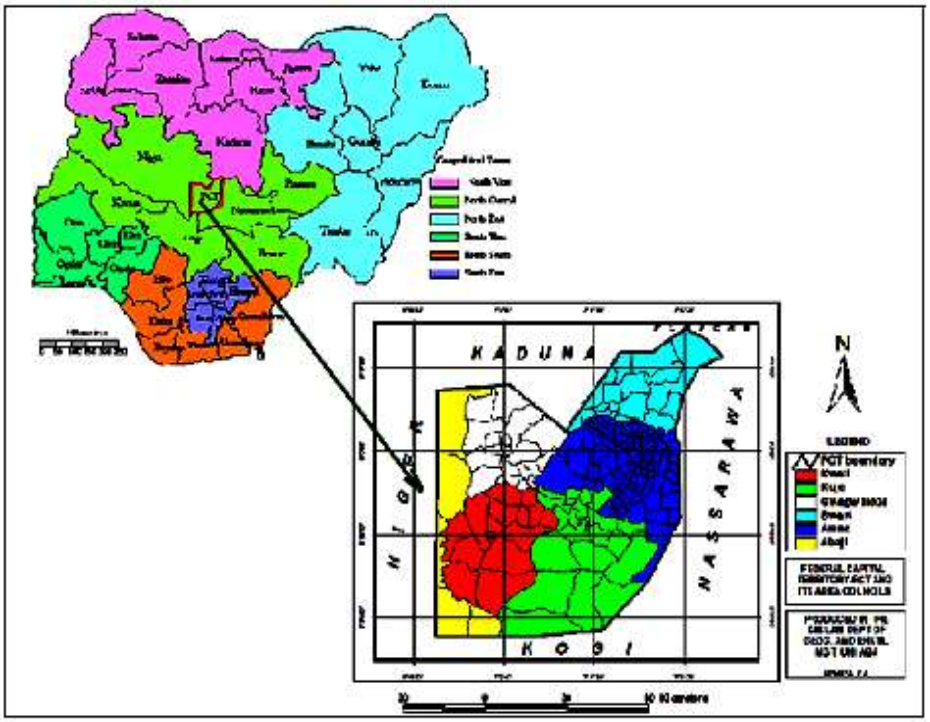

Fig. 1: Map of Nigeria showing the FCT, Abuja

Data Collection

The data collection involved visits to relevant agencies and ministries from where Hydro-meteorological data from 1979 to 2013 was obtained. The field work involved the use of a structured questionnaire and informal interviews to obtain data from household, water managers and Nigerian Metrological Agency (NIMET) officials on climate change and variability perception, impacts on water supply, and adaptation strategies. The number of responses needed for a particular level of confidence for a given population size as suggested by Lwanga and Lemeshow (1991) was adopted. A total of 400 questionnaires were administered and 342 were retrieved and used for analysis.

Data Analysis

In order to study the demographic and social profile of the study area, descriptive statistical values were obtained using *Stata/IC 12.1* statistical packages. However, to analyze, compare and rank the proposed adaptation strategies from the preliminary data gathering process, the concept of Multi-Criteria Decision Analysis (MCDA) was employed. MCDA methods utilize a decision matrix to provide a systematic analytical approach for integrating risk levels, uncertainty, and valuation, which enables evaluation and ranking of many alternatives (Vyas and Misal, 2013). There are several MCDA methods available for resolving complex evaluation and ranking of alternative following some series of basic steps as shown in Fig. 2. The Analytical Hierarchy Process (AHP) which is one of the several methods of MCDA was used for this work and its fundamental procedure as shown in Fig. 3. The AHP as a MCD method was analyzed with the aid of Microsoft excel programme and MAT Lab applications.

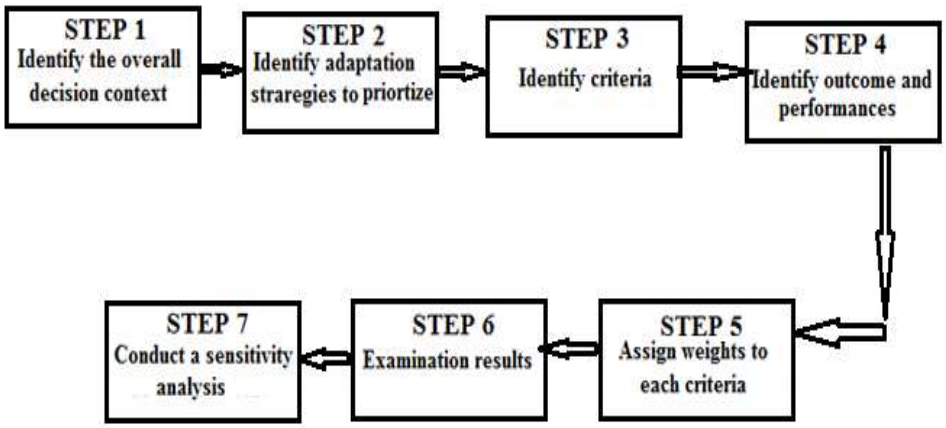

Fig. 2: Schematic flow-chart of steps involved in MCDA methods

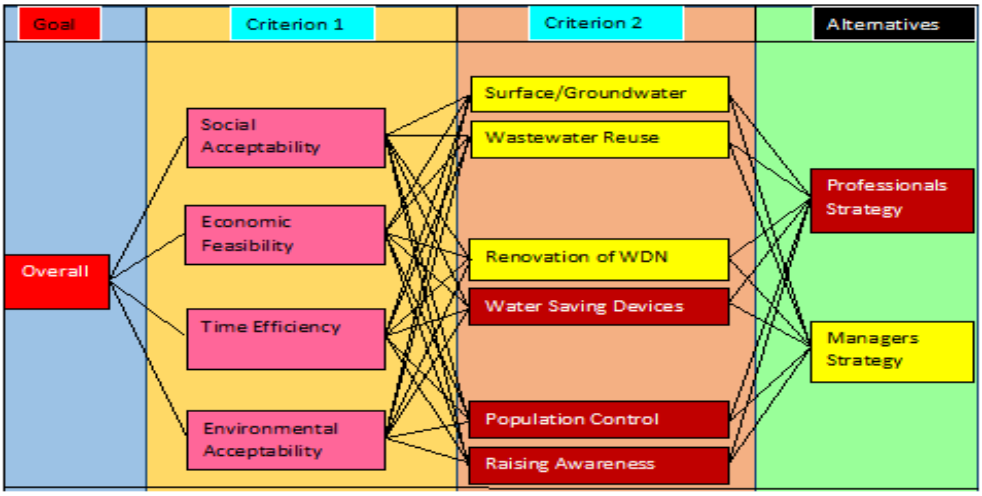

Fig. 3: Schematic Flow diagram of Analytical Hierarchy Process source

AHP is a decision support tool which can be used to solve complex decision problems using a multi-level hierarchical structure of objectives, criteria, sub-criteria, and ranking of alternatives. Accordingly, Aremu (2013) appraised the uniqueness of AHP as a decision making tools as it offers a consistency check. The consistency check offered by AHP can be determined by the maximum Eigen value (λ_{max}) of the pair-wise comparison matrix (Sivaros et al 2014), which is evaluated using the Eigen value approach.

On a final note, a sensitivity analysis (SA) was performed to investigate the extent to which the final ranking is dependent to the changes in any of the attributes. This was done by MCDM approach through a consistency check. The consistency check showed the need for re-evaluation, thus improving on the overall decision making process and the final ranking was descriptively evaluated. The consistency ratio (C.R) which evaluates the consistency of judgment is given in equation 1

$$C.R = \frac{C.I}{R.I} \quad (1)$$

Where C.I = Consistency index and it can be obtained using equation 2, while the Random Consistency Index (R.I.) can be obtained using equations 3.

$$C.I = \frac{(\lambda_{max} - n)}{n-1} \quad (2)$$

$$R.I = 1.98\left\{1 - \left[\frac{n-1}{\frac{n}{2}(n-1)}\right]\right\} \quad (3)$$

Where: λ_{max} is the Maximum Eigen value and n is the number of rows or columns in the comparison matrix

The judgment was considered to be consistent if the consistency ratio (C.R) was less than 0.1 and the priority vector summed up to unity, else the judgment was re-evaluated to ensure proper decision making.

In order to make a comparison, a scale of numbers which showed how many times more dominant an element i is over another element j with respect to the criterion to which they are paired. For this purpose, Saaty (2000) developed the scoring scale of numbers as shown in Table 1

Table 1: Saaty Scoring Scale

Intensity of value	Interpretation
1	Requirements i and j are of equal value
3	Requirement i has a slightly higher value than j
5	Requirement i has a strongly higher value than j
7	Requirement i has a very strongly higher value than j
9	Requirement i has an absolutely higher value than j
2,4,6,8	These are intermediate scales between two adjacent judgments
Reciprocals	If requirements i has a lower value than j

(Adapted from: Saaty, 2000)

RESULTS AND DISCUSSION

Descriptive Analysis

The study revealed that 96% of the respondents are aware of the term "climate change and variability" and 90% of the respondents agreed that climate change impacts water supply (Table 3). The Table also shows a low willingness to pay which can be attributed to the fact that supply at the current charging rate is not regular while some solely depends on borehole for their water needs.

Regarding impacts on climate change and water supply in the FCT, the result of the study revealed that 46% supported sourcing for additional surface and underground water supply to meet the rising demand.

Adaptation Strategies and Measures

Different Adaptation strategies and measures were designed to meet the challenges regarding water supply for FCT-Abuja in the nearest future (2020-2030). These strategies were grouped as manager's strategy which focused on sourcing for more water and the professional strategy which emphasized water demand control. The comparison of the various subdivisions of these strategies based on some well-defined criteria was carried out using the AHP as a MCD method.

The two major strategies proposed to be adapted for meeting the future water demand deficit of the FCT are Managers and Professional Strategies.

Table 2: Socio-Economic Characteristics

Characteristics	**%**	**Characteristics**	**%**
Gender		Education Status	
Male	53	No Formal Education	3
Female	47	Primary School	4
Age (Years)		Secondary School	10
Below 20	4	Graduate	64
Btw. 20-40	41	Postgraduate	19
Btw. 41-60	46	Occupation	
Above 60	9	Civil Servant	28
Household Size		Private Employee	37
<6	59	Business	15
Between 6-10	36	Unemployed	12
Above 10	5	Student	10
House Type		Total income of	
Multi-Tenant	18	Household	
Blocks of Flats	44	< 100,000	63
Duplex	16	Btw 100,000-250,000	28
Bungalow	20	Btw 250,000-500,000	5
Others (Specify)	2	Above 500,000	4

Evaluation and Prioritizing of Adaptation Strategies

Comparison matrix for criterion 1 in selecting adaptation strategies

The overall adaptation strategy to be selected must satisfy some conditions. Such strategy must be economically feasible, environmentally sustainable and acceptable, socially acceptable to the populace and time efficient in implementation. Therefore, in order to meet up with the projected water demand surplus/deficit due to climate change and variability, these criteria were weighed and ranked.

A comparison matrix was developed using the Saaty scale scoring approach for criterion 1 while the normalized matrix which provides the priority vector ranked each of the considered criterion.

When the consistency ratio (CR) was greater than 0.1, the judgment was re-evaluated to ensure better decision making. A set of new paired comparison matrix (Table 4) was developed by pairing the vector priorities for criterion 1 and the re-evaluation was done as presented in Tables 4 and 5.

Table 3: Climate Change Awareness and Adaptation Strategies

Climate change Issue	%	Climate change Issue	%
Awareness about Climate Change	96	**Possibility of solving problems posed by climate change**	81
Perceived Temperature pattern		**Perceived Precipitation pattern**	
Increasing	69	*Increasing*	41
Decreasing	16	*Decreasing*	47
Constant	11	*Constant*	7
Fluctuating	4	*Fluctuating*	5
Perceived Cause(s) of Climate Change		**Ways to tackling the problems of climate change**	
Human activities	53	*Increasing people's awareness on climate change and its impacts*	40
Natural factors	38	*By reducing human activities that causes climate change*	48
Both Human activities and Nature	10	*Strategizing to adapt to the various impacts of climate change*	12
Climate change affects water supply	90	**Observed impacts of climate change on water supply**	
Do you pay for water supply	60	*Increased in water supply due to increasing rainfall*	31
		Decrease in water supply as a result of high temperature and decrease in	
Amount paid monthly for water supply		*rainfall*	57
< 2000	20	*Higher cost of water supply due to scarcity of rainfall*	12
2000-5000	44	**Willingness to pay more in case of water supply scarcity**	37
5000-10,000	27	**Amount people are willing to pay**	
Above 10,000	9	*< 2000*	15
People's perception on water supply and population		*2000-5000*	50
Water supply is constant but population is increasing	31	*Above 5000*	35
Water supply is decreasing while population is increasing	43	**How people adapt to water scarcity**	
Water supply is increasing while population is decreasing	4	*Manage and judiciously use the little water supply available*	47
Water supply is increasing while population is increasing	22	*Explore more water supply options to meet up your needs (buy water)*	50
How can individuals and Government help combat the challenges posed by climate change		*Increment in water supply charges to get more supply*	3
		Suggestive ways to tackle water scarcity challenges in the FCT	
Enlightenment campaign	44	*Getting more water supply sources (surface and underground)*	46
Intensify research efforts and be prepared to face it	16	*Awareness raising(Behavioural Change)*	19
Strict laws and regulations to control activities that causes		*Migration Control*	11
climate change	40	*Water serving device for judicious usage of water*	15
		Wastewater utilization	9

Table 4: Re-evaluated matrix of measures' weight against criterion for assessment (Criterion 1)

Priority/Criterion 1	**Social Acceptability**	**Economic Feasibility**	**Time Efficiency**	**Environmental Acceptability**
Social Acceptability	1.0000	0.3647	0.7571	0.7279
Economic Feasibility	2.7419	1.0000	2.0758	1.9960
Time Efficiency	1.3209	0.4817	1.0000	0.9615
Environmental Acceptability	1.3737	0.5010	1.0400	1.0000
Total	6.4366	2.3474	4.8729	4.6854

Table 5: Normalized matrix for measures' weight against criterion for assessment

	Social Acceptability	**Economic Feasibility**	**Time Efficiency**	**Environmental Acceptability**	**Priority Vector**
Social Acceptability	0.1554	0.1554	0.1554	0.1554	0.1554
Economic Feasibility	0.4260	0.4260	0.4260	0.4260	0.4260
Time Efficiency	0.2052	0.2052	0.2052	0.2052	0.2052
Environmental Acceptability	0.2134	0.2134	0.2134	0.2134	0.2134

(λ_{max}) = 4.00; C.I. = 0.00; R.I. = 0.99; C.R. = 0.00

Since the consistency ratio (C.R = 0.00) is less than 0.1 and the priority vector summed up to unity, the judgement was considered acceptable.

Development of comparison matrix for the two major adaptation strategies (Alternatives)

Sustainability of the current water supply management system and the resultant chosen adaptation strategy is paramount. Hence, the advantages and disadvantages of each proposed strategy was weighed and ranked using the Saaty scale, while it was given the same initial priority and equal chances of being selected. Finally, the ranking was based on judgement made through the questionnaire, consultations with water managers, and water professionals in connection with criterion 1. A comparison matrix (Table 6) was developed using the Saaty scale scoring approach for criterion 1 while Table 7 presents the normalized matrix which provided the priority vector and ranked each of the adaptation strategies (alternatives).

Table 6: Matrix of measures' weight against Alternatives

Priority/Objectives	**Professionals Strategy**	**Managers Strategy**
Professionals Strategy	1.0000	3.0000
Managers Strategy	0.3333	1.0000
Total	1.3333	4.0000

Table 7: Normalized matrix for measures' weight against Alternatives

	Professionals Strategy	**Managers Strategy**	**Priority Vector**
Professionals Strategy	0.7500	0.7500	0.7500
Managers Strategy	0.2500	0.2500	0.2500

(λ_{max}) = 2.0000; C.I. = 0.00; R.I. = 0.00; C.R. = 0.00

Since the consistency ratio (C.R = 0.00) is less than 0.1 and the priority vector summed up to unity, the judgement is considered acceptable.

Overall Ranking and Selection of Adaptation Strategy

The overall rank of the adaptation strategies is obtained as the summation of the global priority vector which is evaluated from the comparison of the two major strategies with the priorities vector (global 1) as shown in Table 8. Based on this, sourcing for additional surface and underground water resources to meet up with the current water demand and the projected water demand deficit has the highest priority vector (0.4348). Sourcing for additional water was the sole focus of the manager's strategy. On the other hand, the use of water saving devices (Professional's Strategy) had the lowest priority vector (0.0458). This strategy was therefore considered the least to be focused on when considering the various measures under its adaptation strategy.

CONCLUSION

This study utilized the Analytical Hierarchy Process (AHP) as a Multi-criteria Decision (MCD) method to satisfactorily compare and select the suitable adaptation strategy to the anticipated impacts of climate change and variability on water supply in the FCT-Abuja. The result of the AHP analysis revealed that the manager's strategy is most suitable based on the factors considered. This strategy focuses on sourcing for additional water to meet the current and future water demand.

This study has begun the process of understanding specifically adaptive measures to impacts of climate change and variability on water supply in an ever-increasing population urban centre in Nigeria such as FCT-Abuja. In order to minimize the negative effect of climate change on water supply it is recommended that sensitization campaign on the causes, impacts of climate change on water supply and adaptation strategies and measure should be encouraged by governmental and non-governmental organizations. Also, Inter-sectorial collaboration between water sector and social planning sectors such as Development Control, Federal Capital Development Authority (FCDA) should be encouraged.

Table 8: Overall rank of proposed adaptation strategies based on criteria considered

ADAPTATION STRATEGIES ALTERNATIVES	CRITERION 2	CRITERION 1				Overall Ranking	Overall Ranking (%)
		Social Acceptability	Economic Feasibility	Time-Efficiency	Environmental Acceptability		
MANAGER'S STRATEGY (0.75)	Surface/Groundwater Sources(S/G)	0.0269	0.0766	0.0379	0.0106	0.152	15.1992
	Wastewater Reuse (WWR)	0.0056	0.0278	0.012	0.0056	0.051	5.0986
	Renovation of Water Distribution Networks (RWDN)	0.0071	0.0254	0.0064	0.0162	0.0551	5.5141
	Water Saving Devices (WSD)	0.0052	0.0158	0.0117	0.0131	0.0458	4.5829
	Population Control (PC)	0.0095	0.0189	0.0097	0.0417	0.0798	7.9837
	Raising Awareness (Behavioural Change)	0.0234	0.0485	0.0249	0.0195	0.1162	11.6215
PROFESSIONAL'S STRATEGY (0.25)	Raising Awareness (Behavioural Change)	0.0701	0.1454	0.0747	0.0195	0.3097	30.9688
	Water Saving Devices (WSD)	0.0157	0.0474	0.035	0.0131	0.1112	11.1213
	Population Control (PC)	0.0285	0.0567	0.0292	0.1251	0.2395	23.9512
	Surface/Groundwater Sources (S/G)	0.0807	0.2298	0.1136	0.0106	0.4348	43.4762
	Wastewater Reuse(WWR)	0.0168	0.0835	0.036	0.0056	0.1418	14.1822
	Renovation of Water Distribution Networks(RWDN)	0.0213	0.0762	0.0193	0.0162	0.133	13.2987

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