OPEN ACCESS

African Journal of Environmental Science and Technology

April 2020
ISSN 1996-0786
DOI: 10.5897/AJEST
www.academicjournals.org

ACADEMIC JOURNALS
expand your knowledge

About AJEST

African Journal of Environmental Science and Technology (AJEST) provides rapid publication (monthly) of articles in all areas of the subject such as Biocidal activity of selected plant powders, evaluation of biomass gasifier, green energy, Food technology etc. The Journal welcomes the submission of manuscripts that meet the general criteria of significance and scientific excellence. Papers will be published shortly after acceptance. All articles are peer-reviewed

Indexing

The African Journal of Environmental Science and Technology is indexed in:

CAB Abstracts, CABI's Global Health Database, Chemical Abstracts (CAS Source Index), China National Knowledge Infrastructure (CNKI), Dimensions Database, Google Scholar, Matrix of Information for The Analysis of Journals (MIAR), Microsoft Academic

AJEST has an h5-index of 14 on Google Scholar Metrics

Open Access Policy

Open Access is a publication model that enables the dissemination of research articles to the global community without restriction through the internet. All articles published under open access can be accessed by anyone with internet connection.

The African Journal of Environmental Science and Technology is an Open Access journal. Abstracts and full texts of all articles published in this journal are freely accessible to everyone immediately after publication without any form of restriction.

Article License

Article Copyright

Self-Archiving Policy

The African Journal of Environmental Science and Technology is a RoMEO green journal. This permits authors to archive any version of their article they find most suitable, including the published version on their institutional repository and any other suitable website.
Please see http://www.sherpa.ac.uk/romeo/search.php?issn=1684-5315

Digital Archiving Policy

The African Journal of Environmental Science and Technology is committed to the long-term preservation of its content. All articles published by the journal are preserved by Portico. In addition, the journal encourages authors to archive the published version of their articles on their institutional repositories and as well as other appropriate websites.
https://www.portico.org/publishers/ajournals/

Metadata Harvesting

The African Journal of Environmental Science and Technology encourages metadata harvesting of all its content. The journal fully supports and implement the OAI version 2.0, which comes in a standard XML format. See Harvesting Parameter

Memberships and Standards

Academic Journals strongly supports the Open Access initiative. Abstracts and full texts of all articles published by Academic Journals are freely accessible to everyone immediately after publication.

All articles published by Academic Journals are licensed under the Creative Commons Attribution 4.0 International License (CC BY 4.0). This permits anyone to copy, redistribute, remix, transmit and adapt the work provided the original work and source is appropriately cited.

Crossref is an association of scholarly publishers that developed Digital Object Identification (DOI) system for the unique identification published materials. Academic Journals is a member of Crossref and uses the DOI system. All articles published by Academic Journals are issued DOI.

Similarity Check powered by iThenticate is an initiative started by CrossRef to help its members actively engage in efforts to prevent scholarly and professional plagiarism. Academic Journals is a member of Similarity Check.

CrossRef Cited-by Linking (formerly Forward Linking) is a service that allows you to discover how your publications are being cited and to incorporate that information into your online publication platform. Academic Journals is a member of CrossRef Cited-by.

Academic Journals is a member of the International Digital Publishing Forum (IDPF). The IDPF is the global trade and standards organization dedicated to the development and promotion of electronic publishing and content consumption.

Contact

Editorial Office: ajest@academicjournals.org

Help Desk: helpdesk@academicjournals.org

Website: http://www.academicjournals.org/journal/AJEST

Submit manuscript online http://ms.academicjournals.org

Academic Journals
73023 Victoria Island, Lagos, Nigeria
ICEA Building, 17th Floor,
Kenyatta Avenue, Nairobi, Kenya.

Table of Content

Vol. 14(4), pp. 92-103, April 2020
DOI: 10.5897/AJEST2020.2828
Article Number: 74E703563495
ISSN: 1996-0786
Copyright ©2020

http://www.academicjournals.org/AJEST

African Journal of Environmental Science and Technology

Full Length Research Paper

The impact of sea water intrusion on the spatial variability of the physical and chemical properties of ground water in Limbe-Cameroon

MOTCHEMIEN Rigobert[1]* and FONTEH Mathias FRU[2]

[1]Department of Rural Engineering, National Advanced School of Public Works Buea, Box 324 Buea, SW Region, Cameroon.
[2]College of Technology, The University of Bamenda, Box 39, Bambili, Mezam Division, NWRegion, Cameroon.

Received 23 February, 2020; Accepted 2 April, 2020

A significant proportion of the population of Limbe, a coastal town in Cameroon, relies on ground water (gw) to satisfy their drinking water needs. The coastal aquifer is threatened by pollution from sea water intrusion and hence the aim of this study was to determine the suitability of the water. Physico-chemical analysis were carried out on samples collected from the study area and the Revelle Index was calculated and used to determine the extent of pollution from seawater intrusion. The water quality index (WQI) was calculated using values of the pH, bicarbonate, chloride, total dissolved solids and the electrical conductivity. The results showed that 23% of the groundwater in the study area is slightly polluted by seawater intrusion. Using the WQI, it was found that about 34.4% of the ground water resources in the study area is currently good for drinking while 65.6% is either poor, very poor or unsuitable for drinking. In order to reduce the intrusion of sea water into the aquifer, a halophyte plant like mangrove should be planted at the mouth of the main river in Limbe.

Key words: Coastal aquifer, pollution, salinity, water quality index, Revelle Index.

INTRODUCTION

In the last few decades, there has been a tremendous increase in the demand for fresh water in the world due to the rapid growth of the population and the accelerated pace of industrialization (Rejith et al., 2009). Limbe, a coastal town in Cameroon on the Atlantic Ocean has a demand for domestic water supply that the water utility company cannot satisfy and hence a significant proportion of the population relies on ground water (gw) to meet their domestic water demands.

Under natural conditions, coastal aquifers are recharged by rainfall, and the gwflows towards the ocean preventing saltwater from encroaching into the freshwater. The global mean sea level (GMSL) increased by an average rate of 1.8 mm/year during the 20th century

*Corresponding author. E-mail: motchemien@yahoo.com. Tel: +237 677579410.

(Douglas, 1997) and the IPCC reported with a high confidence that this rate has been increasing (Bates et al., 2008). The IPCC (2007) estimated that the GMSL increased by 3.1 mm/year from 1993 to 2003, but this change is not spatially uniform worldwide. Nicholls and Cazenave (2010) estimated a GMSL rise of approximately 3.3 mm/year for the period 1992 to 2010.

Motchemien (2015) estimated on the basis of data obtained from the tide gauge installed in Limbe, a rise in the mean sea level of the Atlantic Ocean in the lower part of the Gulf of Guinea of about 10 mm / year. One effect of such an increase is sea water intrusion into coastal aquifers (Werner and Simmons, 2009). Salt water intrusion is a serious problem because about 80% of the world's population lives along the coast and utilize coastal aquifers for their water supply. In addition, over exploitation of coastal aquifers has resulted in falling groundwater levels (gwl). Sea level rise and falling water gwl have resulted in increased pollution of gw due to sea water intrusion resulting in wells previously used to for domestic water supply being abandoned. For example, in New Jersey, more than 120 wells were abandoned because of saltwater contamination (Lacombe and Carleton, 1992).In the study area, about 250 wells has been abandoned because the water has become salty (Motchemien, 2015).

Variations in the sea level and the associated wedge movement can influence the near-shore and/or large-scale submarine discharge patterns and impact nutrient loading levels across the aquifer-ocean interface (Li and Jiao, 2003). While anthropogenic activities, such as over pumping and felling of trees in urbanized coastal areas, are the major causes of salt water intrusion, it is projected that increases in the sea level due to climate change would aggravate the problem (Li and Jiao, 2003). Feseker (2007) modelled the impacts of climate change and changes in land use patterns on the salt distribution in a coastal aquifer and concluded that rising sea level could induce rapid progression of salt water intrusion.

Excessive groundwater withdrawals have been reported to result in hydro-chemical changes in the physical, chemical and microbiological water quality; drop in the water table level; reverse hydraulic gradient and consequently water quality deterioration in coastal areas (Esteller et al., 2012). Poor water quality results in incidences of waterborne diseases and consequently reduces the life expectancy of the population (WHO, 2006). Thus, concern for clean and safe drinking water and protection from contamination is justified because a large proportion of the population in the study area depends on ground water for domestic purposes.

Water quality evaluation is based on the physical, chemical and biological parameters ascertaining the suitability for various uses such as domestic consumption, agricultural, recreational and industrial use (Sargaonkar and Deshpande, 2003). The traditional assessment of water quality consists of comparing the point values of water quality parameters levels with their guideline or standard values based on allocated water use or uses. This type of assessment does not provide an overall assessment of water quality of a water body which is important for managers and decision-makers. To resolve this decision-making problem, several water quality indices have been developed to transform point value water quality parameters into integrated indicator values. Many studies have demonstrated the usefulness of assessing the water quality of gw using a water quality index (WQI). Examples are presented by: Shah et al (2008); Zaharin et al. (2009); Chachadi and Lobo – Ferreira (2001); Akoteyon (2013); Vasanthavigar et al. (2010); Ramakrishnaiah et al. (2009); Rao and Nageswararao (2013), and Sahu and Sikdar (2008).

The aim of this study was to assess the suitability of the gw in Limbe for domestic use. The specific objectives were to: Determine the spatial variation of the physical and chemical properties of the gw; evaluate the extent of sea water intrusion into the aquifer; determine the proportion of the gw suitable for drinking and finally a propose solution to reduce the impact of sea water intrusion on the gw quality.

MATERIALS AND METHODS

Description of the study area

Location

Limbe is located along the coastal area of Fako Division, South-West Region of Cameroon (Figure 1). The study area is located approximately between latitudes 3^{o} 90´ and 4^{o} 05 N and longitudes 9^{o} 29´ and 9^{o} 06´ E. It is bounded in the East by Bimbia, in the North by Bonadikombo, in the South by the Atlantic Ocean and in the West by Mukundange. The population of Limbe is about 130,000 inhabitants spread over a surface area of 596 km^2(INS, 2013).

The town is characterized by a low-lying coastal plain, rising up to a chain of horseshoe shaped hills towards the northeast and east, with the highest point at 362 m above sea level (Njabe and Fobang, 2006). Within the town, small streams flow into larger drainage channels that converge into the main river (Njenguele) that empties into the Atlantic Ocean (Figure 2). These rivers frequently overflow their banks in the rainy season causing floods in the low-lying areas that are only 1 to 2 m above sea level (Ndille and Belle, 2014). The hills that surround the town are made up of loose ferralitic and volcanic soils that easily disintegrate when the water content is high (Nwankiti, 1983).

Climate

The climate of Limbe is the sub-equatorial type with two distinct seasons: a dry season of two months from December to January and a rainy season of 10 months that runs from February to November with a mean annual rainfall of 3,100 mm, ±1,100 standard deviation (Suh et al., 2003). The monthly rainfall frequently exceeds 500 mm and sometimes is over 1,000 mm in June, July and August. The mean annual temperature is about 26°C while the relative humidity is generally above 85% (Fombe and Molombe, 2015).

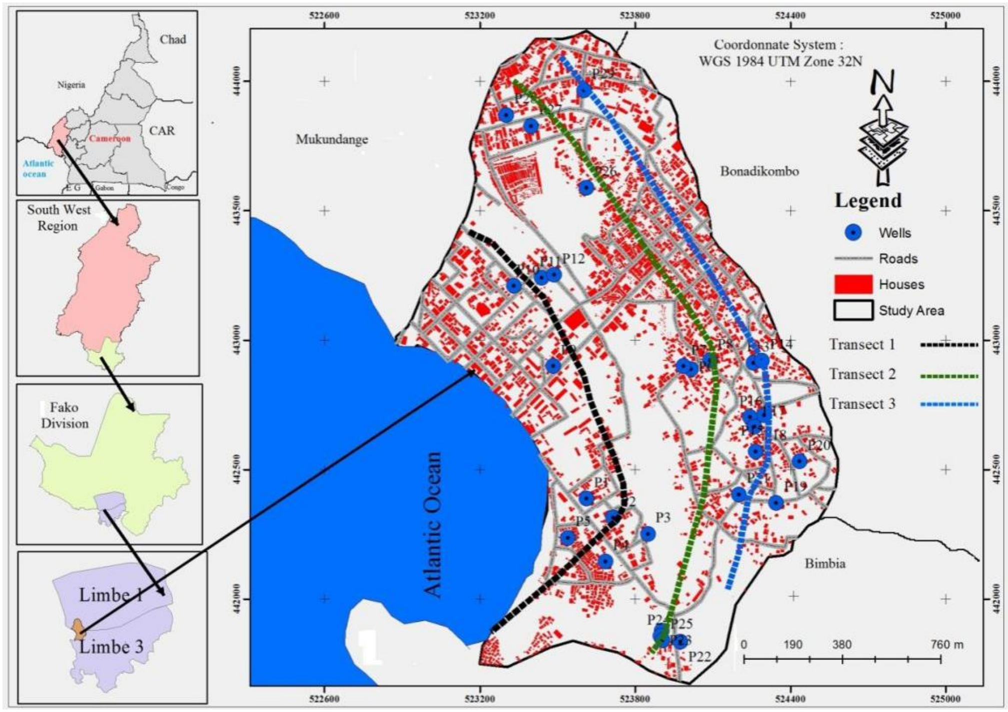

Figure 1. Location of the study area and location of sampling points in Limbe.

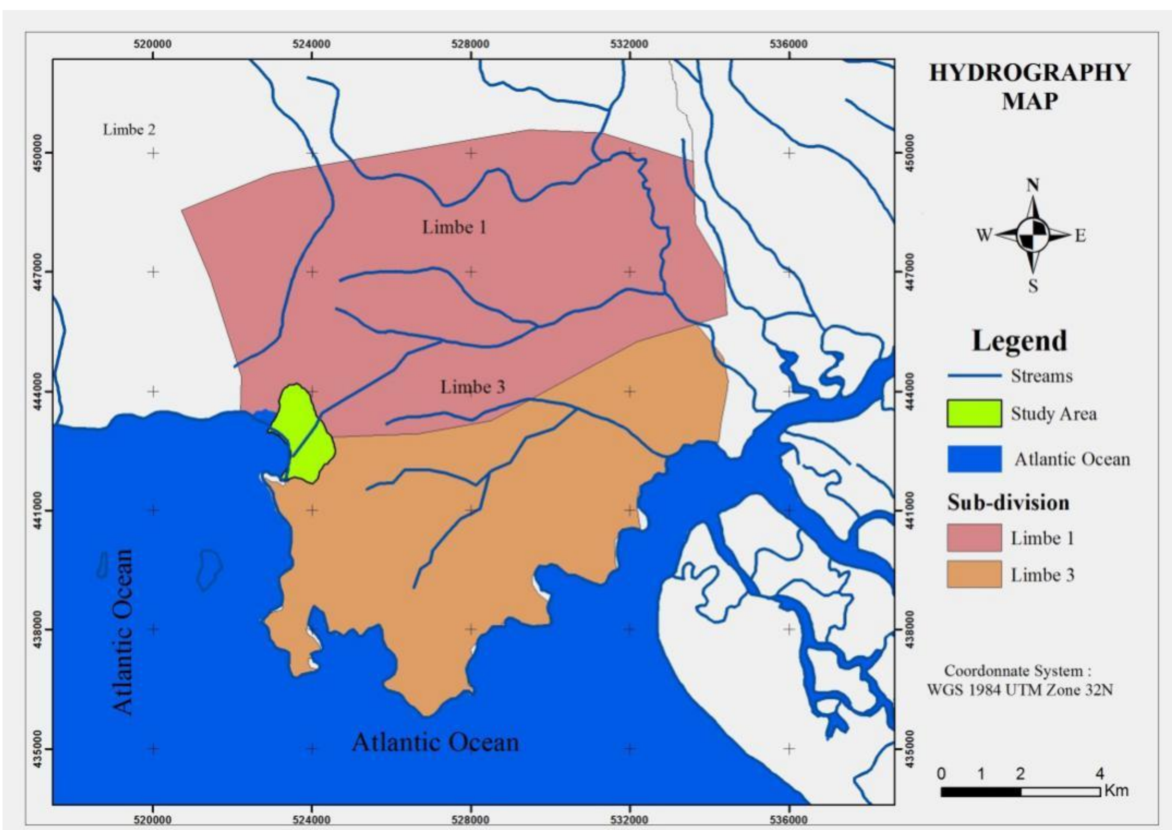

Figure 2. Hydrography of the study area.
Source: Buh(2009).

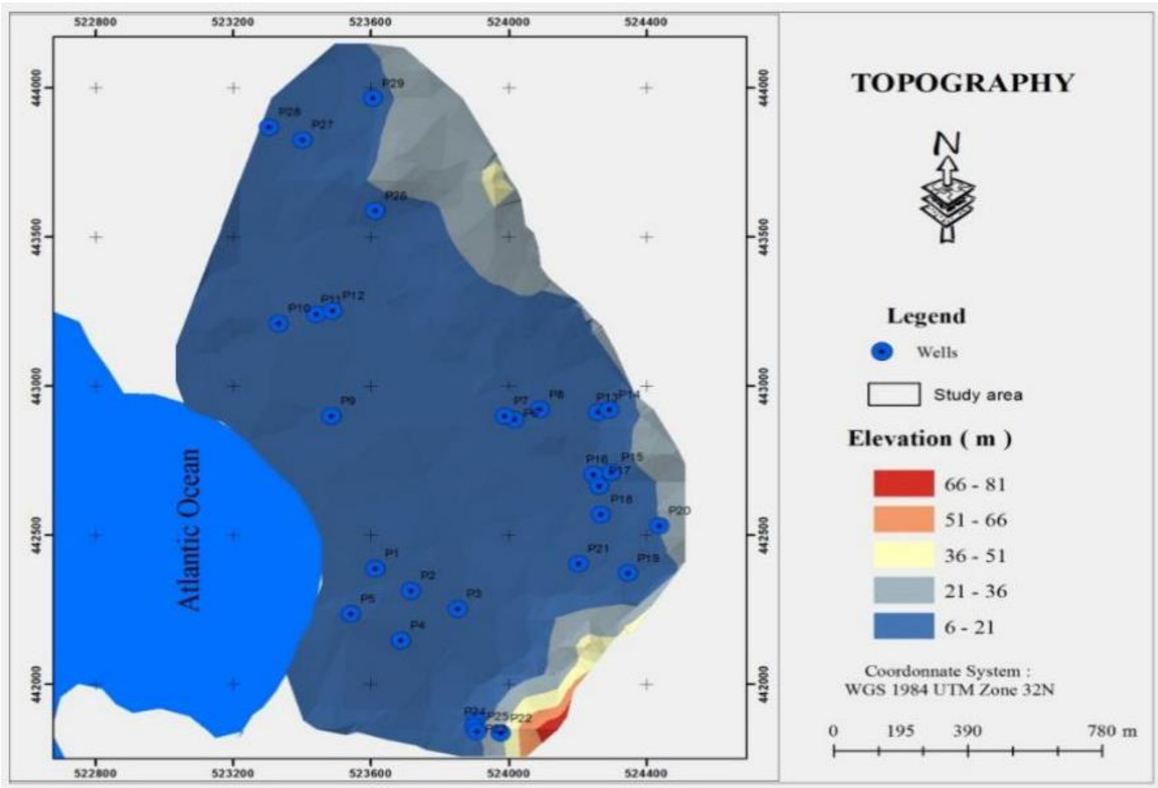

Figure 3. Topographic map of the study area.

Geomorphology and hydrogeology

Geomorphologically, the study area is made up of ridges and deeply incised ravines with a W–E orientation at a high angle to the general NE–SW orientation of Mount Cameroon (Suh et al., 2003). The elevations in the study area range from 0 to about 90 m above sea level with slopes ranging from 0 to 43° (Figure 3). The slopes on the foot of Mount Cameroon are composed of multiple porphyritic basaltic lava flows, punctuated by several strombolian pyroclastic cones to the W and NW and lahar deposit to the east of the study area (Diko et al., 2012). These ridges form part of the Limbe-Mabeta Volcanic Massif, made up of degraded and deeply weathered tertiary basaltic lava flows (Suh et al., 2003). The main rock types within this area include basalts (Figure 4), basanites, lahar deposits, and pyroclastic materials (Buh, 2009).

The hydrogeology is characterized by unfossiliferous sandstone and gravel, weathered from underlying Precambrian basement rock (Longe, 2011). It consists of coastal plain sands (CPS) and recent sediments. The CPS aquifer is the most productive and exploited aquifer in Limbe.

Data

Water samples were collected monthly between July 2017 and June 2018 from thirty hand dug wells located along three transects as shown on Figure 1. The sample size was determined using the formulae presented in Equations 1 and 2 (Howell, 1999):

$$m = \frac{z^2}{\varepsilon^2} * p * (1 - p) \quad (1)$$

$$n = \frac{m}{1 + \frac{m-1}{N}} \quad (2)$$

Where: m = the sample size. n = the correction sample size for a limited population. N = the population. z= the value related with confidence level (1.96 for 95% confidence level). p= the degree of variance between the elements of population (0.5). ε= the maximum error (0.07).

The electrical conductivity (EC), the pH and the total dissolved solids (TDS) were measured *in situ*using a portable hand held, pH-028 six in one monitor. Water samplesfor laboratory analysis were collected in clean 150 ml polyethylene bottles and preserved in ice chests for analyses of chloride and bicarbonate using standard methods (APHA, 1998).

The co-ordinates of the sampled wells were recorded using a Global Positioning System (GPS) and thereafter were plotted using ArcGIS software on the geomorphological map of Limbe. To get a comprehensive picture of the overall quality of groundwater, the WQI was used. WQI is defined as a rating reflecting the composite influence of different water quality parameters on the overall quality of water. Revelle (1941) proposed the following equation for calculating the Revelle Index (RI) which is used to assess groundwater pollution from seawater:

$$RI = \frac{[Cl^-]}{[HCO_3^-] + [CO_3^{2-}]} \quad (3)$$

Where: $[Cl^-]$ = the concentration of chloride in the sample; $[HCO_3^-]$ = the concentration of bicarbonate in the sample; $[CO_3^{2-}]$ = the concentration of carbonate in the sample.

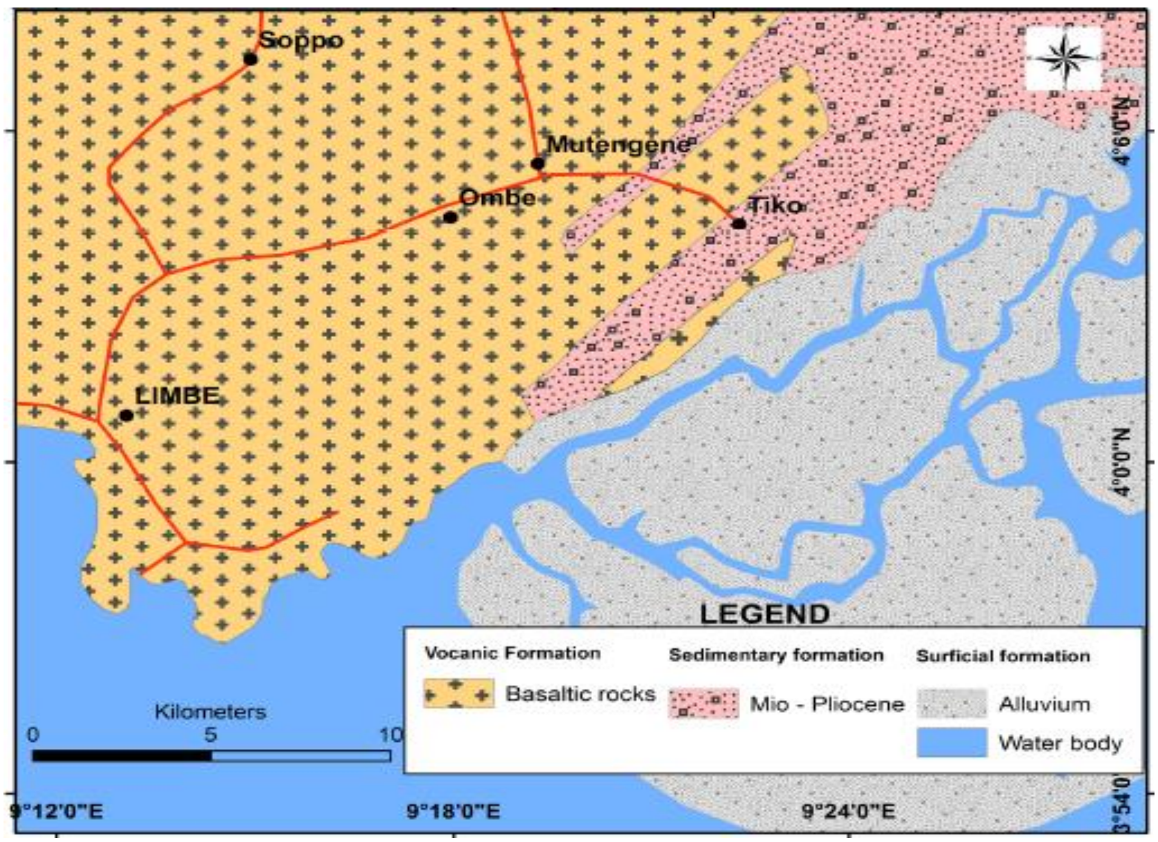

Figure 4. Geologic map of the study area.
Source: Djieto-Lordon et al. (2017).

According to Revelle (1941) when RI < 0.5, this indicates there is no sea water intrusion; when RI is between 0.5 and 6.6, this indicates the gw is slightly affected and when its greater than 6.6 it indicates its strongly affected.

The drinking water quality was assessed using a water quality index (WQI) and the World Health Organization (2006) standard. The stages of calculating the WQI are as follows:

$$q_n = 100\frac{V_n - V_{io}}{S_n - V_n} \quad (4)$$

Where: q_n = quality rating for the n^{th} water quality parameter; n= the water quality parameter and quality rating or sub index (q_n) corresponding to n^{th} parameter, that is, a number reflecting the relative value of this parameter with respect to its standard (maximum permissible value); V_n= estimated value of the n^{th} parameter at a given the sampling point; S_n= standard permissible value of the n^{th} parameter; V_{io} = ideal value of n^{th} parameter in pure water, that is, 0 for all other parameters except pH and dissolvedoxygen (7.0 and 14.6 mg/l respectively).

The unit weight of the n^{th} parameter (W_n) was calculated by a value inversely proportional to the recommended standard value ($S_{n)}$ of the corresponding parameter.

$$W_n = \frac{K}{S_n} \quad (5)$$

Where: S_n = standard value for the n^{th} parameters; K= proportionality constant ($K = \frac{1}{\Sigma(\frac{1}{S_n})}$).

The WQI wasthencalculated using Equation 6:

$$WQI = \frac{\Sigma q_n w_n}{\Sigma w_n} \quad (6)$$

Table 1 shows the classification of water based on the WQI from the point of potability.The coordinates of each sample were determined using a Garmin GPSmap 78S. The values of the RevelleIndex and the Water Quality Index were then exported to the ArcGIS 6.0 software and used to generate maps of their spatial distribution over the study area. The areas referring to each water quality class and the Revelle Index were circumscribed on the map using ArcGIS6.0. They were automatically generated with this software surface function. Finally, slicing options were applied using these ranges of values with five groups of water quality classes to generate a spatial distribution of water quality map (Chatterji and Raziuddin, 2002). The statistical analysis of the examined groundwater parameters was computed using STATA software version 6.0.

RESULTS AND DISCUSSION

Spatial variation of the physical and chemical properties

Table 2 presents the measured parameters in the three transects the descriptive statistics and the recommended values by the World Health Organization.

Table 1. Water quality index and status of water quality.

Water quality index	Water quality class
0-25	Excellent water quality
26-50	Good water quality
51-75	Poor water quality
76-100	Verypoor water quality
<100	Unsuitable for drinking

Source: Chatterji and Raziuddin (2002).

Table 2. Measured parameters and descriptive statistics of groundwater in the study area.

Transect	Wells	EC (µS/cm)	pH	TDS (ppm)	T (°C)	$[Cl^-]$ (mg/l)	$[HCO_3^-]$ (mg/l)	$[Cl^-]/[HCO_3^-]$
T1	P1	592.92	7.19	419.17	28.09	93.21	85.60	1.09
T1	P2	794.17	7.05	558.33	27.89	112.13	82.70	1.36
T1	P3	680	7.26	475.83	27.77	90.29	88.71	1.02
T1	P4	808.33	7.34	566.67	26.88	131.63	105.38	1.25
T1	P5	792.5	7.24	555	27.04	140.4	90.53	1.55
T1	P9	497.27	6.86	340	27.83	65.52	83.47	0.78
T1	P10	451.67	7.26	317.5	27.48	77.42	75.00	1.03
T1	P11	570.83	6.99	399.17	27.83	74.10	90.43	0.82
T2	P6	494	7.2	331.67	26.57	88.53	124.94	0.71
T2	P7	655	7.49	429.17	27.28	83.27	196.83	0.42
T2	P8	698	7.09	455.00	27.2	102.77	160.81	0.64
T2	P12	519	7.22	340.00	27.63	39.59	120.82	0.33
T2	P15	120	6.46	82.50	27.58	34.13	137.96	0.25
T2	P16	145	6.58	100.00	27.98	39.00	107.4	0.36
T2	P17	195	6.66	143.33	27.31	25.94	107.8	0.24
T2	P18	400	6.99	271.67	27.81	39.00	109.6	0.36
T2	P19	121	6.74	85.00	27.67	43.68	128.83	0.34
T2	P21	254	6.64	176.67	27.48	39.00	109.3	0.36
T2	P26	287	6.94	214.17	26.88	40.95	79.5	0.52
T2	P27	452	7.31	316.67	27.7	23.40	103.41	0.23
T2	P28	369	7.12	252.5	27.78	22.43	101.77	0.22
T2	P29	249	6.63	185.83	27.91	25.35	105.36	0.24
T2	P30	327.27	6.96	240.00	27.48	24.38	105.86	0.23
T3	P13	298	7.37	189.17	27.23	25.35	170.7	0.15
T3	P14	262	6.34	185.00	27.5	30.81	128.2	0.24
T3	P20	233	6.2	160.83	27.75	50.12	126.98	0.39
T3	P22	203	6.79	143.33	27.73	41.93	185.95	0.23
T3	P23	222	6.85	153.33	27.03	33.15	159.62	0.21
T3	P24	230	6.84	159.17	27.88	41.73	193.57	0.22
T3	P25	232	6.71	156.67	27.2	59.09	184.32	0.32
Min		**120**	**6.2**	**82.50**	**26.57**	**22.43**	**75**	**0.15**
Max		**808.33**	**7.49**	**566.67**	**28.09**	**140.4**	**196.83**	**1.55**
Mean		**405.1**	**6.94**	**280.11**	**27.51**	**57.94**	**121.71**	**0.54**
Standard dev		**213.61**	**0.32**	**146.58**	**0.38**	**33.67**	**36.26**	**0.39**
WHO norm		**300**	**6.5-8.5**	**500**	**25**	**250**	**300**	

Min = minimum; max = maximum; EC = Electrical conductivity; TDS = Total dissolved solids.

The pH of the gw varied from 6.2 to 7.49 with a mean value of 6.94. The EC values varied from 120.00 to 808.33

Table 3. Spatial variation of the mean values of some physico-chemical parameters of gw along three transects.

Transect	Temp (°C)	pH	TDS (ppm)	EC (µS/cm)	$[Cl^-]$ (mg/l)	$[HCO_3^-]$ (mg/l)	$[Cl^-]/[HCO_3^-]$
T_1	27.60[a]	7.15[b]	453.96c**	648.46c**	98.09c**	87.73a**	1.11c**
T_2	27.48[a]	6.93[b]	241.61b**	352.35b**	44.76b**	120.01b**	0.36b**
T_3	27.47[a]	6.73[a*]	163.93a**	240.00a**	40.31a**	164.19c**	0.25a**

TDS, Total dissolved solids; EC, Electrical conductivity; No significant difference in the columns for the values carrying the same letters (P>0.05); Significant difference in the columns for the values carrying the different letters (* P<0.05; **P<0.001)

µS/cm with a mean value of 405.10 µS/cm which is higher than the norm indicating a high amount of dissolved salts in the water. The values of EC in all wells in transect 1 exceeded the minimum recommended value. The total dissolved solids ranged from 82.50 to 566.67 ppm with a mean value of 280.11 mg/l which is about 50% lower than the norm. Most of the values of the TDS were within the recommended range for drinking water except for values obtained from wells P_2, P_4 and P_5 which exceeded the recommended value. The temperature varied between 26.57and 28.09^{0}C with a mean value of 27.51.

The bicarbonate level varied between 75.00 and 196.83 mg/l with mean value of 121.71mg/l. Chloride values were found to vary from 22.43 to 140.4 mg/l with mean value of 57.94. These values of chloride are within the recommended standard level. A high level of chloride in freshwater is an indicator of pollution (Chandra et al., 2012). The Secondary Maximum Contaminant Limit (SMCL) for chloride is 250 mg/l. This is the level above which the taste of the water may become objectionable to the consumer. In addition, high chloride concentration levels in the water contribute to the deterioration of domestic plumbing materials, water heaters and equipment in municipal water works.The levels of TDS, EC, and Cl^- decreased significantly from transect 1 to 3 as shown in Table 3 while the level of bicarbonate ions increased significantly. This indicated that saline intrusion was more pronounced in sites near the ocean.

Extent of sea water intrusion in the coastal aquifer

In the study area, RI varied from 0.126 to1.551 as shown in Table 4. According to Revelle (1941), this suggests that some areas in the study area have not been affected (RI less than 0.5) while others have been slightly affected (RI is between 0.5 and 6.6). The relationship between the ratios of $\frac{[Cl^-]}{[HCO_3^-]+[CO_3^{2-}]}$ indicates a strong positive linear relation with Cl concentrations (r = 0.94, p < 0.01).This linear relationship indicates the mixing of saline water and fresh groundwater (Zaharin et al., 2009). Figure 5 shows the extent of the groundwater salinization in the study area. From Table 5, about 77% of the groundwater in the study area was unaffected by sea water intrusion, while 23% of the aquifer was slightly affected by pollution from sea water. The hotspots include locations of wells P_1, P_2, P_3, P_4 and P_5. Thus, efforts should be made to reduce the pollution of ground water due to sea level rise in the area.

Extent of the gw suitable for drinking

The suitability of groundwater for drinking purposes in the study area was determined using WHO (2006) guidelines. The computed Water Quality Index (WQI) ranged from 28 to 115 as indicated in Table 6.

The spatial distribution of water quality in the aquifer is presented in Figure 6. The EC, pH, TDS, Cl^- and HCO_3^-all contributed to the WQI values. However, values of chloride and electrical conductivity were the main parameters responsible for the high values of WQI. In some locations, the TDS also significantly increased the WQI.

The area covered by different water quality classes were calculated from the WQI maps and are presented in Table 7. About 34.4% of the gw is currently considered to be good for drinking while 65.6% is either poor, very poor or unsuitable for drinking. Hot spots that require attention are wells P_2, P_3, P_4 and P_5, all along transect 1, which is closest to the sea.

Solution to reduce sea water intrusion

About 23% of the aquifer of the study area is affected by sea water intrusion rendering the water non-potable. In order to reduce the intrusion of ocean water, there are two possibilities; construction of dykes or barriers and planting a halophyte plant. Anti-salt barriers or dykes can be used to combat saline intrusion (Barry, 1988). However, they are limited in that they are effective only in controlling surface sea water flow but, they do not prevent the intrusion of underground sea water (Diawara, 1988).

A more effective solution is the planting of halophyte plants like mangrove trees of the Rhizophoraceae family. They should be planted on both sides of the mouth of the River Njenguele over a distance of 500 m. Mangrove trees stabilize the coastline and serve as a barrier against erosion due to swell by reducing the energy of the waves

Table 4. Revelle Index of gw in the study area.

Transects	Wells	Coordinates (meters)		Revelle index
		X	Y	
T1	P1	523612	442388	1.089
T1	P2	523716	442314	1.356
T1	P3	523850	442252	1.018
T1	P4	523686	442146	1.249
T1	P5	523541	442236	1.551
T1	P9	523484	442900	1.061
T1	P10	523331	443210	1.11
T1	P11	523439	443241	1.136
T2	P6	524016	442888	0.524
T2	P7	523988	442900	0.393
T2	P8	524090	442922	0.461
T2	P12	523488	443253	0.328
T2	P15	524299	442711	0.184
T2	P16	524245	442703	0.287
T2	P17	524262	442665	0.317
T2	P18	524267	442570	0.356
T2	P19	524346	442372	0.201
T2	P21	524202	442404	0.357
T2	P26	523612	443589	0.549
T2	P27	523399	443827	0.485
T2	P28	523303	443870	0.383
T2	P29	523604	443966	0.398
T2	P30	523634	443866	0.313
T3	P13	524259	442912	0.244
T3	P14	524291	442921	0.461
T3	P20	524437	442532	0.322
T3	P22	523976	441835	0.126
T3	P23	523903	441878	0.140
T3	P24	523899	441857	0.131
T3	P25	523907	441841	0.132
Min				**0.126**
Max				**1.551**
Mean				**0.555**
Standard deviation				**0.418**

and by modifying the hydrocirculations (Furukawa et al., 1997). Mangrove trees have a root system that filters water, and can thus exclude up to 90% of salts from interstitial waters thanks to glands located in their leaves (Tymbery et al., 2019). Mangrove trees planted a short distance offshore, control high energy waves which erode the coastline and prevent the meeting of coastal marine waters and fresh waters. In addition, the complex geochemical reactions taking place in the sediment around the trees can immobilize toxic metals and consequently purify coastal waters. Furthermore, mangrove trees serve as a natural barrier against the gradual rise in mean sea level and saline intrusion into aquifers and arable land. They also have a significant refuge value and hence they enhance aquatic biodiversity.

Conclusion

Based on the methodology used in this study and the results obtained, it can be concluded that:

(1) About 23% of the ground water resources in the study area is presently slightly polluted by seawater intrusion.
(2) Ground water contamination by sea water intrusion is a major concern for the fresh water supply in the study

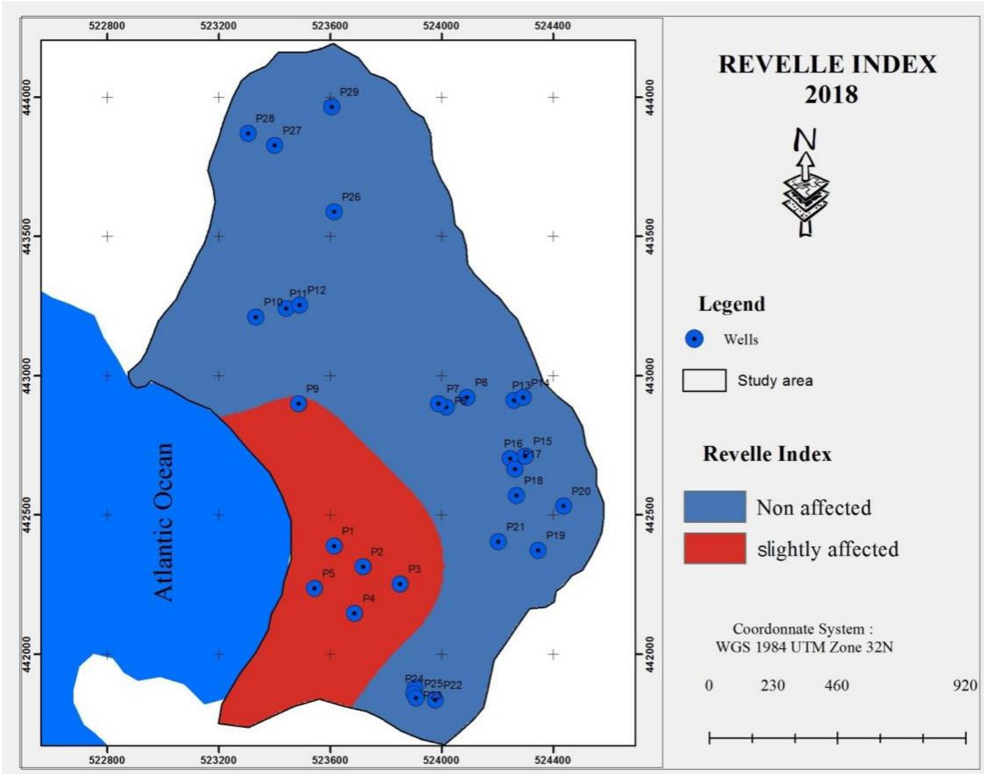

Figure 5. Spatial variation of sea water intrusion into ground water in Limbe.

Table 5. Extent of sea water intrusion into ground water in Limbe.

Degree of sea water intrusion	Area (ha)	Percentage of total
Notaffected	185.96	77
Slightlyaffected	55.36	23
Total	**241.32**	**100**

Table 6. Water quality index in the study area.

Transects	Wells	Coordinates (m)		WQI
		X	Y	
T1	P1	523612	442388	84
T1	P2	523716	442314	108
T1	P3	523850	442252	93
T1	P4	523686	442146	115
T1	P5	523541	442236	114
T1	P9	523484	442900	73
T1	P10	523331	443210	67
T1	P11	523439	443241	84
T2	P6	524016	442888	72
T2	P7	523988	442900	96
T2	P8	524090	442922	97
T2	P12	523488	443253	69
T2	P15	524299	442711	28

Table 6. Contd.

T2	**P16**	**524245**	**442703**	**29**
T2	P17	524262	442665	35
T2	P18	524267	442570	57
T2	P19	524346	442372	28
T2	P21	524202	442404	42
T2	P26	523612	443589	44
T2	P27	523399	443827	64
T2	P28	523303	443870	53
T2	P29	523604	443966	42
T2	P30	523634	443866	48
T3	P13	524259	442912	51
T3	P14	524291	442921	48
T3	P20	524437	442532	41
T3	P22	523976	441835	40
T3	P23	523903	441878	40
T3	P24	523899	441857	44
T3	P25	523907	441841	43
Min				**28**
Max				**115**
Mean				**62**
Standard deviation				**26.41**

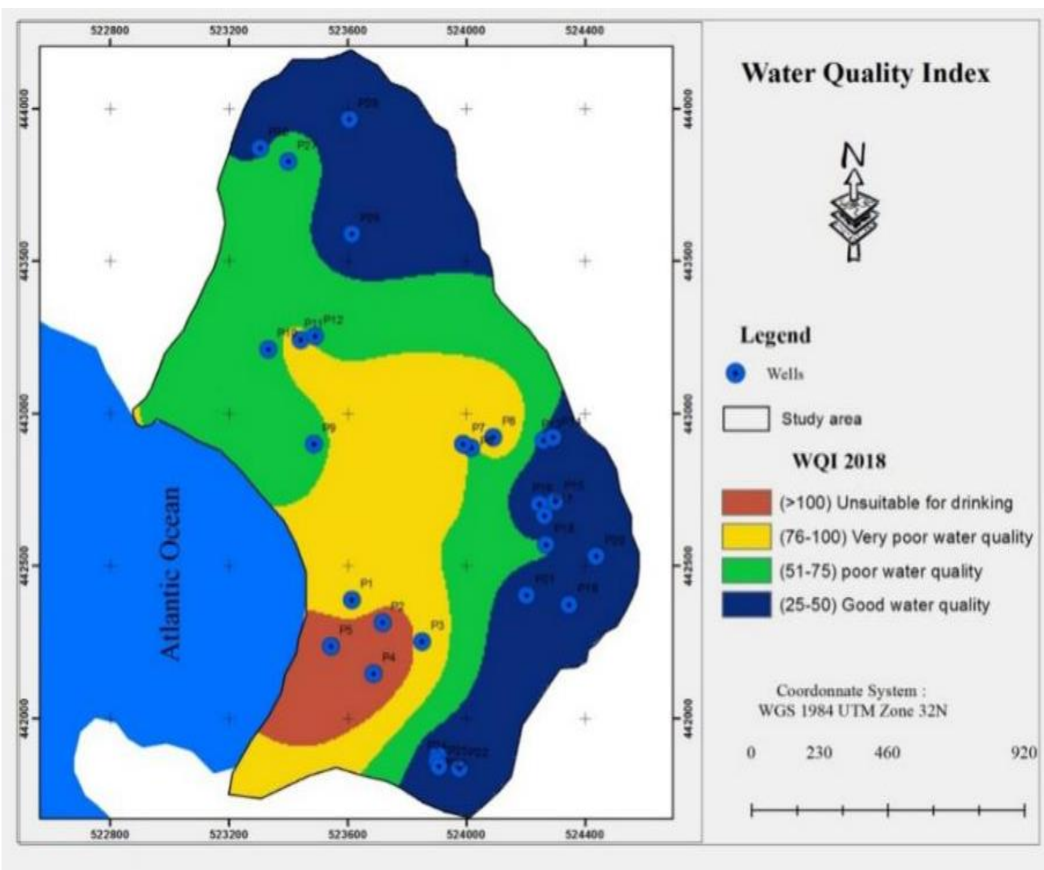

Figure 6. Spatial variation of ground water quality in Limbe.

Table 7. Proportion of different water quality classes in the study area.

Water quality class	Area (ha)	Percentage of total
Unsuitable for drinking	16.38	6.79
Verypoor	60.63	25.12
Poor	81.30	33.69
Good	83.01	34.40
Total	**241.32**	**100.00**

area especially around locations of wells P_2, P_3, P_4 and $P_{5.}$

(3) About 34.4% of the ground water resources in the study area is currently considered to be good for drinking while 65.6 % is either poor, very poor or unsuitable for drinking.

(4) To minimize the impact of sea water intrusion on the quality of gw in the study area a halophyte plant like mangrove should be planted at the mouth of River Njenguele, which is the main natural drain in the study area.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

REFERENCES

Akoteyon IS (2013). Evaluation of groundwater quality using water quality indices in parts of Lagos-Nigeria. Journal of Environmental Geography 6:29-36.

American Public Health Association (APHA) (1998).Standard methods for the examination of water and wastewater.20th edn. Washington DC, USA: APHA.

Barry B (1988). Sécheresse et modification des ressources hydriques en basse Casamance. Conséquences pour le milieu naturel et son aménagement. ORSTOM, Dakar/Paris.

Bates B, Kundzewicz ZW, Wu S, Palutikof J (2008).Climate change and water. Technical Paper of the Intergovernmental Panel on Climate Change. Geneva, Switzerland: IPCC Secretariat.

Buh WG (2009). Geographic information systems-based demarcation of risk zones: the case of the Limbe Sub-Division – Cameroon. Journal of Disaster Risk Studies 1:600-617.

Chachadi AG, Lobo-Ferreira JP (2001).Sea water intrusion vulnerability mapping of aquifers using GALDIT method, In: Proc. Workshop on Modelling in Hydro-geology at Anna University (pp 143-156). Chennai, India: Anna University.

Chandra S, Singh A, Tomar PK (2012). Assessment of waterqualityvalues in Porur Lake Chennai, HussainSagar Hyderabad and Vihar Lake Mumbai, India. Chemical Science Transactions 3:508-515.

Chatterji C, Raziuddin M (2002). Determination of water quality index (WQI) of a degraded river in Asanol Industrial area, Raniganj, Burdwan, West Bengal. Nature, Environment and pollution Technology Journal 2:181-189.

Diawara B (1988). Impact d'un barrage anti-sel sur la dynamique de la nappe superficielle d'un bas-fond. ORSTOM, CDRO-Dakar.

Diko ML, Ekosse GE, Ayonghe SN, Ntasin EB (2012). Physical and geotechnical characterization of unconsolidated sediments associated with the 2005 Mbonjo landslide, Limbe, Cameroon. International Journal of Physical Sciences 7:2784-2790.

DjietoLordon AE, Agyingi CM, Manga VE, Bukalo NN, Beka ET (2017). Geo-electrical and boreholeinvestigation of groundwater in somebasalts on the South-Eastern Flank of Mount Cameroon, West Africa. Journal of Water Resource and Protection 9:1526-1546.

Douglas BC (1997). Global sea level rise: A redetermination. Surveys in Geophysics 18:279-292.

Esteller MV, Rodríguez R, Cardona A, Padilla-Sánche L (2012). Evaluation of hydrochemical changes due to intensive aquifer exploitation: case studies from Mexico. Journal of Environmental Monitoring and Assessment 9: 5725-5741.

Feseker T (2007). Numerical studies on salt water intrusion in a coastal aquifer in northwestern Germany. Hydrogeology Journal 15: 267-279.

Furukawa K, Wolanski E, Mueller H (1997). Currents and sediment transport in mangrove forest. Estuarine Coastal and Shelf Sciences 44:301-310.

Fombe LF, Molombe JM (2015). Hydro-geomorphological implications of uncontrolled settlements in Limbe, Cameroon.International Review of Social Sciences 4:169-183.

Howell DC (1999). Méthodes statistiques en sciences humaines. Liège, Belgique : De Boeck Université.

Institut National de Statistiques (INS) (2013). Annuaire statistique du Cameroun. Yaoundé, Cameroun: INS.

Intergovernmental Panel on Climate Change (IPCC) (2007). Climate change 2007. Cambridge, UK: Cambridge University Press.

Lacombe PJ, Carleton GB (1992). Salt water intrusion into fresh ground-water supplies, southern Cape May County. Proceedings of the national symposium on the future availability of ground water resources April 12-15, 1992 (pp 287-298). New Jersey, USA: USGS

Li HL, Jiao JJ (2003).Tide-induced seawater-groundwater circulation in a multi-layered coastal leaky aquifer system. Journal of Hydrology 274:211-224.

Longe EO (2011). Groundwater resourcespotential in the Coastal Plain Sands Aquifers, Lagos, Nigeria. Research Journal of Environmental and Earth Sciences 3:1-7.

Motchemien R (2015). Effets de la variabilité du niveau de l'Océan Atlantique sur l'inondation continentale en zone urbaine à Limbé – Cameroun. UnpblishedM.Sc thesis, University of Dschang, Dschang, Cameroon.

Ndille R, Belle JA (2014). Managing the Limbe floods: Considerations for disasterriskreduction in Cameroon. International Journal of Disaster Risk Science 5: 147-156.

Nicholls RJ, Cazenave A (2010). Sea-level rise and its impacts on coastal zones. Science 328: 1517-1520.

Njabe RK, Fobang R (2006). Illustrated physical geography and map reading for Cameroon, 3rd ed. Limbe, Cameroon: Sunway.

Nwankiti OC (1983). Man and his environment. London, UK: Longman Group.

Ramakrishnaiah CR, Sadashivaiah C, Ranganna G (2009). Assessment of waterqualityindex for the groundwater in TumkurTaluk, Karnataka State, India. E-Journal of Chemistry 6:523-530.

Rao SG, Nageswararao G (2013). Assessment of groundwater quality using waterqualityindex. Archives of Environmental Science 7: 1-5.

Rejith PG, Jeeva SP, Vijith H, Sowmya M, Mohamed AAH (2009). Determination of groundwaterqualityindex of a highlandvillage of Kerala (India) using geographical information system. Journal of Environmental Health 71:51-58.

Revelle R (1941). Criteria for recognition of seawater in ground water. Transactions of American Geophysical Union 22:593-597.
Sahu P, Sikdar PK (2008).Use of water quality indices to verify the impact of Cordoba city (Argentina) on Suquy´aRiver. Geology Journal 55:823-835.
Sargaonkar A, Deshpande V (2003). Development of an overall index of pollution for surface water based on a general classification scheme in Indian context. Journal of Environmental Monitoring and Assessment 89:43-67.
Shah MC, Shilpkar PG, Acharya PB (2008).Groundwater quality of GandhinagarTaluka, Gujarat, India. E-Journal of Chemistry 5:435-446.
Suh CE, Sparks RSJ, Fitton JG, Ayonghe SN, Annen C, Nana R, Luckman A (2003). The 1999 and 2000 eruptions of Mount Cameroon: eruption behavior and petrochemistry of lava. Bulletin of Volcanology 65:267-28.
Tymbery AJ, Kay GD, Doupe R G, Partridge GJ, Norman HC (2019). The Potential of a salt-tolerant plant (*Distichlisspicata*) to treat effluent from inland saline aquaculture and provide livestock feed on salt-affected farmland. Science of the Total Environment 445-446:192-201
Vasanthavigar M, Srinivasamoorthy K, Vijayaragavan K, Ganthi R, Chidambaram S, Anandhan P, Manivannan R, Vasudevan S (2010). Application of water quality index for groundwater quality assessment: Thirumanimuttar Sub-basin, Tamilnadu, India. Journal of Environmental Monitoring and Assessment 171:595-609.
Werner AG, Simmons CT (2009). Impact of sea level rise on sea water intrusion in coastal aquifers. Ground Water Journal 47:197-204.
World Health Organization (WHO) (2006).Guidelines for drinking water quality. Geneva, Switzerland: WHO.
Zaharin AA, Abdullah MH, Praveena SM (2009). Evolution of groundwaterchemistry in the shallow aquifer of a small tropicalisl and in Sabah. Malaysia. Sains Malaysiana 38(6):805-812.

Vol. 14(4), pp. 104-113, April 2020
DOI: 10.5897/AJEST2020.2840
Article Number: E131C1163635
ISSN: 1996-0786

http://www.academicjournals.org/AJEST

African Journal of Environmental Science and Technology

Full Length Research Paper

Factors affecting the development of effective water resource management policies: The case of the management of Lake Victoria Basin in Uganda

Godfrey Odongtoo[1,3]*, Denis Ssebugwawo[2] and Peter Okidi Lating[3]

[1]Department of Computer Engineering, Faculty of Engineering, Busitema University, P. O. Box 236 Tororo, Uganda.
[2]Department of Computer Science, Faculty of Engineering, Kyambogo University, P. O. Box 1, Kampala, Uganda.
[3]Department of Electrical and Computer Engineering, Faculty of Engineering, Makerere University, P. O. Box 7062 Kampala, Uganda.

Received 22 March, 2020; Accepted 23 April, 2020

Partial least square-structural equation modelling (PLS-SEM) was used to evaluate the factors affecting the development of effective water resource management policies. Researchers employed a purposive sampling method to come up with the most suitable respondents. The sample size of 152 respondents was computed from a population size of 245 water experts within Lake Victoria Basin (LVB) in Uganda. The questionnaire was self-administered to 152 respondents to dig out their views based on their experiences in water resource management. The authors aimed to find out the relationship between efficiency of water allocation, natural hazards and risks, stakeholders' participation, governance and decentralization, socio economic activities and effective water resource management policies. The findings of this study revealed that governance and decentralization, natural hazards and risks, and socio-economic activities had a significant positive effect on effective water resource management policies. Governance and decentralization had the highest path coefficient (β= 0.453 and p-values = 0.000). The R^2 value was scored at 0.680, which collectively explained 68% of the overall variance in the development of the policies. The study recommends putting special attention on governance and decentralization for effective water resource management policies. These findings can support practitioners and decision makers engaged in the management of water resources within LVB and other water bodies worldwide.

Key words: East African Community, National Policies, integrated water resource management (IWRM), Partial Least Square-structural equation modelling (PLS-SEM).

INTRODUCTION

Lake Victoria is the second largest fresh water lake in the world as well as the largest tropical lake. It has a surface area of 68,000 km^2 (Odongtoo et al, 2018). The Lake is shared between Kenya, Uganda, and Tanzania that control 6, 45, and 49 % in sizes respectively (Dauglas et al., 2014). Lake Victoria Basin (LVB) is of great

*Corresponding author. E-mail: godfreyodongtoo@gmail.com.

socioeconomic significance to the riparian states and it is a major source of water for domestic, agricultural, and industrial purposes. It provides large quantity of fish for East African countries as well as United States of America, Australia, European Union countries and Israel (Mongi et al., 2015).

Dauglas et al. (2014) and Okurut (2010) revealed that rapid population growth, increase in commercial activities, industrialization and poor waste management services led to increase in the volume of urban waste being discharged directly into the lake. These affect the quality and quantity of water resources in LVB. In order to avert this problem, there is a need for proper policies on the management of both liquid and solid waste from industrial and domestic sources. There is also need to strengthen, monitor, and control anthropogenic activities in the basin that are the root cause of ecosystems degradation. Government of riparian states managing LVB need to encourage regional interventions and incorporation, policies, strategies, laws, and other agreements into national legislation (Nakiyemba et al, 2013). The unsustainable land use practices such as deforestation, overgrazing, application of agricultural chemicals and uncontrolled urbanization negatively affect water resources and natural drainage systems within the basin (Mongi et al., 2015; Odongtoo et al., 2018). The end results are poor water quality, land degradation and increasing incidence of floods (Nsubuga et al., 2014; Devi et al., 2018). Good policies are necessary since they provide for implementation of laws and regulation governing sustainable use of water resources (Megdal et al., 2017). Water resource policies encompass the policy-making processes that affect the collection, preparation, use and disposal of waste (Afroz et al., 2014; Griffin, 2016). African Development Bank (ADB) (2000) reported that fourteen African countries were already experiencing water stress and water scarcity, and that, the above figure is expected to increase to twenty-five by year 2025 due to high population growth rate.

Poor management of water resources causes contamination of surface and ground water resources which in turn lead to a rise in the incidence of water-borne diseases, land degradation, floods, soil erosion, degradation of ecosystems, and loss of biodiversity (Linuma and Tenge, 2017). This situation is expected to worsen with rapid population growth, urbanization and growing water scarcity in LVB if nothing is done about it (Gichuki et al., 2012). National policies are of fundamental importance as they provide a framework for legislation, strategic planning and operational management (Bakibinge et al., 2011). They provide institutional mechanism for mitigation of such disasters when they occur (Nsubuga, et al., 2014).

According to Nsubuga, et al., (2014), the Uganda National Water Policy was adopted in 1999 and set the stage for water resources management to guide development efforts aimed at improving water supply and sanitation; furthermore, to promote a new integrated approach to water management that guides the allocation of water and associated investments. However, the policies tend to focus on standard policy solution such as liberalization and pricing of water services only. Nsubuga et al. (2014) added that the overall objective of the Uganda's water policy is to manage and develop the water resources in an integrated and sustainable manner, so as to secure and provide water of an adequate quantity and quality. In addition, the policies acknowledge the need for cooperation on trans-boundary water resources management and its decentralization (Bakibinge et al., 2011).

Environmental policies for East Africa deal with management of environment, prevention of illegal trade and movement of toxic chemical substances. For the case of LVB, the challenge is to ensure uniformity of application of this protocol in line with existing national and by-laws in each riparian states (Bakibinge et al., 2011).

According to Nakiyemba et al. (2013), farmers in Uganda are highly dependent on wetlands for their livelihoods and it becomes difficult to realize the expected benefits of policies on wetlands. Furthermore, some policy failures include lack of institutional capacity, poor cooperation and coordination, lack of political support and communication. These had facilitated continuous encroachment on wetland. Linuma and Tenge (2017) reported that people living around LVB were not aware of the formal institutions involved in water resources management. Above authors argued that since the indigenous people have little awareness of policies and legislation concerning water resources, it had accelerated conflicts between formal and informal systems. The objective of this study was to apply PLS-SEM to evaluate the factors affecting development of effective water resource management policies for an integrated water resource management (IWRM) of LVB. PLS-SEM contained a two-step procedure that involved the evaluation of the outer measurement model and evaluation of the inner structural model (Henseler et al., 2009; Shahid et al., 2018).

METHODOLOGY

Brief description of the study area

LVB is a Trans-boundary ecosystem shared among Uganda, Kenya, Tanzania, Rwanda and Burundi. It is situated on the latitudes 50 30"N and 120S and longitude 41050"E and 280 45"E (Mongi et al., 2015). The basin is well endowed with natural resources such as mineral, water, forest, land for agricultural and industrial purposes, human habitat, wildlife and fishery (Odongtoo et al, 2019).

The study was done in the districts of Buikwe, Jinja, Wakiso, Mukono and Kampala. The reason for choosing the above districts was based on that fact that; they heavily depend on LVB for their survival, the areas have water resource management challenges and there were key stakeholders willing to contribute to research

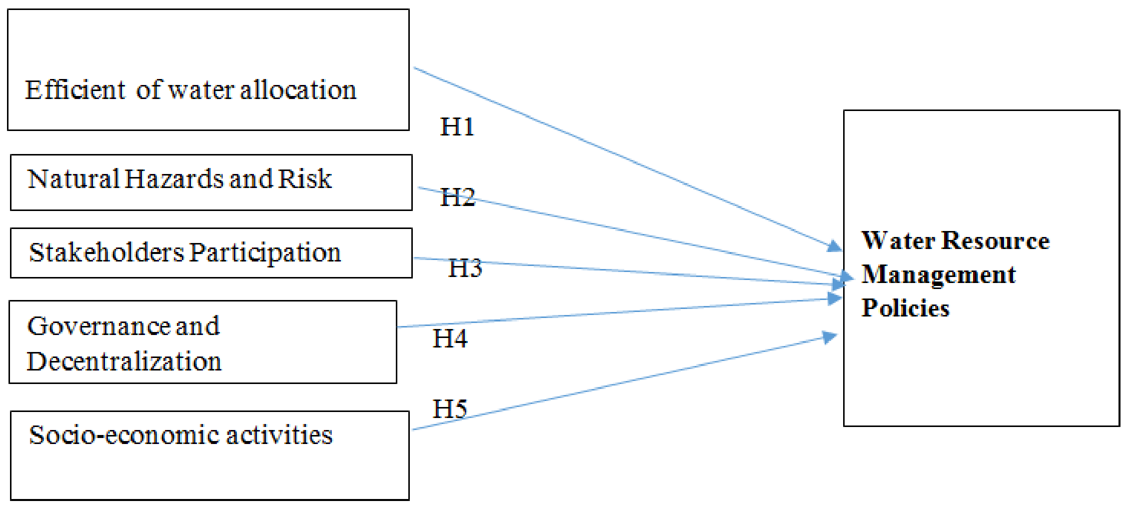

Figure 1. Hypothesized conceptual model.

works. Key stakeholders that were engaged in this study included employees from Lake Victoria Basin Commission, Lake Victoria Fishery Organization, Uganda Forest Authority, National Environment Authority, Ministry of Water and Environment, National and Regional policy making and communication organs and key community leaders.

Method of data collection

The data collection procedures involved three important steps as shown in Figure 2 which was adapted from Shahid et al. (2018). First: Preliminary variables were obtained through literature review to develop the hypotheses. Second: Pilot study was done to gain a better insight and completeness of the questionnaire tool. Third: A survey was conducted to obtain the perception of the respondents.Sample size was computed using Slovin's formulae:

$$n = \frac{N}{1 + Ne^2}$$

where n is the sample size, N is the population size and e is the error margin (Tejada and Punzalan, 2012). Sample size of 152 respondents was computed from a population size of 245 persons, a degree of confidence of 95% and error margin of 5%.

The questionnaire that was used to test the hypothesis consists of two sections. Section one consist of the respondents' personal information and section two was categorized into five groups in accordance with the nature of the factors. The questionnaires were self-administered to different stakeholders having experience of more than 5 years in water sectors including executives, managers, water engineers and IT officers. The data collection process took four months. The summary of the hypothesis are as shown in the conceptual model in Figure 1 which was adapted from Shahid et al. (2018). Hypothesis 1 (H1): Efficiency of water allocation factor has a significant and positive effect on water resource management policies. Hypothesis 2 (H2): Natural hazard and risk factor has a significant and positive effect on water resource management policies. Hypothesis 3 (H3): Stakeholders' participation factor has a significant and positive effect on water resource management policies. Hypothesis 4 (H4): Governance and decentralization factor has a significant and positive effect on water resource management policies. Hypothesis 5 (H5): Socio-economic activities factor has a significant and positive effect on water resource management policies (Figure 2).

Data analysis

The analysis of hypothesized structural model in figure 1 was done using Smart-Partial Least Square version 3. Smart-PLS has advantages over other regression-based methods because of the following reasons; First: it has a good capability of evaluating several latent constructs with various manifest variables. Second: It has a capability to evaluate the constructs when the sample size is small. Third: It has the ability to deal with highly complex models and categorical variables (Hair et al, 2011). Smart-PLS is commonly applied in regression models, covariance models, correlation model, path analysis and confirmatory factor analysis (Shahid et al., 2018). In this study, the sample size was 152 and therefore justifies the use of Smart-PLS.

RESULTS AND DISCUSSION

Demographic information of the respondents

The demographic information is as shown in Table 1. 61.8% were males and 38.2% were females. The highest percentage (34.9%) is the middle age group (30-39 years). 20-29 years were 31.6%; 40-49 years were 23.7%. Those aged 50 years and above were 9.9%. In Figure 5, the highest percentage (44.7%) of the respondents has Master's Degree, followed by those who have Bachelor's degree (44.1%), Diploma (8.6%) and PhD (2.6%) (Figures 3 and 4).

In Figure 6, the highest category of workers (65.8%) were staff/employee followed by mangers/administrators (21.7%), system administrators (5.3%) and ICT Technician (6.6%). Age, sex, qualifications and

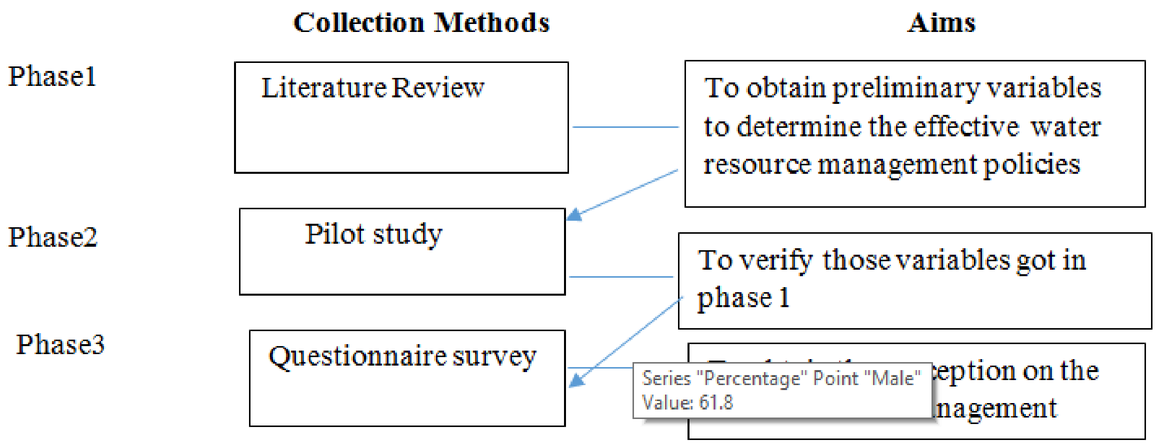

Figure 2. Data collection process.

Table 1. Demographic information.

Variable	Count	Valid percent	Cumulative percent
Gender distribution			
Female	58	38.2	38.2
Male	94	61.8	100
Total	152	100	
Age group distribution			
20 - 29 yrs	48	31.6	31.6
30 - 39 yrs	53	34.9	66.4
40 - 49 yrs	36	23.7	90.1
50 - 59 yrs	14	9.2	99.3
Above 59 yrs	1	0.7	100
Total	152	100	
Academic qualification			
PhD	4	2.6	2.6
Masters	68	44.7	47.4
Bachelors	67	44.1	91.4
Diploma	13	8.6	100
Total	152	100	
Designation of the respondents			
Manager/ Administrator	33	21.7	21.7
Staff/ Employee	100	65.8	87.5
Systems Administrator	8	5.3	92.8
ICT Technician	10	6.6	99.3
Client/ Customer	1	0.7	100
Total	152	100	

Source: Field data.

designation are important in understanding opportunities offered and constraints. It has a significant effect on the perception of a person in terms of information (Mongi et al., 2015). The highest percentage of the age group was

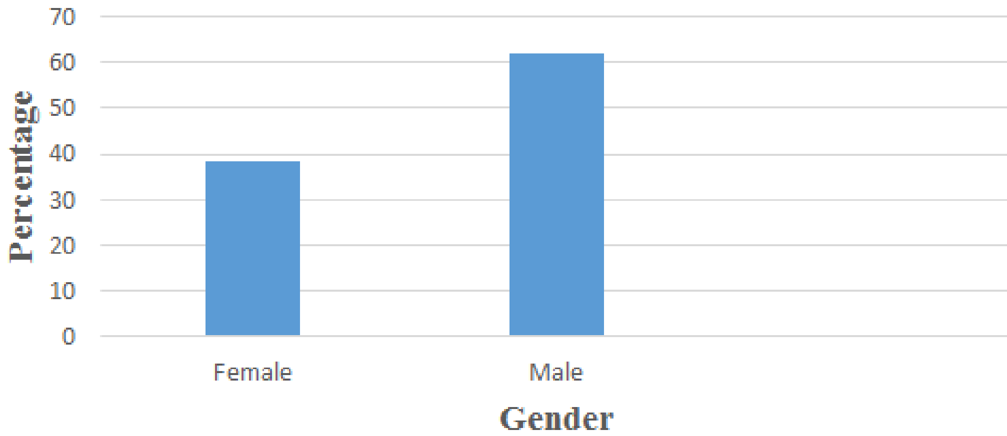

Figure 3. Gender distribution.

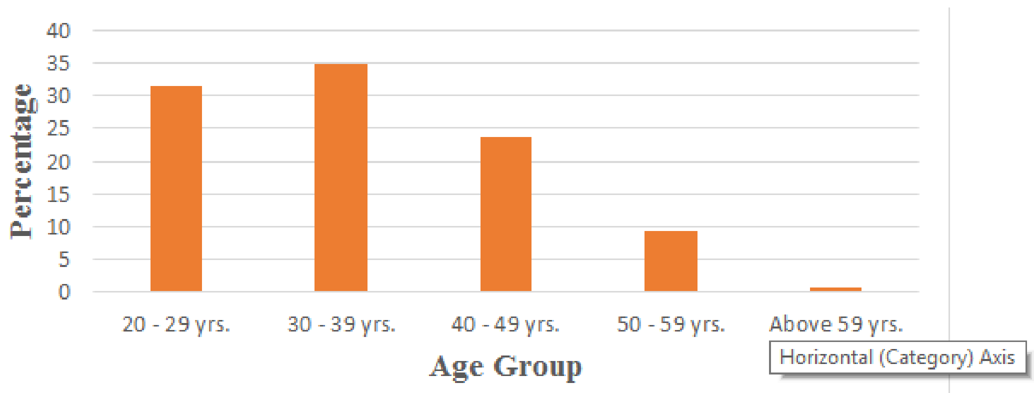

Figure 4. Age group distribution.

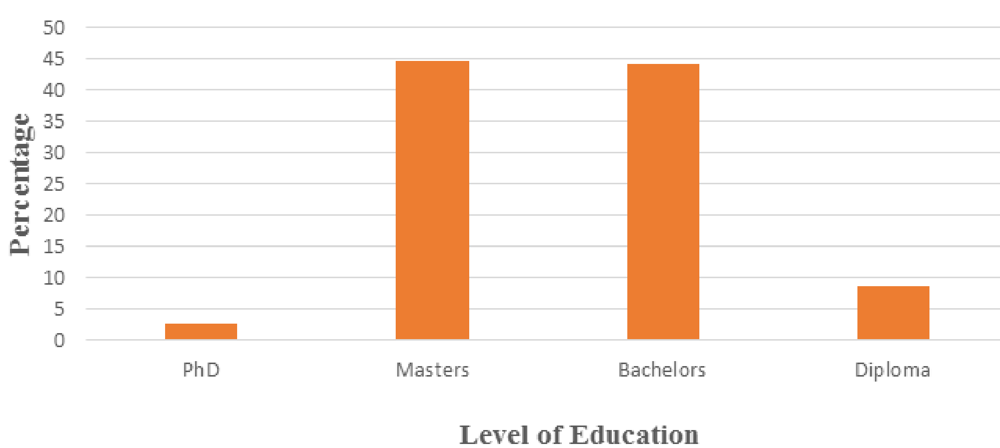

Figure 5. Academic qualification.

the middle group (30-39) years. These are the most active group in water resource management. They can even form social group and association to help manage water resources. Older people tend to have more

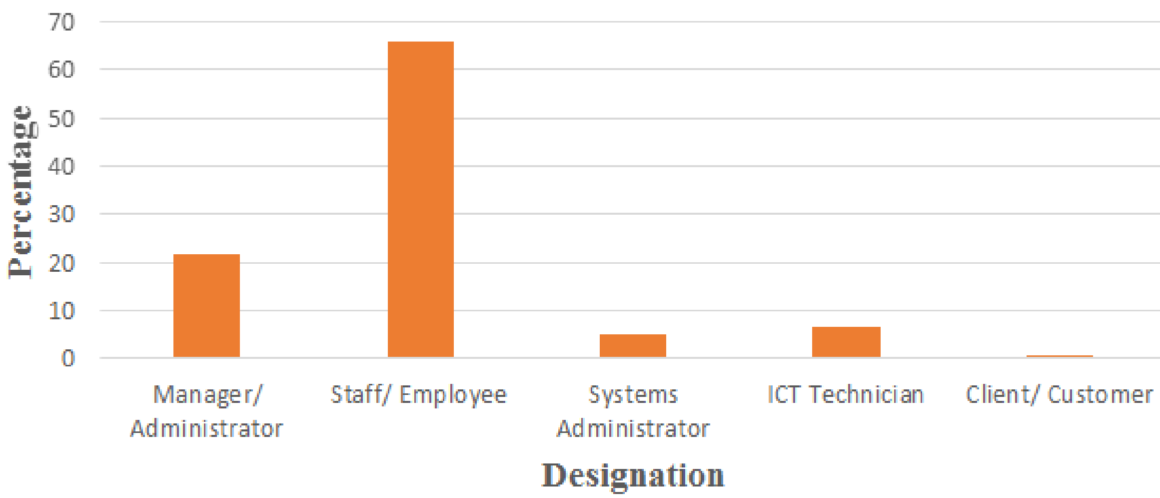

Figure 6. Designation of the respondents.

while highly educated people display more in-depth knowledge on the subject matter. Low level of education has an impact on the use and adoption of technologies. Designation relates more to the skills surrounding the management of water resources.

Evaluation of outer measurement model

Outer loading

To evaluate the factors affecting the development of effective water resource management policies, PLS-SEM was used because it employs a good procedure to determine an association and causal relationship between variables. It computes the path coefficient to assess the validity of the constructs (Hair et al., 2013). PLS-SEM employs a robust bootstrapping technique that computes the significance value of the path coefficient (Shahid et al., 2018). The hypothesized model was analyzed in two different stages; First: it comprised a measurement model that defined the relationship between latent indicators and their manifest variables. Second: a structural model comprising the relationship between the latent variables. A total of 20 latent indicators got through review of literature were named as the observed variables and put into five groups. The five groups were called exogenous latent constructs. The conceptual model presenting the relationship between the five exogenous latent constructs and endogenous latent construct is as shown in Figure 1.

In order to calculate the reliability, internal consistency, and validity of the observed variables, outer loading was used (Gabriel et al., 2016). Consistency evaluations were based on a single observed and construct reliability tests. Convergent and discriminant validity were used for the assessment of validity. Observed variables with an outer loading of 0.7 or greater are greatly acceptable, while the outer loading with a value less than 0.7 is unacceptable and should be dismissed (Shahid et al., 2018). From Table 2, the outer loadings ranged between 0.813 and 0.901and therefore acceptable. Composite Reliability (CR) was used for internal consistency evaluation in the construct reliability. Composite reliability values of 0.6 to 0.7 are acceptable in exploratory research while in more advanced stages of research, 0.7 to 0.9 can be regarded as satisfactory (Nunnally and Bernstein, 1994).

Average variance (AVE)

The lowest 50% of the average variance from the observed variable should be taken by the latent constructs in the model (Hair et al., 2011). From Table 2, all AVE values were more than 0.5, so convergent validity was confirmed for this study model. These results confirmed the convergent validity and good internal consistency of the measurement model. Table 3 shows the Fornell and Larcker criterion test of the model where the squared correlations were compared with the correlations from other latent constructs. It shows that all the correlations were smaller relative to the squared root of average variance exerted along the diagonals satisfying discriminant validity of the model. Table 3 shows that the cross-loading of all observed variables were more than inter-correlations of the construct of all other observed variables in the model. Therefore, these findings confirmed the cross-loadings assessment standards and provided acceptable validation for discriminant validity of the measurement model.

Estimation of path coefficients (b) and p-values (p)

In Table 4, the path coefficients in the PLS and the

Table 2. Construct reliability and validity.

Latent variable	Item	Outer loading	T-statistics	CR	AVE
Natural hazards and risks	NHR1	0.901	44.676	0.849	0.738
	NHR2	0.815	14.197		
Governance and decentralization	GD2	0.893	38.126	0.890	0.802
	GD3	0.898	34.393		
Socio-economic activities	SA1	0.813	13.143	0.810	0.681
	SA4	0.838	23.167		

Table 3. Discriminant validity - for water resource management policies.

Variable	Governance and decentralization	Natural hazards and risks	Socio-economic activities
Governance and decentralization	0.896		
Natural hazards and risks	0.392	0.859	
Socio-economic activities	0.385	0.605	0.825

Table 4. Path coefficient.

Hypothesized path	Standardized beta	P-values
Natural Hazards and risks	0.325	0.000
Governance and decentralization	0.453	0.000
Socio-economic activities	0.255	0.000

standardized *beta (b)* coefficient in the regression analysis were computed. Through the *b* values, the significance of the hypothesis was tested. The *b* denoted the expected variation in the dependent construct for a unit variation in the independent construct(s) as shown below. The *b* values of every path in the hypothesized model were computed; the greater the *b* value, the more the substantial effect on the endogenous latent construct. However, the *b* value had to be verified for its significance level through the p- test which is supposed to be less than 0.05 (Kay, 2013).

In (H_2), we predicted that the natural hazards and risk factor would significantly and positively influence water resource management policies. As predicted, the findings in Table 4 and Figure 7 confirmed that natural hazard and risk factor significantly influenced water resource management policies (*b* = 0.325, p < 0.00). Hence, H_2 was supported. Furthermore, when observing the direct and positive influence of governance and decentralization related factor on effective water resource management policy, the findings from Table 4 and Figure 7 endorsed that the governance and decentralization related factor positively influenced water resource management policy (*b* = 0.453, p < 0.000) showing that (H4) was robustly confirmed. Also the influence of socio economic related factor on water resource management policy was positive and significant (*b* = 0.255, p < 0.000), showing that (H5) was greatly supported. The greater the beta coefficient (*b*), the stronger the effect of an exogenous latent construct on the endogenous latent construct. Table 4 and Figure 7 showed that governance and decentralization related factor had the greatest path coefficient (*b* = 0.453, p< 0.000) when compared to other *b* values in the model. This shows that it has a greater value and therefore exerts a greater influence on water resource management policy. The rest of the hypothesis failed the statistical test hence, were discarded.

Coefficient of determinant R^2

As shown in Figure 3, the R2 = 0.68. The R2 measures the total quantity of the effect which the exogenous latent constructs has on the endogenous latent construct. It is also a measure of the model's predictive accuracy. In this study, the inner path model was scored at 0.68. This means that the three independent constructs substantially explain 68% of the variance in water resource management policies. According to Henseler et al. (2009) and Hair et al. (2011), R2 values of 0.75 and

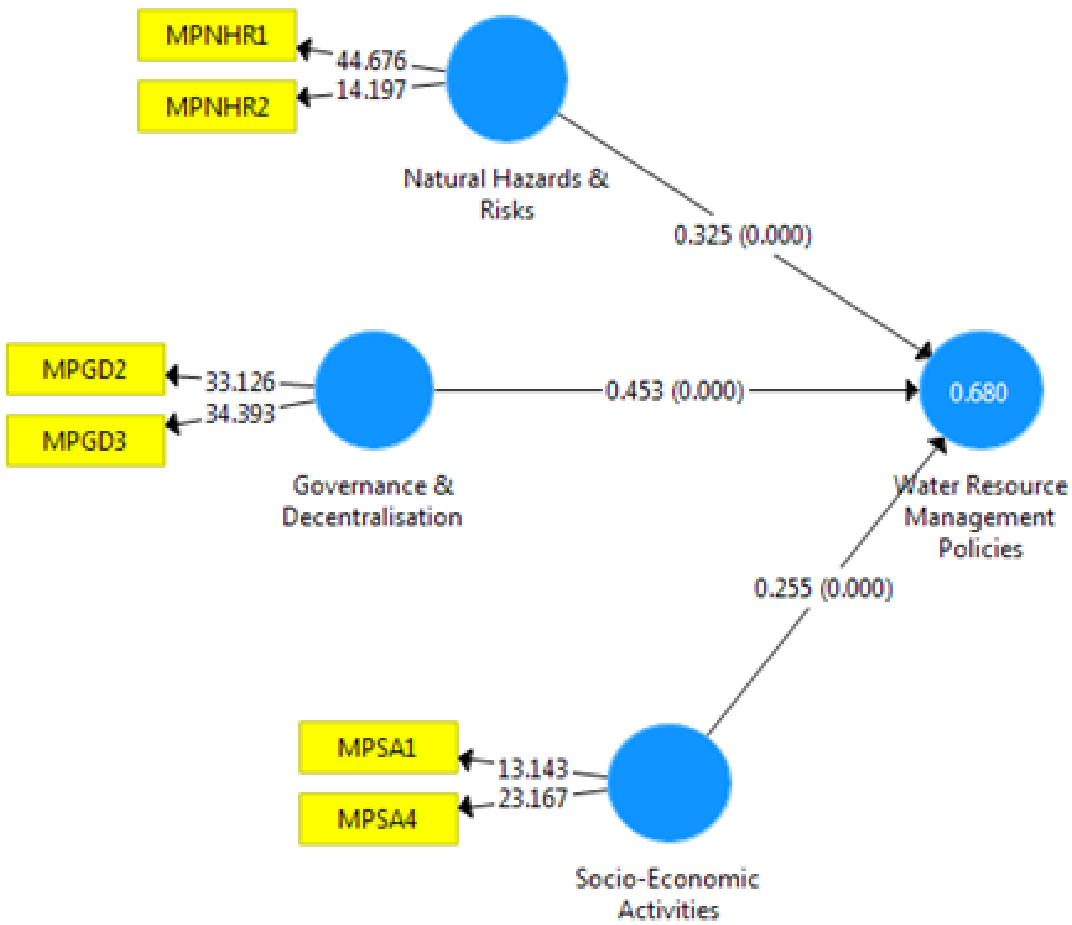

Figure 7. Shows the graphical representation of all path coefficients of the model.

above are considered substantial, while R2 value of 0.50 to 0.75 is regarded as moderate, 0.26-0.50 is acceptable and R2 values of 0.26 and below are considered as weak. Hence, in this study, the R2 value was moderate.

Business benefit

In accordance with the complete analysis of the study, some of the hypotheses as shown in Table 4 were statistically significant and hence were accepted while others failed the analysis and were rejected. These results give accurate information of the factors affecting development of effective water resource management policies. This result can support building a set of strategies to overcome challenges in the management of water resources in LVB. It is therefore important to consider natural hazards and risks, governance and decentralization, and socio-economic factors when developing effective water resource management policies for an integrated water resource management of Lake Victoria Basin.

Limitation and constraints of the study

Lake Victoria Basin covers many countries including Uganda, Kenya, Tanzania, Rwanda and Burundi. For this study it was not possible to visit all the countries of the East African Community (EAC) due to logistical constraints. However, this will be the case in future when the current logistical constraints are solved. There were some research participants who never wanted to either be interviewed or fill the questionnaire after knowing that the research is about the activities they were involved in around the Lake. This took the researchers a lot of time to identify willing participants to take part in the study.

Conclusion

The key contribution of this study was to empirically identify the factors affecting the development of effective water resource management policies using the PLS-SEM technique. It was also to examine the fundamental issues affecting constructs observed by water resource management experts in LVB. The results of the study revealed that natural hazards and risks, governance and decentralization, and socio-economic activities had a significant and positive effect on the effective water resource management policies. The overall results revealed that governance and decentralization had the highest path coefficient (beta= 0.453, p=0.000) which means it had the greatest influence on water resource management policies. Furthermore, the study discovered that there were weaknesses in the enforcement of policies and also little awareness of the policies. This could be so, because of lack of reliable communication strategies which can help stakeholders share and coordinate information on management of water resources. Therefore, water resource managers should pay more attention to governance and decentralization related factors during the development of polices in water resource management. The findings of this study show that not all suggested hypotheses were supported; those that did not pass the test were discarded.

Recommendation

The study recommends that managers of LVB pay more attention to factors related to natural hazards and risks, Governance and Decentralization, and Socio-economic activities for a development of effective water resource management policies with special attention on governance and decentralization. The study further recommends that all stakeholders engaged in LVB be involved in the development of policies. Also more awareness creation on policies managing LVB needs to be done by all respective riparian states of East African Community (EAC) to their citizen.

Lesson learned and further studies

The study revealed that some people living around LVB were not aware of the formal institutions involved in water resources management. That it may be due to less perception of the communities towards these institutions as part of the entity in the management of water resources. Furthermore, the study revealed that indigenous people have little awareness of policies and legislation concerning water resources which had accelerated conflicts between formal and informal systems.

Areas for further studies may include analyzing the relationship between factors for development of effective water resource management policies and effective decision making for an integrated water resource management of Lake Victoria Basin.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

Many thanks to all institutions and key informants involved in the studies for cooperating with the authors in providing the reliable information needed for this study. Special thanks to Makerere University and Busitema University for financial support during data collection.

REFERENCES

African Development Bank (ADB) (2000). Integrated Water Resources Management Policy.

Afroz R, Masud MM, Akhtar R, Duasa J (2014). Water Pollution: Challenges and Future Direction for Water Resource Management Policies in Malaysia. Environment and Urbanization ASIA 5(1):63-81.

Bakibinge-ibembe DJ, Said AV, Mungai WN (2011). Environmental laws and policies related to periodic flooding and sedimentation in the Lake Victoria Basin of East. Africa. African Journal of Environmental Science and Technology 5(5): 367-380.

Dauglas WJ, Hongtao W, Fengting L (2014). Impacts of population growth and economic development on water quality of a lake: case study of Lake Victoria Kenya water. Environmental Science and Pollution Research-Springer-Verlag Berlin Heidelberg 21:5737–5746.

Devi SP, Jothi S, Devi1 A (2018). Data Mining Case Study for Water Quality Prediction using R Tool. International Journal of Scientific Research in Computer Science, Engineering and Information Technology 3(1):262-269.

Gabriel CC, Christian MR, Jörg H, José L (2016). Prediction-oriented modeling in business research by means of PLS path-modeling. Business Research 69:10.

Gichuki J, Omondi R, Boera P, OKurut T, Matano A, Jembe T, Ofulla A (2012). WaterHyacinth Eichhorniacrassipes (Mart.) Solms-Laubach Dynamics and Succession in the Nyanza Gulf of Lake Victoria (East Africa): Implications for Water Quality and Biodiversity Conservation. The Scientific World Journal 2012.

Griffin R (2016). Water Resource Economics: Analysis of scarcity policies, and projects. MIT Press.

Hair FJ, Ringle MC, Sarstedt M (2013). Partial Least Square Structural Equation Modelling: Rigorous Application, better results and higher acceptance. Elsevier 46:1-12.

Hair JF, Ringle C, Sarstedt M (2011). PLS-SEM: Indeed a Silver Bullet. Marketing Theory and Practice 19:139-151.

Henseler J, Ringle C, Sinkovics R (2009). The Use of Partial Least Squares Path Modeling in International Marketing. Advance in International Marketing 20:277-319.

Kay WKK (2013). Partial Least Squares Structural Equation Modeling (PLS-SEM) Techniques Using SmartPLS. Marketing Bulletin 24:1-32.

Linuma OF, Tenge AJ (2017). Challenges of Formal Institutions in Water Resources Management in the Lake Victoria Basin. International Journal of Modern Social Sciences 6(1):34-50.

Megdal SB, Eden S, Shamir E (2017). Water Governance, Stakeholder Engagement, and Sustainable Water Resources Management 9:190.

Mongi HJ, Mvuma AN, Kucel S, Tenge AJ, Gabriel M (2015). Accessibility and utilization of mobile phones for governance of water resources in the Lake Victoria Basin: Constraints and opportunities in Tanzania. African Journal of Environmental Science and Technology 9(5):438-450.

Nakiyemba WA, Isabirye M, Poesen J, Maertens M, Deckers J, Mathijs E (2013). Decentralised Governance of Wetland Resources in the Lake Victoria Basin of Uganda. Natural Resources 4:55-64.

Nsubuga NWF, Namutebi NE, Nsubuga-Ssenfuma M (2014). Water Resources of Uganda: An Assessment and Review. Journal of Water Resource and Protection 6(14):18.

Nunnally JC, Bernstein I (1994). The Assessment of Reliability. Psychometric Theory 3:248-292.

Odongtoo G, Lating PO, Ssebuggwawo D (2018). A Mobile Application Tool To Mitigate Communication Challenges in Water Resource Management of Lake Victoria Basin: Water resources and wetlands, 4th International Conference Water resources and wetlands, 5-9

September 2018, Tulcea (Romania). p. 312.
Odongtoo G, Ssebugwawo D, Okidi LP (2018). Factors Affecting Communication and Information Sharing for Water Resource Management in Lake Victoria. In: Handbook of Climate Change and Biodiversity, p. 211.
Odongtoo G, Okidi LP, Ssebuggwawo D (2019). An integrated Solution for an Integrated Water Resource Management of Lake Victoria Basin. Annals of Valahia University of Targoviste. Geographical Series 19(1):11-21.
Okurut T (2010). Integrated Environmental Protection Approaches: Strengthening the role of Water Supply Operators in Resource Conservation", 15th International African Water Congress and Exhibition Commonwealth Resort, Munyonyo, Kampala, Uganda
.
Shahid H, Fangwei Z, Ahmed FS. Ali Z, Muhammad SS (2018). Structural Equation Model for Evaluating Factors Affecting Quality of Social Infrastructure Projects. Open Access Journal of Sustainability 1415:10.
Tejada JJ, Punzalan JR (2012). On the Misuse of Slovin's Formula. The Philippine Statistician 61(1):129-136.

Related Journals: