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# REVIEW ARTICLE

# WATER QUALITY, QUANTITY AND ACCESSIBILITY ASSESSMENT: VOLCANOES NATIONAL PARK REGION EXPERIENCE IN RWANDA

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**ABSTRACT**

This study 'Water Quality, quantity and accessibility Assessment: Volcanoes national park region experience in Rwanda' established the ways in which water is used, the level of demand, the level of supply, water quality, water quantity and accessibility around Volcanoes nation park of Rwanda. It has been hypothesised that there is a very high demand for water, lower lever of access due to population pressure and limited water sources. A total of 329 household were randomly selected in region around volcanoes national park of Rwanda, and were interviewed through well-structured interviewing schedule under multistage sampling technique. According to the sampled area the average size of private households in region sampled was 4.2 persons, not far from of Fourth Rwanda Population and Housing Census 4.3 persons (NISR, 2012), as result shown 60.8 % of respondents revealed to use 1 to 3 jerricans of water per day, and 1 jerrican is equal to 20 litres, means that the average water consumption per capita in region around volcanoes national park is estimated between 4.7 and 12.3 litres per day which is below minimum as required by WHO, In terms of accessibility as determined primarily by distance and time, 21.58 % of respondents fetch water in distance which is more than 1000 meters and is defined as no access by WHO, and 38.91% of respondents take more than 30 minutes to collect water, in terms of water quality for drinking, cooking, washing and bathing, 71.2 % of the respondents perceived water to be clean and fairly clean in region around volcanoes national park. Thus, it was suggested that provision of safe drinking water to common people must be ensured mostly in region around volcanoes national park, since this region has not attained minimum requirements in terms of water quality and quantity consumption as required by WHO, and that for successful implementation of water programs in region, it is important that community members get fully involved in all processes of the program.

## INTRODUCTION

Water is body's principal chemical component and makes up about 60 percent of body weight. Water is essential for life, health and human dignity. In extreme emergency situations, there may not be sufficient water available to meet basic needs and in these cases, supplying a minimum level of safe drinking-water for survival is of critical importance. According to WHO[1] lactating women who engage in moderate physical activity in above-average temperatures, a minimum of 7.5 litres per capita per day will meet the requirements of most people under most conditions. This water needs to be of a quality that represents a tolerable level of risk. However, in an emergency situation, a minimum of 15 litres is required. A higher quantity of about 20 litres per capita per day should be assured to take care of basic hygiene needs and basic food hygiene.

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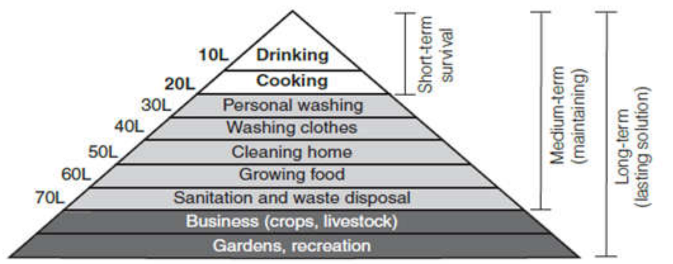
[1] WHO, what is the minimum quantity of water needed? http://www.who.int/water_sanitation_health/emergencies/qa/emergencies_qa5/en/

Laundry/bathing might require higher amounts unless carried out at source. Domestic water supplies are one of the fundamental requirements for human life. Without water, life cannot be sustained beyond a few days and the lack of access to adequate water supplies leads to the spread of disease. Children bear the greatest health burden associated with poor water and sanitation. Diarrhoeal diseases attributed to poor water supply, sanitation and hygiene account for 1.73 million deaths each year and contribute over 54 million Disability Adjusted Life Years, a total equivalent to 3.7% of the global burden of disease (WHO, 2002)

Currently, Africa's seemingly abundant water resources are not being efficiently utilized. With 17 large rivers and more than 160 major lakes, African countries are only able to channel about 4.0 per cent of their annual renewable flows, compared with 70 – 90 percent in many developed countries. Yet water storage is essential to ensure reliable sources of water for irrigation, water supply and hydropower and to provide a buffer for flood management. With the exception of Oceania, Africa has the lowest water coverage in the world. In 2008, 60 percent of the African population had access to improved sources of drinking-water, an increase of 11 percentage points since 1990.This compares favourably with Oceania at 50 percent but dismal overall. (UN-HABITAT, 2011). The purpose of this paper was to conduct Water Quality, quantity and accessibility Assessment in region around Volcanoes national park of Rwanda, to review the evidence in terms of water quantity, quality and access and to provide a basis for the establishment of minimum quantity and/or access targets for domestic water supplies primary data were collected to serve the purpose. The paper draws on an extensive literature review based primarily on the published literature, a review was undertaken of available materials (papers, books, theses, conference proceedings) at WEDC and WHO resource centres.

**Review Literature**

According to WHO (July 2013), People use water for a wide variety of activities. Some of these are more important than others. Having a few litres of water to drink each day, for example, is more important than having water for personal hygiene or laundry, but people will still want and need to wash for the prevention of skin diseases and meeting other physiological needs. Other uses of water have health and other benefits but decrease in urgency as Figure 1.1 demonstrates Hierarchy of water requirements (after Maslow's hierarchy of needs).




(*Source*: adopted from WHO, Technical Notes on Drinking-Water, Sanitation and Hygiene in emergencies. http://www.who.int/water_sanitation_health/publications/2011/WHO_TN_09_How_much_water_is_needed.pdf?ua=1)

People do not always have predictable needs. In some cultures, the need to wash sanitary towels or to wash hands and feet before prayer may be perceived to be more important than other water uses. Talk to people to understand their priorities. People may also have quite specific needs concerning the use of water for anal cleansing. Women and men may have different priorities. Women may be concerned about basic household water requirements and water to wash during menstruation, whilst men may have concerns about livestock. In the assessment, waste spillage and leaks also need to be taken into consideration. The Sphere Standards suggest a basic survival-level water requirement to use as a starting point for calculating demand (see Table 1.2). However, research indicates that 20 litres per capita per day is the minimum quantity of safe water required to realise minimum essential levels for health and hygiene. The basic need for water includes water used for personal hygiene, but defining a minimum has limited significance as the volume of water used by households depends on accessibility as determined primarily by distance and time, but also including reliability and potentially cost. Accessibility can be categorised in terms of service level (see Table 1.3).

## MATERIALS AND METHODS

Williams & Grinnell (1990) stated that methodology means the philosophy of research process. It includes assumptions and values that serve as rational research and the standard criteria the researcher uses for interpreting data and reaching conclusion. The approach used in this study follows a descriptive research design. The qualitative and quantitative approaches were employed based on basic information obtained from an assessment of questionnaires distributed and collected between June 2015 and December 2015 in region steeper of Volcanoes national Park. The quantitative technique was used to collect and analyse data on water quantity, water quality and health and other relevant information according to the purpose of the study.

**Table 1. 2. Drinking water, sanitation and hygiene in emergencies**

| Type of Need | Quantity | Comments |
|---|---|---|
| Survival (drinking and food) | 2.5 to 3 lpd | Depends on climate and individual Physiology |
| Basic hygiene practices | 2 to 6 lpd | Depends on social and cultural norms |
| Basic cooking needs | 3 to 6 lpd | Depends on food type, social and cultural norms |
| Total | 7.5 to 15 lpd | Lpd: litres per day |

**Table 1.3. Accessibility in terms of service level**

| Service level | Access measure | Needs met | Level of health concern |
|---|---|---|---|
| No access (quantity collected often below 5 l/c//d) | More than 1000m or 30 minutes total collection time | Consumption-cannot be assured<br>Hygiene-not possible (unless practised at source) | Very high |
| Basic access (average quantity unlikely to exceed 20 l/c/d) | Between 100m and 1000m or 5 to 30 minutes total collection time | Consumption-should be assured<br>Hygiene-handwashing and basic food,<br>Hygiene possible; laundry/bathing difficult to assure unless carried out at source | High |
| Intermediate access average quantity about 50 l/c/d) | Water delivered through one tap on plot (or within 100m or 5 minutes total collection time) | Consumption-assured<br>Hygiene-all basic personal and food<br>Hygiene assured: laundry and bathing Should also be assured | Low |
| Optimal access (average quantity 100 l/c/d and above) | Water supplied through multiple taps continuously | Consumption -all needs met<br>Hygiene-all needs should be met | Very low |

(*Source*: adopted from WHO, study conducted by Guy Howard, Programme Manager, Water Engineering and Development Centre, Loughborough University, UK and Jamie Bartram Co-ordinator, Water, Sanitation and Health Programme, World Health Organization, Geneva, Switzerland, http://www.who.int/water_sanitation_health/diseases/WSH03.02.pdf)

## Population, Sample Size Calculation and Sampling procedure

### Population

Rwanda is a landlocked country in central Africa covering 26 338 $Km^2$. It shares its borders with Uganda in the north, the Democratic Republic of Congo in the west, Burundi in the south and Tanzania in the east. In 1993 protected areas covered 15% of the total land, but this area has reduced tremendously due to settling and resettling displaced people in the Parks and forests. The PNV (1°21'-1° 35' South, 29°22'-29°44' East) is situated in the North of Rwanda bordering Democratic Republic of Congo (DRC) and Uganda and covers medium and high altitudes towards the south of Virunga Chain ((Plumptre, 1989); The study area is made of the four districts containing the Parc National des Volcans, namely: Rubavu and Nyabihu (in Western Province) and Musanze and Burera (in Northern Province). Each of the districts is further subdivided into Sectors and Cells. The 11 sectors surrounding the PNV are Bugeshi in Rubavu District; Kabatwa, Bigogwe and Jenda in Nyabihu District; Gataraga, Shingiro, Kinigi and Nyange in Musanze District and Gahunga, Rugarama and Cyanika in Burera District. Those sectors are subdivided into 60 cells.

### Sample Size Calculation

The total sample size of this research was calculated using the simplified formula of Yamen (1967:886)

$$n = \frac{N}{1 + N(e)^2} \qquad \ldots\ldots\ldots\ldots (3.1)$$

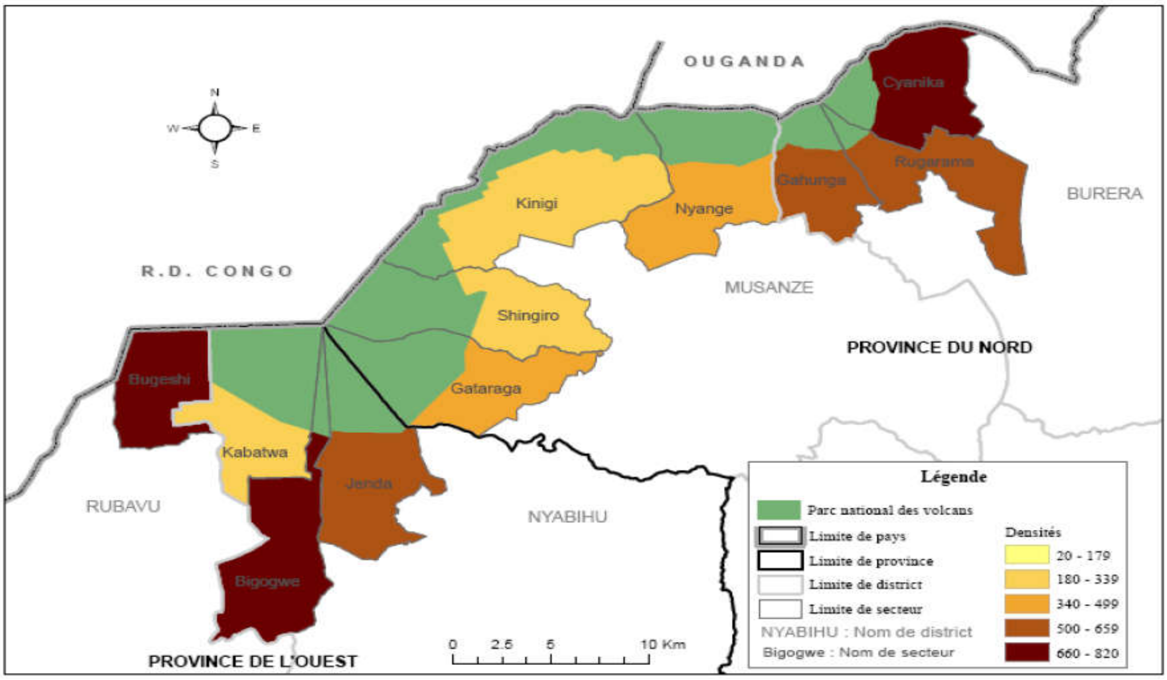
Hence the total sample size of this research is

$$n = \frac{65794}{1 + 65794(0.055)^2} = 328.9 = 329 \qquad \ldots\ldots\ldots\ldots (3.2)$$

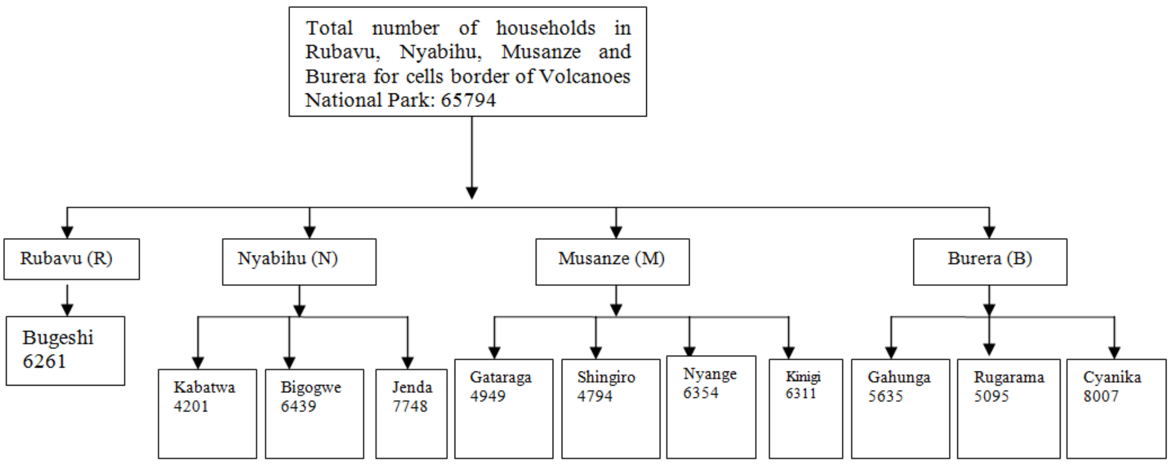
Sudman (1976) suggests that a minimum of 100 elements is needed for each major group or subgroup in the sample and for each minor subgroup, a sample of 20 to 50 elements is necessary. Similarly, Kish (1965) says that 30 to 200 elements are sufficient when the attribute is present 20 to 80 percent of the time (i.e., the distribution approaches normality).

### Allocation of sample over strata

Given a total sample size, "n=329", this n must be allocated among the strata in this case villages, villages to cells, then cells to Districts and proportionate stratification was used, In




(*Source*: adopted from a study by RWANYIZIRI in 2009)



proportionate stratification, an uniform sampling fraction is applied to each strata; that is, the sample size selected from each stratum is made proportionate to the population size of the stratum.

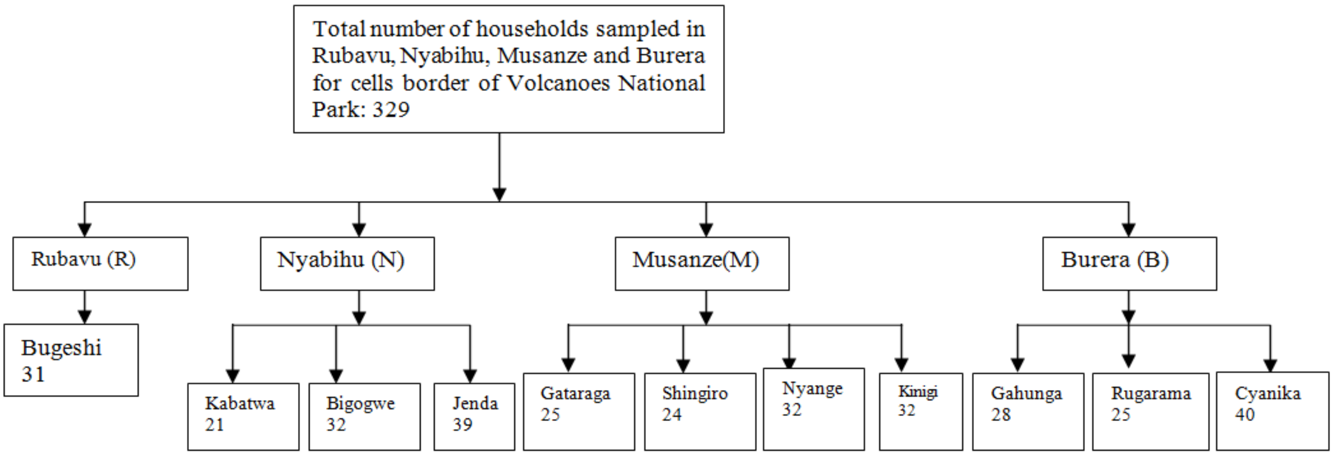
The number of households taken from the $_{nh}$ stratum is

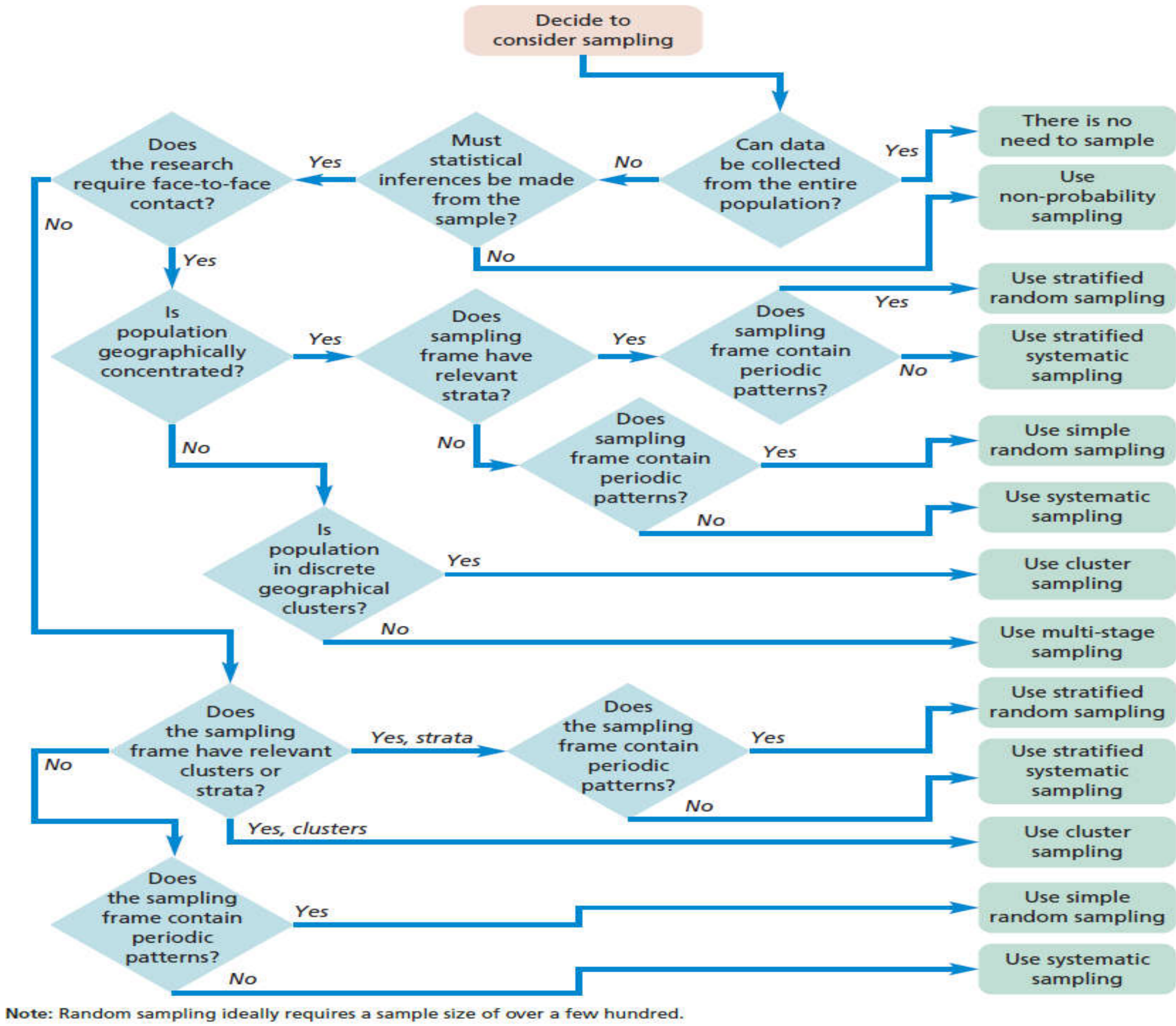
$$nh = (Nh)\frac{n}{N}$$

Where: $nh$ is sample size of each stratum, $Nh$ is size of population in stratum, $n$ is total sample size and $N$ is total population size

**Sampling procedure**

Researchers must be carefully to choose the target population from which they wish to collect data, and a sampling strategy




(*Source*: Mark Saunders, Philip Lewis, Adrian Thornhill,2009, 'Research methods for business students'.5th ed. Pearson Education Limited, Edinburgh Gate, Harlow, Essex CM20 2JE, England. (www.pearsoned.co.uk) PP. 223) to select a sample from that population (Anol Bhattacherjee, 2012, P. 22). So within Logical framework given by Mark.S *et al..*. above we have considered using sampling, and since data could not collected from the entire population and statistical inference had be made from sample, and to avoid a high rate non-response we conducted a face to face interview guided by questionnaire as Wiiliam J. ad Paul K. Hatt called Schedule[2] is the name usually given to a set of questions which are asked and filled in by an interviewer in a face to face situation with another person.

Given that the population was not concentrated geographically and that population was not in discrete geographical cluster this study adopted multi-stage stratified design In order to ensure a representative sample of districts near Volcanoes National Park, all eligible districts were stratified based on closeness to the Volcanoes national Park, The goal of the study was to sample 4 cells per district in the first stage of sampling, then 2 villages per sampled cell in the second stage, and households proportional to the population size per village in the third stage. According to Rajendra Nargundkar[3] , Multi-stage sampling is a combination of cluster sampling and stratified random sampling.

## DISCUSSION AND RESULTS

### Social-Demographic Profile of the Respondents around volcanoes national park of Rwanda

According to the sex of respondent, the majority were females with (69.0%) while males occupy (31.0 %). (Figure 4.1 Append.), Majority of the respondents were between 21-40 years who formed 51.4 % of respondents. It should be noted that the selection of the the respondents was non-biased but reflected the age of household heads in homesteads surrounding the Volcanoes national park of Rwanda. (Figure 4.2 Append.) Majority of the respondents (83.6%) were not very educated. 51.1% had attended only primary school and 32.5% had no formal education (Figure 4.3 Append.)

### Land use around volcanoes national park of Rwanda

The current agricultural practice is changing since introduction of comparative advantage in agriculture. Most people are now shifting from the traditional land use patterns that involved mixture of culture to the monoculture, however Majority of the respondents (46.50%) revealed that they still practice together livestock and cultivation on the same land, followed by woodlot, livestock and cultivation with 20.36% then on land where people practice cultivation only occupies 19.45 % (Figure 4.4 Append) Most of the arable farms that we were able to observe in the field do not have provisions to hold the soil from erosion. There was evidence of sheet and rill erosion as well as the deep gullies as a result of sediment run-off during the wet periods. Local residents revealed that when it rains, crops are washed away due to poor land use practices. This therefore means that poor agricultural practices are responsible for soil erosion on the steep slopes and flooding in the valleys.

[2] Wiiliam J. Goode and Paul K. Hatt: Methods in Social Research, McGraw Hill, Tokyo, 1952, P.133.

[3] Rajendra nargundkar,(2008), 'Marketing Research: Text and Cases'3rd Ed, McGraw Hill, New Delhi,P.104.

### Water Sources and Access around volcanoes national park of Rwanda

The sources where people fetch water were established in all the eleven cells surrounding volcano national park. During the period of the study, it had been established that people around volcanoes national park fetch water from both protected and unprotected water sources. The protected sources were found to be the main sources of water. Figure 4.5 append. Shows how communities ranked the importance of protected and unprotected sources where they collect water, 27.36% ranked protected spring as main source, followed by protected roof catchments with 24.92% then protected tab with 20.67%.

### Water Use, Demand and Supply around volcanoes national park of Rwanda

The study established the ways in which water is used, the level of demand and the level of supply in and around Volcanoes nation park of Rwanda. It has been hypothesised that there is a very high demand for water due to population pressure and limited water sources. The study found out that it is true. The cells round volcanoes national park are inhabited by many people averaging 415 people per square kilometre (RPHC4-NISR, 2012). When respondents were asked whether they have a constant water supply through the year, 39.21% answered in negative (Figure 4.6 Append). The major reason given was annual seasonality. It was found out that during rainy seasons, people have more than enough water especially from roof catchment. However, when it comes to the dry seasons, things change. People experience water scarcity and it becomes very difficult to access water. The amount of water local people use in their household chores was estimated. The selected water uses included domestic chores, livestock watering and arable farming. This was meant to collate the demand for water, get an on what the ideal its use and the level of supply, the main use of water in region is domestic use, in some families domestic use was associated with livestock, crop farming and pesticides use, except in some families due to water scarcity water was used only for domestic purpose with 20.67 %, while in families where domestic use was associated with livestock we had 44.07% followed by 21.58 for domestic use associated with crop farming then 13.68 for domestic use associated with pesticides (Figure 4.7 Append)

Figure 4.8 Append, indicates that majority of the respondents use one to three jerricans per day of water for all the three major household chores. Respondents attributed the use of little water to water scarcity and distance to water sources. Water use in the household is always highly regulated so that low volumes are used. Note that the differing water usage is due to seasonal effect. During the wet season, the usage of water for domestic purposes is quite high compared to the dry season when it is used sparingly, not also the number of respondents for not stated was quite high for water usage in case of livestock purpose and arable farming, means that in region surrounding volcano national park people don't use water for those latter purposes, a little water they get, they use for domestic purpose as stated by the majority (60.80%). Figure 4.9 reveal that, in terms of water quality for drinking, cooking, washing and bathing, majority of the respondents (71.2 %) perceive water to be clean and fairly clean. Few respondents perceive the water as dirty or very dirty for all the water use categories (drinking, cooking, washing and bathing). The perception of respondents on water quality was based on water colour, presence of substances and suspended particles and what they thought would happen to their health if they consumed the water. Circumstances affecting the quality of water included flooding and soil erosion as a result of heavy run-offs, and wild animals like buffaloes from the park. Clean water perception was attributed to the permanence of some water sources and use of rain and gravity flow water. Results show that places with permanent water sources and those that use mostly rainy water are likely to perceive the water to be clean or very clean whereas places with no permanent water regimes, steep terrains and high run-offs were likely to perceive water as dirty or very dirty. Figure 4.10 Append, depicts waterborne diseases in region, majority of respondents (45.29%) revealed to have amoebiasis, while only 34.95% have not affected by any of waterborne diseases, the remaining have affirmed also being affected by either diarrheal illness, typhoid and many others.

**Average Time and Distance travelled to Access Water Source**

We investigated the challenge of the distance walked by household members to access water sources. This was measured in terms of perceived time it takes for members of the household to fetch water for domestic, livestock and arable farming. However, much attention was given to water used for domestic chores. Figure 4.11 Append, shows the responses on approximate time to and from main source water in the region. The majority of respondents (29.48%) use approximately 5-15 minutes to arrive to the source of water, fetch water and return back home, we found out that for people fetching water in minutes less than 5 (15.2 %), they have their own tabs. While those using between 5 to 15 minutes they fetch water from neighbours within distance less than 200 meters from their home, 22.80 % use more than 30 minutes while 16.11 % takes them more than hour to bring water home, assume that in all cases they use less than one minute to fill up a jerrican (gallon of 20 litres). Figure 4.12 Append. , shows that majority of respondents(27.05 %) run between 10 to 200 meters to fetch water, then 21.58% walk more than a kilometre to fetch water while 20.06 % walk between 501 to 1000 meters.

**Physical parameters**

The general situation for water quality in terms of physical parameters is that most of sampled water sources were in normal range of quality for drinking water as recommended by standards. In terms of turbidity, the most sources were slightly in higher ranges compared to standards. The sampled rain water capturing tanks and temporary rivers were the ones with high levels of turbidity. Comparing wet and dry seasons, you find that water quality during wet season was better that dry season. Especially for non-treated water sources, like rain water harvesting, rivers and lakes. For pH, the general view is that the water was slightly acidic. For conductivity, the level was high in certain sources and in normal range for others. (Table 1.1 Append.)

**The chemical parameters**

The chemical parameters of water sources in the sampled area were analysed and compared with the standard. The parameters in ranges above standards are underlined see Table 1.2 Append. In general, the quality of water in region is better. In parameters analysed, aluminium content proved to be very low. The quality of water in terms of chemical parameters is influenced by the type of source. The hardness for example is high for water sources from rain water harvesting and unprotected water sources. It is also influenced by the level of calcium and magnesium. High level of these elements is not very dangerous to the consumers but they are a problem since they influence water hardness. Concerning nitrates and phosphates, the level was in normal ranges. (Table 1.2 Append.)

**Conclusion**

It is important to note that, communities around volcanoes national park of Rwanda are vulnerable in terms of water quality and quantity. However, this defers from cell to cell and village to village. The current agricultural practice is changing since introduction of comparative advantage in agriculture. Most people are now shifting from the traditional land use patterns that involved mixture of culture to the monoculture. However, 46.50% still practice together livestock and cultivation on the same land, while people practice cultivation only occupies 19.45 %. In terms of water quality for drinking, cooking, washing and bathing, 71.2 % of the respondents perceive water to be clean and fairly clean in region around volcanoes national park. But remember that their perceptions depend on water colour, presence of substances and suspended particles.

The general situation for water quality in terms of physical parameters, In terms of turbidity, the most sources were slightly in higher ranges compared to standards. For pH, the general view is that the water was slightly acidic. For conductivity, the level was different for each source of water but most water sources in normal range. The quality of water in terms of chemical parameters is influenced by the type of source. It is also influenced by the level of calcium and magnesium. The both latter also influence water hardness. Concerning nitrates and phosphates, the level was in normal ranges. According to the sampled area the average size of private households in region sampled was 4.2 persons, not far from of Fourth Rwanda Population and Housing Census 4.3 persons (NISR, 2012), as result shown 60.8 % of respondents revealed to use 1 to 3 jerricans of water per day, and 1 jerrican is equal to 20 litres, means that the average water consumption per capita in region around volcanoes national park is estimated between 4.7 and 12.3 litres per day which is below minimum as required by WHO.

In terms of accessibility as determined primarily by distance and time, 21.58 % of respondents fetch water in distance which is more than 1000 meters and is defined as no access by WHO, and 38.91% of respondents take more than 30 minutes to collect water. Thus, it was suggested that provision of safe drinking water to common people must be ensured mostly in region around volcanoes national park, since this region has not attained minimum requirements in terms of water quality and quantity consumption as required by WHO, and that for successful implementation of water programs in region, it is important that community members get fully involved in all processes of the program. The community, particularly community leaders and decision-makers should understand the benefits of the sought programs but not only acting as receivers.

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**Appendix**

**Figure 4.1.**

| Sex of respondent | | | | | |
|---|---|---|---|---|---|
| | | Frequency | Percent | Valid Percent | Cumulative Percent |
| Valid | female | 227 | 69.0 | 69.0 | 69.0 |
| | male | 102 | 31.0 | 31.0 | 100.0 |
| | Total | 329 | 100.0 | 100.0 | |

**Figure 4.2.**

| Age of respondent | | | | | |
|---|---|---|---|---|---|
| | | Frequency | Percent | Valid Percent | Cumulative Percent |
| Valid | <20 | 20 | 6.1 | 6.1 | 6.1 |
| | >60 | 38 | 11.6 | 11.6 | 17.6 |
| | 21-40 | 178 | 54.1 | 54.1 | 71.7 |
| | 41-60 | 91 | 27.7 | 27.7 | 99.4 |
| | not stated | 2 | .6 | .6 | 100.0 |
| | Total | 329 | 100.0 | 100.0 | |

**Figure 4.3.**

| Education of respondent | | | | | |
|---|---|---|---|---|---|
| | | Frequency | Percent | Valid Percent | Cumulative Percent |
| Valid | No formal education | 107 | 32.5 | 32.5 | 32.5 |
| | Not stated | 4 | 1.2 | 1.2 | 33.7 |
| | Primary school | 168 | 51.1 | 51.1 | 84.8 |
| | Secondary school | 41 | 12.5 | 12.5 | 97.3 |
| | Technical school | 4 | 1.2 | 1.2 | 98.5 |
| | University degree | 5 | 1.5 | 1.5 | 100.0 |
| | Total | 329 | 100.0 | 100.0 | |

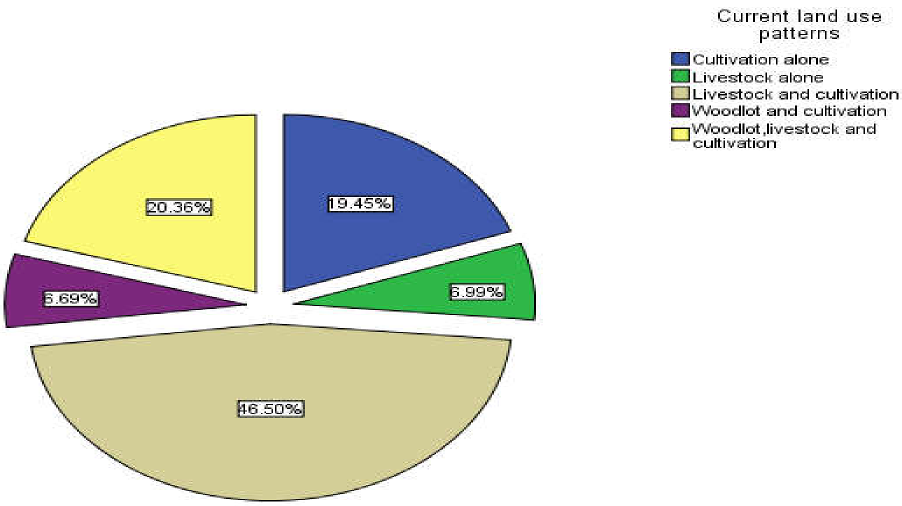


**Figure 4.4.**

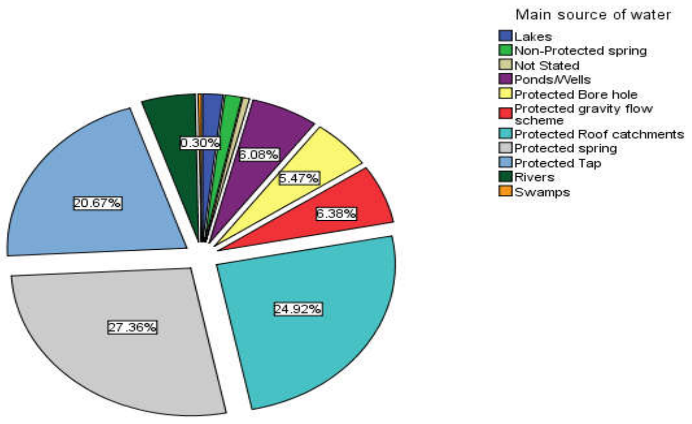


**Figure 4.5.**

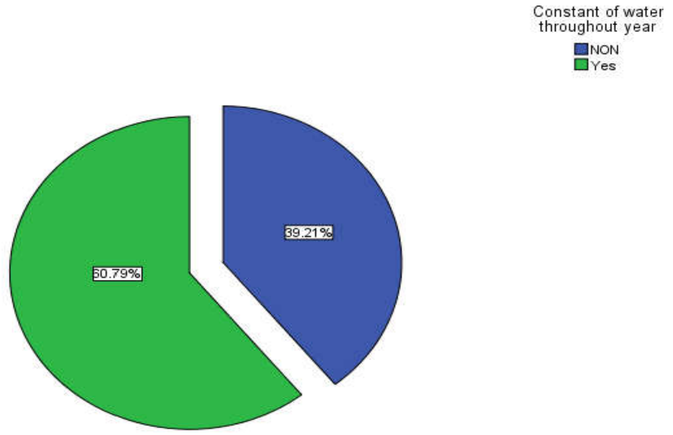


**Figure 4.6.**

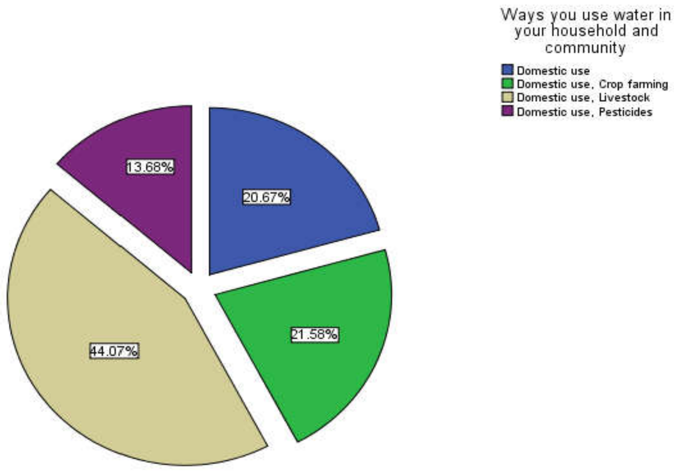


**Figure 4. 7.**

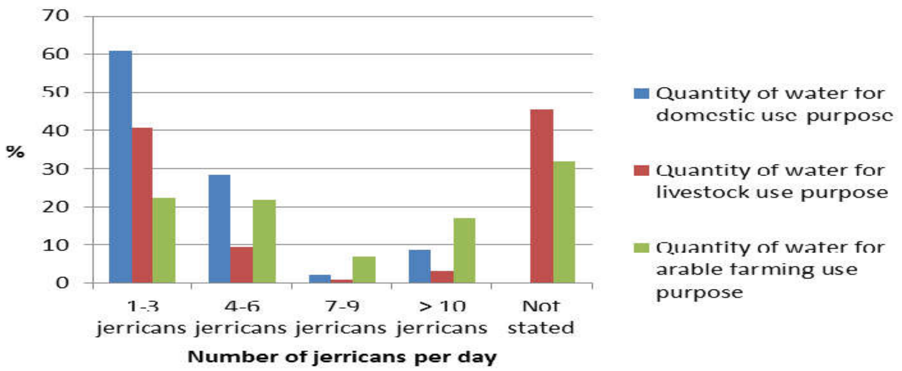


**Figure 4.8.**

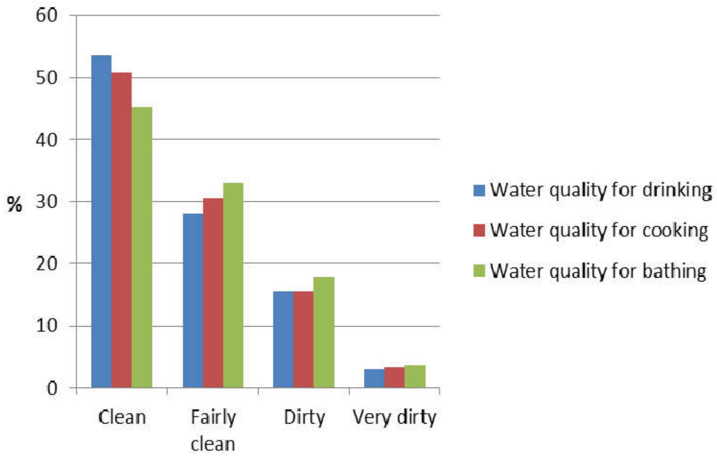


Figure 4.9.

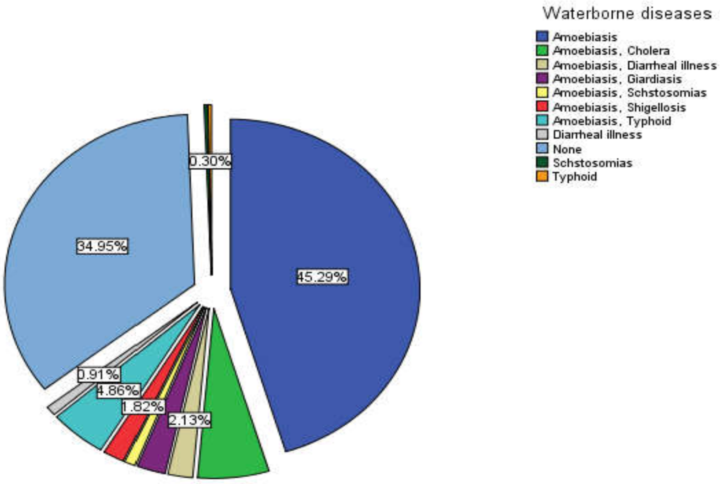


Figure 4. 10.

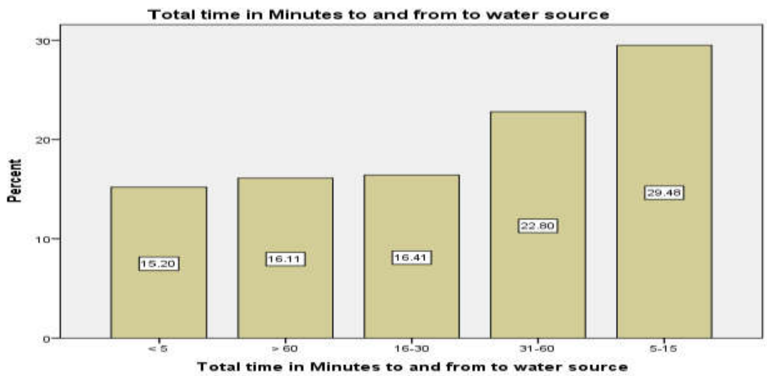


Figure 4.11.

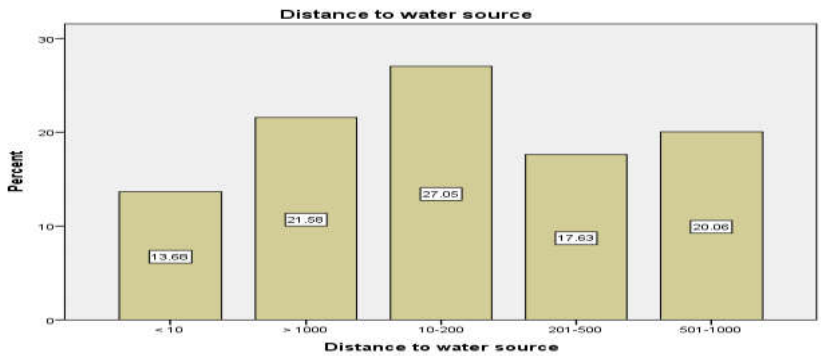


Figure 4.12.

**Table 1.1.**

| no | Water source | Turb. (NTU) Dry season | Turb.(NTU) Wet season | PH Dry season | PH Wet season | Cond. µS/cm Dry season | Cond. µS/cm Wet season |
|---|---|---|---|---|---|---|---|
| 1 | Cyamvumba -Kabatwa | 15.6 | 7.80 | 5.10 | 5.30 | 1500 | 800 |
| 2 | Batikoti -Kabatwa | 5.50 | 5.50 | 8.90 | 8.40 | 1580 | 1480 |
| 3 | Nyirakigugu -Jenda | 9.10 | 4.10 | 6.00 | 6.30 | 1570 | 570 |
| 4 | Kareba -Jenda | 13 | 8.00 | 6.10 | 6.40 | 1580 | 430 |
| 5 | Basumba -Bigogwe | 20.90 | 12.4 | 5.30 | 5.70 | 1570 | 670 |
| 6 | Arusha -Bigogwe | 4.10 | 3.1 | 6.00 | 6.20 | 1570 | 830 |
| 7 | Rubindi-Gataraga | 4.39 | 4.39 | 6.90 | 6.90 | 896 | 501 |
| 8 | Mutobo-Gataraga | 3.49 | 3.49 | 7.30 | 7.00 | 670 | 540 |
| 9 | Nyakigina-Kinigi | 15.24 | 15.24 | 6.40 | 6.40 | 546 | 130 |
| 10 | Butorwa-Kinigi | 0.65 | 0.65 | 8.00 | 8.00 | 70 | 61 |
| 11 | Upstream Lake Burera-Burera | 5.43 | 2.65 | 6.10 | 6.10 | 678 | 590 |
| 12 | Downstream Lake Burera-Burera | 4.63 | 0.43 | 6.30 | 6.20 | 960 | 580 |

**Table 1.2**

| No | Water source | *TDS mg/l* | T. H. mg/l | Al3+ g/l | Mg2+ mg/l | Ca2+ mg/l | NO3- mg/l | PO43- mg/l |
|---|---|---|---|---|---|---|---|---|
| 1 | Cyamvumba -Kabatwa | 480 | 510 | 0 | 101 | 220 | 8.26 | 0.50 |
| 2 | Batikoti -Kabatwa | 740 | 131 | 0 | 150 | 0 | 8,25 | 0,58 |
| 3 | Nyirakigugu -Jenda | 342 | 426 | 0 | 123 | 76 | 8,60 | 1,20 |
| 4 | Kareba -Jenda | 258 | 410 | 0,01 | 102 | 98 | 14,19 | 0,9o |
| 5 | Basumba -Bigogwe | 402 | 146 | 0 | 161 | 32 | 8,20 | 0,60 |
| 6 | Arusha -Bigogwe | 498 | 182 | 0 | 28 | 98 | 14,50 | 0,90 |
| 7 | Rubindi-Gataraga | 300,60 | 129 | 0 | 44,10 | 106 | 7,9 | 1,40 |
| 8 | Mutobo-Gataraga | 324 | 125 | 0 | 46,70 | 150 | 7,8 | 1,30 |
| 9 | Nyakigina-Kinigi | 78 | 0 | 0 | 2 | 0 | 0,50 | 0,06 |
| 10 | Butorwa-Kinigi | 36,50 | 12 | 0 | 40 | 1 | 0,88 | 1,10 |
| 11 | Upstream Lake Burera-Burera | 354 | 296 | 0 | 23,50 | 95 | 7,95 | 0,70 |
| 12 | Downstream Lake Burera-Burera | 348 | 145 | 0 | 92 | 147 | 8,58 | 0,50 |

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