District Water Conservancy contrivance an approach for Water resource Management in lessening Water Scarcity and Floods in Rwanda-East Africa

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Abstract-

Water is vital for human health, industry, agriculture and ensuring the integrity and sustainability of the ecosystem. The water resources are the top affected by climate variability hence causing floods and droughts, the rapid population growth also increases water demand and affects water allocation systems as well as water resource management plans to suit the basic water needs for both human and nature hence causes the scarcity of water. Rwanda is among the countries that experiences and is expecting to continue undergoing such situation if nothing is done for skirmishing the existing conditions. Counting on water problems, inadequate capacity of water supply systems for Rwanda, we are suggesting this approach for sustainable water resources access employ and management in Rwanda and the involvement of systems for capturing water such as reservoirs, Dams, Concrete underground tanks would be precisely measures for dealing with Rwandan water problems and we are advocating for the adoption of the suggested approach.

Basing on Meteo norm 7 software, A 10-year flood protection level employed to determine the rate of urban damage, its effects on Gross Domestic Product (GDP) and the Population at risk. It is observed that Rwanda has more than 20% probability of inland flooding in any given year however a 10-year flood has a 10% probability of occurring in any given year and could cause roughly $6.1 million urban damage; $865.6 million affected GDP and 837.2 thousand affected population if there is no flood protection. Flood and drought events cannot be totally eradicated but their consequences can be tampered with the proposed approach in this paper as well as the inclusiveness of preparedness before its occurrence. Taking into account the population of Rwanda which is approximately 13 million heading to about 25 million in 2050 and be under the changing climate where since 1970 temperature rose by 1.4°C and is foreseen that in 2050 to be about 2.5°C it confirms a predictive severe effects on water resources in Rwanda for the next couple of years.

Keywords: climate change, population growth, water resource, water scarcity status in Rwanda.

INTRODUCTION

Water is important for human health, agriculture, industry and in ensuring the integrity and sustainability of the ecosystem. Most parts of the world are facing water scarcity due to different reasons, and this could be due to physical shortages (Physical water scarcity), institutional failures or lack of adequate infrastructures to ensure regular supply even in places where water is abundant (economic water scarcity) and lack of lessening and adaptation capabilities **[1, 2].** The world population significantly grew after the industrial revolution from 3.7 billion in 1970 to 6.08 billion in 2000 heading to about 9.7 and 11.2 billion by 2050 and 2100 respectively **[3].** Over the last centuries water use has grown at more than twice the rate of population increases globally and it is still increasing in all sectors. The effect of climate change will intensify the risks of droughts as well. Over 2billion people live in countries experiencing high water stress by today and the scale is expected to keep on increasing. Thus, balancing the available water and its growing needs mainly driven by population growth and the changing climate creates a big challenge to the governments and its subordinating institutions for water resources management**[4].** Hence alternatives for supplementing the existing planning needs to be altered and adopting them. Like any other countries, Rwanda's water resources are basic to many sectors including power generation, agriculture and fishery. However, water resources are the top affected by climate variability and population growth **[2, 5, 6].** The discernible and potential effect of climate change on water resources in Rwanda includes flooding, landslides, and change in the periodic droughts **[7, 8].**

Rwandan Water Resources Overview

Description of the study area

Rwanda occupies a surface of 26,338 km ^{2} on the eastern shoulder of the Kivu-Tanganyika Rift in Africa. It lies between 1°4' and 2°51' south latitude and 28°53' and 30°53' east longitude**[9].** Rwanda has two rainy seasons the first begins from March to May and the last begin from October to November with an average rainfall of 110-200 mm per month. The first and short dry season starts from December to the end of February while the longer one lasts from June to early September. Rwanda's average temperature ranges between 19 to 27°C **[10-12].** Rwanda is made up of five administrative subdivisions locally known as provinces (Northern, Southern, Eastern and Western Province + Kigali City being the capital); each province is further subdivided into five to eight districts (Figure1). Rwanda is relatively rich in water resources about **188,190 ha** are occupied by lakes (Table 1 and figure 1) approximately **7,260 ha** are for rivers, while wetlands seize an approximate area are **77,000 ha**. The surface water generally has a pH ranging between 6 and 8 **[13, 14].** This expresses that Rwanda has many water resources being lakes, rivers and marshlands. Nevertheless, rapid population growth, Climatic changes, inappropriate household and industrial wastewater management, insufficient measures for rainfall harvesting and monitoring that affects topography (steep slope) and facilitating the sediments and nutrients transport into Watersheds becomes water pollutants in Rwanda as well as water scarcity. All these phenomena have multiple implications on the quantity and quality of water like reducing the river flows and lake levels drying up of some water sources and undermining water biodiversity. Therefore, this expresses the problem of water quality and quantity in Rwanda and calls for appropriate adaptation measures. In this manner, the objectives of this Paper are to designate status and causes of water problems and suggesting appropriate approaches to undertake for sustainable water supply in Rwanda.

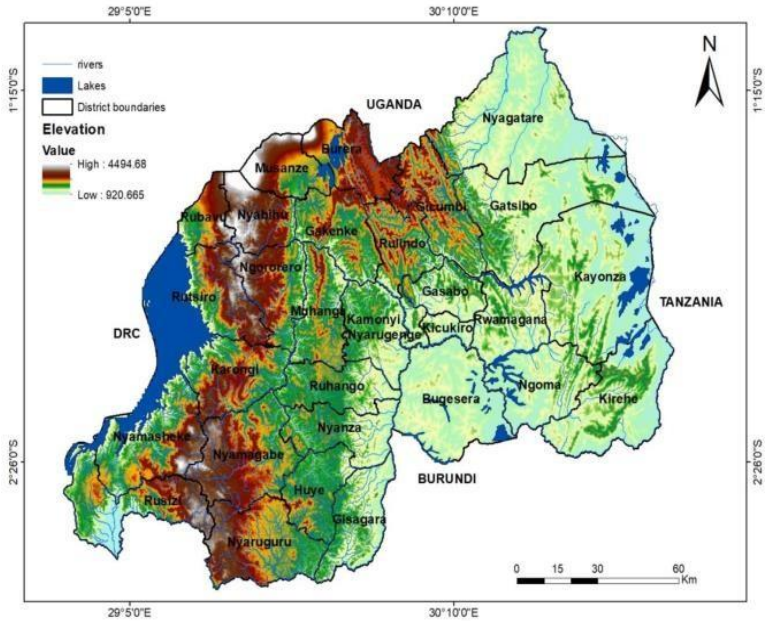

Figure 1:Water resources network of Rwanda

Table1: Rwandan Major Lakes and their corresponding characteristics **[15]**

Lakes	Surface area (Km^2)	Surface area in Rwanda ($Km^{2)}$	Mean elevation above the sea level (m)	Maximum Depth (m)	Minimum Depth (m)
Kivu	2700	1330	1460	480	220
Muhazi	34.6	34.6	1443	13.8	10.1
Burera and Ruhondo	28	28	1862	3.9	2.1
Cyohoha, South	630	100	1553	11	5.2
Mugesera	40	40	1300	3.8	2.2
Rweru	100	20	1160	2.1	3.9
Ihema	90	90	1292	7.0	5.0

Trends of water in Rwanda

Climate change and population growth is the most considerable factors that are affecting the ecosystems consequently, the impact of climate change on water is attributed to changing hydrology and air temperature **[16, 17].** The water quality in Rwanda is being exposed to several degrading and polluting forces being natural and man-made.

Water availability

The water availability in Rwanda, Table 2, is another issue. The National water resources management policy notes that the data on water consumption in Rwanda is scarce and incomplete **[18].** Most estimations of the current water use of any catchment are based on a number of assumptions: water availability and discharge from springs or boreholes, the production capacity of piped water supply systems; the water capacity of rainwater harvesting irrigation ponds and marshlands. the different yearly supply of irrigation from surface or groundwater resources for western and eastern areas and the different volumes of irrigation water expected from dam sites in eastern and western areas.

Table 2: Water statistics 2011-2013 **[19].**

	2012		2013	
Items	**Status**	**Potentials**	**Status**	**Potentials**
Surface water	101 lakes covering an area of 149.48ha, and 861 rivers of total length 6,462km	7-6 billion m^3/year	101 lakes covering an area of 149.48ha, and 861 rivers of total length 6,462km	6.826billion m^3/year
Ground Water		5-4.5billion m^3/year		4,554 billion m^3/year
Rain water		28-25 billion m^3/year		27,505 billion m^3/year
Water yield/person		1,135-193 m^3/person/year		670 m^3/person/year
Water storage/Person		7-5m^3/person/year		447m^3/person/year

Pressure and impacts

There are a number of challenges to water provision and threats include poor water resources management, population growth, urbanization, droughts and floods that will be increased by the climate change and the lack of water resources management skills. Industrial water users including coffee industries need 30 m^3 to produce one ton of a fully washed coffee, mineral processing, tanning and other industries are pressuring water resources in Rwanda. The tourism and increase in irrigation and other activities that involve water retention affect fish and aquatic biodiversity as well as water from human consumption [**19]**. Land use practices consider also threats to water resources in Rwanda, Wetlands in Rwanda are mainly threatened by reclamation and degradation especially those outside national parks. Human activities threatening wetlands in Rwanda include settlements and road construction drainage, unplanned conversion to agriculture, industrial pollution sewage and excessive harvest of products. A study on water quality conducted by the National University of Rwanda in 2002 confirmed that water quality is an issue in the country **[19].** Water resources have been subjected to a heavy pollution due to the untreated wastewaters (both domestic and industrial). Inadequate institutional operational framework contributes to the degradation of water resources **[19].** Climate change predictions show that with increasing rainfall variability, Rwanda will experience extreme weather patterns (flooding and droughts) **[20].** Rwanda is a densely populated country made up of hills and valleys and erosion is a problem. Flood and drought constitute the major part of natural disasters in Rwanda the north western is highly affected due to its topography high rainfall intensity and degradation of land cover. According to a report on natural disasters and hazards in Rwanda flood is the most occurred extreme event in Rwanda but third on the list after epidemics with regards to loss of lives however, drought is the second on the list with regards to loss of lives but third in terms of occurrence of natural disasters in Rwanda**[21].** About 237 people out of 4.16 million people have lost their lives from 1900 to 2015 because of drought events, however, about 183 people out of almost 82,000 people lost their lives from 1900 to 2015 due to flood events[**21]**. Six drought events have occurred in Rwanda because of long periods of dry season or delayed in rainy season: a long dry period from 1998-2000 and an annual drought from 2002-2005 resulting in 237 deaths and affecting almost 4.2 million people. During this period, the country's economy was affected especially in the agricultural sector due to food insecurity. This affected crop yield and reduced livestock production especially in the Eastern and Southeastern parts of Rwanda **[22].**Due to the prolonged drought in 2005, water-levels in Burela and Ruhondo lakes declined to result in a deficit in hydropower production leading to power crisis[**21]**. In May 2016, the BBC News reported that at least 53 people have been killed by landslides and floods caused by heavy rains in Rwanda, said by Government officials and most of the victims were believed to have been children**[23].** The worst hit areas were the districts of Gakenke and Muhanga. As many as 34 people died in Gakenke, 8 in Muhanga, 4 in Rubavu and 3 in Ngororero. Around 26 injuries also were reported. The Ministry of Disaster Management and Refugee Affairs (MIDIMAR) reported that over 500 houses were destroyed leaving thousands homeless**[24].** Future projections show that temperatures will increase to 2.70C and 40C in 2050 and 2080 respectively. Rainfall projections on the other hand show an increase of 20% by 2050 and 30% by 2080 which means that the increase in temperature and rainfall in Rwanda will result in more floods and droughts events in the future **[21].**

Table 3: Rwanda Water Stress Index

	2000 (P'ple)	2010 (P'ple)	2020 (P'ple)	2030 (P'ple)
Water Stress	1,745,800	1,988,098	2,724,863	0
Water Scarcity	1,221,727	3,991,852	2,373,304	6,204,669
Absolute Scarcity	1,631,416	2,150,409	4,387,060	5,325,795
% of people living in water scarce area	36%	58%	50%	70%
Total Population	7,956,772	10,546,509	13,477,414	16,396,486

Methodology

The methodology used to conduct this study is based on the comparable cases strategies. The comparative methodology focuses on rationale rather than statistical significance in nature **[25].** The extensive policy research is usually restricted to policy inputs and outputs. Secondary data was used through as preference of water resources management policies and the existing institutional operational frameworks in Rwanda and the existing infrastructures, after we suggest to apply for new measures as mentioned in the paper.

Results

Rwanda is a water scarce country. Water is the most valuable of the natural resources of the country. Due to the climatic changes, population and the economic growth development of Rwanda, the Government of Rwanda has put in place the institutional framework for the conservation, protection, and management of the country's water resources resulted in the formulation of the water and sanitation policy of 2004 revised in 2011 and became the National Policy for Water Resources Management and the Water Law No. 62/2008 to strengthen the water resources management sub-sector. Government of Rwanda together with its water and sanitation stakeholders has set priorities to achieve in terms of water supply in line with Economic Development and Poverty Reduction Strategy (EDPRS) by the government by 2012 and the Vision 2020 as an umbrella under which all the programs and policies are supposed to contribute to. Moreover, aligning programs with Millennium Development Goals (MDGs) was a prime goal which governments including Rwanda government have been striving to achieve. Government has been giving promises to overcome such persistent challenge of spreading water in Kigali. By implementing this strategy Rwanda government was expecting to achieve 85% water supply coverage by 2015. "We have a number of projects to address this shortage. One of the projects is Nzove II to add 25, 000 cubic metres. Work is expected to be completed by the end of November and it will be full productive by the end of December 2015," said WASAC Director General. Though there were promises to combat this challenge in Kigali city, still the water treatment plant capacity is not sufficient to cover the entire country. Being insufficient for the city means, its capability of supply the whole country is still low, that is why we have brought up with another proposed strategy that can support the existing one and that is **"District surface storage or District Water conservancy contrivance"**

Proposed approach for sustaining and alleviating water scarcity and floods in Rwanda.

For properly mitigating the scarcity of Water in Rwanda, adequate planning needs to be involved basing on the real basis life of citizens, proper measures and techniques needs to adopted and implemented as well. For this issue, we have proposed new system of constructing surface storages (dams, reservoirs) having the capacity to serve at least 5 neighboring districts when combined and introducing new system of rain harvesting which is construction of concrete underground Cisterns (UST). These tanks may serve as storage tanks for channeled floods and the stored water may be used for irrigation systems during drought seasons.

The construction of mini dams and reservoir in the districts as mentioned will serve as the supplement water supply to the insufficient existing supply systems with in the country where people in districts shall have full access on water with in their respective districts and it may also promote fishing, power generation, irrigation systems as well and control of floods. Whereas for mitigating floods cannels, Municipal storage centers (MSC) and national reservoir centers (NRC) should be constructed where the municipal storage centers (MSC) feeds into national reservoir center (NRC) and the waters for NRC may be used for different purposes.

Conclusions and Recommendations

Water quality and scarcity are widespread problems and its sustainable management is becoming a quite challenge. Even though a range of resolving suggestions have been provided such as provision of investment in water infrastructure maintenance, water reuse, recycle flotation, chemical precipitation, ion exchange and membrane filtration and coagulation-flocculation, the rapid human population growth, increase on point and non- point water pollution sources are threats to water quality. The government of Rwanda has launched the Integrated Water Resources Management, an approach of developing, monitoring and managing water resources. Nonetheless for the policy to be fruitful and sustainable there is a great need of managing the wastewater, the rapid expanding urbanization and informal settlements, industrial and mining activities. Therefore, the followings are suggested for the water quality management, Control of floods and total eradication of water scarcity in Rwanda.

Rapid population growth is increasingly leading to natural resources degradation we are advising to set a fixed number of children per family with penalties or tax incentives to those disregarding the policy.

Since Rwanda is rich in precipitation throughout the year it is good to consider maximum rain harvest this will increase the Underground storage and enables local communities to supply water to their infrastructure and reduces sediments carried into watershed.

Population growth requires sufficient food to do so irrigation is proposed to boost the agricultural production however it is good to first check on environmental pros and cons of every irrigation technique (sprinkler and flood irrigation drip irrigation) before use.

Rwanda as a developing country with high water demand, water reuse and desalination would help much, where industrial, saline water and household wastewater can be turned into usable water for other uses such as garden watering, carwash, toilet uses. This will be a good option and reduce the wastewater associated consequences.

It is suggested to promote environmental research and education from basic schools; hydrological data sharing and free access for water quality management enhancement.

Although the government prioritized Crop Intensification Program (CIP) with one crop at appropriate location, it would be good to initiate and promote break crop system, different crops at once this will enhance soil fertility and maintain soil at a level of not demanding high chemical fertilizers and reduces water pollution.

Even though environmental management is a cross Cutting issue at every decision-making level monitoring and evaluation of its execution and success basing on community's reality and national development plans is highly suggested.

We are advocating to the government for promoting district underground concrete tank systems in order for disseminating sufficient water supply program.

Urbanization is the key vital when it comes to allocation or distribution of water to the citizens. We recommend the government of Rwanda to manage the land use by owning the land and after leading the use of it according to the designed masterplans and allocating people in a modernized system.

REFERENCE

[1] D. Muhirwa, I. Nhapi, U. G. Wali, N. Banadda, J. Kashaigili, and R. Kimwaga, "Characterization of wastewater from an Abattoir in Rwanda and the impact on downstream water quality," *International Journal of Ecology & Development*, pp. 30-46, 2010.

[2] S. Piao, P. Ciais, Y. Huang, Z. Shen, S. Peng, J. Li, *et al.*, "The impacts of climate change on water resources and agriculture in China," *Nature*, vol. 467, pp. 43-51, 2010/09/01 2010.

[3] A. Richard, V. Philip, and B. Tom, "Civil War, Crop Failure, and Child Stunting in Rwanda."Economic Development and Cultural Change," vol. 59, pp. 777-810, 2011.

[4] R. K. Andrew and C. S. Catherine, "DETERMINANTS OF GROUNDWATER RETENTION IN WELLS: A CASE OF KEIYO NORTH DISTRICT, ELGEYO MARAKWET COUNTY, KENYA," *Journal of Water Security*, vol. 3, 2017.

[5] B. Kifle Arsiso, G. Mengistu Tsidu, G. H. Stoffberg, and T. Tadesse, "Climate change and population growth impacts on surface water supply and demand of Addis Ababa, Ethiopia," *Climate Risk Management*, vol. 18, pp. 21-33, 2017/01/01/ 2017.

[6] C. J. Vörösmarty, P. Green, J. Salisbury, and R. B. Lammers, "Global Water Resources: Vulnerability from Climate Change and Population Growth," *Science*, vol. 289, p. 284, 2000.

[7] K. C. Urama and N. Ozor, "IMPACTS OF CLIMATE CHANGE ON WATER RESOURCES IN AFRICA: the Role of Adaptation," 2010.

[8] H. Bizimana and S. Osman, "Landslide Occurrences in The Hilly Areas of Rwanda, Their Causes and Protection Measures," *Disaster Science and Engineering (DSE)*, vol. 58, pp. 1-7, 2015.

[9] K. Fidele, Z. Chi, N. Felix, N. Lamek, K. Alphonse, K. O. James, *et al.*, "The Need for Awareness of Drinking Water Loss Reduction for Sustainable Water Resource Management in Rwanda," *Journal of Geoscience and Environment Protection*, , vol. 4, pp. 74-87, 2016.

[10] O. P. Abimbola, J. Wenninger, R. Venneker, and A. R. Mittelstet, "The assessment of water resources in ungauged catchments in Rwanda," *Journal of Hydrology: Regional Studies*, vol. 13, pp. 274-289, 2017/10/01/ 2017.

[11] N. Lamek, L. Lanhai, K. Alphonse, K. Fidele, M. Christophe, N. Felix, *et al.*, "Agricultural impact on environment and counter measures in Rwanda," *African Journal of Agricultural Research*, vol. 11, pp. 2205-2212, 2016.

[12] N. Felix, G. Hao, B. Anming, G. Hui, K. Fidele, and K. Alphonse, "Understanding the Spatial Temporal Vegetation Dynamics in Rwanda, Remote Sensing," *MDPI*, vol. 8, 2016.

[13] N. H, M. F, and K. N. D, "Some physico-chemical characteristics of ground water in Rwanda," *Rwanda Journal*, vol. 25, 2012.

[14] E. Cavallo, S. Galiani, I. Noy, and J. Pantano, "Catastrophic Natural Disasters and Economic Growth," *The Review of Economics and Statistics*, vol. 95, pp. 1549-1561, 2013.

[15] I. L. E. C. (ILEC). (2018). *2018 WLDB Lake List in Republic of Rwanda [online (:http://wldb.ilec.or.jp/Search/LakeListCountryCode/RW. ed.)*.

[16] H. Nasim, J. Jacinda, and L. Karl-Erich, "Impacts of Climate Change on the Water Quality of a Regulated Prairie River," *MDPI*, vol. 9, p. 199, 2017.

[17] W.-C. Liu, "Assessment of Climate Change

Impacts on Water Quality in a Tidal Estuarine System Using a Three-Dimensional Model," *Water*, vol. v. 8, p. 2016 v.8 no.2, 2016-02-17 2016.

[18] MINIRENA. (2011, National Policy for Water Resources Management. *National Policy for Water Resources Management*

[19] REMA, "State of the environment and outlook report, Kigali:," ed. Rwanda, 2015.

[20] V. d. Meene, S. Joy, and R. R. Brown, "Towards an institutional capacity assessment framework for sustainable urban water management," *Rainwater and Urban Design Conference 2007.*, pp. 1 - 8, 2007.

[21] S. Asumadu-Sarkodie, P. Rufangura, H. M. Jayaweera, and P. A. Owusu, "Situational Analysis of Flood and Drought in Rwanda," *International Journal of Scientific & Engineering Research*, vol. 6, pp. 960-970, 2015.

[22] REMA, "Climate Change and Natural Disasters, Kigali:," ed. Rwanda: REMA, 2013.

[23] BBC, "BBC AFRICA," in *BBC ONLINE*, http://www.bbc.com/news/world-africa-36248334 ed, 2016.

[24] D. Richard, "Rwanda – at Least 49 Killed in Floods and Landslides, 500 Homes Destroyed," in *Flood list,Reporting floods and flooding news since 2008*, ed, 2016.

[25] F. Eugenia, M. Mita, and D. A. L. Quagliarotti. (2002). *The role of formal and informal institutions in the The role of formal and informal institutions in the water sector water sector water sector*