REPUBLIC OF RWANDA

NORTHERN PROVINCE
GICUMBI DISTRICT

Water Resources Management Plan for the Water Sources and Mwange River Watershed in Gicumbi District

Prepared by

Best Associated Consultants

Financed by

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September 2018

Final Report

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Glossary

Access to safe water supply[1]:	Percentage of people with access to an improved source of drinking water within 500 meters in rural areas and 200 meters in urban areas. This access should be reliable, affordable, and provide an adequate quantity (minimum 20 L/person/day) within reasonable time. Improved water sources are piped water, protected wells and springs, as well as rainwater collection. Water quality is assumed to be acceptable for improved water sources but shall be tested for compliance with national and WHO standards for potable water.
Watershed area:	The entire geographical area drained by a river and its tributaries; an area characterized by all runoff being conveyed to the same outlet. Also called *watershed basin.* In order to determine the quantity of available water resources in Rwanda, the country was sub-divided into nine Watersheds of level one and twenty watersheds of level two. (See the 2015Rwanda National Water Resources Master Plan).
Sub-Watershed:	A sub-watershed is usually a smaller area of land draining to a single tributary of a larger river
Evapotranspiration:	Is the sum of evaporation from the surface, plus transpiration from plants. Evaporation accounts for the movement of water to the air from sources such as the soil, canopy interception, and waterbodies.
Spring:	A spring is a point where water flows out of the ground. A spring may flow the whole year or only sometimes.
Sustainable water supply:	This study will put out the capability of the current water sources in Gicumbi district vis a vis the water use that will be in the area in 25 years to come (i.e. from 2018 to 2043).
Watershed:	A watershed is an area of land that drains all the streams and

[1]MININFRA,2010. National Policy and Strategy for Water Supply and Sanitation Services

	rainfall to a common outlet such as the outflow of a reservoir, mouth of a bay, or any point along a stream channel. The word **watershed** is sometimes used interchangeably with drainage basin or **watershed**.
Water Demand:	Is a virtual quantity of water that is needed to satisfy some perceived need from a user, either for primary use (drinking water, household requirements, small garden, etc.), livestock or for commercial purposes.
Water for domestic and municipal use[2]:	Domestic and municipal water use is taken to include clean water supply to households and institutions (schools, health facilities, prisons, public offices) for drinking, cooking, hygiene and other purposes.
Water supply services:	The abstraction from a water resource, conveyance, treatment, storage and distribution of potable water, including all the organizational and sensitization arrangements necessary to ensure sustainable services and benefits. This includes domestic water supply (drinking water and other household uses) as well as the provision of water for economic activities through public piped networks.

[2]MINIRENA,2010.Water Resources Management Sub Sector Strategic Plan (2011–2015)

1. Introduction

1.1 Background of the project

Water For People (WFP), Gicumbi District and the Ministry of Infrastructure represented by The Water and Sanitation Corporation (WASAC ltd) have been working together to implement a water supply program known as "Gicumbi WASH Program" aiming at bringing the district to full access to safe drinking water and build institutions that will sustain water services[3]. A total of Ninety-Seven (97) water supply systems were identified in the district, some of them are functional, others need to be rehabilitated and new ones will be constructed in the coming years. The sustainability of water services relies heavily in a proper water resource management.

The District of Gicumbi lies between 1° 51' and 1° 23' South latitude and 29 ° 56' and 30°17'East longitude. Located in Northern Province, Gicumbi District has 828 km^2 with 395,606populations and 478persons/km^2 inhabitants. It is composed of 21 sectors, 109 cells and 630 villages. The district has a more rural economy. Gicumbi is characterized by a mountainous topography with steep slopes. It is covered by the Buberuka highland agro-ecological zones. This plateau is surrounded by steep ravines with small valleys segmented by multiple swamps.

The Water Resources of Rwanda faces growing challenges arising from pressures due to rapidly changing demographic patterns, demands of intensified socio-economic development, degradation resulting from unsustainable and inappropriate land use practices; and uncertainties created by climate change, among others. At the same time, the Rwanda Water Resource is expected to meet many conflicting water use demands and so contributing in the access to water for everyone. Meeting the above challenges requires a comprehensive planning.

As most of the region in Rwanda, the District of Gicumbi has a bimodal rainfall pattern with two rainy seasons and two dry seasons. Ordinary the first rainy season begins in September to December followed by a short dry season extends from January to February while the second rainy season extends from March to May. The long dry season begins from June to August. The Gicumbi District Development Plan has indicated that the climate is changing significantly although the range of annual rainfall varies between 1200mm to 1500mm; therefore the land is still largely suitable to rainfed agriculture. Gicumbi has humid climate and should not be scarce in water, but in reality as most of the hilly part of Rwanda access to

[3]WFP, 2017. Terms of Reference for the development of a WRMP inGicumbi district

water is constrained by the topography. This is the main reason the country will continue to invest in water infrastructure. The district of Gicumbi has set as priority water as number 2 (Water and Sanitation Priority Actions)[4]. It should be noted that Mwange River was purposely included in this study considering the ongoing project by WASAC to use the river for water supply to the population.

With that intention, WFP contribute to the Government of Rwanda development agenda and in particular for Gicumbi district by increasing the provision of sustainable water, sanitation services and hygiene education resulting in improved health. Water for People is an international non-governmental organization (NGO) that works with people and partners to develop innovative and long-lasting solutions to the water, sanitation and hygiene problems in the developing countries. It is in this background that WFP, hired the Best Associated Consultants (BAC) firm based in Rwanda to carry out a water resources management plan study in the district of Gicumbi that will enable partners of Gicumbi WASH Program to have a clear picture of available water sources versus demand, water quality and recommend appropriate measures for effective protection and use of water resources.

1.2 Objectives of the assignment

1.2.1 General objective

To develop a water resources management plan for the water sources and Mwange River located in the sub Watersheds of the Gicumbi district.

1.2.2 Major phases and tasks

Phase I - Water Resources Inventory (expected for the interim report)

1. Database of the potable water sources in Gicumbi that includes the following type of information for each source:
    - GPS locations of all the water sources;
    - Delineation of the sub-watersheds associated to the water sources identified;
    - Discharge of all water sources identified in the district;
    - Water quality tests of 101 sources and Mwange River for the following parameters: pH, Turbididty, Total Coliforms, Total Phosphorous, Total Nitrogen, Iron and Manganese.
2. Water demand analysis
    - Identify all the current water users and their water demand;
    - Water demand projection per sector for 25 years horizon;

[4] Gicumbi District, 2013. District Development Plan 2013-2018

3. Watershed characteristics (land use, land cover, slopes, erosion potential, land ownership, current and potential source of contamination of sources, hydrological information, etc.).
4. Existing or current Watershed protection measures.

Phase 2 – Water Resources Management Plan

1. Water Resources Management Plan that includes the following components:
    - Current and proposed Legal and institutional framework for Water Resources Management
    - Characterization of potable water sources and watersheds
    - Prioritization of watersheds based on the risk of contamination and water demand analysis
    - Water balance analysis for 25 years (2018-2043);
    - Proposed protection and mitigation measures;
    - Proposed monitoring framework and tools
2. Training Package for Database management
3. Budget for the implementation of the study recommendations.

1.2.3 Scope of the assignment

1) The study will cover the entire District consisting of 21 sectors, 109 cells and 630 villages.
2) The WRMP would be developed for a 25 years' horizon.
3) The study will be conducted in line with hydrological boundaries at watershed and sub- watershed levels for water sources (springs) and surface water (Mwange River) with data collected during rain and dry seasons.

2. Study Area

2.1 Administrative entities in the study area

Gicumbi District is one of the 30 districts in Rwanda, and is located in the Northern Province as illustrated on figure 1. The surface area of the District of Gicumbi is estimated to be 829.53 square kilometers.

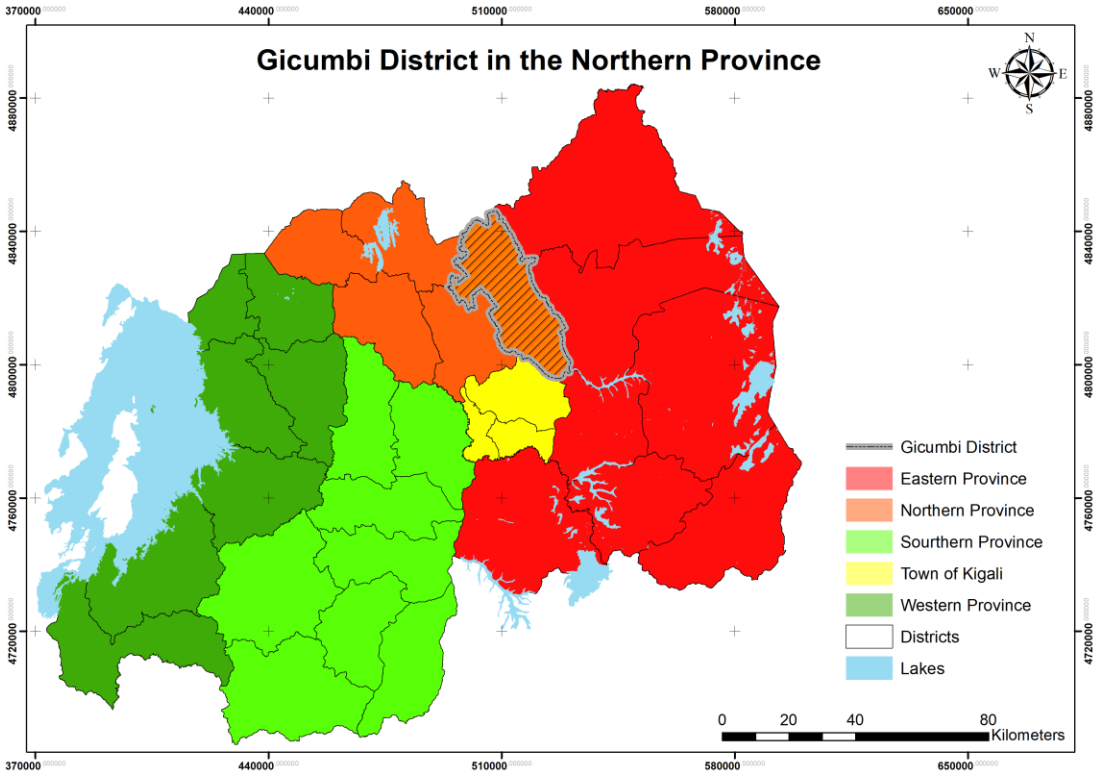


Figure 1: Administrative location of Gicumbi District.

The District administrative entities are composed of 21 Sectors, 109 cells and 630 villages as illustrated in figure 2.

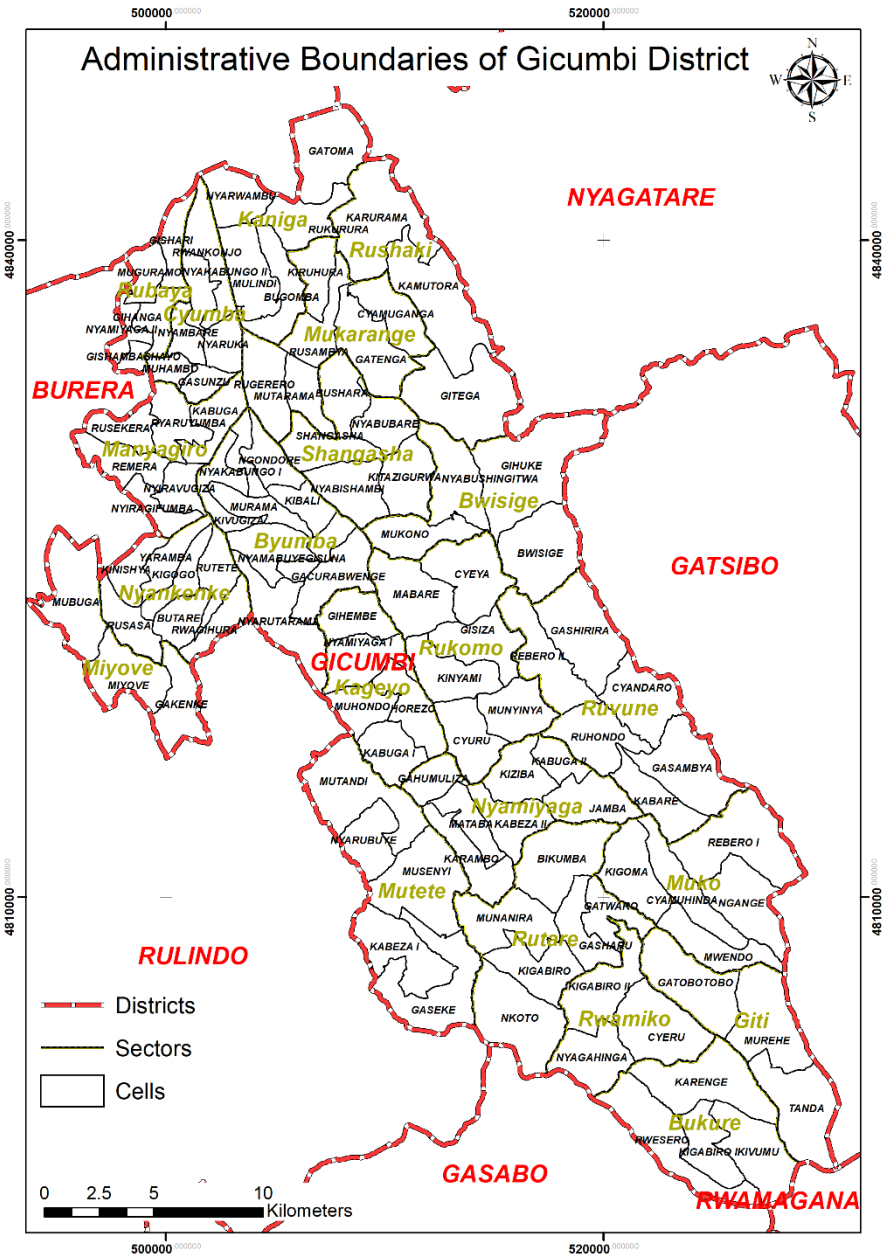


Figure 2: Administrative entities in Gicumbi District.

2.2. Topography of the study area

Gicumbi District is characterized by a complex topography with altitudes varying between 1,340 and 2,409 m a.s.l. A topographical illustration of the Gicumbi District is provided in figure 3. Abrupt changes of elevation in relatively short distances resulting into steep slopes are observed in the entire Gicumbi District.

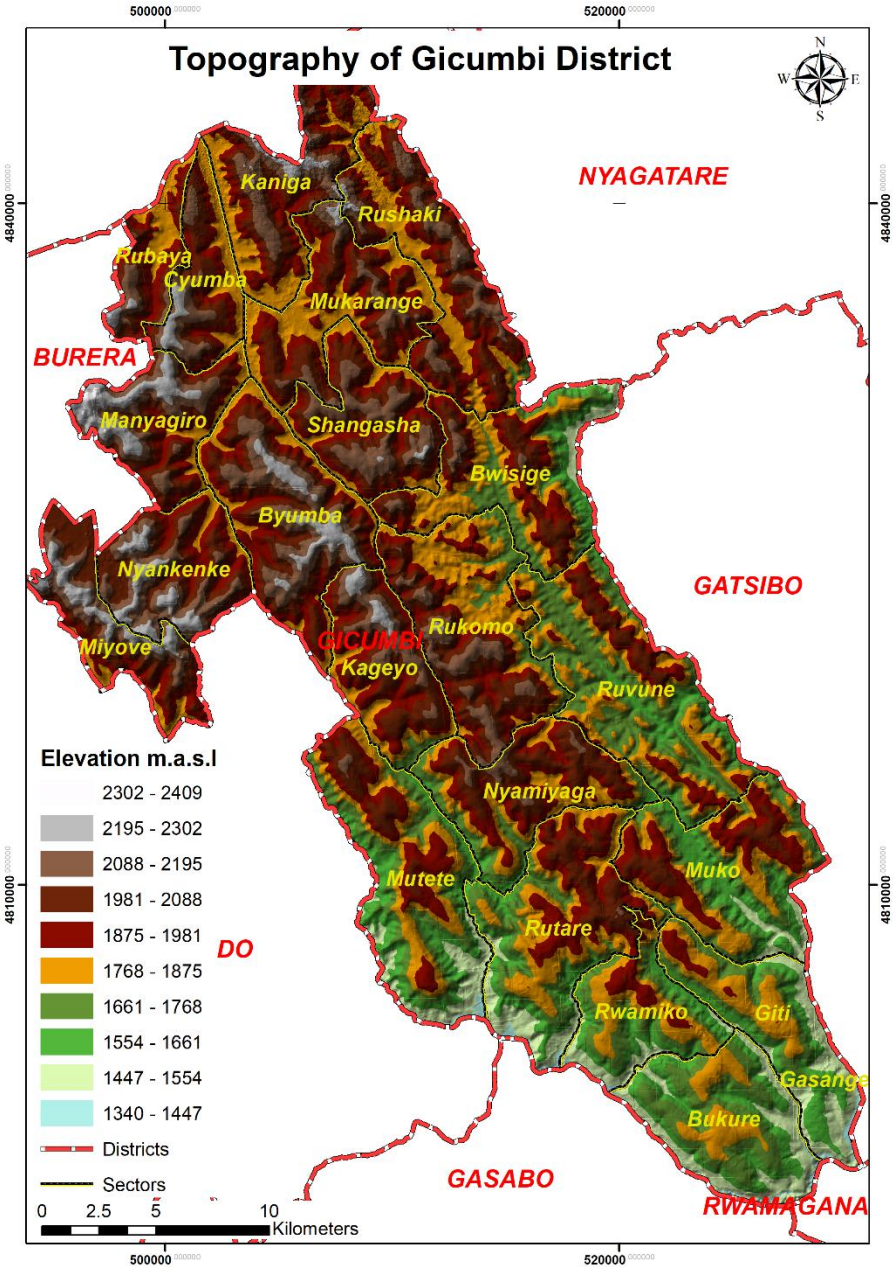


Figure 3: Topographical illustration of Gicumbi District.

2.3. Climate of the study area

Rwanda has a bimodal climate distribution and four seasons are experienced in the country. Two rainy periods, the first being from March to May and a less intensive from October to December are experienced. In addition, a small dry season starting from mid-December to February, characterized by occasional light rainfall and varying from dry to moderately wet days. A heavy dry season starting from June to mid-September, characterized by little to no

rain particularly in highlands. The heavy rainy season starts from March to May with the wettest days in the year. Finally, the small rainy season starts from mid-September (early October) to mid- December. The annual rainfall and potential evapotranspiration (PET) variation in the study area, based on the Rwanda Meteorological Agency(RMA) database, ranges approximately between 903 to 1,349 mm and 596 to 1,140 mm respectively. High rainfall, PET, relative humidity and low temperature values were observed in the watershed (refer to figure 4).

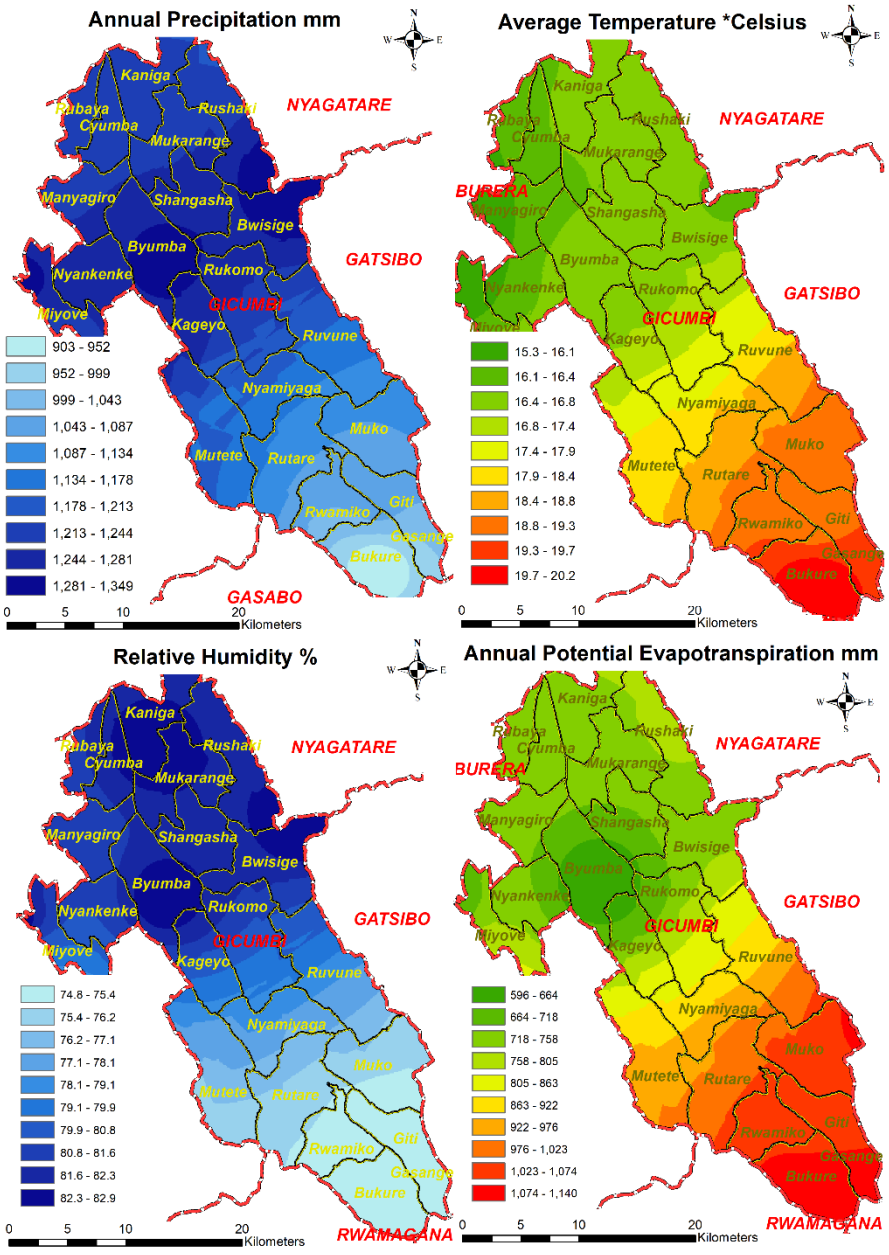


Figure 4: Climatology of Gicumbi District.

2.4. Land Use/Land Cover of the study area

In Gicumbi District, similarly to Rwanda in general, agriculture is the dominant land use. An overview of the main land use and land cover, obtained from the Rwanda Water and Forestry Authority (RWFA) database, is provided in figure 5. Other land use classes in the study area are forests, irrigation, built up areas and open lands.

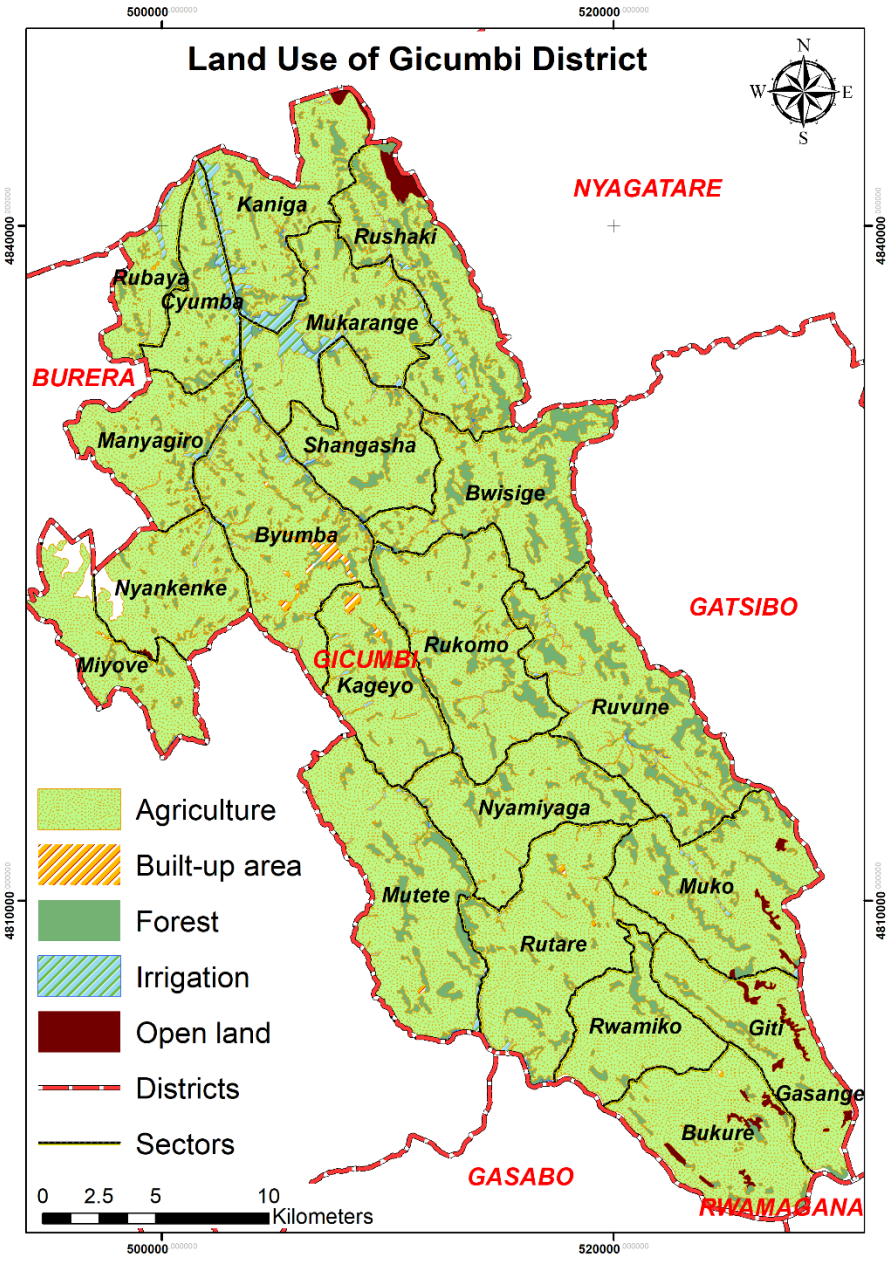


Figure 5: Land Use/Land Cover of Gicumbi District.

2.5. Groundwater potential of the study area

The characterization of groundwater potential in most cases is done using geological and lithological information. In fact, rocks are the most valuable clues of all. As a first step, geologic maps and cross sections showing the distribution and positions of the different kinds of rocks are prepared for both the surface and underground, as these provide information on favorable conditions for groundwater development. The types of groundwater, as represented through their aquifer types, is very much dependent on the area landscape.

In Gicumbi District, many investigations of these kinds were done during the National Water Resources Masterplan indicating a high groundwater development potential in the District. In Gicumbi District the existing aquifers contains a number of suspended aquifers. This is illustrated by the numerous number of spring sources located in the area. Figure 6 provides an illustration of the identified aquifers in Gicumbi District.

A majority of fractured aquifers is located in Gicumbi District. The major aquifers identified in the area are mainly a permeable fractured aquifer made of quartzite and schist base, a semi-permeable fractured aquifer made of schist, mica and quartzite, also a low permeable fractured aquifer made of schist and mica-schist. An extensive network of alluvial aquifers is also observed spread in the area as illustrated on figure 6. In the Northern-western part of the District, a peat formation can be observed.

Alluvial aquifers are generally shallow sand and gravel deposits laid down over time in a river channel or floodplain with an un-layered nature of the material (often silt, clay, sand, and gravel) deposited by running water in and around rivers. These aquifers often known as tributary aquifers exchange water back and forth with surface streams.

Fractured rock aquifers are common in the mountainous areas as depicted in Gicumbi District. Underneath a layer of soil and loose rocky material, aquifers exist in bedrock full of cracks and fractures created by the natural folding and faulting of the rock over millions of years. These cracks can be filled with water supplied by infiltrating rain. Not all fractures contain water, however springs can arise where fractures intersect the land's surface. Depending on the density of the fracture these rocks have, they are classified as low-permeable, semi-permeable and permeable fractured aquifers.

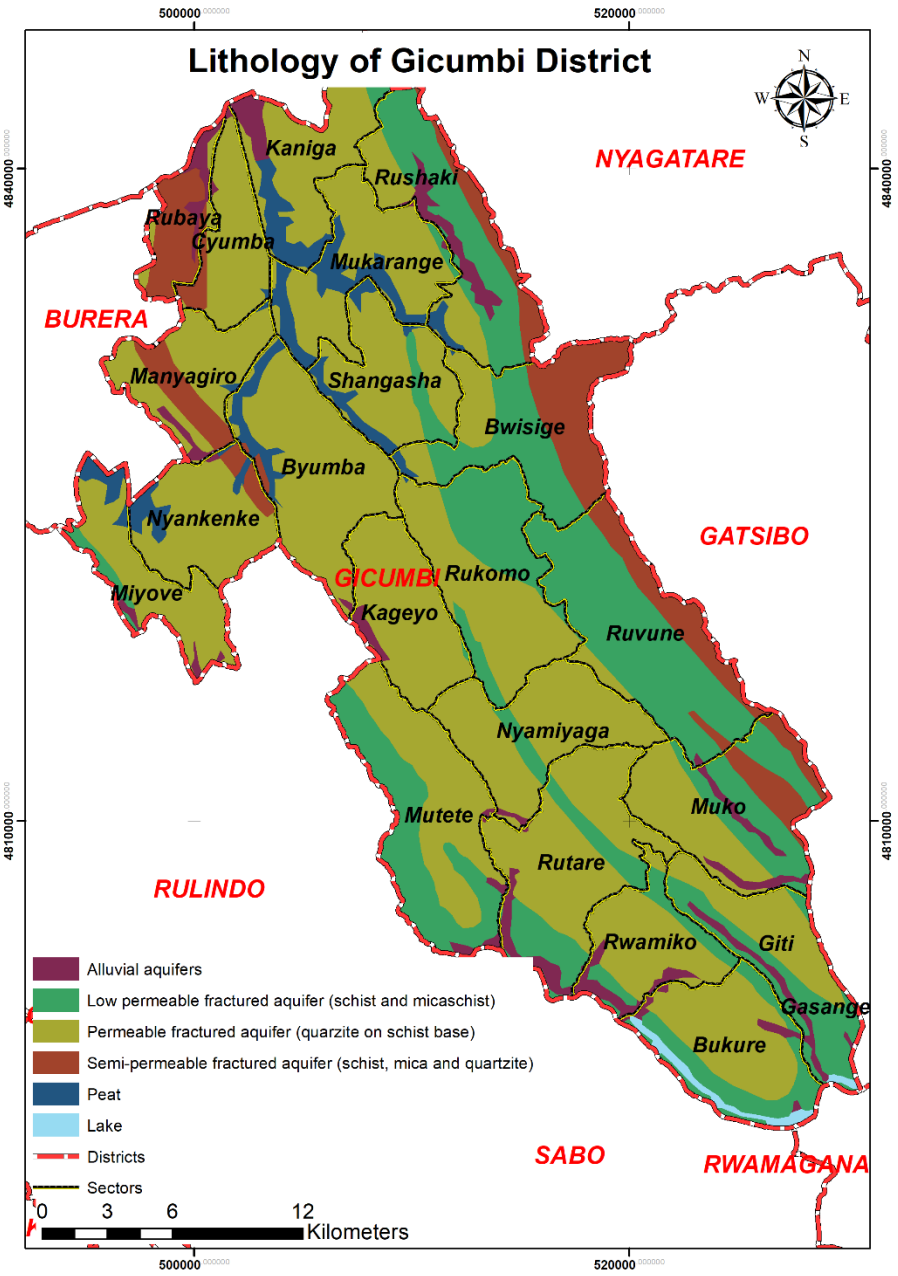


Figure 6: Aquifer in Gicumbi District.

2.6. Socio-economic characteristics of the study area

In Gicumbi District, the population is estimated to 395,606 according to the 2012 population census[5], of which 188,671are males while 206,935 are female. Considering the surface area of Gicumbi District, the results from the later census implies a population density of 478 per Km^2, where the urban and rural population's distribution is respectively 9 and 91 %. The 2012 census indicated that the average annual growth of the Rwandan population is 2.3% between

[5]NISR, 2014. Main indicators report. Fourth Population and Housing Census in Rwanda for 2012.

the first and fourth population census of 1978 and 2012 respectively. However, an average annual growth rate of 1.4% was recorded within the third and fourth census in Rwanda (2002-2012).

According to EICV3 (2013-2014), 9% of the Northern province households have no access to an improved drinking water source; in Gicumbi District, this is slightly higher with a 10.4% estimate. 58.9% of households have access to water in Gicumbi District through protected springs; 17.3% through public standpipes; 9% trough piped water into dwelling/yard; 0.4% through borehole; 2.5% through protected wells; and 1.3% of households use rainwater.

3. Methodology

The study covered the District of Gicumbi by focusing on water sources and Mwange River and included different approaches. In this section, a descriptive summary of the applied methodology is described.

3.1. Field visits

Intensive field visits were conducted across the watersheds in the Gicumbi District. These field visits were very vital in this assignment as they helped the team to understand the status of different watersheds in Gicumbi District, the current management of spring's sub-watersheds, the potential threat to the water sources in the study area as well as the environment in general. In addition to this, geographical coordinate for different spring sources were collected. Furthermore, the outcomes from the field visits were analyzed and different maps were generated in order to enable the illustration of the status and physical characterization of sub-watersheds in Gicumbi District.

3.2. Literature Review/Desk study

A literature review was carried out with the aim of accessing additional information that were used for the assessment of the status of the Gicumbi sub-watersheds. The data were sourced from different Governmental and Private Institutions such as MoE, MININFRA, MINECOFIN, RWFA, RLMUA, WASAC, WFP, as well as Gicumbi District and its Sectors. This review focused mainly on the available technical reports, official and institutional documents as detailed in references.

The implementation of the watersheds management plan requires a very wide stakeholders' participation and a strong institutional framework. To know the main actors involved, Gicumbi watersheds stakeholders were analyzed.

The stakeholder analysis and identification provided the essential information about:

- The individuals, groups and institutions affected or benefiting from services provided in the watershed and their various interventions;
- The capacities that these individuals, groups and institutions possess for appropriate water management;
- The people, organizations and institutions who could influence, and contribute to, the planning and management processes;
- The past, current and potential relationships between people and natural resources; and
- The current and potential resource use and management conflicts.

Stakeholder identification will be carried out in following 3 steps as described below:
Step 1: Consist of listing various natural resources within the site e.g. land, water, forest...
Step 2: Consist of listing all functions and uses for each of the resources – e.g. for tourism, source of craft material or agriculture.
Step 3: Consist of identifying groups and actors that have a stake in each of the functions and uses of the various water source by asking the questions like:

1. Who uses the (re)source(s)?
2. Who uses the Mwange River and for which type of activities.
3. Who benefits from the use of the source(s)? Who wishes to benefit but is unable to do so?
4. Who has impacts on the (re)source, whether positively or negatively?
5. Who has rights and responsibilities over the use of the source(s)?
6. Who would be affected by a change in the status, regime or outputs of the management?
7. Who makes decisions that affect the use and status of the source(s), and who does not?

These questions will be answered using field observations, discussions with key persons, literature reviews, consultant team's experience and questionnaires.

The stakeholder analysis exercise aim at answering questions such as:

1. What are the current and future interests of the various stakeholders in the use and management of Gicumbi watersheds? What are their needs and expectations? How do they use services provided by Gicumbi watersheds and what benefits do they derive?
2. What are their past and current power, rights and responsibilities, both formal and informal? What are the networks and institutions of which they are part?
3. What are the social and environmental impacts, both positive and negative, of their past and current exploitation of watershed?
4. How ready and willing are they to participate in and contribute to the management?
5. What are the potential areas of agreement and shared interest, upon which consensus and collaboration can be developed?
6. What are the human, technical and financial resources that they are prepared to contribute to the management process?
7. What is the current volume of water needed per capita/ person/day?

3.3. Focus group discussions and Interviews

A focus group discussion (or meeting) was conducted with environmental experts from different sectors of the District and community representatives to optimize the limited time had for field visit and interviews. The discussion had a gender sensitive basis to ensure capturing the role of women and children in the results obtained.

The meeting helped the team to identify among others the areas of the District under threat, the types and causes of the problems faced, and efforts and plans already in place, etc. The interviews pointed out some indicators showing possible ongoing trends for appropriation beyond the water supply project timeframe: challenges, way forward/suggestion for improvements. In addition, for sustainability purpose, the interviews assessed the trends for long-term impacts of the project: planned, executed, challenges met, causes, lessons learnt, and suggestions for the way forward.

During the interviews, Water Suppliers, Sectors Agronomists, District Environmentalist, Representatives of Famers, Representatives of Women Associations, Representative of Youth, Forest Managers, Representation from Members of the Local Community, etc. were approached.

The interview focused on **water users associations** and **water resources management committees** at Sector and District levels. According to the water law nº 62/2008 of 10/09/2008 putting in place the use, conservation, protection and management of water resources regulations; these water resources management committees are composed of local government officials, NGOs representatives, representatives of water users' associations, farmers' representatives and private sector. Thus, depending on the water resources management issue to be discussed, some of the following members are (will be) interviewed:

At District level:
1. Vice Mayor for Economic Affairs;
2. Sector Executive Secretaries;
3. District Environment Officer;
4. District Agronomist;
5. District Women Council Representative;
6. District Youth Council Representative;
7. District representative of water user organizations in the field of agriculture;
8. The staff of the National Authority in charge of Natural Resources operating at the level of the hydrographical basin;
9. District representative of domestic water users;
10. Two farmers' representatives;
11. NGO representative;
12. District private sector representative

At Sector level:
1. The Executive Secretary of the Sector
2. The in charge of water at sector level
3. The in charge of agriculture, animal resources, land, settlement, urbanization, forests, infrastructure and environment at the Sector level;

4. A representative of the Executive Committee of each Cell in the Sector elected by his/her peers;
5. A representative of the National Women's Council at the Sector level;
6. A representative of the National Youth Council at Sector level;
7. Two (2) representatives of farmers at the Sector level;
8. A representative of water domestic users at the Sector level;
9. Two (2) representatives of non-governmental organizations working in the field of water resources at the Sector level;
10. A representative of water user organizations in the field of agriculture at the Sector level;
11. A representative of the private sector at sector level

3.4. Flow measurements

3.4.1. Estimating spring flow

The spring yield was measured in liters per second (l/s). The measurement process involved two persons. One person collecting water with a container of a known volume (1 L) while the other measuring the time needed to fill the container. Three readings were taken during the measurement and the averages were made and expressed in l/s/spring.

3.4.2. Estimation of the river and stream flow

The mechanical current meter method was used to measure the stream flow of the Mwange River. This is a standard method used for flow measurement. The stream channel cross section was divided into numerous vertical subsections (refer to figure 7). In each subsection, the area was obtained by measuring the width and depth of the subsection, and the water velocity using the mechanical current meter. The discharge in each subsection was computed by multiplying the subsection area by the measured velocity. The total discharge was then computed by summing the discharge of each subsection (using the midsection method), following equation 1.

$$Q = \left(\frac{d_1 + d_2}{2}\right) * v_A * w_1 + \left(\frac{d_2 + d_3}{2}\right) * v_B * w_2 + \left(\frac{d_3 + d_4}{2}\right) * v_C * w_3 \quad (1)$$

Where Q = discharge, di = depth, v = velocity, W = width

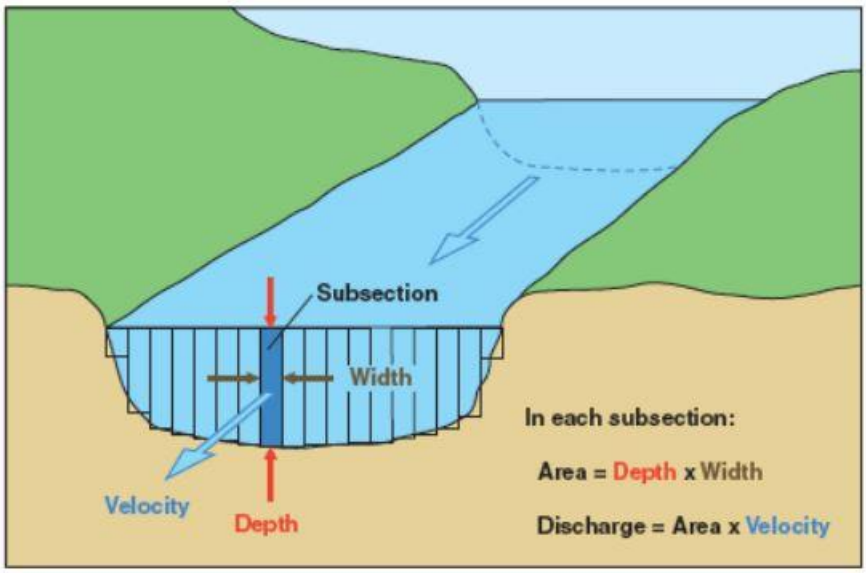


Figure 7: Mechanical current meter methods.

3.5. Recharge watershed mapping

To illustrate the key physical characteristics of the Gicumbi District sub-watersheds, a GIS environment was used. A geodatabase was developed comprising all the springs' localization and characteristics as well as all the physical characteristics of the Gicumbi District sub-watersheds. Data that were stored in the geodatabase were, but not limited to, administrative boundaries of the study area, sub-watersheds boundaries within the study area, existing land use and land cover classes in the study area, drainage networks in the study area, socio-economic infrastructures and miscellaneous data in the study area. The ArcGIS 10.2.2 software package and GPS devices were used for handling all spatial analysis tasks and watershed mapping during this study. The geodatabase was designed using Arc-Catalogue as an ArcGIS application dedicated for spatial database creation and management. During the design of the geodatabase, the spatial referencing system that was used is the customized WGS84 known as TM Rwanda for easy harmonization and integration of all datasets.

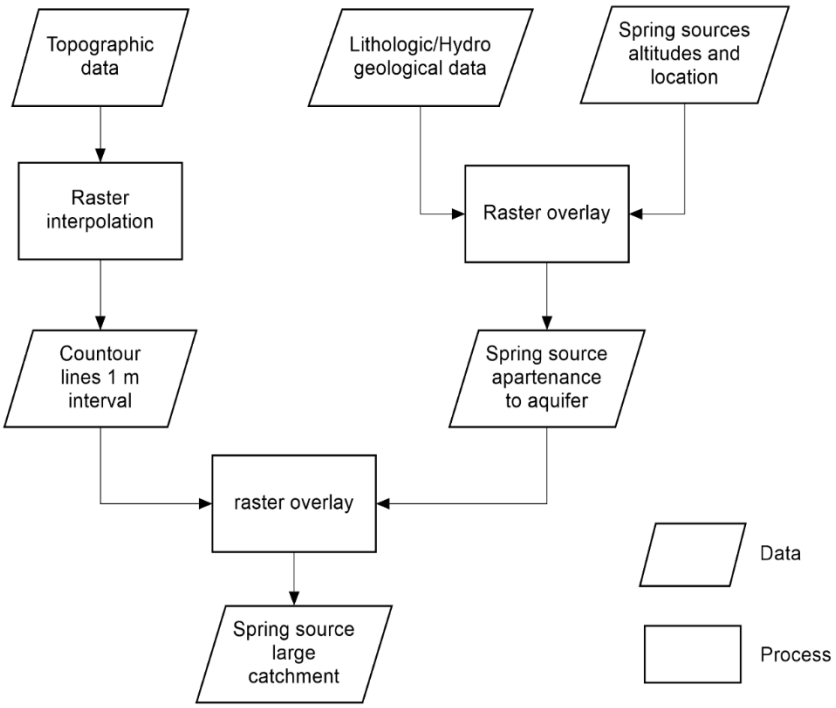


Figure 8: Delineation of the recharge spring sources watersheds.

A conceptual framework, of the approach used to delineate the existing recharge watershed in Gicumbi District, is provided in figure 8.

Table 1: Data need and application.

Required data	Application/analysis
Administration boundaries (cells, Sectors and District)	Administrative delineation of the study area
Digital Elevation Model (DEM)	Watershed delineation , slope and topographic analysis and hillsides illumination, contour lines for generating 3D information such as Triangulated Irregular Network (TIN)
Aerial photographs	Land cover/Land use analysis and mapping
Topographic map at 1:50000	Watershed delineation and drainage pattern analysis
Meteo and hydrologic data	Meteo and Hydrograph analysis
Statistics on population and Socio-economic infrastructures	Thematic mapping at cell level and Analysis of socio-economic characteristics

3.6. Recharge catchment management plan

The methodology used to develop the management measures was based on land husbandry technologies and stakeholders' engagement taking into account the need of the local population and consisted of 2 major stages. The first stage was to determine the land resilience units in the different recharge catchments using the available data. The second stage

was to incorporate the agro-climatic parameters in the land resilience units in order to select the appropriate management measures that have to be implemented in the recharge catchment areas. The applicability of the proposed measures was verified during the extensive fieldwork that was done within the framework of this study.

3.6.1. Soil resilience units

To identify the land resilience units in the project area, a comprehensive approach consisting of a spatial combination of slope classes and soil depth classes in the project area based on the land unit matrix provided in table 2, was applied. Fifteen classes were identified representing land husbandry land units in increasing order of care requirement (this classification also incorporate limitation for production per land units). In other words, the classification obtained indicates the level of technical and financial investment required to treat the different classes of land units identified.

Table 2: Land resilience unit's matrix

Soil depth	Slope Categories				
	0-6%	6-16%	16-40%	40-60%	>60%
0-50 cm	9	10	11	12	15
50-100 cm	4	5	6	8	14
>100 cm	1	2	3	7	13

In the above matrix, the 15 land husbandry units identified were classified into 4 categories of land resilience as illustrated in table 3 (note that the color coding is based on the national standards provided by MINAGRI for soil mapping), the basis of this classification is that **Soil resilience** refers to the ability of a soil to resist or recover their healthy state in response to destabilizing influences (this is a subset of a notion of environmental resilience). The meaning behind the classification provided in table 3 is that for each class a specific set of treatment (or activity) are ideal for it to recover its healthy state (in general a healthy soil is a soil state in which the soil meets its range of ecosystem functions as appropriate to its environment, for example in agriculture a healthy soil would be a soil producing healthy crops with minimal amount of external inputs and few or no adverse ecological impacts).

The first 2 land resilience categories were set for a similar kind of treatment known as agroforestry because of 2 main reasons. The first reason is the zero grazing policy in place in Rwanda resulting in no need for rangelands development in the area and the last reason is the government efforts in place for promoting agroforestry instead of traditional agriculture in the country.

Table 3: Land resilience unit's matrix

#	Code	Level of care requirement	Land Resilience Unit
1		Low	Croplands
2		Medium	Forest plantation
3		High	Rangelands/Croplands
4		Very High	Natural forest

The following combination and categorization was applied to the project area in a GIS environment and an overall spatial distribution of these categories per spring recharge catchments are illustrated in thematic maps provided in this report.

3.6.2. Management measures

Finally, to select the adequate recharge catchments management measures in the project area, agro-climatic factors were considered. These management measures are better implemented as land husbandry technologies which depended on resilience of soil and its agro-climatic characteristics. The agro-climatic characteristics are mostly categorized into agro-climatic zones where the Gicumbi District falls in the Eastern part the Buberuka Highlands and the Northern part of the Central plateau and plateau near the East Savanah. Additionally, the altitude and annual rainfall distribution were considered in the project area to complement its agro-climatic parameterization. Four zones were determined as wet highland (W. H. L), wet mid land (W. M. L), moist mid highland (M. M. H. L) and moist lowland (M. L. L) in the project area.

Table 4: Recharge catchment management measures.

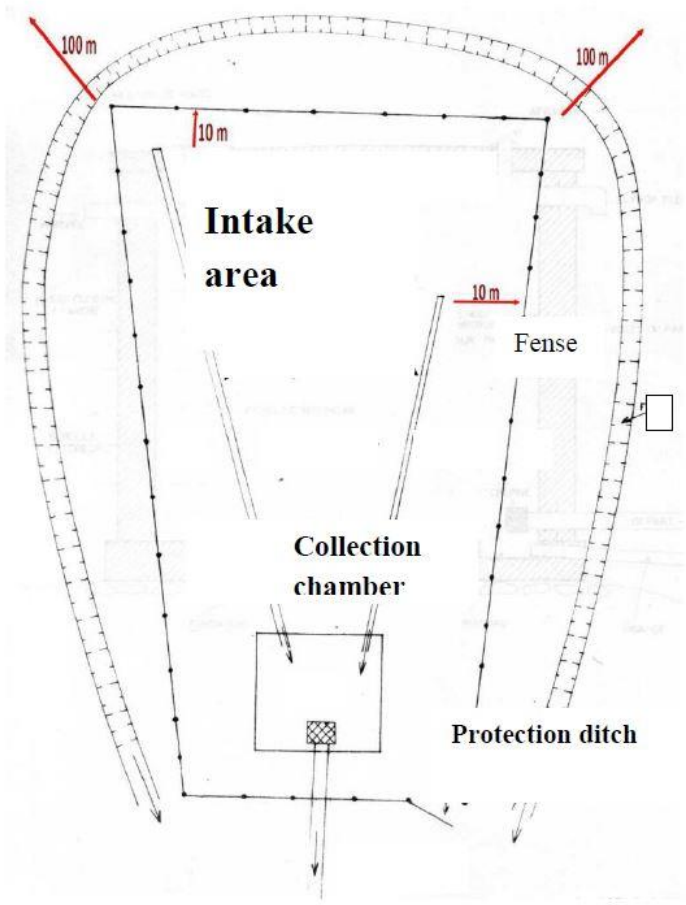
		Land Resilience Units			
		Croplands	Rangelands	Forest plantation	Natural forest
Agro climatic zones	**M. L. L**	Agro forestry + simple management	Agroforestry + average management (Progressive terraces)	Forest plantation	Natural forest
	M. M. H. L	Agroforestry + average management (Progressive terraces)	Agroforestry + advanced management (Radical terraces)	Forest plantation	Natural forest
	W. M. L	Agroforestry + advanced management (Radical terraces)	Agroforestry + advanced management (Radical terraces)	Forest plantation	Natural forest
	W. H. L	Natural forest	Natural forest	Natural forest	Natural forest

Table 4 illustrates the classification matrix that was used for implementation measures. The later table was applied to the project area in a GIS environment and an overall spatial distribution of these management measures per spring recharge catchments were obtained provided in this report.

3.6.3. Spring sources immediate catchment technical management measures

The management measures recommended for immediate spring catchment are standards. In Rwanda, the standard is fixed by MININFRA through WASAC Ltd as the only drinking water supplier in Rwanda, who at the same time look at urban and rural areas supply. These management measures are easy to understand, implement, maintain and do not require extensive design and studies and therefore are cost effective. From the above fieldwork observations, quite a number of spring sources do not fulfil all the standard management measures of their immediate catchment. According to the WASAC Ltd manual of Operation and Maintenance of Gravitational Rural Water Systems, the following graph and table illustrates the technical management measures of the immediate spring catchment.

Table 5: Immediate spring catchment management measures

	**Upstream protection zone:** • 45^0 Arc radius of 100 meters upstream outside the protection ditch, • No potential pollution source is allowed (latrines, life stock grazing), nor roots of trees in that zone **Direct protection area:** • Radius of 10 meters around the surface of catchment area within the fence, • Should be fenced, • No farming activities allowed (no plants, no animals within the fence. **Protection ditch:** • Circle the catchment area, • Drain surface waters downstream, • Limit direct infiltration into the capture. **Collection chamber / departure:** • Should be securely locked.

Source: WASAC Ltd

3.7. Water quality sampling and analysis

The water quality parameters were collected and stored in 600 ml plastic bottles and placed in a cooler box with ice pending after sampling. The plastic bottles were rinsed before with HCl (1M) and then with distilled water at the laboratory to insure their cleanness. Furthermore, sampling bottles were also rinsed twice with sample water before final collection.

The Mn and Fe samples were analyzed according to APHA[6] standard methods, i.e. few drops of concentrate nitric acid were added while sampling of total coliforms samples were preceded by the sterilization of both the sampling bottles and the spring pipe. The analysis of the collected samples was done following the already developed SOPs for pH, Turbidity, Total Coliforms, Total Phosphorous, Total Nitrogen, Iron and Manganese as these samples were analyzed by UR laboratories specialized in water quality control. The results from the analysis was compared to RSB and WHO standards for drinking water.

3.8. Estimation of water demand based on actual use data

Collection of the actual consumption data

As WFP works with residential water users including households, schools, health centers, industries, etc., the data collection phase covered all those areas.

- One of the first steps in collecting the actual water consumption for each spring was to identify the number of residential users that were served by a particular spring. These data were expected to be obtained from WFP and the Gicumbi District.
- The next step was to identify the total water consumed collected from private operators or WASAC,
- The last step was the calculation of the residential water use per capita per day

Residential water per capita per day = (Residential Use ÷ Residential Population)
• Residential Use = Single-Family Use + Multi-Family Use
• Residential Population = the residential population of the service area.

The outcome from the above calculation was confronted with the standard of WHO to assess the level of water demand satisfaction.

- For the areas which are not yet supplied; the demand was estimated based on the number of population staying in these areas.

[6] APHA, AWWA, WEF, 1998. Standard methods for the examination of water and wastewater, 20 edn. American Public Health Association, Washington, D.C.

3.9. Estimation of water Demand in 25 years to come (2018-2043)

The water use demand was estimated based on the existing data available in the study area. This demand was expected to be domestic water supply from the existing water supply scheme in the study area. The main outcome of this section was water demand estimates per use and on a monthly basis in terms of volume of water per spring. This allowed relating these water use demands to the water balance. In this estimation, the main task was to estimate the population of the area in 25 years to come. Mathematically, the population estimates was done as shown below.

$$P_t = P_0 (1 + r)^t$$

Where:

P_0 = initial population

P_t = population t years later

r =growth rate

t= time horizon

The projected population was confronted to the available water to assess whether the demand would still be met.

4. Institutional and legal framework for the management of water resources in Gicumbi District

Water is the most precious of the natural resources of Rwanda as it is indispensable for human health and for economic activities. So we must take care of it, protect it and manage it properly. This requires a strong institutional and legal framework to ensure that management of water resources, its development; its use and protection are done in a coordinated and regulated manner.

In this regard, a lot has been made at national level in setting up institutions to deal with water resources management on different levels and adopting different laws and regulations relating to the management, use and protection of water resources. The institutional and legal frameworks are established to indicate clearly who does what in terms of water resources conservation, protection and management. We cannot separate institutional framework from legal framework as long as institutional framework for water resources management is provided for by different policies and legal instruments.

4.1. Institutional structure for water resources management

Currently institutions in charge of water resources management are structured from national level to the lowest level (user level).

4.1.1. Institutions at National level

4.1.1.1. The Ministry (Ministry of Environment)

The Ministry has the mission to ensure the conservation, protection, management and development of water resources. Specifically, the Ministry is responsible for the following:

- To develop and disseminate water resources policy and its implementing strategies and programs;
- To develop laws and regulations to ensure protection, conservation, management and development of water resources;
- To mobilize the necessary resources for the conservation, protection, management and development of water resources.

4.1.1.2. Authority (Rwanda Water and Forestry Authority)

Law N°62/2008 of 10/09/2008 putting in place the use, conservation, protection and management of water resources regulations in its article 17 (Water Law) provides for establishment of a National Water authority and this has been established by Law Nº06/2017 of 03/02/2017 establishing Rwanda Water and Forestry Authority and determining its mission, organization and functioning.

In terms of water resources management, the Authority's mandate is to implement policies, laws, strategies and Government decisions related to the management of water resources and to undertake technical research, studies and other relevant technical activities for a better management and use of water resources.

4.1.1.3. National Water Consultative Commission

Water is a cross cutting resource affected by and affecting different sectors. It thus implies that institutions and stakeholders which have a stake on water resources discuss and have a common understanding not only on water resources related issues but also on water development projects to be undertaken by various institutions so as to avoid over up of the projects. The National Water Consultative Commission was then established to serve as a discussion forum for that purpose.

As established by Water Law, the National Consultative Commission will be consulted on planning, water supply and management or development projects in water domain elaborated to the national level or the big hydrographic basin level as well as the big projects of the same category of provincial character. According to Prime Minister's Order No 143/03 of 24/05/2013 determining the organization, functioning and composition of the National Consultative Commission, the Commission shall meet once in six months and whenever it is considered necessary and the meetings are chaired by Minister in charge of water resources.

4.1.1.4. Water Inter-ministerial Committee

The Water Interministerial Committee is a technical committee composed of ministerial department representatives concerned with water in their domain. The Ministry in charge of water resources ensures the organization and functioning of the Water Interministerial Committee and convenes its meetings whenever deemed necessary.

The Water Interministerial Committee is consulted on all legislative drafts/Bills regarding planning in the water domain elaborated at the national level, as well as on matters of national, regional or international level. It plays also a technical advisory role concerning matters to be decided by the National Water Consultative Commission.

4.1.2. Institutions at District level

Water resources development and management requires involvement and participation of water users, planners, policy makers at all levels (central and decentralized levels), communities and other stakeholders where decisions regarding water resources managements are made through participatory approach by each and everyone involved. This reflects the idea of decentralization following which the design and implementation of water management and allocation policies are transferred from the Central Government to local institutions, which are supposed to have a better knowledge of water related issues at catchment level and where representatives of local water stakeholders are able to negotiate and decide jointly water management strategies and measures to be put in place. This was put into practice through establishment of hydrographic basin committees at District and Sector levels.

4.1.2.1. District hydrographic basin committees

The Districts hydrographic basin committees were provided for by the Water Law in its article 20 and its composition, organization and functioning are determined by a Ministerial Order Nº005/16.01 of 24/05/2013 determining the organization and functioning of hydrographic basin committees. The members of the Committees are representatives of the following:

1° administrations concerned by water (central and local);
2° elected representatives of the local decentralized communities (women and youth)
3° representatives of the different categories of water users;
4° representatives of Non-Governmental Organizations operating in the water sector and private sector.

The District hydrographic basin committees have the mandate, among others, to formulate orientations and proposals concerning the planning and management of the water resources within the basin/catchment, to propose the management units for which an integrated management of the water resource must be done where necessary and provide opinions on all technical or financial questions that are submitted to it by the administration.

Currently 29 hydrographic basin committees were established in all Districts except the Kamonyi District.

4.1.2.2. Hydrographic basin committees at Sector level

As District hydrographic basin committees, the Water Law has stipulated that the same committees have to be established at Sector level and shall have the following responsibilities:

1° to propose the initial version of the local master plan/management plan for water resources;

2° to fix management procedures for water resources management at the Sector level;
3° to provide any propositions and opinions on water related issues.

The structure and functioning of this committee is the same as set out for the basin committee at the District level but the composition is a bit different because there are no representatives of the District and Authority in charge of water resources otherwise, the members are the same but at Sector level. The hydrographic basin committees at Sector level are not yet established.

N.B: According to the proposed amendment of the current Water Law, these hydrographic basin committees will be replaced by Catchment management committees.

4.1.3. Water user associations/User level

The water law stipulates that water users may create a water use association. Those associations are of paramount importance as long as their members have the common understanding and interest in the use of water resources hence participate actively in water resources management activities. On the other hand, the water use associations are considered as platform where water users in the same field of activity discuss and decide on water related issues at the grass root and defend their interests where need arises. They also play a big role in water conflicts management where conflicts may be settled by and among themselves without intervention of local or central Government authorities.

Currently we have Water Users Associations in irrigation as established by Ministerial Order N°001/11.30 of 23/11/2011 establishing irrigation Water Users Associations in irrigation schemes. These associations are established at every segment of irrigation scheme and they play a key role in water resources management and use in irrigation.

4.2. Legal framework for water resources management

Although the institutions for water resources management were put in place, the implementation of strategies, management plans and development projects cannot be successful or may cause adverse effects if are not done in regulated manner. Policies delimit the activities of all water management stakeholders including the Government itself and lead to the development of laws and rules designed to achieve policy goals.

The legal framework for managing water resources is mainly governed by the National water resources management policy (2011), the National policy for water supply and sanitation (2010), the environment policy, the water law (2008) and the organic law on environment protection (2005). These Policies and Laws have statements or provisions related to the

management of water sources or provide guidelines and requirements for development projects in a way that is friendly to water resources in particular and environment in general.

4.2.1. Review of Policies

4.2.1.1. National Policy for water resources management, 2011

Through the National Policy on Water Resources Management, Government is outlining its vision for the water resources management sub-sector. The Policy contains guiding principles upon which water resources of Rwanda shall be managed and highlights its statements and related strategic actions to be implemented to meet the policy objective which is ”to manage and develop the water resources of Rwanda in an integrated and sustainable manner, so as to secure and provide water of adequate quantity and quality for all social and economic needs of the present and future generations with the full participation of all stakeholders in decisions affecting water resources management”.

Given the fact that water is a cross-cutting resource phenomenon, affecting and affected by multiple sectors, including domestic consumption, agriculture, commerce, industry, transport and energy as well as ecological functions for environmental conservation, the water policy has introduced the management of water resources in integrated manner to ensure that different uses and users of water resources and all other relevant factors are taken into consideration in resource management, development and allocation.

Another important aspect of water resources management introduced by the water policy is the catchment-based approach where water resources are managed without considering administrative boundaries but rather taking into account local decisions, businesses, landowners, water uses, any activity affecting water resources and the community that share a specific geographic area, to secure positive environmental improvements for rivers and catchments. The objectives of the catchment based management approach are to deliver positive and sustained outcomes for the water environment by promoting a better understanding of water related issues at a local level; and to encourage local collaboration and more transparent decision-making when both planning and delivering activities to improve the water environment.

4.2.1.2. Environment policy

The National Environment Policy of 2003 sets out overall and specific objectives as well as fundamental principles for improved management of the environment, both at the central and local level, in accordance with the country’s current policy of decentralization and good governance. But the policy puts particular emphasis on challenges that water resources are facing including but not limited to frequent climatic disturbances and increase of competitive

demands due to socio-economic development activities and population growth. All these factors contribute increasingly to the reduction of water availability and during the rainy seasons, water constitutes a danger and causes considerable damage due to lack of rain water harvesting and conservation techniques.

In response to the above mentioned challenges, the Environment policy states some strategic actions aiming at protecting water resources at the same time improving their quality and increasing the quantity.

4.2.1.3. National Water Supply Policy, 2016

The National Water Supply Policy provides a clear direction for the implementation of activities in the water supply sub-sector. The Policy outlines initiatives to overcome challenges and exploit existing opportunities in an integrated manner, and contributes effectively towards achieving the goals of the National Development Agenda.

The policy states that all Water Supply and Sanitation projects and programs shall abide by the relevant water resources and environmental laws of Rwanda to make sure that all measures comply with the standards, permits and regulations with respect to the rational and sustainable utilization of water resources and environmental protection and conservation of water resources. This is to acknowledge the importance of water resources in Water Supply and Sanitation projects and to make sure that all necessary measures are undertaken to ensure availability and protection of water resources are respected and implemented by each and every one who has a stake on water resources.

4.2.1.4. National Sanitation Policy, 2016

The Government of Rwanda has the ambition to improve the quality of life of its population by provision of adequate sanitation services. To reach this objective, the National Sanitation Policy has been developed as an Umbrella Policy that provides guiding principles for all aspects of sanitation, including liquid and solid waste, industrial waste, nuclear waste, health-care waste and hygiene as well as storm water management.

The National Sanitation Policy provides for a range of various activities and means to be implemented so as to ensure expended access to safe and sustainable sanitation services including improving operation and maintenance of sanitation facilities and designing projects to mitigate urban storm water issues among others. Given its impact on water flows and quality, the management of storm water in urban areas will contributes a lot in improving water resources quality and at the same time reducing storm water runoff impact on different infrastructures.

4.2.2. Review of Laws and regulations

Policy statements and actions on water resources management need to be translated into legal and binding provisions in order to be implemented by all persons, institutions and the Government itself and to provide for penalties for those who act against or omit to do what is required by the law. In this regards, different laws and regulations were enacted to that effect as discussed here bellow.

4.2.2.1. Rwanda Water law, 2008

The Water Law incorporates many cutting edge principles of sustainable water resources management and provides for institutional framework for the coordination of water resources management, a key ingredient of integrated water resources management. Given the fact that the water law has been developed following water and sanitation policy of 2004, the law is being revised to encompass new features introduced by the current water policy including catchment based management among others.

4.2.2.2. Organic law on environmental protection, 2005

The organic law on environmental protection offers special protection to water resources in as far as it bans the conduct of activities within a specified distance from the shores of lakes, rivers and streams in order to prevent their pollution and obliges the Government to implement measures aiming at protecting and preserving catchment areas around wells from where drinking water is drawn from. The organic law also requires that any act concerned with water resources be subject to prior environmental impact assessment before its implementation and in accordance with relevant regulations.

4.2.2.3. Law governing land in Rwanda, 2013

The Law N° 43/2013 of 16/06/2013 governing land in Rwanda was introduced to regulate the use and management of land in a way that both improves the livelihoods of people and protects the water resources. The law identifies land which can be used for various activities and the land which is protected or reserved for environmental protection. It is in this regard that the land occupied by lakes and rivers, shores of lakes, rivers and streams, land occupied by springs and wells, were classified in the category of state land in the public domain.
Concerning the boundary of the area around a water source that is considered to be part of the public domain and therefore requiring protection, Ministerial Order N° 007/16.01 of 15/07/2010 determining the length of land on shores of lakes and rivers transferred to public property, which was established to implement the 2005 organic law on environmental protection, provides for 50 m width for lakes (article 2), 10 m width for big rivers, 5 m width for small rivers and 2 m width for other rivers not listed in the order including wells and springs.

For protection purposes of the above determined water sources buffer zone, no activities or buildings are authorized on the said land except activities aiming at protecting lakes, rivers, shores or activities authorized by the Minister in charge of environment and when such activities are deemed not destructive to the environment on condition that a prior environmental impact assessment study has been done.

Therefore, Legal frameworks are an important and integral part of effective integrated water resources management. In order to be effective, the rules devised under legal frameworks for water resources management as discussed above must be fully implemented (i.e. put into practice) and be capable to be enforced (i.e. where the rules are not followed, they can be required to be followed through enforcement mechanisms). Institutions and individuals are key prayers in implementation and enforcement process and have to be capacitated for them to fulfill their mandates as provided for by different laws and regulations.

4.3 Protection of the water resources (springs) at the district level

Under the general principles provided for by the water law (article 5) on the management of water resources, one of them is on *"the prevention of the pollution with priority to the sources* "and the other one is the "user-payer and polluter payer" principles according to which the user of water and the polluter support a significant part of expenses resulting from measures of prevention, of pollution reduction and restoration of the resource in quality and in quantity".

In respect to the above, the District should implement measures to protect and reserve catchment area around wells and springs from where drinking water is drawn as provided for by article 51 of Organic Law on environmental protection. This kind of measures includes protective fences to surround places where water is drawn for human consumption as required by article 16 of the same Organic Law. In addition to this, each well or spring should have a Protection Committee of at least three members elected from the users of the well or the spring. The Protection Committee will ensure the protection and management of the well or spring on a daily basis and report to local authorities who pollute the water sources in order to ensure implementation of "user-payer and polluter payer" principles.

More specifically institutions at lowest level/user level (water user's associations /water user's committees) have to be created and their capacities enhanced as far as water resources management and protection are concerned as per subsidiarity principle.

5. Spring sources characterization

The following section provides a landscape and geomorphological characterization of the spring sources catchment in the Gicumbi District. The following section provides the location spring sources and the recharge catchments delineated.

5.1. Spring sources location

An overall equal distribution of spring sources was observed in the Gicumbi District. It is also observed that a limited number of spring sources were captured for water supply, which indicates a large opportunity to develop the water supply in the District. The sectors of Kageyo, Rushaki and Kaniga have been observed to have a high density of spring sources compared to other sectors.

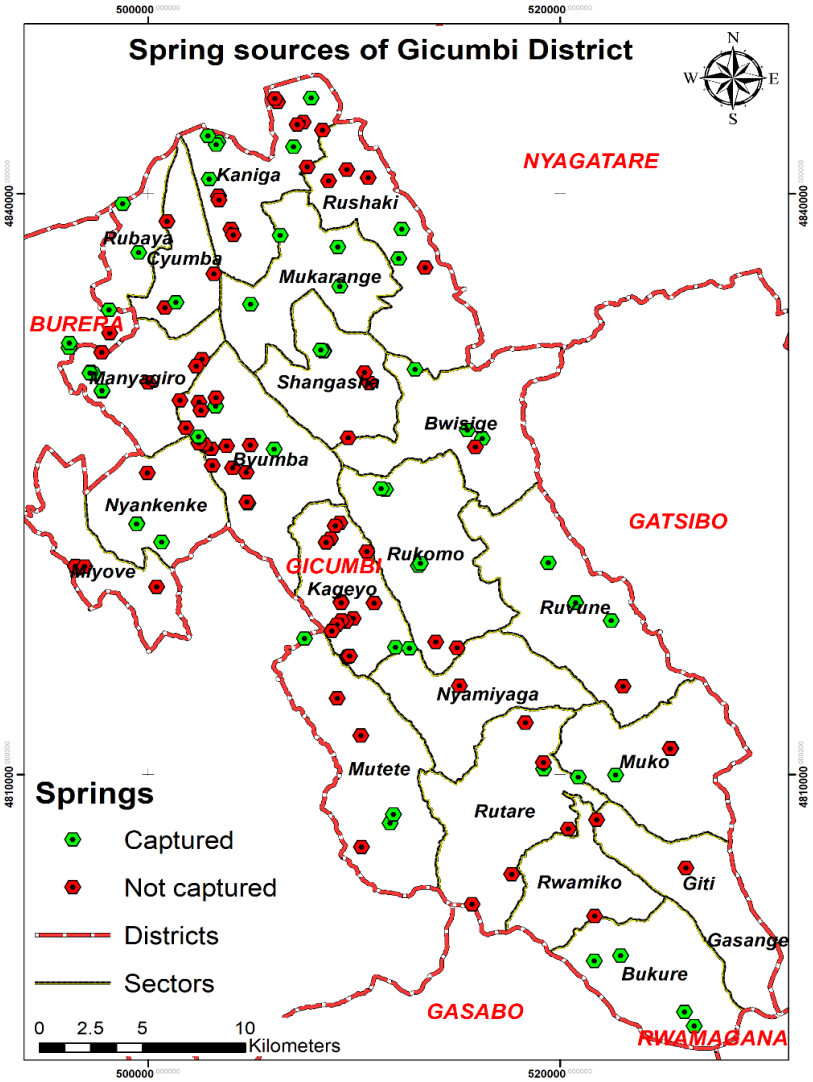


Figure 9: Location of studied spring sources in Gicumbi District.

5.2. Surface and recharge watersheds in Gicumbi District

Topography is a major parameter to consider in delineating surface and recharge catchments. Surface catchments is based on the surface topography while recharge catchment are based on contour lines and altitudes of spring sources. In this study, the surface and recharge catchments were delineated. Figure 8 and 9 illustrated the surface and recharge catchments in Gicumbi District.

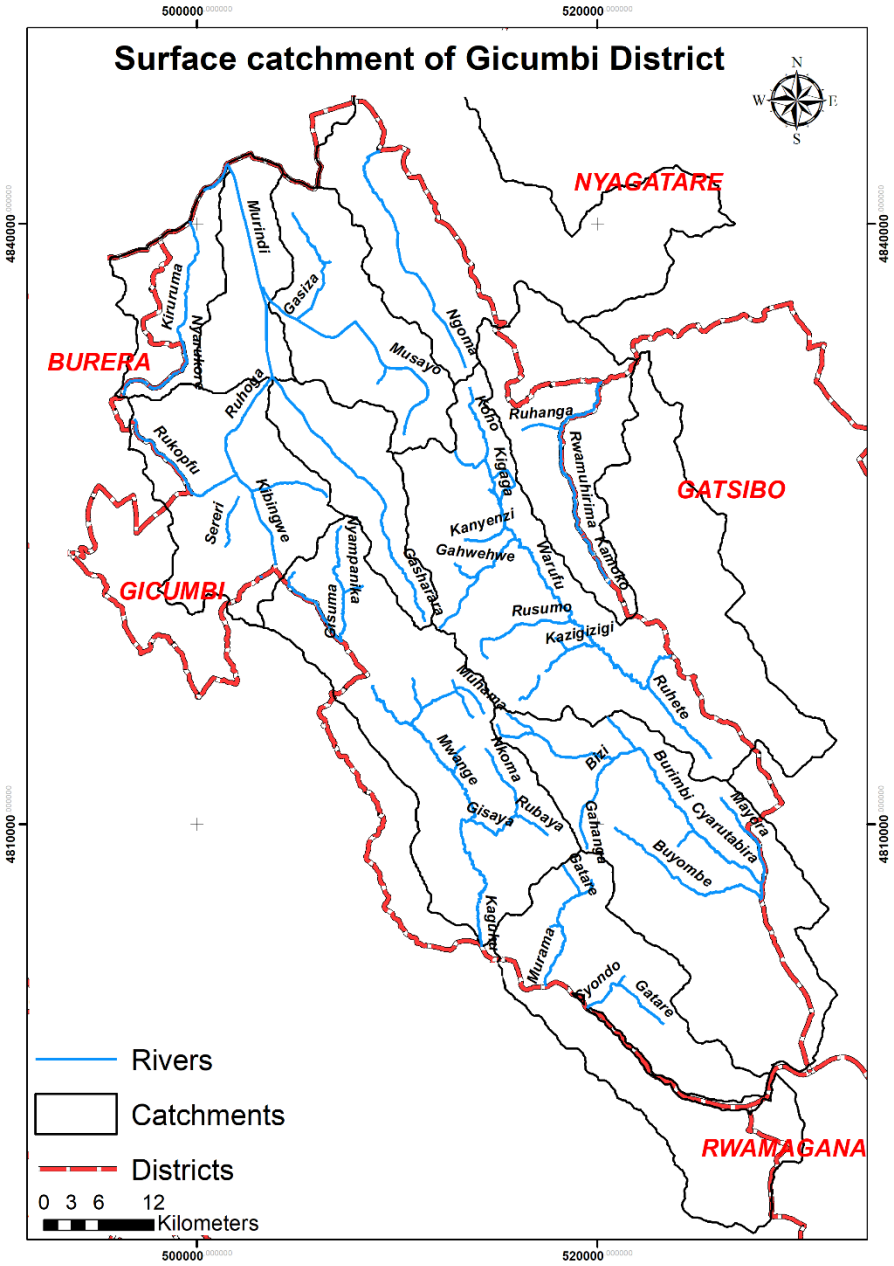


Figure 10: Gicumbi District surface water catchment.

Figure 10 illustrates eleven surface catchments that were identified in Gicumbi District and named after their main rivers. Table 1 provides the list of the delineated surface catchments in Gicumbi District.

Table 6: Gicumbi District Surface Catchment List.

#	Name	Area Km^2
1	Ngoma	149.4715
2	Murindi	38.22582
3	Kiruruma	36.1763
4	Musayo	64.47537
5	Rwamuhirima	71.88115
6	Warufu	209.2106
7	Ruhoga	79.42354
8	Gasharara	41.45291
9	Mwange	128.9916
10	Burimbi	145.5519
11	Murama	116.1636

On figure 9, the delineated recharge catchments are illustrated. A total number of seven large recharge catchments were delineated in and around the Gicumbi District. It was observed that many spring sources originate from the same recharge catchment but in different locations.

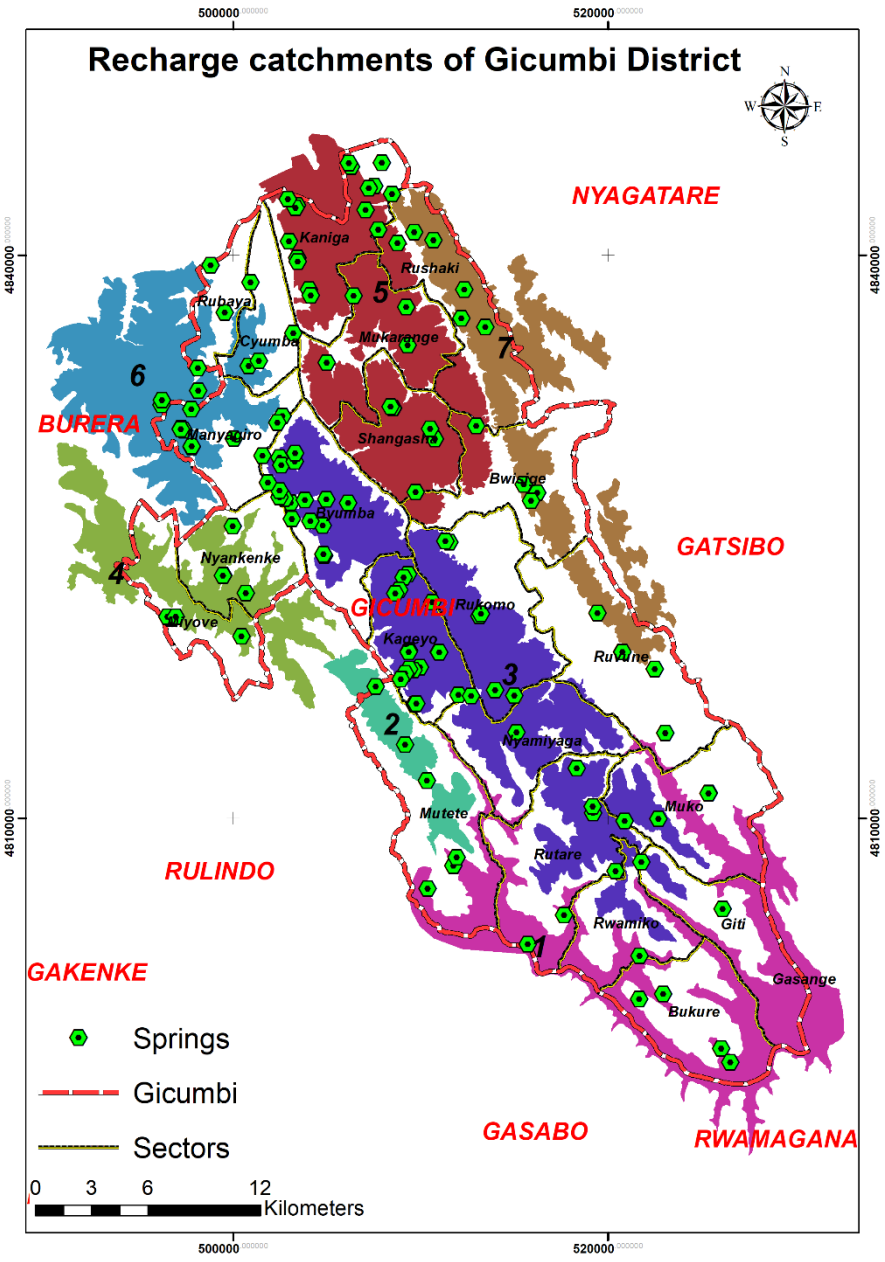


Figure 11: Spring Sources Recharge catchments in Gicumbi District.

A descriptive summary of all recharge catchments is provided in table 3.

Table 7: Descriptive summary of the spring recharge catchments in the study area.

#	Spring recharge catchment	Area sq.km	Administrative location		Number of sample springs
			Districts	Sectors	
1	Recharge catchment 1	121.2	Gasabo, Gicumbi, Gicumbi, Rwamagana, Gatsibo	Gikomero, Fumbwe, Rutunga, Bukure, Gasange, Ntarabana, Giti, Rwamiko, Muhura, Rutare, Muko, Mutete, Nyamiyaga, Ruvune	13
2	Recharge catchment 2	20.1	Gicumbi, Gicumbi	Kisaro	3
3	Recharge catchment 3	149.6	Gicumbi	Giti, Rwamiko, Rutare, Muko, Nyamiyaga, Kageyo, Ruvune, Rukomo, Byumba	63
4	Recharge catchment 4	55.1	Gicumbi, Burera, Gicumbi	Kisaro, Rukozo, Cyungo, Miyove, Nyankenke, Ruhunde	6
5	Recharge catchment 5	119.3	Gicumbi	Bwisige, Shangasha, Mukarange, Rushaki, Kaniga	29
6	Recharge catchment 6	84.2	Burera, Gicumbi	Manyagiro, Gatebe, Bungwe, Rubaya, Cyumba, Kivuye	16
7	Recharge catchment 7	73.2	Gicumbi, Nyagatare, Gatsibo	Ruvune, Gatsibo, Bwisige, Nyagihanga, Rushaki, Mukama, Kiyombe	12

5.3. Recharge catchment management plan

In this section the management plan of each recharge catchment is provided. As described in section 3.6, a standard land husbandry technological approach (based on the Rwandan standard) was adopted to develop these management plans. In this section, each recharge catchment is described separately, while all the component to making up the management plan is discussed as a whole.

5.3.1. Spring recharge catchment 1

The description of the spring recharge catchment 1 is provided in table 7.

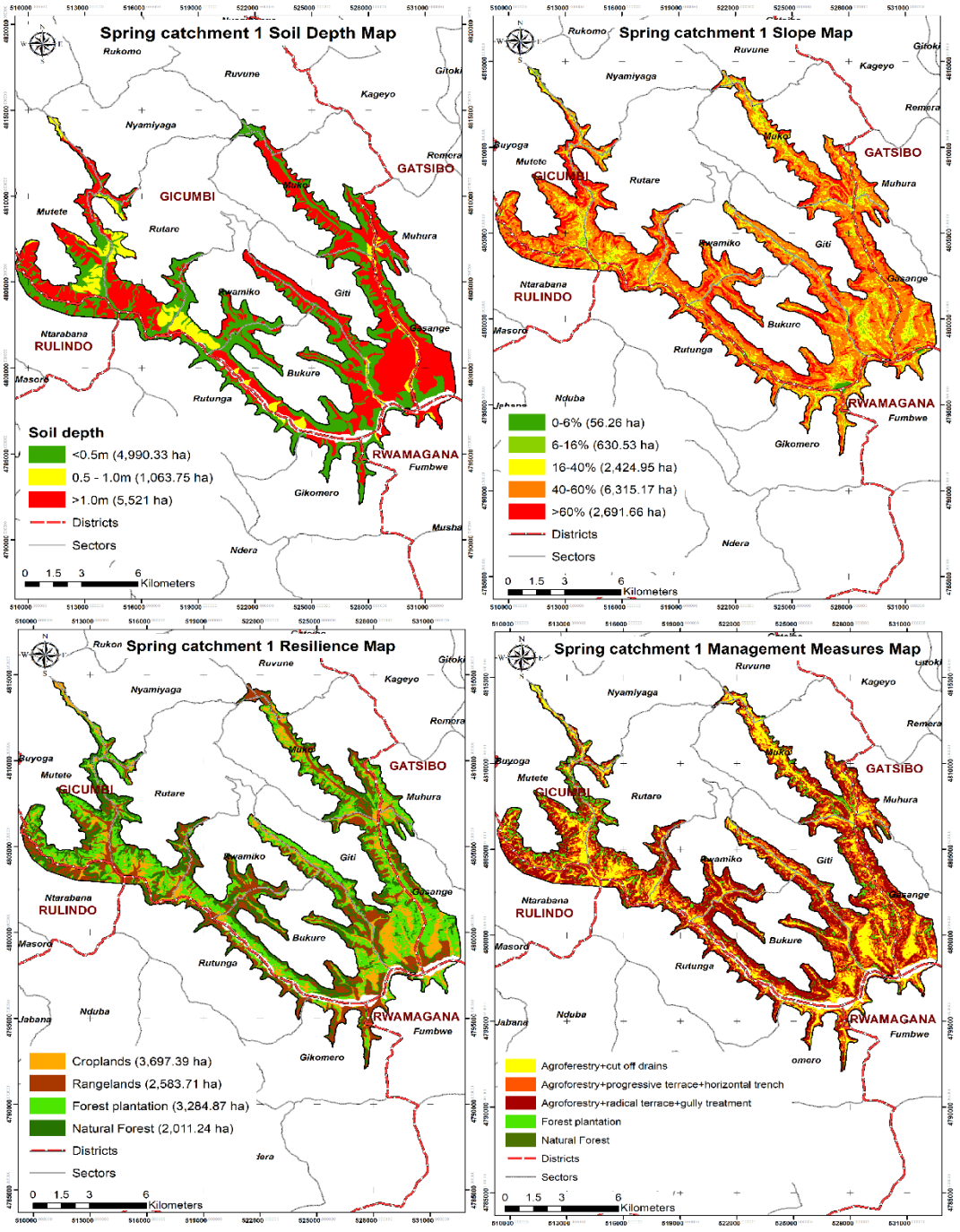


Figure 12: Recharge catchment 1 management plan.

A dominance of deep soil (above 1 m depth covering 5,521 ha) is observed in the recharge catchment 1. In combination to its topographical set up (having 6,315.17 ha of slope varying

between 40-60%), this makes the recharge catchment suitable for radical terracing mostly as the resilience in the area is favorable to croplands and rangelands. Forestry is also included at a potential of more than 5,000 ha. An illustration of the recharge catchment 1 management plan is provided in figure 12.

5.3.2. Spring recharge catchment 2

The description of the spring recharge catchment 2 is provided in table 7.

A dominance of deep soil (above 1 m depth covering 1,173.86 ha) is observed in the recharge catchment 2. In combination to its topographical set up (having 964.49 ha of slope varying between 40-60%), this makes the recharge catchment suitable for radical terracing mostly as the resilience in the area is favorable to croplands and rangelands. Forestry is also included at a potential of more than 1,200 ha. An illustration of the recharge catchment 2 management plan is provided in figure 13.

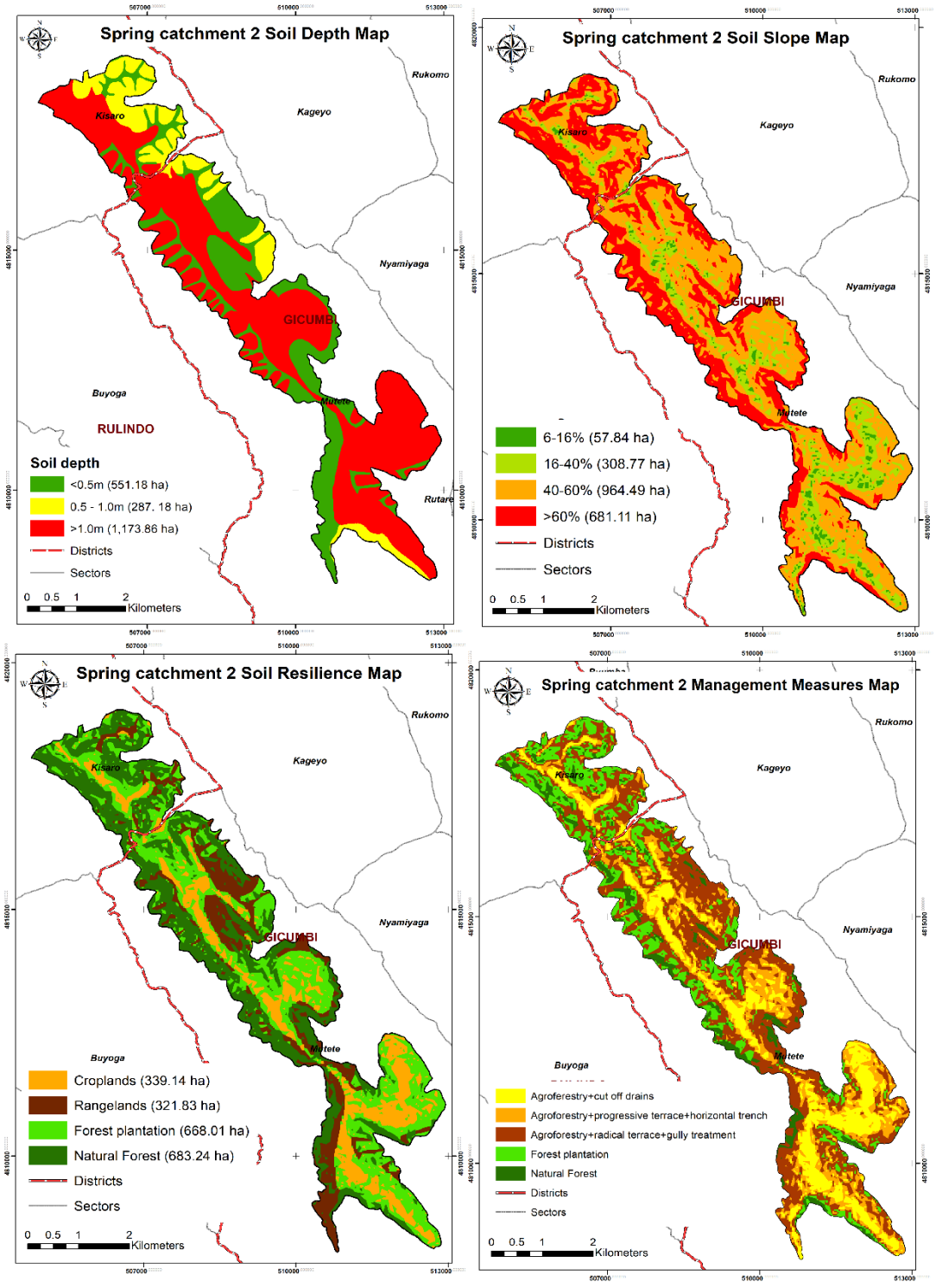


Figure 13: Recharge catchment 2 management plan.

5.3.3. Spring recharge catchment 3

The description of the spring recharge catchment is provided in table 7.

A dominance of deep soil (above 1 m depth covering 7,714.61 ha) is observed in the recharge catchment 3. In combination to its topographical set up (having 7,372 ha of slope varying between 40-60%), this makes the recharge catchment suitable for radical terracing mostly as the resilience in the area is favorable to croplands and rangelands. Forestry is also included at a potential of more than 10,000 ha. An illustration of the recharge catchment 3 management plan is provided in figure 14.

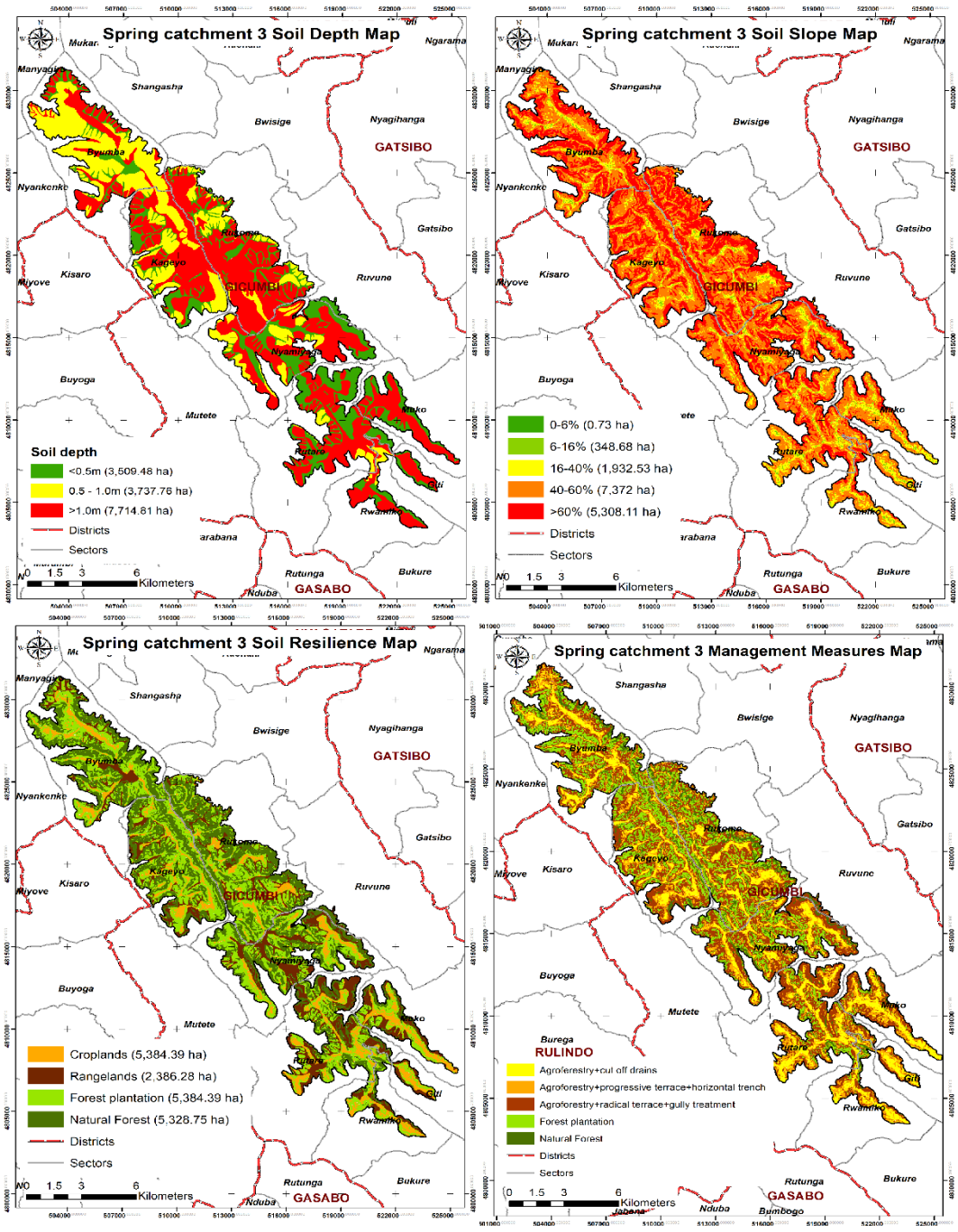


Figure 14: Recharge catchment 3 management plan.

5.3.4. Spring recharge catchment 4

The description of the spring catchment 4 is provided in table 7.

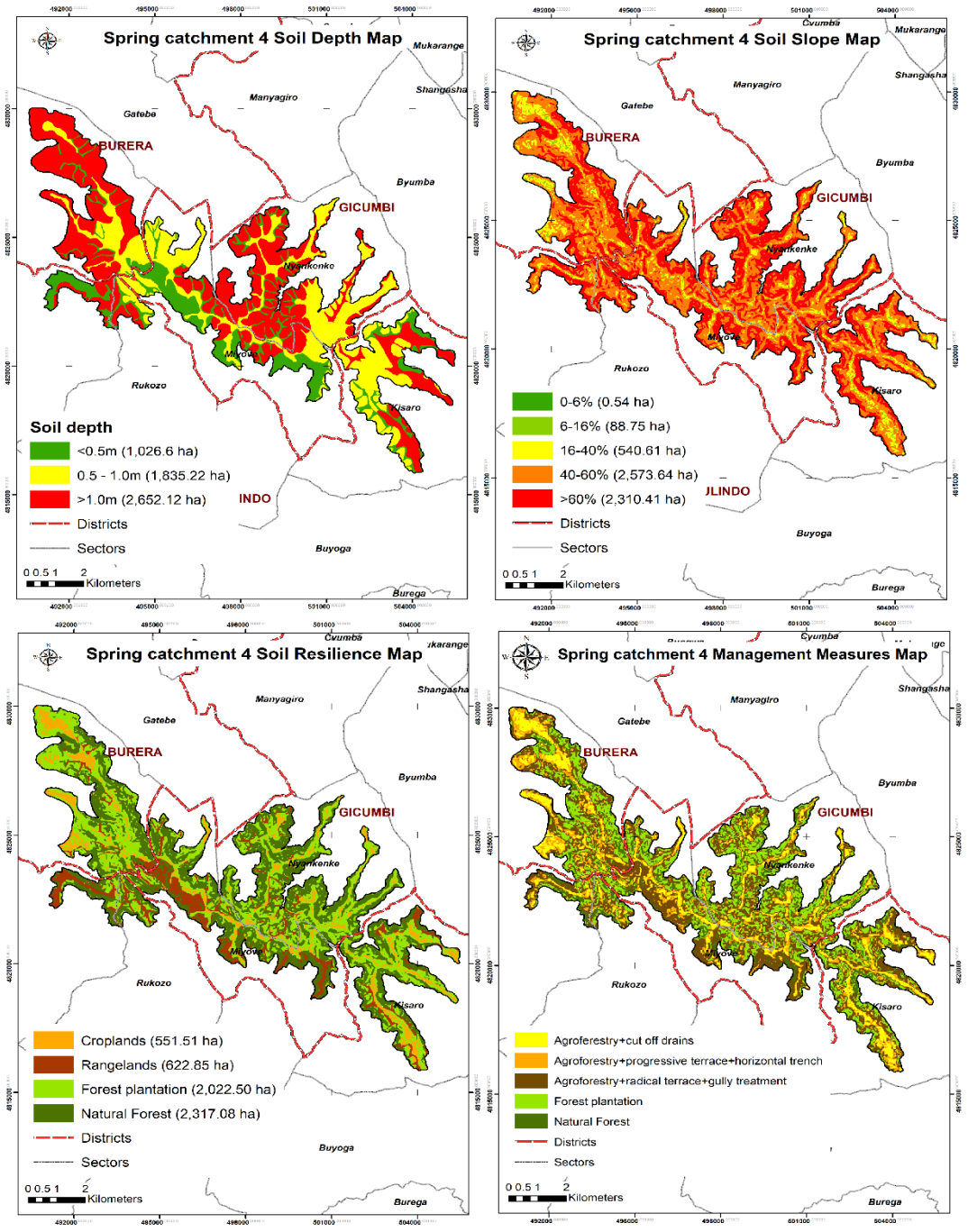


Figure 15: Recharge catchment 4 management plan.

A dominance of deep soil (above 1 m depth covering 2,652.12 ha) is observed in the recharge catchment 4. In combination to its topographical set up (having 2,573.64 ha and 2,310.41 ha) of slope varying between 40-60% and above 60% respectively), this makes the recharge

catchment suitable for radical terracing mostly as the resilience in the area is favorable to croplands and rangelands. In addition, forestry is a major component, with more than 4,000 ha, in this area due to its topography. An illustration of the recharge catchment 4 management plan is provided in figure 15.

5.3.5. Spring recharge catchment 5

The description of the recharge catchment 5 is provided in table 7.

A dominance of moderately deep soil (between 0.5 to 1 m depth covering 6,110.7 ha) is observed in the recharge catchment 5. In combination to its topographical set up (having 4,816.96 ha and 4,722.91 ha of slope varying between 40-60% and above 60% respectively), this makes the recharge catchment suitable for Forestry with a potential of more than 7,000 ha and to some extent radical terracing. An illustration of the recharge catchment 5 management plan is provided in figure 16.

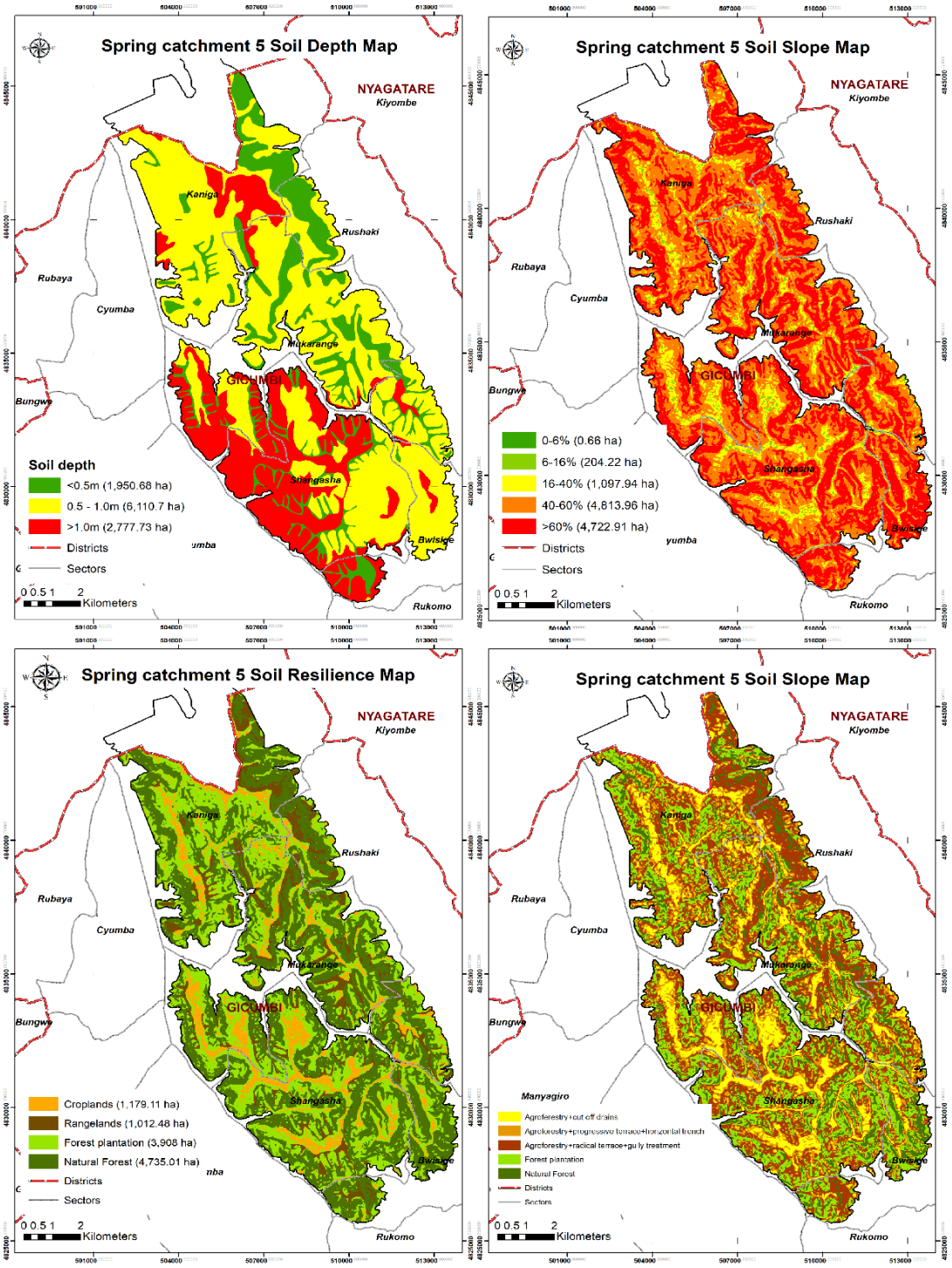


Figure 16: Recharge catchment 5 management plan.

5.3.6. Spring recharge catchment 6

The description of the recharge catchment 6 is provided in table 7.

A dominance of deep soil (above 1 m depth covering 4,380.66 ha) is observed in the recharge catchment 6. In combination to its topographical set up (having 3,606.41 ha and 3,592.27 ha of slope varying between 40-60% and above 60% respectively), this makes the recharge catchment suitable for radical terracing mostly as the resilience in the area is favorable to croplands and rangelands and forestry as well, with a potential of more than 5,000 ha. An illustration of the recharge catchment 6 management plan is provided in figure 17.

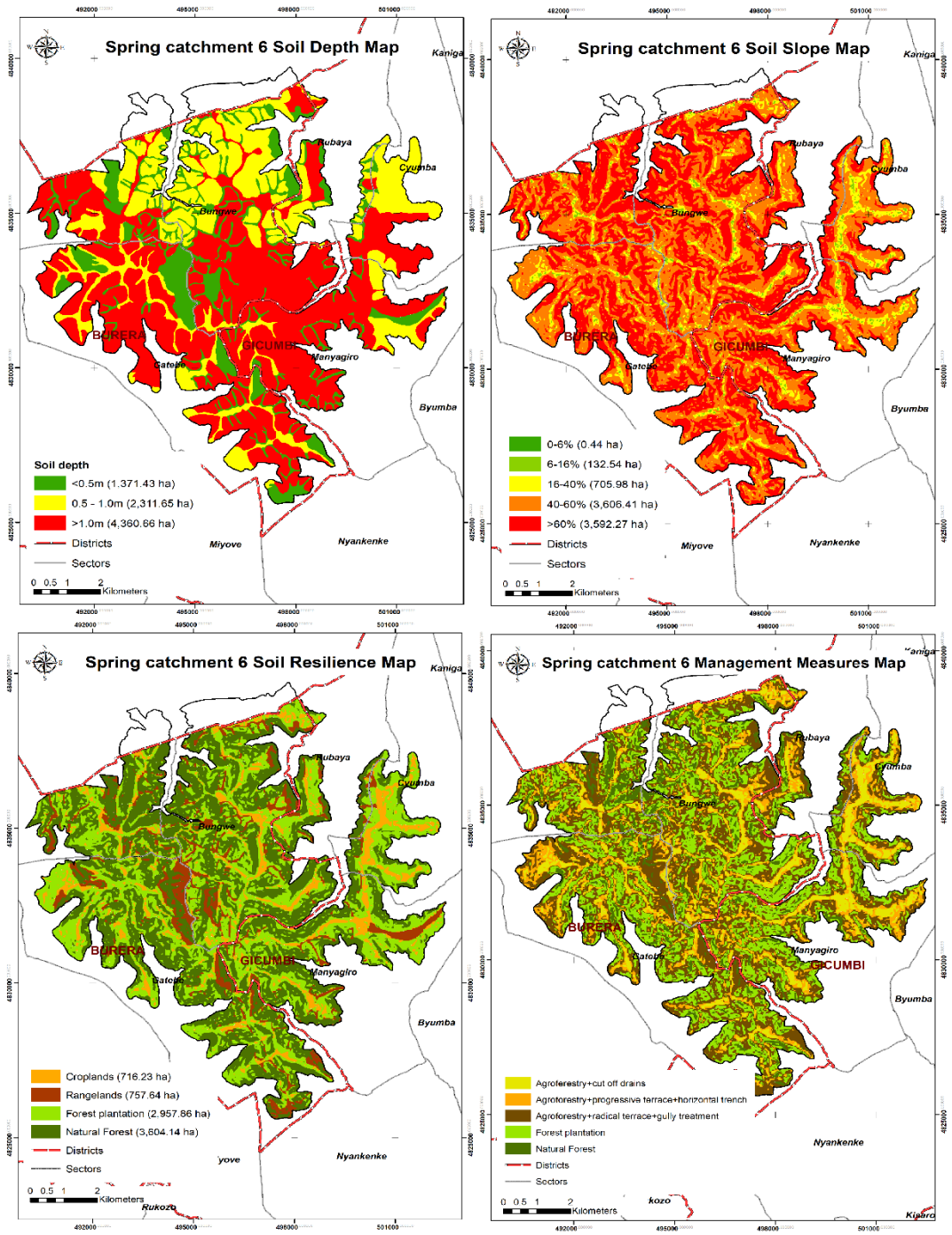


Figure 17: Recharge catchment 6 management plan.

5.3.7. Spring recharge catchment 7

The description of the recharge catchment 7 is provided in table 7.

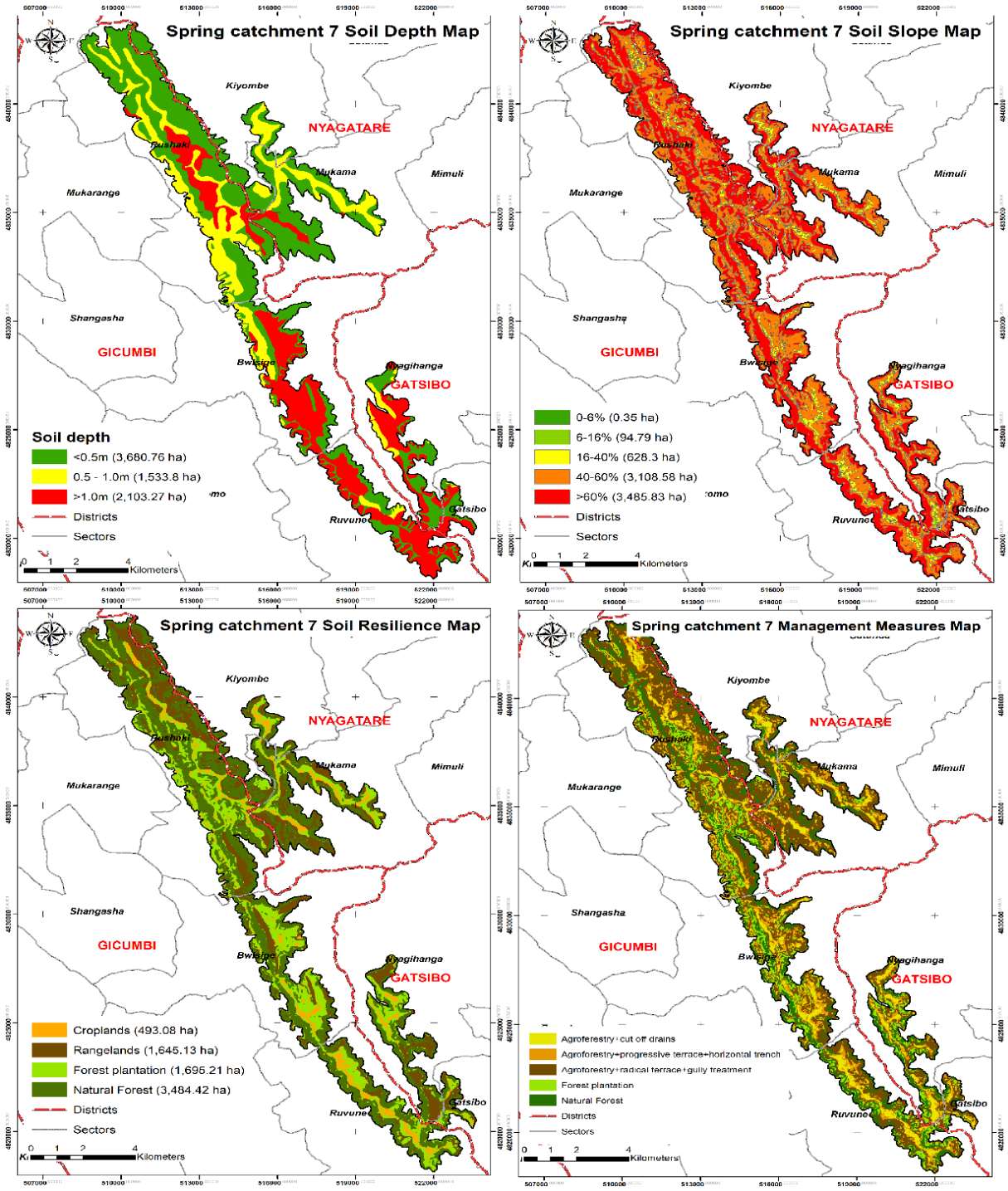


Figure 18: Recharge catchment 7 management plan.

A dominance of shallow soil (less than0.5 m depth covering 3,680.76 ha) is observed in the recharge catchment 7. In combination to its topographical set up (having 3,108.58 ha and 3,485.83 ha of slope varying between 40-60% and above 60% respectively), this makes the recharge catchment suitable for forestry with a potential of more than 4,000 ha and limited radical terracing especially in the Northern East part of the recharge catchment 7. An illustration of the recharge catchment 7 management plan is provided in figure 18.

6. Hydrology

6.1. Physical description of the Mwange River catchment

Mwange River catchment is approximately 123 sq. km. agriculture is the major land use in the catchment. Forest cover is very limited in the catchment and its location is in the lowland, especially near the outlet of the catchment. The topography of the catchment is complex, in the sense that abrupt changes on small distance, resulting in steep slopes are observed along the catchment. It varies approximately between 1,435 and 2,283 m a.s.l. The soil classes in the catchment are mainly composed of humic soils (indicate high organic matter content in the soil). Dystric soils (poor in nutrients and found in tropical area) are also spread across the catchment area. In addition Umbric soils (dark soil rich in organic matter) are concentrated at the outlet of the catchment, where an irrigation scheme is located. Four geological formation are observed in the catchment area. The main formation is the Rk (known as the Rukomo formation: Conglomerate of gravel, sandstone grain size and schist regularly alternating between beds and bench). In addition, these formations Ho (Alluvial of valley, lower & middle terraces, cones of dejection. Holocene & Pleistocene undifferentiated), Bus (Base formation: Pelitical dominant matrix with graphitic membranes of black schist and thick regular bedding membranes of fine sandstone and schist with large benches of isolated sandstone) and Bi (Bulimbi formation: Pelitical dominant matrix with very thick membranes made of a regular alternation of sandstone and schist beds. Local levels volcano-sedimentary character) are also observed in the catchment area. The Rk formation is known to favor high infiltration into the soil as a result of its physical characteristics (soil mechanics).

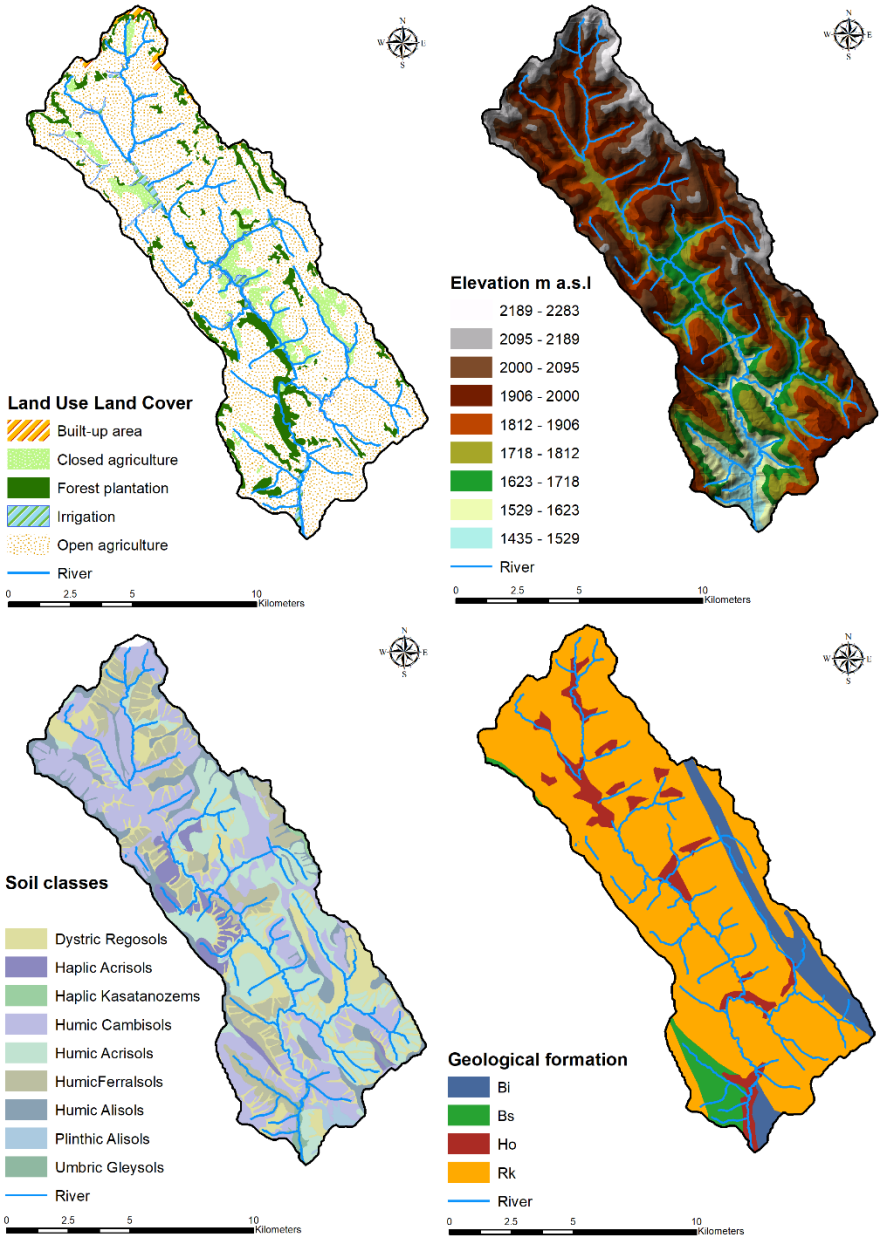


Figure 19: Physical characteristics of the Mwange River catchment.

6.2. Climate of the Mwange River catchment

The Mwange River catchment has a humid climate, related to its altitude. Its annual rainfall distribution varies approximately between 1,000 and 1, 200 mm per year, making the catchment heavily wet throughout the year. Its potential evapotranspiration (Potential ET on figure 20) is high due to the land cover of the area. The annual variation of the PET in the Mwange River catchment is between 590 and 1,000 mm per year approximately. Due to high altitude and high rainfall in the area, the temperature are low and relative humidity high. Their respective averages per year vary between 16.5 ^{0}C to 19 ^{0}C and 73% to 83% respectively.

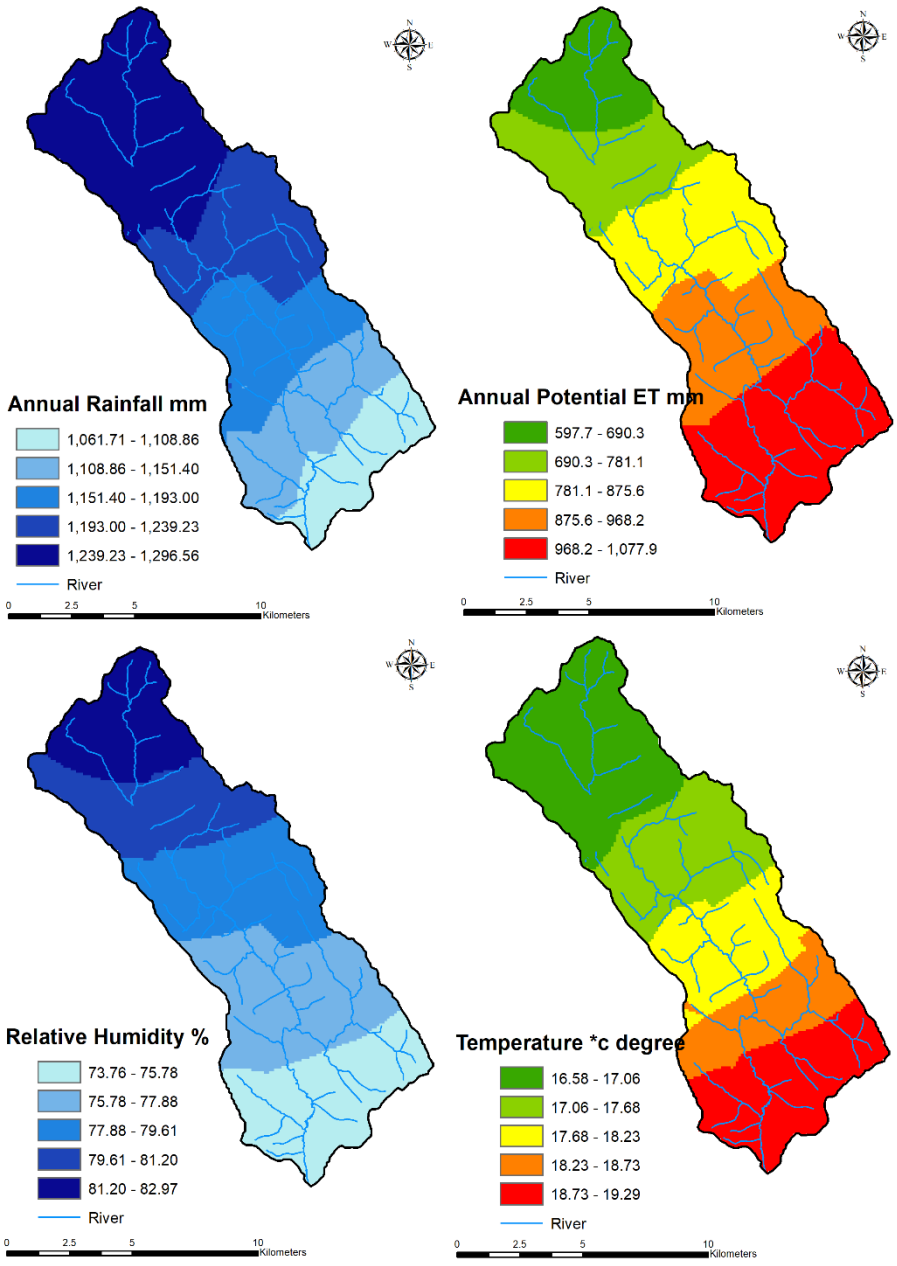


Figure 20: Climate of Mwange River catchment.

6.2.1. Daily Rainfall of the Mwange River catchment

The average daily rainfall pattern of a typical hydrological year in the Mwange River catchment has 4 seasons. Heavy rainfall up to approximately 14 mm a day is experienced in the beginning of the year followed by a heavy dry season with rainfall of approximately 2 mm per day and less in the middle of the year and medium rainfall depths of up to approximately 4 mm in the last part of the year. Figure 21 illustrates the above-mentioned rainfall pattern.

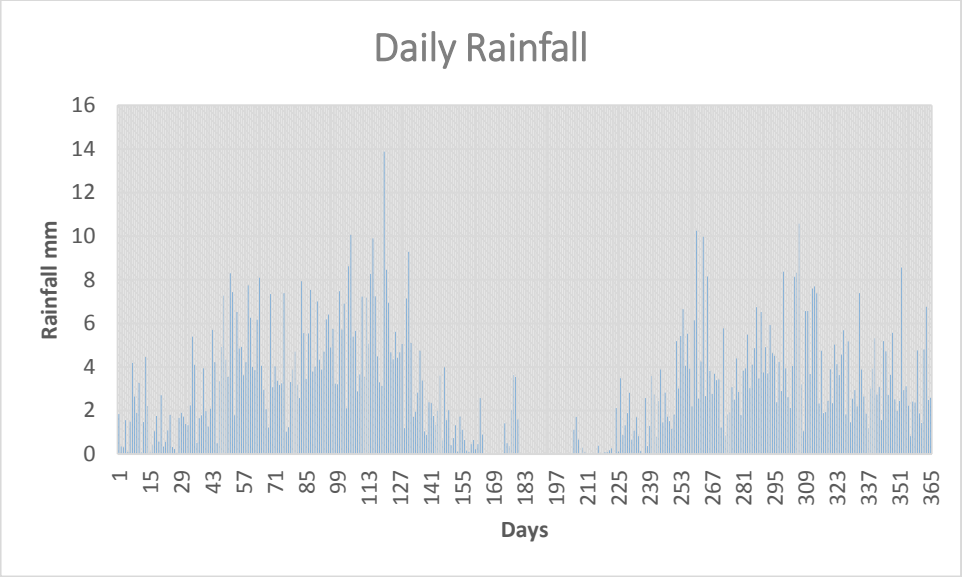


Figure 21: Daily rainfall pattern.

The same pattern is observed in terms of monthly figures as illustrated on figure22. This clearly shows that the months of March, April and May constitute the biggest supply of rainfall water and therefore aquifer recharge. This is followed by the heavy dry period representing the biggest water consumption period lasting from June to August. The rest of the months representing a medium recharge period. Depending on the degree of water consumption (especially when unplanned) this period can easily serve for only recharging lightly the natural water system.

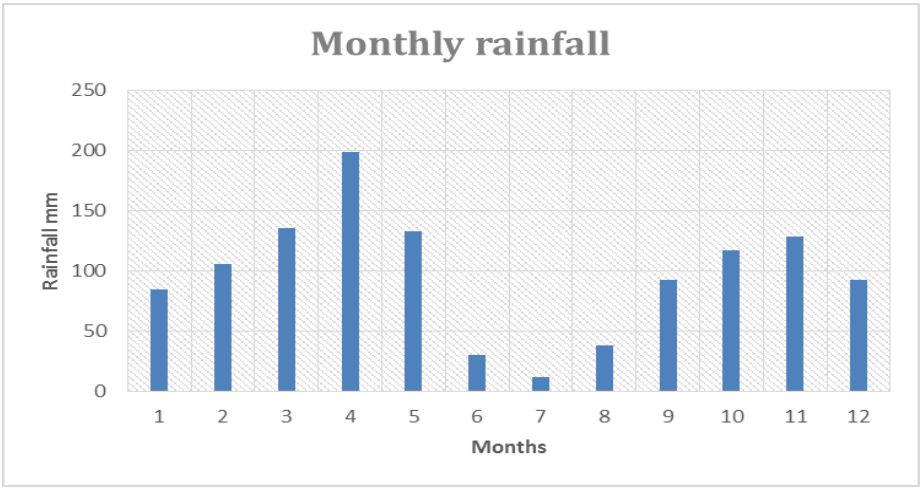


Figure 22: Monthly rainfall.

6.2.2. Daily Temperature of the Mwange River catchment

The temperature pattern varies between 20^0 and 23^0 Celsius as illustrated on figure 23. On average the catchment is observed to be a cool area. The pattern of temperature indicate normally that the sun energy supply, which consequently provides indication on how much water losses are to be expected through evapotranspiration in the area.

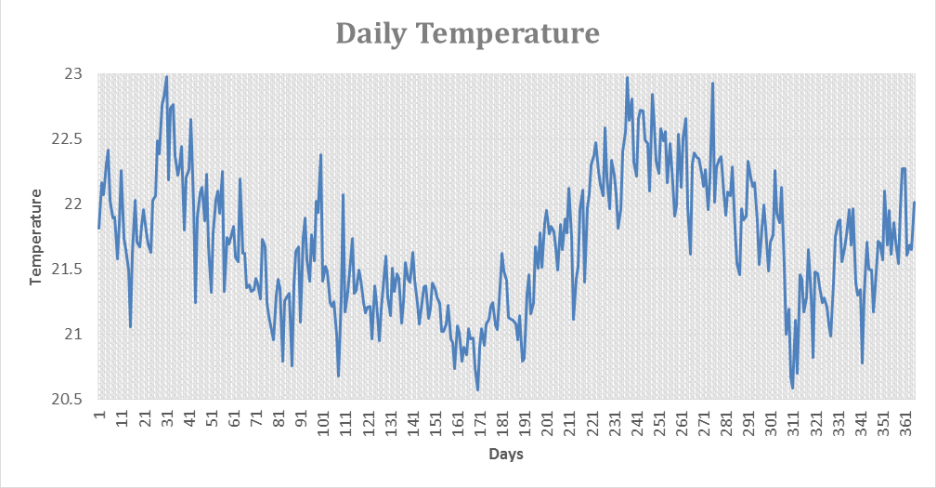


Figure 23: Daily temperature.

The pattern is clearly shown on the monthly figures illustrated in figure 24. Two patterns of high temperature are observed at the beginning of the year (January and February) and the middle end of the year (August, September and October).

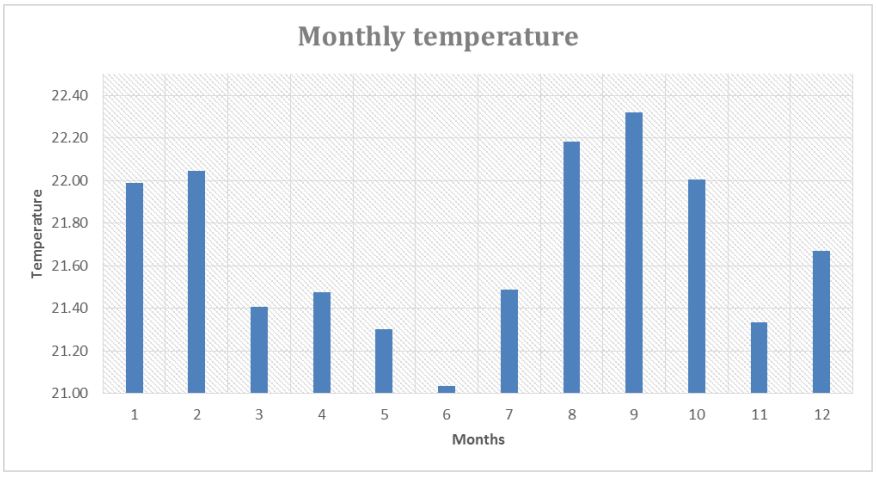


Figure 24: Monthly Temperature.

6.2.3. *Daily Evapotranspiration of the Mwange River catchment*

The evapotranspiration constitutes the biggest natural water loss of the Mwange River catchment. This process is a component of the water cycle, technically it is not a water loss however; for the purpose of water resources management it is considered as such because it cannot be harvested nor used. Its pattern differ from the rainfall. It can be observed from figure 25 that heavy daily evapotranspiration occurs in August. The reason of this trend can be explained by the fact that evapotranspiration occur when energy, water and plants are available. In August there is enough energy from the sun mixed with water in the natural system, additionally for the month of July an explanation of the high evapotranspiration will be related to the probable heavy transpiration from plants.

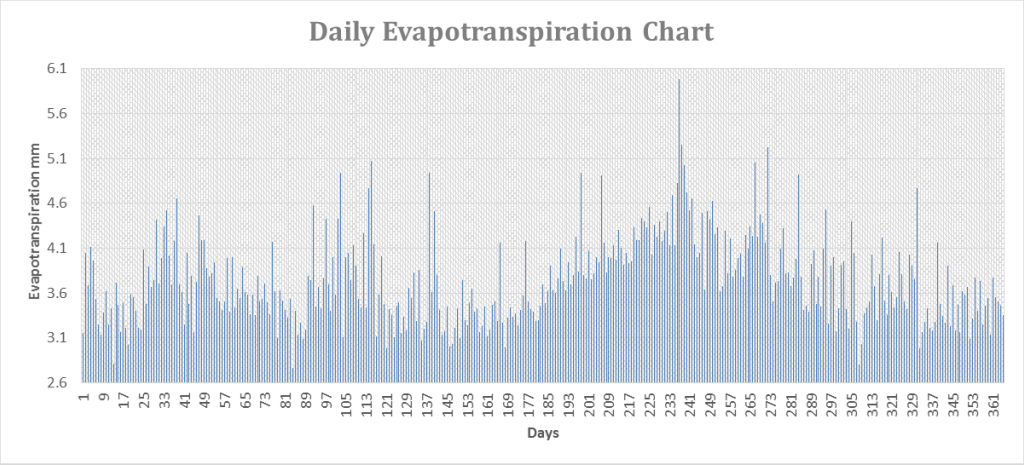


Figure 25: Daily evapotranspiration.

The pattern is clearly shown on the monthly figures illustrated in figure 26. The last part of the year has high evapotranspiration, considering the medium rainfall contribution; this will constitutes a limited recharge period for the catchment water resources system in general.

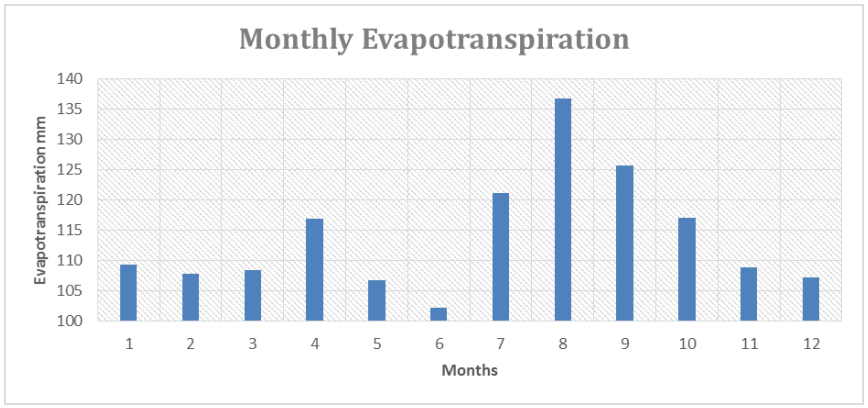


Figure 26: Monthly evapotranspiration of Gicumbi.

6.3. Existing flow data

The illustrated catchments in figure 10 are the entire river system considered with either the whole catchment included in the Gicumbi District or a portion of it but which can be easily accessed from within the District. There is an existing gauging station on Mwange River. The flow data from this station was analyzed in this study to provide a basic indication of the availability of the water resources in terms of surface water.

The following section discuss the available flow data. These were obtained from the existing database of the Rwanda Water and Forestry Authority. The available data were limited but they served to estimate an average daily flow at the gauging station of the Mwange river. Note that, flow data are a result of water level data that were converted into flow data using a rating curve developed at the gauging station section of the Mwange river.

The Mwange River has a flow variation between 0.1 and 0.5 cubic meters per second on daily average within its hydrological year. The potential of this river is limited, however possibility of combining many river resources for exploitation is not to be excluded.

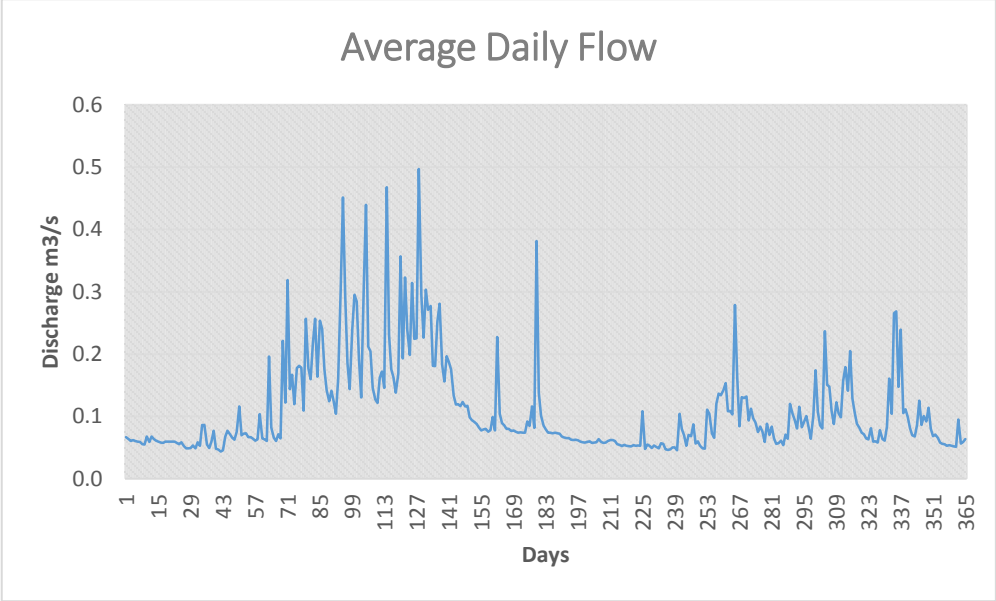


Figure 27: Mwange River Daily Flow.

The pattern of the Mwange River indicates that the River Mwange has a direct response to rainfall in the area. Also, the Base flow of the river is quite high compare to the size of the river indicating that this river maybe easily polluted from the surrounding activities in the area. As the pattern is directly linking to rainfall, it is advised for proper river water utilization, to think about storing the water during the rainfall period and using tit during the

dry season. It is important to note that, this types of river normally have a very sensitive ecosystem, which requires a proper determination of its environmental flow during dry and wet periods respectively.

6.4. Infiltration estimation

Infiltration data in Mwange River catchment were missing, however with the existing soil data an estimation of the potential for infiltration within the area was possible. Using the available soil data, the saturated hydraulic conductivity (exprssed in inch per hour) was analyzed as this is related to the soil texture and structure. The hydraulic conductivity, in principle, describes the ease with which a soil material can let water move through its pore space and sometimes fractures. Analyzing this parameter under saturated conditions provided a picture of the recharge sensitivity and capacity of the aquifers of the Mwange River catchment. Figure 28 provides the variation of the saturated hydraulic conductivity obtained for the catchment area.

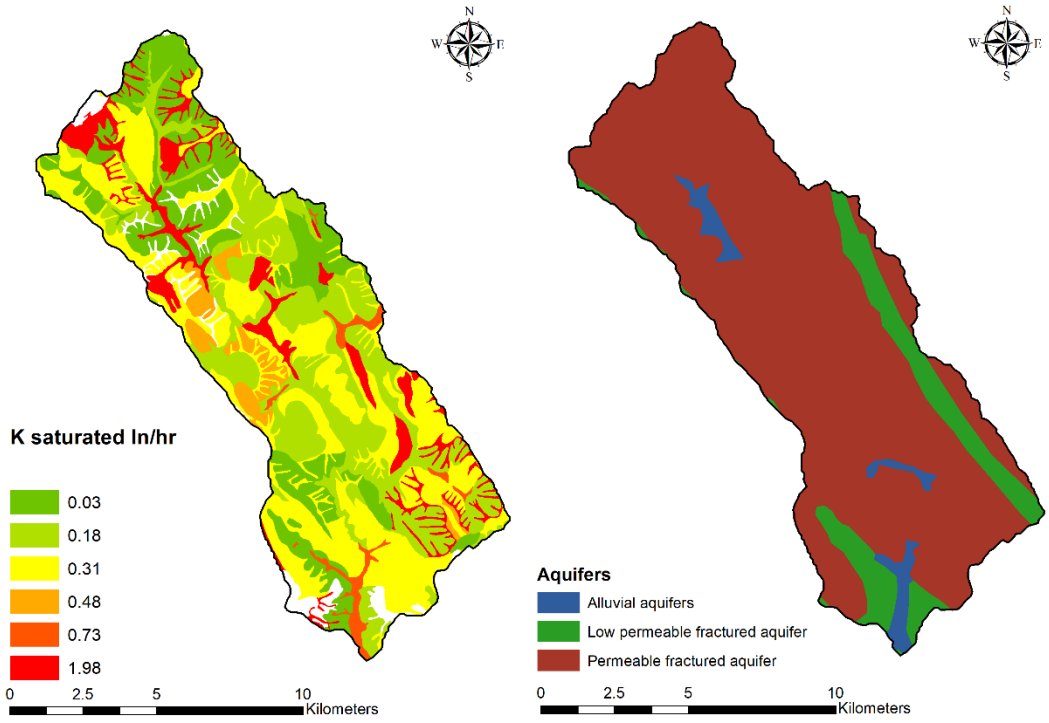


Figure 28: Saturated Hydraulic Conductivity and lithology maps.

A general description of Mwange River catchment saturated hydraulic conductivity indicates that it varies mostly from low to medium hydraulic conductivity during saturated conditions. Saturated conditions represent maximum water flow within the soil, at this stage all the pore space are filled with water and water can move easily within the soil, implying that for small

and very high hydraulic conductivities in the area, the high the sensitivity of the soil-water system to the land use/land cover. This particularly lead to promoting soil management measures which will consequently conserve, restore and/or improve the infiltration capacity of the soil in the area, therefore positively affecting the infiltration capacity of the soil and ultimately the recharge rate of the aquifers. Note that, the type of aquifers under the Mwange River catchment do not hold water because of the fractures meaning that pumping them maybe easy similarly as polluting them. There is also a probability of baseflow contribution from these aquifer during the dry period. In this case, any pollution from the catchment may ultimatly be observed in the River. Attention has to be taken when implementing any kind of measures to protect the soil and conserve water in this catchment. Also, the use of pit latrines as a sanitation technology pauses a quality threat to the groundwater resources in the area.

7. Water demand and balance estimation

The water demand was performed to assess the sustainability of a proposed development for each sector as far as it's the equilibrium between available water resource and demand is concerned. This analysis for Gicumbi District was done per sector per each 5 years up to 2043 (a horizon of 25 years).

7.1. Available water sources

During the field work, a good number of water springs were identified. These identified springs were combined with previously identified water sources by WFP with a crosschecking for the springs mentioned in the hydraulic plan of the Gicumbi District. The following table shows the number of springs recorded for each sector and the spring discharge, GPS coordinates and if the spring is captured or not captured. In addition, an excel sheet presenting in detail each spring is annexed to this report.

Table 8: Number of springs and total discharge in dry season per sector

Sector	No. of springs	Discharge (L/S)
Bukure	**7**	4.3
Bwisige	**13**	8.8
Byumba	**61**	73.5
Cyumba	**7**	4.4
Giti	**6**	4.3
Kageyo	**31**	17
Kaniga	**22**	11.8
Manyagiro	**27**	13.1
Miyove	**14**	12.7
Mukarange	**13**	13.7
Muko	**15**	10.4
Mutete	**13**	9.7
Nyamiyaga	**11**	14.2
Nyankenke	**11**	3
Rubaya	**10**	9.6
Rukomo	**11**	1.9
Rushaki	**23**	8.8
Rutare	**21**	8.8
Ruvune	**5**	2.7
Rwamiko	**7**	5.6
Shangasha	**29**	15.2

7.2. Estimation on water demand

7.2.1. Consumption rate of National Master Plans

According to Rwanda National Water Resources Master Plan, following gradually improving living standards and gradually converges between rural and urban population, the water demand per capita will be changing as follows:

Table 9: Projected standard for water consumption per capita in Gicumbi District.

Year	*2018*	*2023*	*2033*	*2043*
L/capita/day	40	60	80	100

Therefore for the future plan different scenario considering the above demand were made for 40, 60, 80 and 100 liters/capita/day. According to the ToR, water demand should be estimated in 25 years from 2018. The current demographic statistics were gathered in 2012, population were projected taking the time horizon of 31 years (from 2012-2043) as illustrated in table10 below.

Table 10: Estimated population per sector.

Sector	Population in 2012	Population in 2018	Population in 2023	Population in 2028	Population in 2033	Population in 2038	Population in 2043
Bukure	16,498	17,933	19,224	20,608	22,092	23,682	25,387
Bwisige	15,429	16,771	17,979	19,273	20,660	22,147	23,742
Byumba	35,106	38,160	40,907	43,852	47,009	50,393	54,020
Cyumba	14,838	16,129	17,290	18,535	19,869	21,299	22,832
Giti	14,000	15,218	16,313	17,488	18,747	20,096	21,543
Kageyo	31,327	34,052	36,504	39,131	41,948	44,968	48,205
Kaniga	14,711	15,991	17,142	18,376	19,699	21,117	22,637
Manyagiro	19,495	21,191	22,716	24,352	26,105	27,984	29,999
Miyove	16,612	18,057	19,357	20,751	22,244	23,846	25,562
Mukarange	17,296	18,801	20,154	21,605	23,160	24,827	26,615
Muko	16,914	18,385	19,709	21,128	22,649	24,279	26,027
Mutete	23,977	26,063	27,939	29,950	32,106	34,418	36,895
Nyamiyaga	17,826	19,377	20,772	22,267	23,870	25,588	27,430
Nyankenke	19,889	21,619	23,176	24,844	26,632	28,550	30,605
Rubaya	10,668	11,596	12,431	13,326	14,285	15,313	16,416
Rukomo	24,096	26,192	28,078	30,099	32,266	34,589	37,078
Rushaki	12,505	13,593	14,571	15,620	16,745	17,950	19,242
Rutare	22,602	24,568	26,337	28,233	30,265	32,444	34,780
Ruvune	18,782	20,416	21,886	23,461	25,150	26,961	28,901
Rwamiko	12,456	13,540	14,514	15,559	16,679	17,880	19,167
Shangasha	15,759	17,130	18,363	19,685	21,102	22,621	24,250
Total	**390,786**	**424,782**	**455,362**	**488,143**	**523,282**	**560,952**	**601,333**

Regarding public institutions, the water needs of centers and health posts were established at the rate of 100 liters while for educational institutions was considered 50 liters per pupil per day as the average because in non-boarding school the water consumption is generally low. For Market and office space an additional 10 liters per day per person was computed to account for extra used by citizen of Gicumbi while using the facilities.

7.2.2. Water demand scenarios

Two scenarios have been used to compute the water consumption based on the two main driving factors of water demand which are population growth and the change in livelihood and lifestyle. The first scenario was based on conservative growth rate of the population estimating that all rural sectors will have a consumption rate of 20 liters per person and per day while the urban area (Byumba, Kageyo, Miyove, Rubaya and Rukomo sectors) will have a consumption rate of 20 liters per person and per day. Boarding student were considers as urban areas while the other schools and centers and office had an increment of 5 liters per day per person additional.

A second dynamic scenarios was considering a dynamic consumption rate according to the national water master plan as presented in the section 7.2.1., the other consumptive demand were kept identical in the two scenario.

7.2.3. Other consumptive demand

According to Rwanda National Water Resources Master Plan, the daily water consumption for the different kind of cattle commonly raised in Rwanda is as detailed in table 11.

Table 11: Water demand per cattle.

Cattle type	*Assumed daily water demand [l/head/day]*	*Number of local cow equivalent*
Cow - local	20	1
Cow - improved - milk	50	2.5
Goat	8	0.4
Sheep	8	0.4
Swine	15	0.75
Chicken / Rabbit	0.5	0.025

For the records of livestock, we used the records at sector level. Considering the availability of grazing and fodder land, we assumed that the number of cattle remains more or less constant over the life time of this projection; the assumption was also used in Rwanda National Water Resources Master Plan. The majority of cattle breeds are cross breed, which increasingly tend to improve breeds, the daily water for cattle is 35l/head/day to be

42.5l/head/day in 2028 and 50l/head/day in 2038. Appendix 1 provides the estimated water demand for each sector.

In addition, the water demand for industries was included in this report based on the few existing industries in the district but also on the planned industries in the near future. The data for planned and existing industries were obtained from the Gicumbi District Strategy of Transformation, the Gicumbi District Master Plan as well as the Gicumbi district hydraulic plan. Appendix 2 provides the type of industry that was considered per each sector for the water demand estimation. Thus, the water demand were estimated per each five years until 2043 considering the population growth and the increase of other water demand activities such as livestock and industrial consumption. Irrigation is very insignificant in Gicumbi with only 1.7 % of irrigation monitored by the seasonal agriculture survey in 2017 (NISR, 2018). The evapotranspiration was calculated based on average of Rwesero and Byumba meteorological station with 3mm/day for surface irrigation and 0.8 mm for traditional irrigation.

Figure 29: Water demand for Gicumbi District per sector estimation (A) conservation water consumption rate scenario; (B) scenario based on National Water Master Plan consumption rate

7.3. Water demand and balance in Gicumbi District

Figure 30 illustrates the findings from the water demand and balance analysis for each Sector of Gicumbi District. Attention is required to understand that the water demand/balance analysis was done based on the daily basis with quantities expressed in liters per day. The deficit and surplus (or in other words the water balance) were calculated as the difference of water available (from existing spring sources) and water demands. In this particular case, the unit is a representative "per capita" demand measure that encloses all the types of consumers

in one single unit (i.e. all the water users such as humans, livestock, industries, etc.) are all represented by the term "per unit". This was done for appropriate illustration and analysis. An integrated water resource development plan is supposed to consider all the water uses and this is facilitated with the "per unit" approach as it considers all the uses and scale per day consumption. The water demand estimation used population growth scenarios and water consumption rate projection presented in the section 7.2.

As shown in figure 30, under a conservative scenario A for water consumption rate nearly ½ of sectors are non-water deficit, but with a modest surplus. Under this scenario in 20 years, only Shangasha and Rushaki will be non-water deficit sectors, while in 10 years Byumba, Manyagiro and Rubaya will still be non-water-deficit.

In a dynamic water consumption rate scenario B, the general observations are that the Sectors of Byumba, Miyove, Kageyo, Rushaki, Nyamiyaga, Rubaya and Shangasha are currently (2018) the only non-water deficit Sector of all. Byumba and Rubaya Sectors under the population growth and water demand per capita scenario will remain the only non-water deficit sector for the next 10 years. The reason of the deficit is not mainly the water demand (Byumba sector having the highest) but the number of springs captured and managed that favored Byumba sector with more than 60 springs used for the water supply of the Town.

Some sectors required specific attention given the number springs known and managed that are very low (the detailed list of springs and their status is presented in a separate excel sheet appended to this report). The sector Cyumba, Ruvune, Rwamiko and Giti Sectors are particularly deficient in water supply considering the number springs (less than 10), particularly Cyumba and Ruvune Sectors with total discharge of less than 5 liters per second.

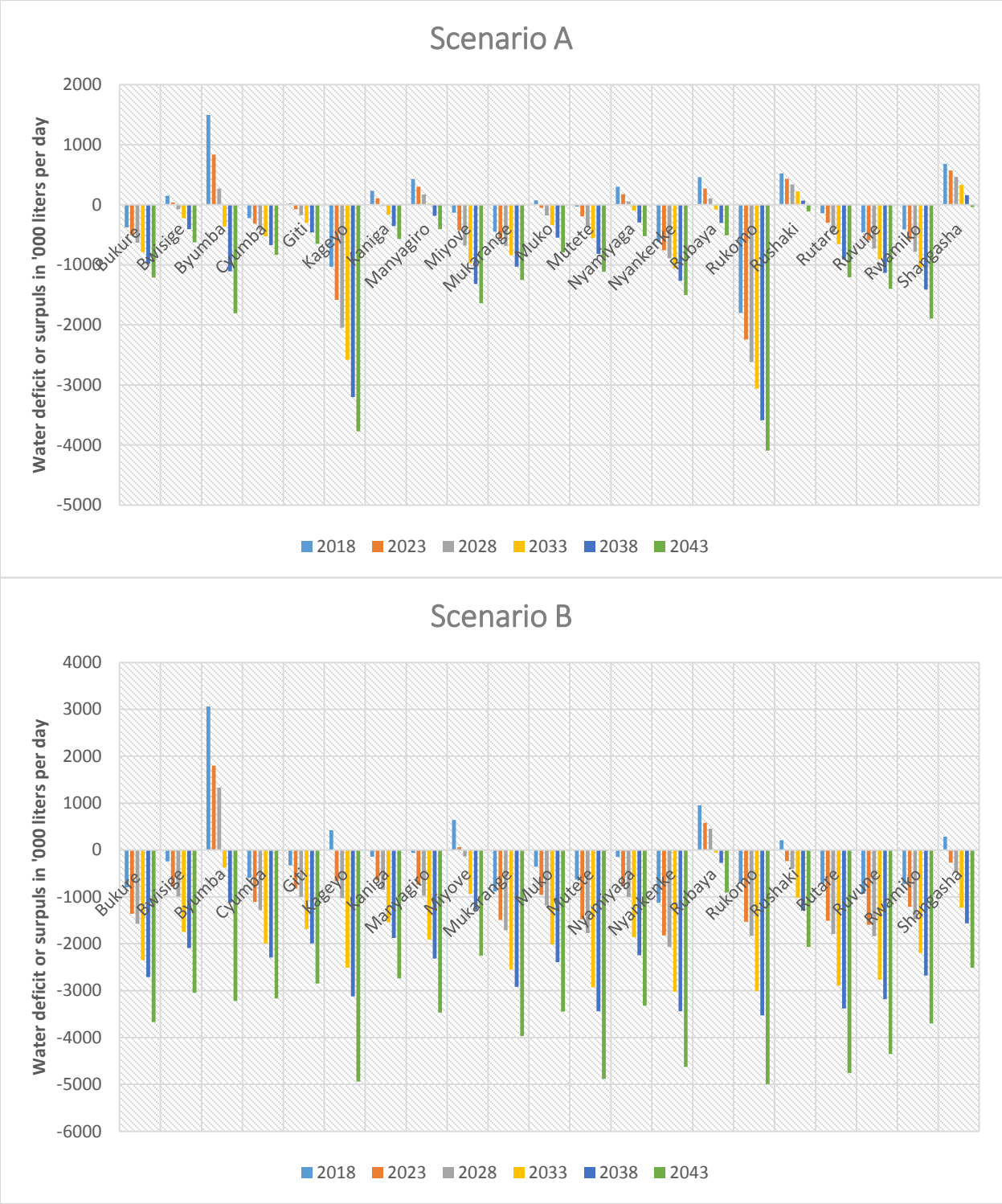


Figure 30: Deficit vs Surplus of water in Gicumbi District (A) conservation water consumption rate scenario; (B) scenario based on National Water Master Plan consumption rate

8. Water quality analysis

Water quality analysis was conducted during the rain season in April and beginning May 2018 and during the dry season in the beginning of August 2018. In total, 100 water sources and Mwange River located in Gicumbi district were analyzed for pH, Turbididty, Total Coliforms, Total Phosphorous, Total Nitrogen, Iron and Manganese. These parameters were analyzed by the UR laboratories specialized in water quality control. The analysis of results were compared to Rwanda standards and WHO guideline standards for drinking water. Table 7 shows the laboratory results from the rain season (RS) and the dry Season (DS). The gray color shading in the results indicate that sampled water has exceeded the Rwanda standard limit or range.

Table 12: Water quality analysis.

SN	Name of Water source	District/Sector/Cell/Village/name	pH		Turb (NTU)		Fe (mg/l)		Mn (mg/l)		TN (mg/l)		TP (mg/l)		Tot Col (CFU)	
			RS	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS
1	Kavure	Gicumbi/Byumba/Kivugiza/Karambi	4.98	4.56	0.54	0.20	0.03	0.03	0.078	0.004	1.49	0.09	0.32	0.4	0	0
2	Gatuku	Gicumbi/Byumba/Kivugiza/Mugando	5.38	4.82	0.40	0.29	0.03	0.01	0.057	0.004	1.48	0.05	0.08	0.32	3	0
3	Ndungutse	Gicumbi/Byumba/Kivugiza/Kivugiza	4.90	4.97	0.59	0.92	0.03	0.04	0.054	0.013	1.49	0.07	0.1	0.33	0	0
4	Nyiragicyiye	Gicumbi/Byumba/Kivugiza/Kivugiza	5.35	4.75	0.73	0.82	0.04	0.03	0.057	0.009	1.49	0.04	0.08	0.35	0	6
5	Sehuku	Gicumbi/Byumba/Kivugiza/Kivugiza	5.18	4.76	0.26	0.27	0.02	0.04	0.015	0.007	1.49	0.03	0.08	0.45	0	1
6	Gasiza 2	Gicumbi/Byumba/Nyamabuye/Gasiza	4.77	5.77	0.80	0.98	0.08	0.06	0.065	0.01	1.47	0.02	0.07	0.28	0	0
7	Nyakagezi	Gicumbi/Byumba/Kivugiza/Kabingo	5.36	5.20	0.48	0.11	0.04	0.02	0.092	0.024	1.49	0.01	0.09	0.34	2	0
8	Nyamusangwa	Gicumbi/Byumba/Kivugiza/Mugando	5.31	5.08	20.50	0.45	0.4	0.1	0.095	0.000	1.46	0.02	0.11	0.71	0	0
9	Byavu	Gicumbi/Byumba/Nyamabuye/Kumana	5.02	4.43	0.60	0.09	0.05	0.03	0.066	0.002	1.48	0.01	0.07	0.32	0	0
10	Gasiza 1	Gicumbi/Byumba/Nyamabuye/Gasiza	5.30	5.47	85.50	2.45	2.24	0.06	0.078	0.049	1.44	0.01	0.13	0.94	140	0
11	Gatare	Gicumbi/Byumba/Kivugiza/Karambi	5.21	7.03	0.63	0.90	0.06	0.03	0.009	0.012	1.49	0.06	0.14	0.45	0	0
12	CGM	Gicumbi/Byumba/Nyamabuye/ Mugomero	5.82	5.37	10.80	0.46	0.24	0.02	0.01	0.01	1.46	0.02	0.00	0.41	0	0
13	Kabageshi 1	Gicumbi/Kageyo/Gihembe/Munini	5.87	5.33	54.20	9.47	0.92	0.07	0.039	0.033	1.38	0.06	0.12	0.46	620	0
14	Nyakabingo	Gicumbi/Kageyo/Gihembe/Gitaba	5.08	4.53	0.95	0.25	0.05	0.01	0.035	0.033	1.49	0.01	0.14	0.54	0	18
15	Gahondo	Gicumbi/Kageyo/Gihembe/Gitaba	5.97	4.89	125.00	0.54	2.27	0.07	0.089	0.019	1.21	0.02	0.19	0.66	0	0
16	Gikuru	Gicumbi/Kageyo/Gihembe/Mwange	5.12	5.14	0.64	0.12	0.05	0.05	0.074	0.024	1.45	0.04	0.09	0.52	0	0
17	Mugomero 1	Gicumbi/Kageyo/Horezo/Nyirangoga	4.38	4.62	4.53	0.13	0.11	0.14	0.02	0.031	1.5	0.02	0.09	0.66	0	0
18	Rwunga	Gicumbi/Kageyo/Muhondo/ Kamanyundo	4.31	4.42	12.60	0.67	0.19	0.3	0.027	0.044	1.49	0.01	0.08	0.57	0	0
19	Kanyenga 2	Gicumbi/Kageyo/Mwange	5.65	4.54	27.80	0.85	0.41	0.02	0.015	0.084	1.45	0.00	0.09	0.55	50	8
20	Ruhita 1	Gicumbi/Kaniga/Mulindi/Ruhita	5.37	6.15	1.14	1.08	0.04	0.01	0.006	0.006	1.48	0.02	0.09	0.56	5	0
21	Kinyogo	Gicumbi/Kaniga/Mulindi/Rukizi	5.36	5.64	166.00	2.71	2.07	0.03	0.119	0.012	1.35	0.02	0.14	0.62	91	0
22	Ruboroga 1	Gicumbi/Kaniga/Nyarwambu/Cyasaku	5.40	5.75	11.80	1.42	0.22	0.02	0.015	0.011	1.30	0.03	0.04	0.71	100	2

23	Ruboroga 2	Gicumbi/Kaniga/Nyarwambu/Cyasaku	5.37	5.80	8.63	2.04	0.14	0.16	0.063	0.016	1.49	0.01	0.06	1.01	0	0
24	Cyasaku	Gicumbi/Kaniga/Nyarwambu/Cyasaku	5.21	6.13	8.60	1.09	0.08	0.05	0.037	0.074	1.46	0.08	0.05	0.50	9	9
25	Rwungo 1	Gicumbi/Manyagiro/Remera/Shingura	4.84	4.29	162.00	0.11	0.02	0.00	0.156	0.015	1.43	0.45	0.08	0.62	33	0
26	Rwungo 2	Gicumbi/Manyagiro/Remera/Shingura	3.94	4.48	6.82	0.31	0.19	0.03	0.094	0.007	1.49	0.04	0.07	0.57	0	0
27	Rwungo 3	Gicumbi/Manyagiro/Remera/Shingura	3.65	5.37	10.60	4.00	0.01	0.06	0.16	0.008	1.46	0.07	1.85	0.60	1	1
28	Rwungo 4	Gicumbi/Manyagiro/Remera/Shingura	3.70	4.25	235.00	0.28	0.31	0.05	0.11	0.104	1.45	0.05	0.1	0.56	71	0
29	Rwungo 5	Gicumbi/Manyagiro/Remera/Shingura	5.78	4.62	151.00	0.23	1.61	0.01	0.11	0.029	1.39	0.08	0.16	0.47	60	2
30	Kanyirabuki	Gicumbi/Bwisige/Gihuke/Kuwindege	4.71	5.01	3.89	1.19	0.11	0.04	0.006	0.011	1.41	0.01	0.6	0.95	0	0
31	Rwangabo	Gicumbi/Bwisige/Gihuke/Kaminini	4.84	4.93	0.71	0.26	0.02	0.04	0.006	0.031	1.51	0.06	0.16	0.58	0	0
32	Kagorogoro	Gicumbi/Bwisige/Bwisige/Rutoma	4.53	4.78	1.83	0.18	0.03	0.05	0.061	0.040	1.52	0.01	0.13	0.480	18	0
33	Ryaruganzu	Gicumbi/Bwisige/Nyabusingitwa/ Musayo	4.92	5.43	0.69	0.91	0.01	0.09	0.003	0.027	1.38	0.01	0.1	0.670	0	0
34	Kigaga	Gicumbi/Bwisige/Mukono/Murambi	4.79	5.23	0.54	0.12	0.07	0.06	0.079	0.031	1.39	0.01	0.41	0.84	0	0
35	Nyakabingo 1	Gicumbi/Shangasha/Bushara/Nyakabingo	4.85	5.08	0.57	0.43	0.05	0.01	0.01	0.000	1.5	0.03	0.41	0.49	0	18
36	Nyakabingo 2	Gicumbi/Shangasha/Bushara/ Nyakabingo	5.36	5.57	3.53	1.16	0.15	0.01	0.023	0.013	1.32	0.00	0.31	0.75	0	0
37	Nyakabingo 3	Gicumbi/Shangasha/Bushara/ Nyakabingo	4.16	4.53	0.24	1.15	0.03	0.02	0.031	0.031	1.29	0.05	0.18	0.64	0	0
38	Nyakabingo 4	Gicumbi/Shangasha/Bushara/Gasura	4.23	4.78	0.49	0.25	0.05	0.01	nd	0.002	1.43	0.10	0.95	0.67	0	0
39	Nyakabingo	Gicumbi/Muko/Kigoma/Gatobotobo	5.03	4.68	53.40	0.12	1.08	0.04	0.061	0.031	1.42	0.02	0.23	0.85	100	0
40	Bureranyana	Gicumbi/Rutare/Gatwaro/Bureranyana	4.89	5.23	0.64	0.09	0	0.04	0.019	0.005	1.47	0.01	0.15	0.62	0	0
41	Gahama	Gicumbi/Cyamuhinda/Rwamitembe	5.19	5.41	3.73	0.51	0.13	0.12	nd	0.01	1.50	0.02	0.21	0.54	0	0
42	Ruhondo	Gicumbi/Giti/Murehe/Gatare	5.37	5.78	15.80	2.58	0.28	0.05	0.025	0.024	1.41	0.06	0.19	0.57	0	0
43	Kanyana	Gicumbi/Giti/Murehe/Butare	5.11	5.41	30.50	2.68	0.65	0.03	0.034	0.015	1.29	0.03	0.09	0.62	25	0
44	Gasharu	Gicumbi/Rutare/Gasharu/Kagarama	5.34	4.86	2.50	0.12	0.04	0.04	0.041	0.052	1.33	0.04	1.23	0.63	0	0
45	Karangara	Gicumbi/Rutare/Bikumbo/Marembo	5.06	4.68	3.39	0.23	0.05	0.05	0.038	0.015	1.49	0.06	0.22	0.67	0	0
46	Mwange River	Gicumbi/Kageyo/Muhondo/Mwange	6.62	7.61	231	228	1.35	0.87	0.391	0.216	1.36	0.00	0.21	0.64	360,000	302
47	Kabere	Gicumbi/Nyankenke/Butare/Kabere	4.69	4.78	40.00	4.59	0.78	0.04	0.034	0.014	1.49	0.04	0.33	0.54	33	0

48	Gikombe	Gicumbi/Nyankenke/Butare/Gikombe	4.73	4.60	4.15	1.00	0.08	0.03	0.070	0.019	1.38	0.05	0.32	0.38	0	0
49	Rwambeho	Gicumbi/Nyankenke/Butare/ Rwambeho	5.33	5.51	3.03	0.56	0.07	0.05	0.261	0.002	1.39	0.08	0.21	0.69	0	4
50	Kagomero	Gicumbi/Ruvune/Cyandaro/ Nyankokoma	4.76	5.24	6.65	0.54	1.04	0.01	0.022	0.010	1.49	0.07	0.13	0.59	4	0
51	Kariba 1	Gicumbi/Rukoma/Kinyami/Kariba	4.67	4.35	0.28	3.41	0.04	0.02	0.528	0.017	1.46	0.05	0.23	0.47	0	0
52	Kariba 2	Gicumbi/Rukoma/Kinyami/Kariba	4.26	4.23	2.17	0.86	0.05	0.03	0.018	0.019	1.47	0.06	2.44	0.84	0	1
53	Gaseke	Gicumbi/Rwamiko/Kigabiro/Mutambiko	5.32	5.48	60.00	4.87	0.98	0.05	0.077	0.089	1.44	0.07	0.21	0.67	15	0
54	Nyakagezi 1	Gicumbi/Rwamiko/Cyeru/Nyagasozi	5.39	5.64	3.72	0.58	0.03	0.01	nd	0.003	1.42	0.09	0.46	0.59	25	0
55	Kiruhura	Gicumbi/Bukure/Karenge/Gasharu	5.66	5.87	8.14	0.46	0.05	0.06	0.012	0.017	0.26	0.04	0.06	0.45	0	0
56	Gahama	Gicumbi/Bukure/Rwesero/Nyarubira	5.68	5.52	4.96	0.24	0.01	0.01	0.012	0.035	1.32	0.06	0.09	0.67	6	0
57	Bulimbi	Gicumbi/Rebero	5.06	4.12	2.36	0.22	0.03	0.01	nd	0.001	5.94	0.01	2.2	0.87	0	0
58	Nangara	Gicumbi/Rebero	5.06	5.47	4.19	0.57	0.14	0.03	0.241	0.024	0.45	0.27	0.18	0.47	1	0
59	Rwimbogo	Gicumbi/Mukarange	5.29	5.99	2.38	1.13	nd	0.03	0.013	0.019	0.48	0.02	2.22	0.48	4	0
60	Gisiza 1,2,3	Gicumbi/Rukomo/Kinyami/Kariba	5.68	4.45	1.52	3.41	0.21	0.02	0.037	0.017	2.27	0.05	0.5	0.41	100	0
61	Nyagafunzo	Gicumbi/Nyankeke/Yaramba/Mwenyi	5.20	4.17	5.38	0.33	0.19	0.03	0.564	0.007	1.92	0.03	0.69	0.56	100	0
62	Nyakagezi - Rwesero	Gicumbi/Rwamiko/Cyeru/Nyagasozi	6.10	5.49	0.00	0.23	0.01	0.01	nd	0.001	1.03	0.04	1.38	0.64	0	0
63	Kabingo	Gicumbi/Cyumba/Nyakabungo/Gatoki	5.10	5.66	16.40	2.74	0.70	0.04	0.061	0.008	0.5	0.04	0.03	.0.65	0	0
64	Kabagabo	Gicumbi/Rutare/Gasharu/Kabagabo	4.88	5.14	0.45	0.13	0.15	0.02	0.138	0.016	3.2	0.04	5.6	0.66	0	0
65	Museke	Gicumbi/Miyove/Gakenke/Museke	4.56	4.87	0.65	0.13	0.73	0.02	0.009	0.011	1.35	0.06	3.76	0.63	10	0
66	Mpinga	Gicumbi/Miyove/Miyove/Mpinga	4.34	4.89	5.59	0.54	0.03	0.01	0.830	0.024	10.1	0.04	0.05	0.61	0	0
67	Rukombe	Gicumbi/Manyagiro/Ryaruyumba/ Nyarukombe	4.61	4.60	5.75	1.00	nd	0.03	0.241	0.024	3.6	0.06	0.07	0.68	0	0
68	Akavuzo	Gicumbi/Bwisige/Mukono/Akavuza	5.12	5.38	79.10	10.80	1.99	0.17	0.048	0.031	0.5	0.01	0.49	0.56	1	3
69	Kabuga	Gicumbi/Byumba/Nyakabungo/Kabuga	5.26	7.03	47.60	15.90	nd	0.03	0.026	0.009	0.5	0.05	0.11	0.55	3	0
70	Kagano	Gicumbi/Cyumba/Nyakabungo/ Burambira	5.27	5.80	12.60	0.52	0.18	0.06	0.081	0.125	1.1	0.08	0.12	0.54	9	0
71	Akabacuzi	Gicumbi/Giti/Gatobotobo/Kabacuzi	5.24	5.74	2.34	0.21	nd	0	0.411	0.003	2.5	0.04	0.36	0.64	12	0
72	Gashanga	Gicumbi/Muko/Kigoma/Cyerere	4.36	4.78	10.20	0.54	0.08	0.04	0.164	0.026	2.6	0.03	0.32	0.68	20	0
73	Rwimbeho	Gicumbi/Muko/Cyamuhinda/ Rwamitembe	4.34	5.21	5.59	1.34	nd	0.05	0.129	0.021	10.1	0.01	0.47	0.67	0	0

74	Rurembo	Gicumbi/Mukarange/Rugerero/ Rurembo	5.19	5.05	4.97	1.76	0.12	0.02	0.107	0.029	1.5	0.13	0.15	0.63	3	0
75	Nyagashanga	Gicumbi/Nyamiyaga/Karambo/ Kinyinya	4.62	5.39	9.57	0.99	nd	0.03	0.040	0.000	1.2	0.04	0.37	0.66	6	0
76	Gasura	Gicumbi/Shangasha/Bushara/Gasura	5.17	4.93	1.39	0.61	0.03	0.01	0.083	0.025	4.5	0.07	0.18	0.67	20	0
77	GAKERI	Gicumbi/Rutare/Gasharu/Yogi	5.24	5.14	0.90	0.15	0.08	0.05	0.038	0.012	0.01	0.06	3.00	0.49	101	0
78	NYARUBANDE	Gicumbi/Byumba/Nyarutarama/ Rugandu	4.86	4.98	34.90	3.45	1.24	0.02	0.196	0.015	0.09	0.06	1.88	0.45	1	0
79	KIDOGO 1	Gicumbi/Muko/ngange/Kimpongo	6.18	5.21	0.81	0.82	nd	0.1	0.025	0.003	0.04	0.02	0.75	0.58	2	2
80	KIDOGO 2	Gicumbi/Muko/ngange/Kimpongo	3.54	5.18	0.53	0.44	nd	0.04	0.025	0.002	0.32	0.10	0.73	0.54	0	0
81	KIVOMO	Gicumbi/Mukarange/Cyamuganga/ Burambira	4.02	5.72	0.87	1.30	0.12	0.1	0.030	0.008	0.08	0.01	2.12	0.74	33	1
82	GAKORE	Gicumbi/Nyamiyaga/Kabeza/Mugorore	4.83	5.12	4.69	0.57	nd	0.01	0.044	0.003	0.06	0.07	0.19	0.78	0	0
83	KAZIRANKURWE	Gicumbi/Shangasha/Nyabubare/ Nyamiyaga	4.58	4.91	1.48	0.15	0.17	0.04	0.153	0.045	0.05	0.01	0.05	0.68	0	7
84	RUSAVE	Gicumbi/Mutete/Kabeza/Kagarama	5.38	5.85	2.07	0.46	0.2	0.11	0.036	0.050	7.04	0.03	0.12	0.74	3	0
85	MAGANGA	Gicumbi/Mutete/Mutandi/Kamaganga	4.36	4.49	10.20	0.12	0.08	0.05	0.005	0.001	2.61	0.03	1.42	0.54	20	0
86	Marumba	Gicumbi/Mutete/Karama/Mutandi	5.24	4.49	2.34	0.28	0.04	0.06	0.052	0.004	2.52	0.04	1.2	0.64	12	0
87	RWIMBOGO	Gicumbi/Mutete/Kabeza/Kabasenga	5.19	5.26	4.97	0.39	0.06	0.05	0.032	0.008	1.53	0.01	0.94	0.56	3	3
88	NYAMATA	Gicumbi/Mutete/Gaseke/Runyinya	4.62	5.33	9.57	2.45	1.21	0.05	0.082	0.155	1.20	0.01	0.89	0.84	6	0
89	NYAMABUYE 1	Gicumbi/Rukomo/Cyuru/Karengo	4.88	4.85	0.45	0.52	0.09	0.02	0.062	0.003	3.15	0.03	1.57	0.68	0	0
90	NYAMABUYE 2	Gicumbi/Rukomo/Cyuru/Karengo	6.28	4.40	24.70	0.67	0.06	0.05	0.048	0.010	1.83	0.13	1.29	0.45	52	6
91	KABERE	Gicumbi/Nyankenke/Butare/Kabere	6.69	6.38	87.00	2.54	0.08	0.02	0.058	0.051	0.60	0.04	2.47	0.46	100	0
92	NYAKARIBA	Gicumbi/Nyankenke/Butare/ Rwambeho	7.21	7.45	43.90	1.13	0.05	0.03	0.06	0.019	1.35	0.01	2.31	0.44	100	0
93	KU ITARE	Gicumbi/Nyankenke/Butare/Gikombe	5.47	5.75	1.50	0.54	0.24	0.08	0.08	0.014	0.76	0.06	0.43	0.42	0	0
94	GATARE	Gicumbi/Nyankenke/Yaramba/Mwenyi	5.00	5.33	0.70	0.09	0.18	0.16	0.04	0.012	6.87	0.04	0.76	0.94	0	0
95	GATARE	Gicumbi/Bwisige/Gihuke/Kumunini	5.50	5.43	9.53	1.91	0.32	0.09	0.061	0.027	0.30	0.01	0.92	0.45	78	0
96	GISUMA	Gicumbi/Bwisige/Guhuke/Kuwendege	4.45	5.43	0.82	1.91	0.07	0.09	0.104	0.027	3.39	0.01	1.27	0.41	0	0
97	NYAGASHANGA	Gicumbi/Bwisige/Nyabushingitwa/ Musayo	4.45	4.48	0.56	0.12	0.28	0.09	0.021	0.032	2.10	0.04	1.73	0.45	0	0
98	NANGURU GOMO	Gicumbi/Bukure/Kivumu/Butare	6.14	5.30	74.40	0.25	0.31	0.04	0.054	0.016	1.44	0.06	0.97	0.54	43	8

99	CYAKABARI	Gicumbi/Bukure/Kivumu/Butare	5.56	5.23	324.00	0.14	0.08	0.02	1.045	0.041	1.08	0.05	0.63	0.66	101	1
100	KABINGO	GicumbiRuvune/Gashirira/Nyarurama	3.79	4.65	0.66	0.46	0.06	0.03	0.058	0.056	3.51	0.04	0.49	0.52	0	0
101	KABAYI	Gicumbi/Shangasha/Kitazigurwa/ Rugarama	4.83	4.66	4.69	0.22	0.07	0.05	0.094	0.031	2.25	0.01	0.91	0.57	0	0
		Rwanda Standards (RSB)	6.5 - 8.5		5		0.3		0.1						0	
		Wolrd Health Organisation Guilde line (WHO)	6.5 - 8.5		5		0.3		0.1						0	

8.1. Interpretation of results

8.1.1. Hydrogen potential (pH)

The pH is actually the measure of hydrogen ion (H^+) availability or activity. At the distinctive temperature of groundwater, a pH of 7 is considered neutral. Therefore, a pH less than 7 is acidic and a pH greater than 7 means the water is alkaline. The lower the pH, the more acidic is the water. The hydrogen ion is very small and is able to enter and disrupt mineral structures so that they contribute dissolved constituents to groundwater. Consequently, the greater hydrogen availability, the lower is pH in the water (Ngendo, 2013).

According to the study conducted by Ngendo (2013), on landscape based assessment of soil acidity and risk for soil acidification in Rwanda, the study revealed that Rwanda's soil is acidic. This doesn't have to give the impression that all soils in Rwanda are acid because statistics showed that only 66.7% of soil profiles are below pH of 5.5, so this means that 33.3% have soil pH higher than 5.5 units.

The frequency distribution of pH as shown in figure below reveals that an important number of the Rwandan soil exhibits soil pH value within the range between 4 and 5.5 and this has been confirmed by the statistical analyses which showed that 58% (832 out of 1429 profiles) of soil profiles are within this range.

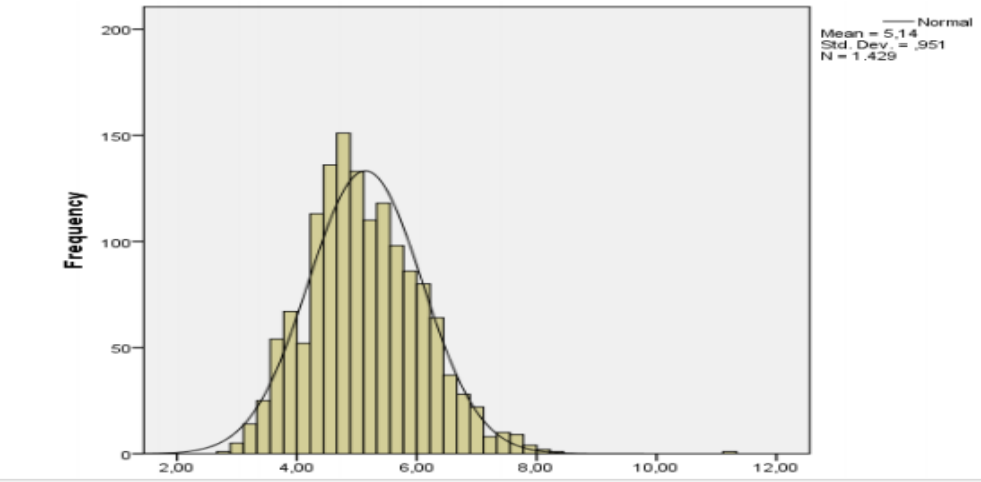


Figure 31: Frequency histogram and normal curve for soil pH in Rwanda

Source: Ngendo, 2013

A hundred and one sampling sites (water sources) were selected in Gicumbi district. The recorded pH values range between 3.54 and 7.21 units in rain season. The lowest value (3.54) was recorded at Kidogo 2 water source and the highest value (7.21) was recorded at

Nyakariba water source. The recoded pH values range between 4.12 and 7.61 units in dry season. The lowest value (4.12) was recorded at Bulimbi water source and the highest value (7.61) was recorded at Mwange River (refer to figure 32). In general, all sampling sites in rain season, 98 water sources representing 97.03% of sampled water sources demonstrated pH values less than WHO and RSB accepted range (6.5-8.5) for drinking water Standard and only 3 water sources representing 2.97%, fell within the range during the rainy season.

However, the pH values in dry season for water sources demonstrated that 97 water sources representing 96.04%, shown pH values less than WHO and RSB acceptable range (6.5-8.5) for drinking water standard and only 4 water sources representing 3.96%, fell within the range in dry season. Therefore, most of water sources are slightly acidic which could be explained by the acidic soil of Rwanda.

Attention:

The lower pH value was found in three water sources Rwungo 2, 3, 4 with a pH value (3.94, 3.65 and 3.70 respectively). These three sources are from the same type of soil and pH has been measured on the field in the water tank, but separately each other. The pH meter used is the same for all 101 water sources tested and it was calibrated on the field. Three buffer solutions (4.01, 7.00 and 10.00) for pH calibration was used when something not normal occurred. The lower pH is due to the chemicals characteristics of Soil in Rwanda, which is acidic. Rwungo is a Pumping system of five water sources and the pH has been measured in the same conditions for the five sources (Rwungo 1, 2, 3, 4 & 5).

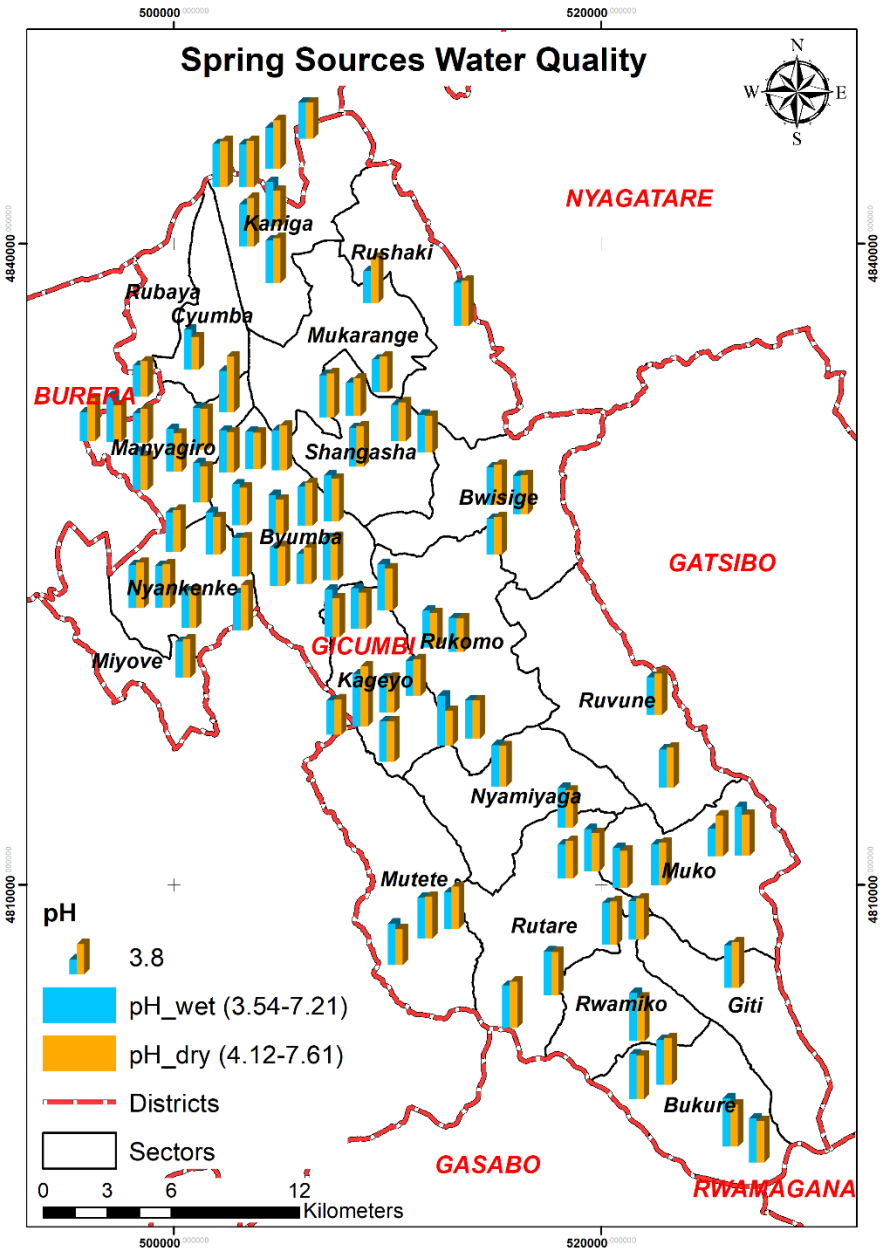


Figure 32: pH map

8.1.2. Turbidity

Turbidity measures the scattering effect that suspended solids have on light: the higher the intensity of scattered light, the higher the turbidity. The common guess is that the turbidity in groundwater indicates a fast transport pathway connecting potentially contaminated surface water with the aquifer. Groundwater will normally look clear and clean because the ground natural filters out particulate matter. But natural and human induced pollutants can be found in ground water and industrial discharge, urban activities, agriculture, and disposal of waste

and all these can affect groundwater quality which results in increased turbidity of ground water.

The turbidity values for the water sources ranged from 0.00-324.00 NTU in rain season and from 0.09-228 NTU in dry season. The lowest turbidity value in rain season was observed at Nyakagezi-Rwesero water source and the highest turbidity value in rain season was observed at Cyakabari water source. On the other hand, the lowest turbidity values in dry season were observed at Byavu, Bureranyana and Gatare water sources and the highest turbidity value in dry season was observed at Mwange River respectively.

Generally, 58 water sources in rain season representing 57.43% of sampled water sources demonstrated turbidity values less than 5 NTU which is a WHO and RSB standard for drinking water and 43 water sources in rain season representing 42.57% of sampled water sources demonstrated turbidity values greater than 5 NTU which means that they are out of the drinking water accepted standard set by WHO and RSB in rain season. On the other hand 97 water sources in dry season representing 96.04% of the sampled water sources demonstrated turbidity values less than 5 NTU and only 4 water sources representing 3.96% demonstrated a turbidity values greater than 5 NTU. As observed, water sources are best fit with the accepted turbidity limit for drinking water in dry season than during the rainy season.

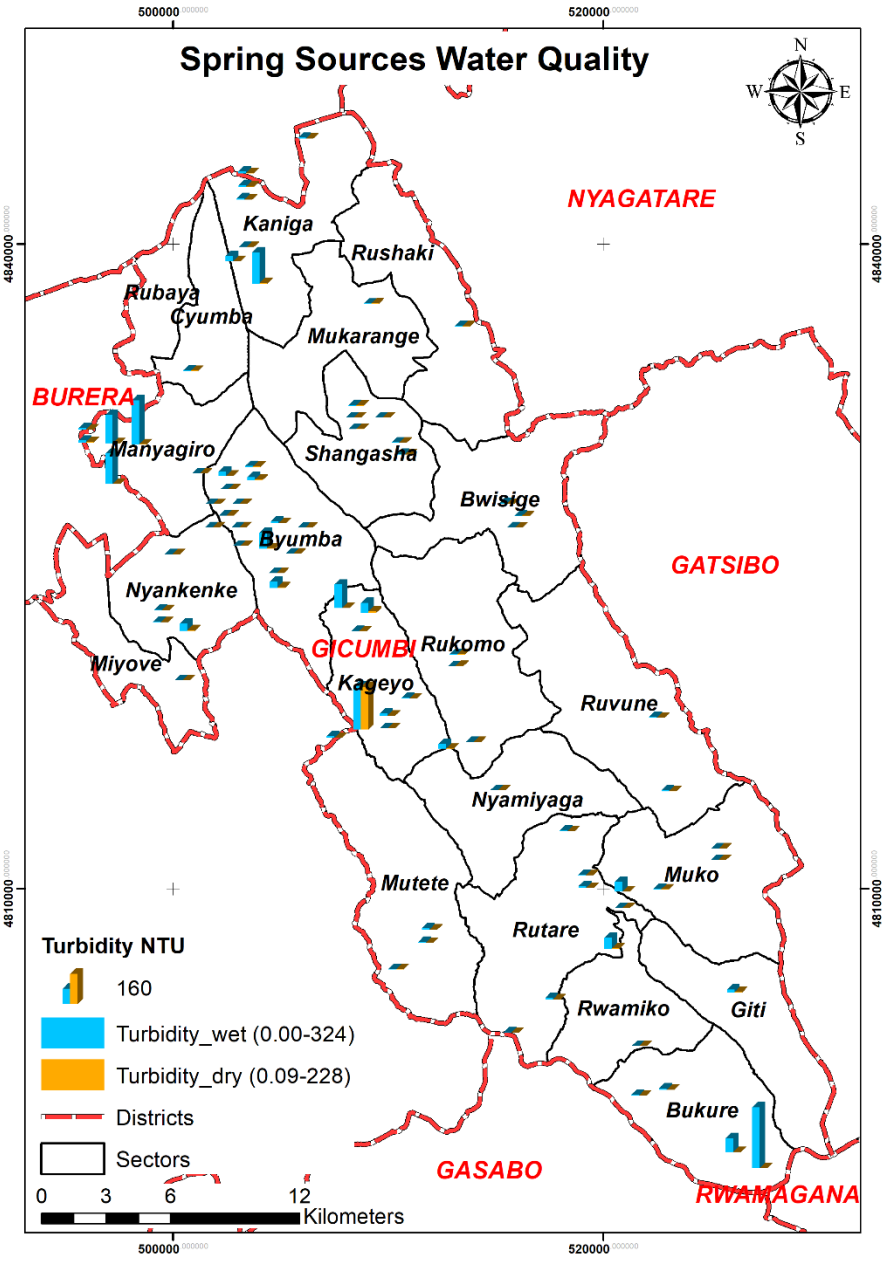


Figure 33: Turbidity map

8.1.3. Iron (Fe)

Iron is a secondary aesthetic contaminant in groundwater. It produces red and brown stains, giving the water the appearance of being impure. Ferrous iron is soluble and normally does not cause any problem by itself. Ferrous iron is oxidized to ferric iron on contact with oxygen in the air or by the action of iron related bacteria. Iron in source waters occurs as soluble ferrous. It is required in low concentrations in relation to their availability in fresh waters (UNEP/GEMS, 2008). Based on WHO standard for iron in drinking water, a level above

0.3mg/l of iron content in water is staining laundry and plumbing fixtures. A turbidity and color may develop at the concentration of iron greater than 0.3 mg/l (WHO, 4th ed).

For the sampling sites, the concentration of iron in some water sources was below the accepted standard limit, not detected, and above the accepted standard limit. Starting with the rain season, the results shows that 74 water sources representing 73.27% of sampled sources demonstrated iron concentration which is below 0.3 mg/L meaning that were responding to the accepted standard limit of WHO and RSB. Moreover, 18 water sources representing 17.82% of sampled water sources demonstrated iron concentration above the accepted standard limit and 9 water sources representing 8.91%, their iron concentration was not detected meaning that the concentration of iron in these water sources is out of range of detection limit of an analytical instrument used for the analysis.

On the other hand, dry season results shows that 100 water sources representing 99.01% of sampled water sources demonstrated an iron concentration below 0.3mg/L which is an accepted iron standard limit for drinking water and only 1 water source representing 0.99%, which is Mwange River, and demonstrated an iron concentration greater than 0.3mg/L. Mwange river is the only water source in dry season not responding to accepted iron concentration standard limit of WHO and RSB for drinking water.

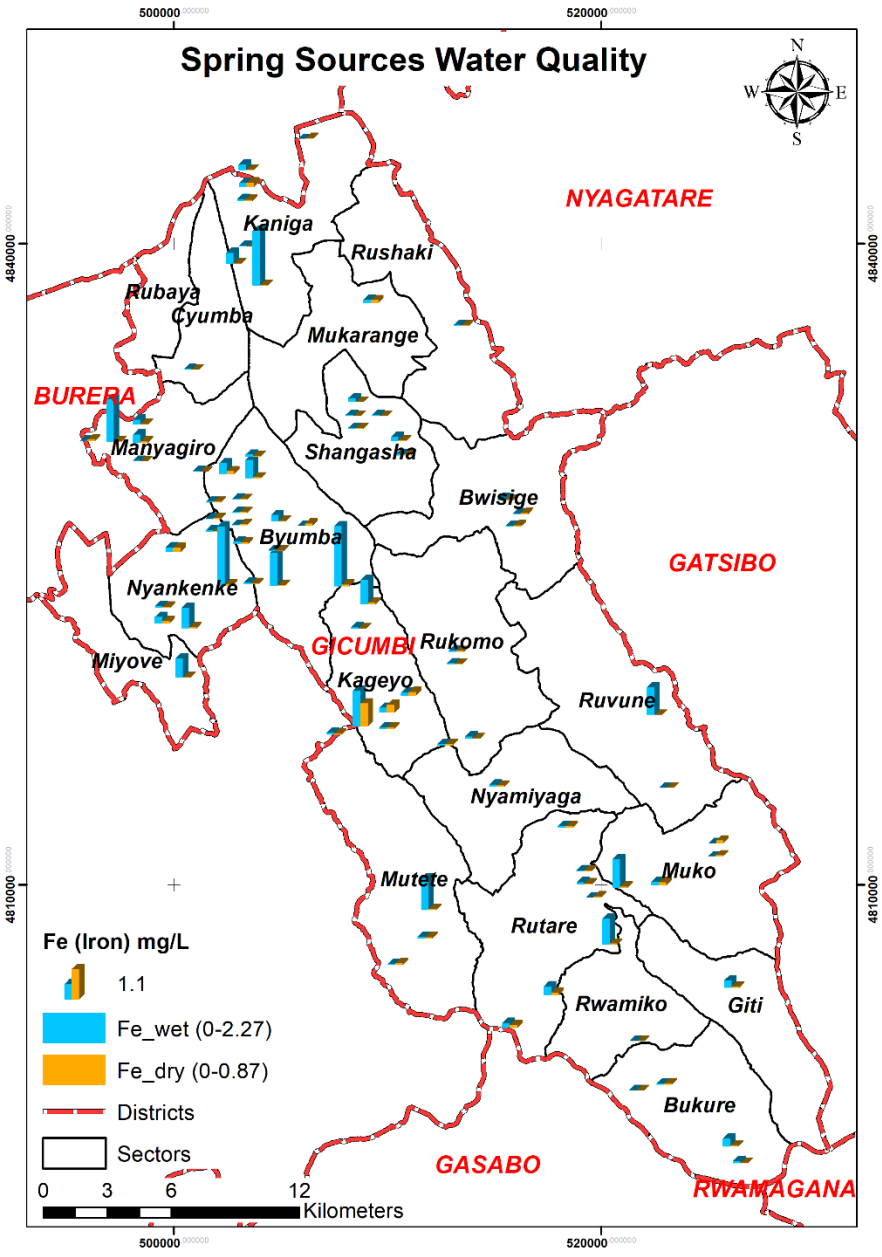


Figure 34: Fe map

8.1.4. Manganese (Mn)

Manganese is one of the most abundant metals in Earth's crust, usually occurring with iron. It is a component of over 100 minerals but is not found naturally in its pure (elemental) form. Manganese is an element essential to the proper functioning of both humans and animals, as it is required for the functioning of many cellular enzymes and can serve to activate many others. Manganese can exist in 11 oxidative states; the most environmentally and biologically important manganese compounds are those that contain Mn^{2+}, Mn^{4+} or Mn^{7+} (WHO, 2011).

For the sampling sites analyzed for manganese concentration content, it has been observed that its concentration in some water sources is below the accepted standard limit and in other sources it is above the accepted standard limit. To begin with the rain season, 75 water sources representing 74.26% of the sampled sources demonstrated manganese concentration below 0.1mg/L which is an acceptable manganese concentration limit for drinking water. In addition, 21 water sources representing 20.79% of sampled water sources demonstrated manganese concentration greater than 0.1mg/L, i.e. they were greater than accepted standard limit set by WHO and RSB for drinking water. The concentration of five water sources representing 4.95% were not detected during the analysis.

Right the contrary, dry season as shown by the results, water sources demonstrated manganese concentration content below 0.1 mg/L. 97 water sources representing 96.04% of sampled water sources were found containing manganese concentration less than 0.1mg/L meaning that were responding to acceptable manganese concentration limit of WHO and RSB for drinking water, only 4 water sources representing 3.96%, were above the acceptable standard limit for drinking water.

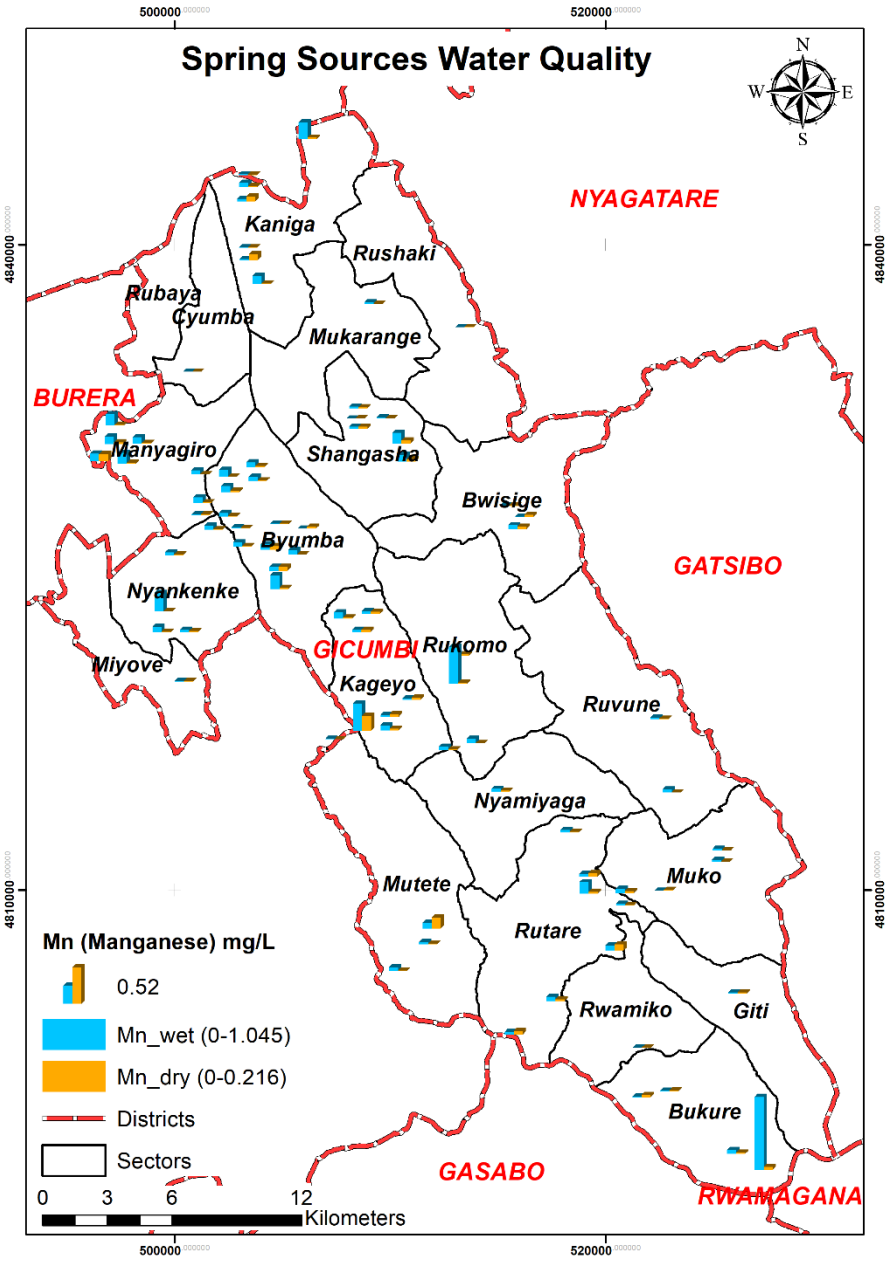


Figure 35: Mn map

8.1.5. Total Nitrogen (TN)

Total Nitrogen is an essential nutrient for plants and animals. However, an excess amount of nitrogen in a waterway may lead to low levels of dissolved oxygen and negatively alter various plant life and organisms. Sources of nitrogen include: wastewater treatment plants, runoff from fertilized lawns and croplands, failing septic systems, runoff from animal manure and storage areas, and industrial discharges that contain corrosion inhibitors (EPA, 2013).

There are three forms of nitrogen that are commonly measured in water bodies: ammonia, nitrates and nitrites. Total nitrogen is the sum of total kjeldahl nitrogen (ammonia, organic and reduced nitrogen) and nitrate-nitrite. It can be derived by monitoring for organic nitrogen compounds, free-ammonia, and nitrate-nitrite individually and adding the components together. An acceptable range of total nitrogen is 2 mg/L to 6 mg/L, though it does not have a standard value for drinking water as shown above; it is a total of all compound of nitrogen. Each species has its own standards value for drinking water (EPA, 2013).

Total nitrogen as described before, does not have a standard for drinking water. But the results demonstrated that the concentration of total nitrogen varied from 0.01mg/L to 10.1mg/L in rain season and the lowest concentration (0.01mg/L) of total nitrogen was observed at Gakeri water source and the highest concentration (10.1mg/L) of total nitrogen was observed at Mpinga and Rwimbeho water sources in rain season. During the dry season, total nitrogen varied from 0.00mg/L to 0.45mg/L and the lowest concentration (0.00mg/L) was observed at Kanyenga 2, Nyakibingo 2, and Mwange River water sources and the highest concentration (0.45mg/L) was observed at Rwungo 1 water source during the dry season. These results imply that there is a high infiltration of runoff water to aquifers, which also carry the nitrogen, during the rainy season.

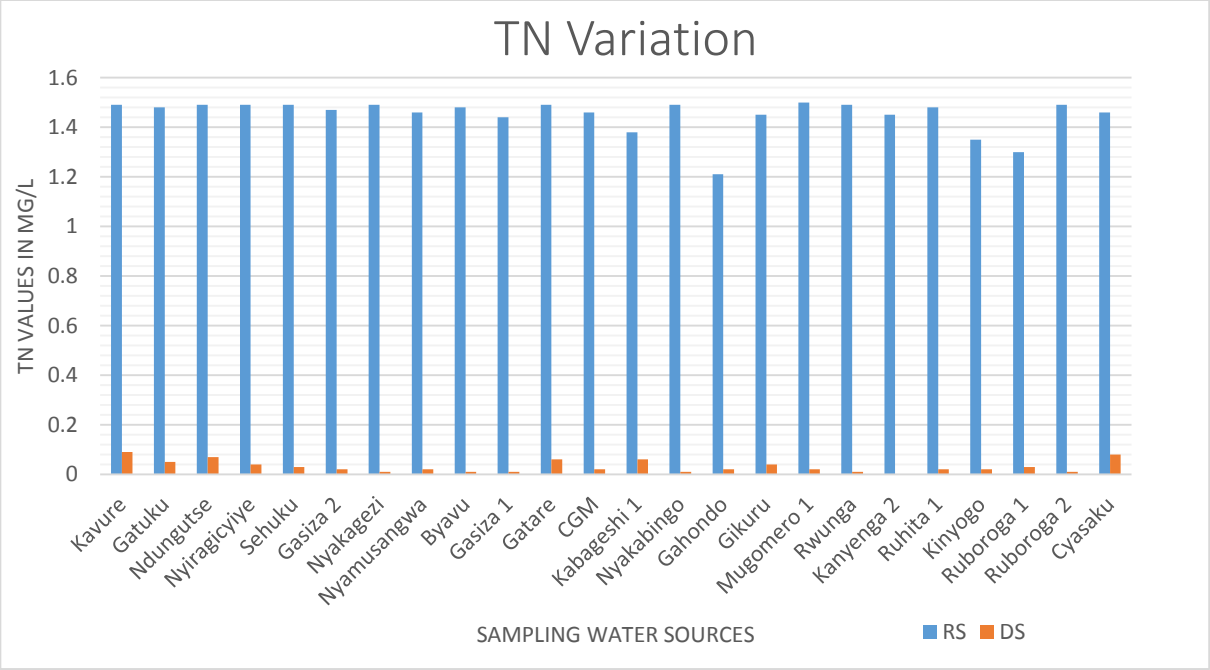


Figure 36: Variation in concentration of Total nitrogen in the first 24 water sources

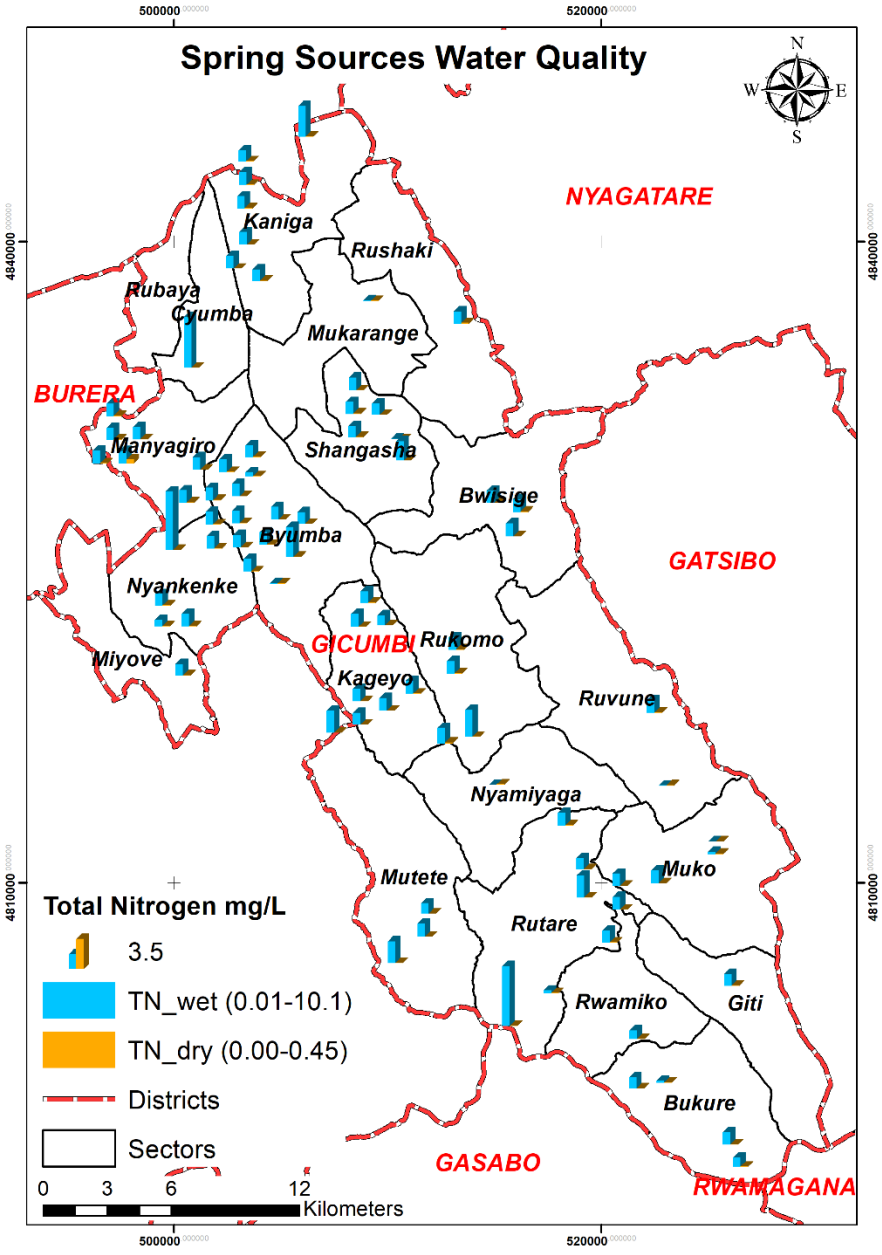


Figure 37: TN map

8.1.6. Total Phosphorus (TP)

Total Phosphorus is an essential nutrient for plants and animals. It is naturally limited in most fresh water systems because it is not as abundant as carbon and nitrogen; introducing a small amount of additional phosphorus into a waterway can have adverse effects. Sources of phosphorus include soil and rocks, wastewater treatment plants, runoff from fertilized lawns and cropland, runoff from animal manure storage areas, disturbed land areas, drained wetlands, water treatment, decomposition of organic matter, and commercial cleaning preparations (EPA, 2013).

The addition of even a small amount of phosphorus to a water body can have negative consequences for water quality. Those adverse effects include: algae blooms, accelerated plant growth, and low dissolved oxygen from the decomposition of additional vegetation. An acceptable range for total phosphorus is 10 µg/L to 40 µg/L (EPA, 2013).

Total Phosphorus does not have a standard for drinking water. But the results demonstrated that the concentration of total phosphorus differ from 0.00mg/L to 5.6mg/L in rain season and the lowest concentration (0.00mg/L) of total Phosphorus was observed at CGM water source and the highest concentration(5.6mg/L) of total phosphorus was observed at Kabagabo water source in rain season. During the dry season, total Phosphorus differ from 0.28mg/L to 1.01mg/L and the lowest concentration (0.28mg/L) was observed at Gasiza 2 water source and the highest concentration (1.01mg/L) was observed at Ruboroga 2 water source during the dry season.

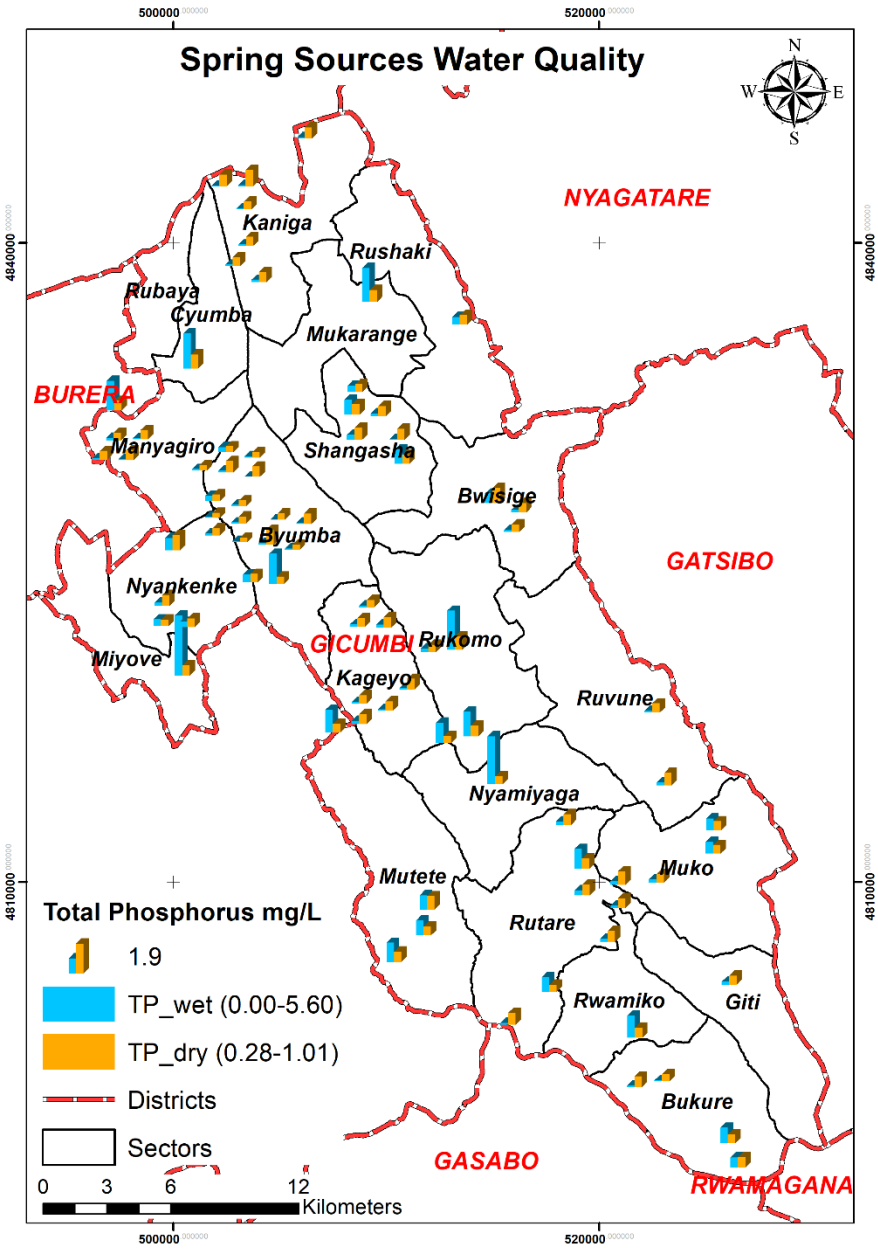


Figure 38: TP map

8.1.7. Total Coliform (Tot Col)

Total coliforms are a group of bacteria commonly found in the environment, for example in soil or vegetation, as well as the intestines of mammals, including humans. Total coliform bacteria are not likely to cause illness, but their presence indicates that your water supply may be vulnerable to contamination by more harmful microorganisms (WHO, 2011).

Escherichia coli (E.coli) is the only member of the total coliform group of bacteria that is found only in the intestines of mammals, including humans. The presence of E.coli in water

indicates recent fecal contamination and may indicate the possible presence of disease-causing pathogens, such as bacteria, viruses, and parasites. Although most strains of E.coli bacteria are harmless, certain strains, such as E.coli 0157:H7, may cause illness. In water, coliform bacteria have no taste, smell, or color. They can only be detected through a laboratory test (WHO, 2011).

The health effects of exposure to disease-causing bacteria, viruses, and parasites in drinking water area varied. The most common symptoms of waterborne illness include nausea, vomiting, and diarrhea. Infants, the elderly, and those with compromised immune systems may suffer more severe effects. In extreme cases some pathogens may infect the lungs, skin, eyes, nervous system, kidneys, or liver and the effects may be more severe, chronic, or even fatal.

For the sampling water sources, rain season appeared to be the most contaminated with total coliforms whereby a 360000 Cfu/100ml were found in Mwange River. In general, 50/101 water sources representing 49.5% of sampled water sources demonstrated coliform content which is greater than 0.00 Cfu/100ml ranging from 1-360000 Cfu/100ml while 51/101 water sources representing 50.5% of sampled water sources demonstrated no coliform content (0.00 Cfu/100ml) in rainy season. Therefore, 49.5% of all sampled water sources were not responding to WHO and RSB coliform accepted standard limit.

On the other hand, Mwange River in dry season appeared also to be the most contaminated with total coliforms whereby 302 Cfu/100ml were found. 20/101 water sources representing 19.8% of all sampled water sources demonstrated coliform content which is greater than 0.00 Cfu/100ml ranging from 1-302 Cfu/100ml and the remaining portion 81/101 water sources representing 80.2% of the all sampled water sources was free from coliforms, hence responding to WHO and RSB coliform accepted standard limit.

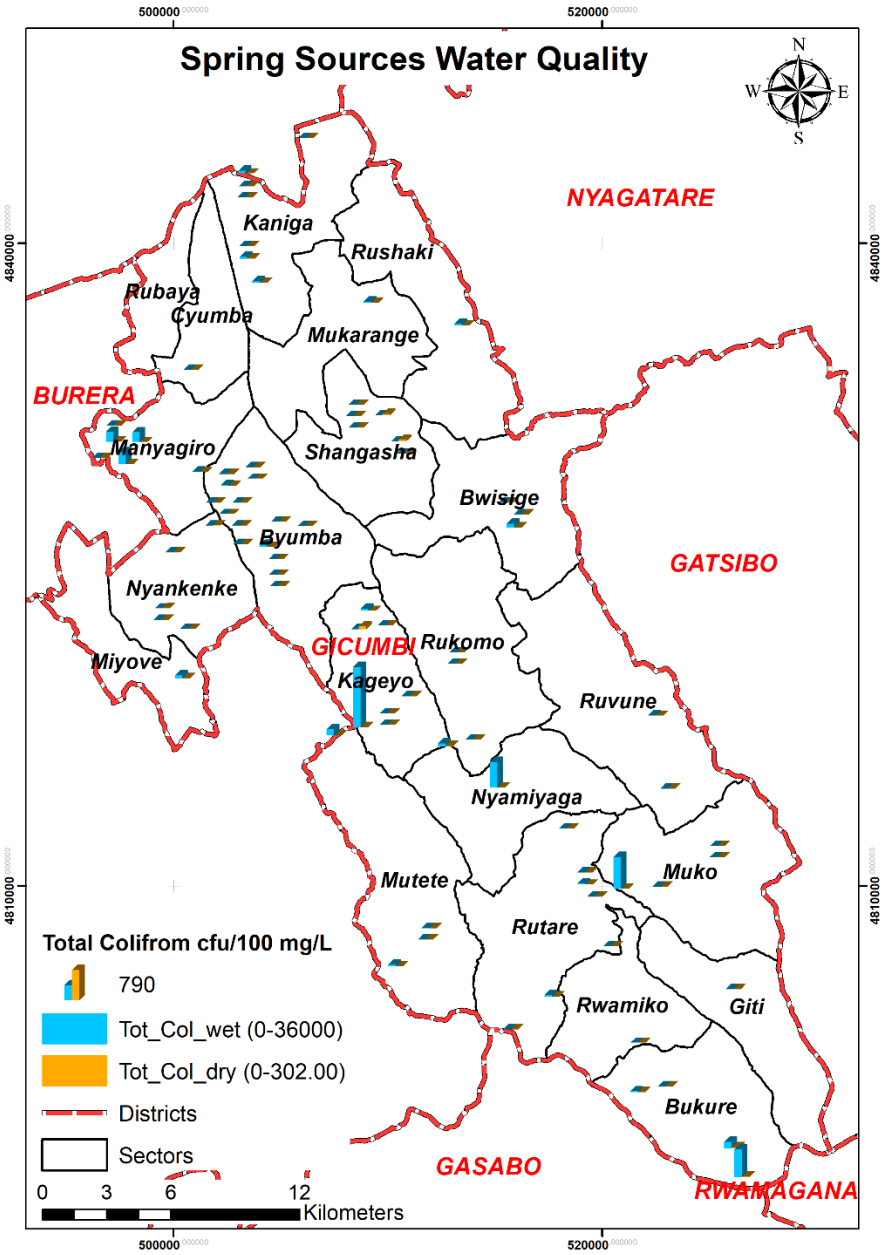


Figure 39: T_Col map

9. Strategic management plan for selected springs and their recharge catchment in Gicumbi District

To insure the sustainability of the use and sufficiency of springs in the Gicumbi District, a number of activities are required. These activities vary from one spring to another and their respective recharge catchment. However, their implementation needs special coordination mechanisms overseen by a strong working institution framework that fits into the country context.

9.1. Proposed institutional framework for the management of water sources

Article 3 of the water law provides that water is a good belonging to the State public domain. Its use constitutes a recognized right in force to all in the scope of laws and regulation in use and its article 4 provides that protecting and appropriately using water resources, in the natural balance respect, are of general interest and constitute an imperative duty for all, notably the State, the local communities, private sector, civil society and citizens.

The same water law, under article 5 gives the primary responsibility for managing water sources to the water user's associations whereas the article 24 provides that ***"Users of water can constitute a local association of water having legal entity in view of management, of enhancement of production, and protection of the water resources and fight against flooding. The management of local water association is composed of representatives who have a role in the exploitation of rivers, streams and lakes."***

Above these water users associations, the water law within its articles 21, 22 and 23 provides for the establishment of water resources management committees at Sector level and District level. These committees are composed of local government officials, NGOs representatives, and representatives of water users' associations, farmers' representatives and private sector.

At District level, the membership of a hydrographic basin committee is as follow:

1. Vice Mayor for Economic Affairs;
2. Sector executive secretaries;
3. District Environment Officer;
4. District Agronomist;
5. District Women Council Representative;
6. District Youth Council Representative;
7. District representative of water user organizations in the field of agriculture;
8. The staff of the National Authority in charge of Natural Resources operating at the level of the hydrographical basin;

9. District representative of domestic water users;
10. Two farmers' representatives;
11. NGO representative;
12. District private sector representative

At Sector level, the hydrographic basin committee is composed of:

1. The Executive Secretary of the Sector
2. The in charge of water at sector level
3. The in charge of agriculture, animal resources, land, settlement, urbanization, forests, infrastructure and environment at the Sector level;
4. A representative of the Executive Committee of each Cell in the Sector elected by his/her peers;
5. A representative of the National Women's Council at the Sector level;
6. A representative of the National Youth Council at Sector level;
7. Two (2) representatives of farmers at the Sector level;
8. A representative of water domestic users at the Sector level;
9. Two (2) representatives of non-governmental organizations working in the field of water resources at the Sector level;
10. A representative of water user organizations in the field of agriculture at the Sector level;
11. A representative of the private sector at sector level

However, the article of the water law providing for the establishment of water users associations does not give details on their composition apart of what is stated above. In addition to this, it is provided under the article 25 of the water law that Districts may delegate to local water associations the management of water utilization as well as the infrastructure in accordance with the same law.

Based on the provisions of the water law, it is recommended that a water users association is established and operationalized to manage each water source or where possible two or more water sources to be managed by one association. These water users associations will be supervised by the water resources management committees at Sector level and District level where they are operational, otherwise this supervisory role will be played by local authorities from Cell to District level.

Considering that the law does not provide the number of people to be part of a water user association, it is suggested that all the beneficiaries getting water from a water source elect at least 10 people, five men and five women, to constitute the water users association. The 10 elected members of the water users association will be composed of a president, a vice president, a secretary and the others being just members.

In case, there is a private operator contracted by the local authorities or any other organ to manage water infrastructures as it is the case for many springs in Gicumbi District, this one will be part of the water users association as an observer. This means that he/she doesn't have the voting right.

In fact, as per the public-private sector partnership which is an approach being promoted by the Government of Rwanda in many areas including domestic water supply, the Districts which are the owners of rural water supply infrastructures normally delegate their management to authorized Water Users Associations(WUA) or private professional operators. In this case, a District enters into a contractual arrangement whereby the responsibilities of each party are highlighted as follow:

Main obligations of the private operator:

1) To manage domestic water supply infrastructures in a sustainable manner and at the satisfaction of the water users;
2) To carry out a regular maintenance of the infrastructures so as to meet their fixed lifespan at the beginning of the contract;
3) To manage waste water generated from water treatment plants and water points in collaboration with water users associations;
4) To ensure that the quality of water supplied is in accordance with the applicable drinking water standards in Rwanda;
5) To make sure that water is always supplied to the users except in case of force majeure;
6) To ensure a good collaboration with the water users association;
7) To carry out a cost recovery of the provided services in accordance with the tariff fixed by the District in consultation with the water users associations and the private operator for each water supply system

Main obligations of the District:

1) To ensure the sustainability of water supply infrastructures and the access of the population to adequate drinking water in accordance with National strategies;
2) To provide support to the private operator for a good quality service and including the cost recovery;
3) To ensure the involvement of water users associations in the sensitization of water users and conflicts resolutions;
4) To avail funds for major rehabilitation and extension of the water supply systems and this including the replacement of water pumps;

5) To take the overall responsibility in case the private operator is facing serious difficulties and in any case the management of water infrastructures is threatened or a poor service to the water users.

The above elaborated governance framework for water sources can be illustrated by the following chart:

9.2. Required activities and their estimated costs

9.2.1. Spring sources activities and their budget

Activities required to sustainably use the 144 spring sources identified in the Gicumbi District are illustrated in table 13 with their estimated budget. These springs will serve as a reference project for the water resources management plan in Gicumbi District given that most of the springs are either captured or planned for water supply project in the District. These activities may be considered as short-term intervention for the rehabilitation and protection of the water sources studied. The total budget required for the short term measures for the identified spring sources is estimated at Four Hundred Fifty Six Million and Five Hundred Thousand Rwandan Francs.

Table 13: Priority, Activities and Budget for identified spring sources protection.

SN	Water sources	Sector	Cell	Village	X	Y	Z	Status	Recommendation (details in appendix 3)	Estimated short term rehabilitation cost (FRW)
1	Sehuku	Byumba	Kivugiza	Kivugiza	503075.53	4826822.50	1773.33	Not captured not protected	Establishment of : immediate spring catchment, fences, a water diversion ditch	1,800,000
2	Nyiragice	Byumba	Kivugiza	Kivugiza	502741.07	4827039.50	1836.32	Not captured not protected	Establishment of : immediate spring catchment, fences, a water diversion ditch	1,800,000
3	Ndungutse	Byumba	Kivugiza	Kivugiza	502479.70	4827108.50	1834.74	Not captured not protected	Establishment of : immediate spring catchment, fences, a water diversion ditch	1,800,000
4	Gatare	Byumba	Kivugiza	Karambi	502468.13	4827454.00	1875.47	Captured not protected	Immediate rehabilitation and maintenance of the collection chamber	6,000,000
5	Kavure	Byumba	Kivugiza	Karambi	501854.39	4827893.00	1846.23	Not captured not protected	Establishment of immediate spring catchment and fence it.	1,200,000
6	Gatuku	Byumba	Kivugiza	Mugando	501566.55	4829327.50	1824.61	Not captured not protected	Establishment of : immediate spring catchment, fences, a water diversion ditch	1,800,000
7	Nyamusangwa	Byumba	Kivugiza	Mugando	502472.71	4829228.50	1848.19	Not captured not protected	High turbidity in RS. Establishment of immediate spring catchment and fence it with imiyenzi.	1,600,000
8	Miriku	Byumba	Kivugiza	Kabingo	503281.07	4829019.50	1904.06	Captured	Establishment of a water diversion way as well as the reinforcement of the upstream progressive terraces.	1,200,000
9	Nyakagezi	Byumba	Kivugiza	Kabingo	502572.96	4828811.00	1921.57	Not captured not protected	Recapture the spring	3,300,000
10	CGM	Byumba	Nyamabuye	Mugomero	504966.52	4827007.66	1950.22	Not captured not protected	High turbidity in RS.Maintenance of immediate spring catchment and fence it	1,600,000

SN	Water sources	Sector	Cell	Village	X	Y	Z	Status	Recommendation (details in appendix 3)	Estimated short term rehabilitation cost (FRW)
11	Byavu	Byumba	Nyamabuye	Kumana	504782.57	4825600.40	1907.13	Not captured	Maintaince of the spring immediate catchment and fence it.	800,000
12	Gasiza 1	Byumba	Nyamabuye	Gasiza	504111.63	4825830.39	1878.95	Not captured not protected	High level of FC & High turbidity. Establishment of immediate spring catchment and fence it	1,600,000
13	Gasiza 2	Byumba	Nyamabuye	Gasiza	503129.93	4825959.77	1857.00	Not captured not protected	Establishment of immediate spring catchment and fence it	1,800,000
14	Kabageshi 2	Kageyo	Gihembe	Nyaruvumu	509320.47	4823005.77	2032.91	Not captured not protected	Establishment of immediate spring catchment and fence it	1,800,000
15	Kabageshi 1	Kageyo	Gihembe	Munini	509092.03	4822836.83	2070.69	Not captured not protected	High level of FC & High turbidity. Immediate rehabilitation of the entire source and the distribution system as well.	3,300,000
16	Gahondo	Kageyo	Gihembe	Gitaba	508862.34	4822174.00	1982.06	Not captured not protected	High turbidity in RS. Establishment of : immediate spring catchment, fences, a water diversion ditch	3,300,000
17	Nyakabingo	Kageyo	Gihembe	Gitaba	508652.72	4821988.50	1970.23	Not captured not protected	Establishment of : immediate spring catchment, fences, a water diversion ditch	3,300,000
18	Kagwa	Kageyo	Muhondo	Kagwa	509379.72	4818936.00	1907.12	Not captured not protected	Establishment of : immediate spring catchment, fences, a water diversion ditch	1,600,000
19	Munini	Kageyo	Muhondo	Kamanyundo	509375.25	4818869.50	1899.84	Not captured	Establishment of fences around water catchment area and protect it.	1,200,000
20	Rwunga	Kageyo	Muhondo	Kamanyundo	509969.25	4818048.50	1878.43	Not captured	High turbidity in RS. Regular maintenance of the spring catchment area	1,200,000
21	Gikuku 1	Kageyo	Kabuga	Mukennye	509610.44	4817898.00	1843.06	Not captured	Establishment of fences around water catchment area and protect it.	800,000

SN	Water sources	Sector	Cell	Village	X	Y	Z	Status	Recommendation (details in appendix 3)	Estimated short term rehabilitation cost (FRW)
22	Gikuku 2	Kageyo	Muhondo	Mwange	509395.13	4817956.50	1837.76	Not captured	Reinforce the existing fences and regular maintenances of the spring is required	800,000
23	Gikuku 3	Kageyo	Muhondo	Mwange	509180.16	4817727.50	1825.77	Not captured and not protected	Establishment of the adequate water diversion ditch is required as well as the fences and protection	900,000
24	Mwange	Kageyo	Muhondo	Mwange	508932.81	4817407.50	1805.53	Not captured not protected	Establishment of the adequate water diversion ditch is required as well as the fences and protection	1,800,000
25	Nyiraruzenga 1	Kageyo	Kabuga	Gatobotobo	509672.53	4816069.50	1806.77	Not captured not protected	Establishment of the adequate water diversion ditch is required as well as the fences and protection	1,800,000
26	Nyiraruzenga 2	Kageyo	Kabuga	Gatobotobo	509715.16	4816084.00	1812.00	Not captured not protected	Establishment of the adequate water diversion ditch is required as well as the fences and protection	1,800,000
27	Nyiraruzenga 3	Kageyo	Kabuga	Gatobotobo	509782.03	4816116.00	1823.64	Not captured not protected	Immediate total rehabilitation of the spring	3,300,000
28	Mugomero 2	Kageyo	Horezo	Nyirangoga	510982.79	4818860.31	1986.62	Not captured not protected	Immediate total rehabilitation of the spring	3,300,000
29	Mugomero 1	Kageyo	Horezo	Nyirangoga	510988.91	4818851.46	1796.28	Not captured not protected	Immediate total rehabilitation of the spring	3,300,000
30	Ruboroga (Gatuna) 1	Kaniga	Nyarwambu	Cyasaku	503386.97	4842668.52	1966.99	Captured not protected	High level of FC & High turbidity. Regular and proper cleanig is required and a proper water capturing	3,300,000
31	Ruboroga (Gatuna) 2	Kaniga	Nyarwambu	Cyasaku	503407.66	4842668.41	1970.40	Captured	High turbidity in RS. Regular and proper cleanig is required	900,000

SN	Water sources	Sector	Cell	Village	X	Y	Z	Status	Recommendation (details in appendix 3)	Estimated short term rehabilitation cost (FRW)
32	Cyasaku	Kaniga	Nyarwambu	Cyasaku	503318.64	4842522.91	1949.73	Captured	High level of FC & High turbidity. Regular and proper cleanig is required and a proper water capturing	1,600,000
33	Nyangorogoro	Kaniga	Nyarwambu	Nyamabare	502922.18	4842987.51	1959.17	Captured	Establishment of : immediate spring catchment, fences, a water diversion ditch	1,600,000
34	Nyakega	Kaniga	Nyarwambu	Kabeza	502983.13	4840743.61	1889.51	Captured not protected	Re-capture the source to make all water of spring useful	1,600,000
35	Ruhita 2	Kaniga	Mulindi	Ruhita	503431.55	4839873.36	1896.99	Captured not protected	Establishment of fences around source catchment is required.	800,000
36	Ruhita 1	Kaniga	Mulindi	Ruhita	503413.97	4839863.74	1892.84	Captured not protected	FC observed in RS. Proper cleanig is required and a proper water capturing	3,300,000
37	Kanyega	Kaniga	Mulindi	Kanyega 2	503446.23	4839660.52	1877.17	Captured not protected	Rehabilitation of the collection chamber is required to ensure the quality of source water.	1,800,000
38	Kinyogo	Kaniga	Mulindi	Rukizi	504035.07	4838167.68	1880.66	Not captured not protected	High level of FC & High turbidity. Regular and proper cleanig is required and a proper water capturing	3,300,000
39	Rutaha	Kaniga	Mulindi	Kagorogoro	504147.56	4837855.55	1876.27	Not captured not protected	Establishment of immediate spring catchment area to protect both water quality and quantity of the spring.	1,200,000
40	Rurengeri	Rushaki	Karurama	Mbuga	503202.72	4835846.40	1768.85	Not captured not protected	Total rehabilitation	3,300,000
41	Rwabona / Rukurura	Kaniga	Rukurura	Ngabira	508471.67	4843274.74	1980.34	Not captured not protected	Suround the catchment area with fences	800,000
42	Nyagahanga 1	Rushaki	Karurama	Nyaruhanga	507740.53	4841376.82	1974.71	Not captured not protected	Suround the catchment area with fences	800,000
43	Nyaruhanga	Rushaki	Karurama	Nyaruhanga	508765.56	4840659.12	1886.13	Not captured not protected	Establishment of a water diversion ditch.	1,600,000

SN	Water sources	Sector	Cell	Village	X	Y	Z	Status	Recommendation (details in appendix 3)	Estimated short term rehabilitation cost (FRW)
44	Nyagahanga 2	Rushaki	Karurama	Ngabira	509651.99	4841232.58	1874.94	Not captured not protected	Establishment of fences around the immediate spring catchment area, protect it, and remove bushes.	1,600,000
45	Nyarurenga	Rushaki	Nyarurama	Gatonde	510693.61	4840805.76	1930.12	Not captured	Regular maintenance of the spring is required	800,000
46	Kivomo	Mukarange	Cyamuganga	Burambira	509224.00	4837233.72	1939.52	Captured	High level of FC in RS. Reinforcement of distribution line rehabilitation works	3,300,000
47	Mbanda	Bungwe	Tumba	Nyarukore	497761.48	4831795.01	2098.98	Not captured not protected	Introduction of fences and protection of catchment area	800,000
48	Gitaba	Manyagiro	Remera	Gitaba	497781.86	4829796.68	2189.71	Captured	Introduce fences around the catchment area and terraces upstream of the source	1,800,000
49	Murehe 2	Manyagiro	Kabuga	Murehe	502632.74	4831440.43	1856.20	Not captured not protected	Total rehabilitation	3,300,000
50	Murehe 1	Manyagiro	Kabuga	Murehe	502632.96	4831442.53	1854.96	Not captured not protected	Total rehabilitation	3,300,000
51	Butyazo	Ruvune	Kagasha	Gashirira	519432.85	4820927.85	1845.35	Not captured not protected	Establish the catchment area, fence it, and protect it.	1,200,000
52	Rusave	Mutete	Kabeza	Kagarama	515727.92	4803295.30	1521.09	Not captured not protected	Establish the catchment area, fence it, and protect it. Clearance of the spring's surrounding is required.	1,600,000
53	Maganga	Mutete	Mutandi	Kamaganga	507610.56	4817017.67	1805.43	Captured not protected	High level of FC & High turbidity in RS. Regular and proper cleanig is required and a proper water capturing	1,600,000
54	Marumba	Mutete	Karama	Mutandi	510369.35	4806251.36	1789.82	Not captured not protected	High level of FC in RS. Regular and proper cleanig is required and a proper water capturing	1,600,000

SN	Water sources	Sector	Cell	Village	X	Y	Z	Status	Recommendation (details in appendix 3)	Estimated short term rehabilitation cost (FRW)
55	Gisiza	Mutete	Kabeza	Kabasega	511756.46	4807487.28	1643.67	Captured not protected	High level of FC in RS. Regular and proper cleanig is required and a proper water capturing	3,300,000
56	Nyamata	Mutete	Gaseke	Runyinya	511925.37	4807932.63	1601.90	Captured not protected	High level of FC & High turbidity in RS. Regular and proper cleanig is required and a proper water capturing	1,600,000
57	Kabahura	Nyankenke	Rwagihura	Kabahura	512015.97	4816574.45	1992.70	Captured and protected	Establish water diversion pathways	800,000
58	Ryaruganzu	Byumba	Murama	Gacaca	506139.60	4826800.44	1955.12	Captured and not protected	The immediate rehabilitation of the source is required	1,800,000
59	Mugomero	Rukomo	Cyuru	Sabiro	515004.58	4816537.78	1982.51	Not captured not protected	Introduce fences and protect the catchment area	1,600,000
60	Nyamabuye 1	Nyamiyaga	Cyuru	Karengo	513979.77	4816834.93	1968.55	Not captured not protected	Introduce fences and protect the catchment area. Reinforcement of the existing terraces	1,600,000
61	Nyamabuye 2	Nyamiyaga	Cyuru	Karengo	512694.89	4816519.79	1834.80	Captured not protected	High level of FC & High turbidity in RS. Introduce fences and protect the catchment area. Stop grazing in the vicinity of the source	3,300,000
62	Kabingo	Byumba	Kivugiza	Kabingo	503281.89	4829017.30	1912.00	Captured	Establishment of a water source immediate protection area with fences	800,000
63	Gihanga	Byumba	Kivugiza	Kabingo	503304.49	4829452.28	1937.00	Not captured not protected	Maintaince of the spring immediate catchment and fence it	1,600,000
64	Runyenyeri	Byumba	Kivugiza	Kivugiza	503823.44	4826957.45	1887.00	Not captured not protected	Establishment of a water source immediate protection area with fences	1,600,000
65	Nyarukore (Burera)	Bungwe	Tumba	Mubuga	498144.80	4832789.21	2012.23	Not captured not protected	Protect the catchment area and fence it	1,600,000

SN	Water sources	Sector	Cell	Village	X	Y	Z	Status	Recommendation (details in appendix 3)	Estimated short term rehabilitation cost (FRW)
66	Kwa Sebukangaga (Burera)	Bungwe	Tumba	Mubuga	496174.78	4832040.45	2278.99	Captured and protected	Well protected, need regural maintenance	-
67	Kwa Bigimbo (Burera)	Bungwe	Tumba	Mubuga	496190.80	4832285.57	2254.94	Captured and protected	Well protected, need regural maintenance	-
68	Rwungo 1	Manyagiro	Remera	Shyigura	497784.20	4829819.01	2173.49	Captured and partially protected	High level of FC & High turbidity. Introduce fences around the catchment area. Check if the water was properly captured	1,600,000
69	Rwungo 2	Manyagiro	Remera	Shyigura	497234.30	4830788.54	2159.87	Captured and partially protected	High turbidity in RS. Introduce fences around the catchment area and maintain the existing terraces	1,200,000
70	Rwungo 3	Manyagiro	Remera	Shyigura	497227.74	4830768.53	2156.62	Captured and partially protected	High turbidity in RS. Introduce fences around the catchment area and regular maintainance	1,200,000
71	Rwungo 4	Manyagiro	Remera	Shyigura	497362.48	4830687.71	2145.61	Captured, runoff water infiltration	High level of FC in RS & High turbidity. Establishment of a water diversion ditch and check if the water was properly captured	1,600,000
72	Rwungo 5	Manyagiro	Remera	Shyigura	497199.47	4830733.04	2154.78	Captured, runoff water infiltration	High level of FC in RS & High turbidity. Establishment of a water diversion ditch and fences and check if the water was properly captured	1,600,000
73	Mureko	Miyove	Mubuga	Mubuga	502358.24	4831075.79	2120.46	Not captured and not protected	Introduce fences and protect the catchment area. Introduce the water diversion paths.	1,600,000
74	Maya	Miyove	Miyove	Mukaka	496654.29	4820647.93	1870.41	Not captured and not protected	Introduce fences and protect the catchment area. Introduce diversion paths.	3,300,000
75	Kwa Shondori	Miyove	Miyove	Mukaka	496485.17	4820751.75	1844.95	Not captured and not protected	Introduce fences and protect the catchment area. Total rehabilitation of the source.	3,300,000

SN	Water sources	Sector	Cell	Village	X	Y	Z	Status	Recommendation (details in appendix 3)	Estimated short term rehabilitation cost (FRW)
76	Mu Kadogo	Miyove	Miyove	Mukaka	496943.13	4820737.82	1989.61	Not captured and not protected	Properly capture the source, introduce fences and protect the catchment area.	3,300,000
77	Kabere	Nyankenke	Butare	Kabere	500664.70	4821996.84	2106.05	Captured and not protected	High level of FC in RS & High turbidity. Establishment of a water diversion ditch and fences and check if the water was properly captured	3,300,000
78	Rwambeho	Nyankenke	Butare	Rwambeho	499474.61	4822958.64	2039.69	Captured and protected	Regular maintenance of the spring is required	-
79	Ku Itare	Nyankenke	Butare	Gikombe	499460.03	4822939.51	2061.73	Captured and protected	Regular maintenance of the spring is required. Reinforce the existing fences	-
80	Gatare	Nyankenke	Yaramba	Mwenyi	499971.74	4825570.82	1973.08	Not captured not protected	Establishment of: immediate spring catchment, fences, a water diversion ditch	1,600,000
81	Nyarukombe	Manyagiro	Nyarukombe	Ryaruyumba	500025.26	4830235.85	1909.60	Not captured not protected	High turbidity in RS. Establishment of: immediate spring catchment, fences, a water diversion ditch	3,300,000
82	Nyarubande	Byumba	Nyarutarama	Rugandu	504857.08	4824000.43	2027.15	Captured not protected	High turbidity in RS. Establishment of: immediate spring catchment, fences, a water diversion ditch	3,300,000
83	Kabingo	Ruvune	Gashirira	Nyarurama	504807.12	4824074.07	1803.01	Not captured and protected	A new source that need to be captured	6,000,000
84	Kagomero	Ruvune	Cyandaro	Nyankokoma	522495.59	4817945.96	1652.62	Captured	FC observed in RS. Total rehabilitation	3,300,000
85	Kariba 1	Rukomo	Kinyami	Kariba	513138.08	4820790.31	1789.88	Captured not protected	Install a collection chamber and it should be secured and locked	3,300,000
86	Kariba 2	Rukomo	Kinyami	Kariba	513224.54	4820905.74	1882.32	Captured not protected	Install a collection chamber, secure it and lock it	3,300,000
87	Nyakabingo 1	Shangasha	Bushara	Nyakabingo	508541.60	4831867.51	1886.83	Not captured	High level of FC in DS. Introduce fences around the catchment area. Check if the water was properly captured	3,300,000

SN	Water sources	Sector	Cell	Village	X	Y	Z	Status	Recommendation (details in appendix 3)	Estimated short term rehabilitation cost (FRW)
88	Nyakabingo 2	Shangasha	Bushara	Nyakabingo	508516.56	4831861.88	1903.17	Captured and partially protected	Introduces fences arround the immediate water catchment area	1,600,000
89	Nyakabingo 3	Shangasha	Bushara	Bushara	508517.57	4831861.32	1889.66	Captured and partially protected	Introduces fences arround the immediate water catchment area	1,600,000
90	Nyakabingo 4	Shangasha	Bushara	Gasura	508395.62	4831929.21	1938.82	Captured not protected	FC observed in RS. Introduces fences, clear and protect the catchment area. Install a water collection chamber, secure it and lock it	3,300,000
91	Kabayi	Shangasha	Kitazigurwa	Rugarama	510757.57	4830214.38	1946.99	Not captured not protected	Introduces fences to protect the catchment area. Establish of a water diversion ditch	1,600,000
92	Kazirankurwe	Shangasha	Nyabubare	Nyamiyaga	510518.70	4830760.25	1929.32	Not captured not protected	Establishment of: immediate spring catchment, fences, a water diversion ditch	1,600,000
93	Rwangabo	Bwisige	Gihuke	Kumunini	516230.24	4827353.66	1854.25	Captured not protected	Total rehabilitation	25,000,000
94	Kagorogoro	Bwisige	Bwisige	Rutoma	515896.52	4826916.40	1870.78	Not captured and not protected	High level of FC in RS. Maintain fences around the catchment area. Check if the water was properly captured	3,300,000
95	Kanyirabuki	Bwisige	Gihuke	Kuwindege	515511.48	4827788.11	1830.84	Captured not protected	Introduces fences and protect the catchment area. Establish a water diversion ditch downstream	1,600,000
96	Ryaruganzu	Bwisige	Nyabushingitwa	Musayo	512976.53	4830918.34	1903.52	Captured not protected	Recapture the source and introduces diversion paths. Introduce fences and protect the catchment area	3,300,000
97	Kigaga	Bwisige	Mukono	Murambi	510547.49	4795925.62	1818.09	Not captured and not protected	Protect both the source and the catchment area and introduces fences	1,600,000
98	Gahondo	Rukomo	Kinyami	Gahondo	510632.55	4821508.78	1874.07	Not captured and not protected	Introduces fences, and protect the catchment area	1,600,000

SN	Water sources	Sector	Cell	Village	X	Y	Z	Status	Recommendation (details in appendix 3)	Estimated short term rehabilitation cost (FRW)
99	Nyakabingo	Muko	Kigoma	Gatobotobo	520889.39	4809862.83	1797.63	Not captured and not protected	High level of FC and turbidity in RS. Total rehabilitation	6,000,000
100	Bureranyana	Rutare	Gatwaro	Bureranyana	520892.50	4809859.07	1803.01	Captured and partially protected	Reinforce the existing fences and terraces and also plant passparum in the catchment area	1,800,000
101	Gatare	Rutare	Nkoto	Murehe	517661.79	4804846.25	1622.96	Not captured and not protected	Establishment of: immediate spring catchment, fences, a water diversion ditch	1,600,000
102	Gahanga	Rutare	Gasharu	Kagarama	519211.97	4810282.03	1847.31	Captured not protected	Immediate rehabilitation of distribution line is required	3,300,000
103	Gasharu	Rutare	Gasharu	Kagarama	519194.54	4810626.55	1821.40	Not captured and not protected	Rehabilitate the spring and remove the banana plantation in vicinity of the source	3,300,000
104	Karangara	Rutare	Bikumbu	Marembo	518326.44	4812677.94	1811.12	Not captured and not protected	Total rehabilitation	6,000,000
105	Kanyana	Giti	Murehe	Butare	507145.36	4790903.38	1665.98	Not captured and not protected	High level of FC and turbidity in RS. Maintain fences around the catchment area. Check if the water was properly captured	3,300,000
106	Ruhondo	Giti	Murehe	Gatare	526109.43	4805178.83	1673.57	Not captured and not protected	High turbidity in RS. Reinforce the existing fences and establish a water diversion ditch downstream	3,300,000
107	Gahama	Muko	Cyamuhinda	Rwamitembe	522697.81	4809973.32	1708.22	Captured not protected	Total rehabilitation	6,000,000
108	Kidogo 1	Muko	Ngange	Kimpongo	525380.32	4811347.12	1755.08	Not captured and not protected	FC observed in RS. Total rehabilitation including terraces	6,000,000
109	Kidogo 2	Muko	Ngange	Kimpongo	525358.52	4811331.09	1754.45	Not captured and not protected	Total rehabilitation including terraces	6,000,000
110	Gakore	Nyamiyaga	Kabeza	Mugorore	523060.00	4814540.72	1934.61	Not captured and partially protected	Establishment of: immediate spring catchment, fences and a water diversion ditch	1,800,000
111	Gakeri	Rutare	Gasharu	Yogi	515118.83	4814587.85	1883.54	Not captured and not protected	High level of FC in RS. The source should be properly captured	3,300,000

SN	Water sources	Sector	Cell	Village	X	Y	Z	Status	Recommendation (details in appendix 3)	Estimated short term rehabilitation cost (FRW)
112	Gaseke	Rwamiko	Kigabiro	Mutambiko	520405.15	4807192.52	1788.55	Not captured and not protected	High level of FC and turbidity in RS. Total rehabilitation	3,300,000
113	Nyakagezi	Rwamiko	Cyeru	Nyagasozi	521676.47	4802684.99	1556.97	Not captured and not protected	High level of FC in RS. Total rehabilitation	3,300,000
114	Kiruhura	Bukure	Karenge	Gasharu	522949.89	4800642.05	1625.26	Captured and partially protected	High turbidity in RS. Establishment of: immediate spring catchment and a water diversion ditch	3,300,000
115	Gahama	Bukure	Rwesero	Nyarubira	521658.87	4800371.75	1615.44	Captured and partially protected	High level of FC in RS. Immediate rehabilitation of the distribution system	3,300,000
116	Nangurugomo	Bukure	Kivumu	Butare	526048.40	4797743.65	1585.47	Captured and partially protected	High level of FC and turbidity in RS & DS. Immediate rehabilitation of the collection chamber and deviate the runoof water	3,300,000
117	Cyakabari	Bukure	Kivumu	Butare	526521.57	4797008.33	1498.62	Captured and partially protected	High level of FC and turbidity in RS & DS. Immediate rehabilitation of the collection chamber and deviate the runoof water	3,300,000
118	Rutare	Kaniga	Gatoma	Nyakagera	506287.17	4844726.68	1984.00	Not captured and not protected	Capture the source, introduce fences, and protect the catchment area	3,300,000
119	Runoni	Kaniga	Gatoma	Nyakagera	506171.51	4844907.76	1990.00	Not captured and not protected	Establishment of: immediate spring catchment, fences and a water diversion ditch	1,800,000
120	Ku Ibuye/ Rugarama	Kaniga	Gatoma	Rugarama	507930.56	4844931.43	1895.00	Captured and partially protected	Reinforcement of existing fences, clean and rehabilitate the source	1,200,000
121	Ku Musigiti	Kaniga	Gatoma	Nyakibande	507534.92	4843690.20	1829.00	Not captured and not protected	Establishment of: immediate spring catchment, fences and a water diversion ditch	1,800,000
122	Bikurungu	Kaniga	Gatoma	Nyakibande	507241.82	4843566.06	1839.00	Not captured and not protected	Establishment of: immediate spring catchment, fences and a water diversion ditch	1,800,000
123	Ku Rutare	Kaniga	Gatoma	Gashiru	507070.63	4842409.12	1948.00	Captured and partially protected	Introduce fences and protect the catchment area, clean the source properly	1,800,000

SN	Water sources	Sector	Cell	Village	X	Y	Z	Status	Recommendation (details in appendix 3)	Estimated short term rehabilitation cost (FRW)
124	Nyakagezi	Kaniga	Kamutora	Mabare	513454.07	4836170.69	2011.00	Not captured and partially protected	Introduce fences and protect the catchment area. Clean the surrounding of the source.	1,800,000
125	Kamutora	Rushaki	Kamutora	Kamutora	512182.16	4836650.26	1867.00	Captured and not protected	Total rehabilitation	3,300,000
126	Nyakene	Rushaki	Kamutora	Kabuga	512329.87	4838163.35	1933.00	Captured and partially protected	Establishment of: immediate spring catchment, fences and a water diversion ditch	1,600,000
127	Rwengwe	Mukarange	Gatenga	Nyange	509312.19	4835206.59	1924.00	Captured and protected	Clean the distribution system surrounding	-
128	Gitoma	Mukarange	Mutarama	Rugeshi	504992.57	4834280.64	1891.00	Captured and partially protected	Introduce fences and protect the catchment area. Clean the source point and stop agricultural activities in the source vicinity	1,800,000
129	Kiruhura	Mukarange	Kiruhura	Kariba	506429.85	4837835.44	1840.00	Captured and protected	Clean the distribution system surrounding	-
130	Kirimbi	Rubaya	Gishambashayo	Gasharu	498115.25	4833991.26	2012.00	Captured and partially protected	Introduce fences and protect the catchment area. Introduce diversion pathways around the source	1,800,000
131	Rwagashyashya	Rubaya	Gihango	Gomba	499550.27	4836957.17	1865.00	Captured and partially protected	Introduce fences and protect the catchment area. Introduce diversion pathways around the source	1,800,000
132	Kiriba	Rubaya	Muguramo	Mabare	498787.13	4839477.76	1832.00	Captured and protected	Clean the distribution system surrounding	800,000
133	Bulindi 1	Cyumba	Muhambo	Centre	500825.94	4834106.52	2047.00	Not captured not protected	Introduce fences and protect the catchment area. Introduce diversion pathways around the source	1,800,000

SN	Water sources	Sector	Cell	Village	X	Y	Z	Status	Recommendation (details in appendix 3)	Estimated short term rehabilitation cost (FRW)
134	Bulindi 2	Cyumba	Muhambo	Rugerero	501360.57	4834382.82	1950.00	Captured and not protected	Introduce fences and protect the catchment area. Rehabilitate the water diversion pathways. Stop the agricultural activities in the catchment area	3,300,000
135	Gashija	Cyumba	Nyakabungo	Gashija	500931.53	4838569.49	1929.00	Not captured not protected	Introduce fences and protect the catchment area. Introduce diversion pathways around the source	1,800,000
136	Museke	Miyove	Gakenke	Museke	500431.32	4819694.72	2011.00	Not captured not protected	High level of FC in RS. Total rehabilitation	6,000,000
137	Gatare	Shangasha	Nyabishambi	Matyazo	509727.49	4827379.75	1902.00	Not captured not protected	Introduce fences and protect the catchment area	1,800,000
138	Rwagahunde	Giti	Gatobotobo	Matyazo	521781.27	4807668.63	1894.00	Not captured not protected	Introduce fences and protect the catchment area	1,800,000
139	Kariku	Mutete	Nyarubuye	Nyenzi	509182.14	4813930.57	1890.00	Not captured not protected	Introduce fences and protect the catchment area	1,800,000
140	Gahondo	Mutete	Nyarubuye	Gitega	510330.45	4812007.37	1787.00	Not captured not protected	Total rehabilitation	6,000,000
141	Rwimilindi 1	Ruvune	Cyandaro	Kigarama	520758.74	4818873.32	1685.04	Not captured not protected	Introduces fences and protect the catchment area. Remove banana plantation in direct protection zone and rehabilitate the spring	1,800,000
142	Rwimilindi 2	Ruvune	Cyandaro	Kigarama	520769.09	4818867.02	1684.71	Captured and not protected	Establishment of: immediate spring catchment, fences and a water diversion ditch	3,300,000
143	Karitushi	Rukomo	Mabare	Kanyiramana	511531.73	4824718.53	1794.45	Captured and partially protected	Maintain the immediate spring catchment, fences and a water diversion ditch	3,300,000

SN	Water sources	Sector	Cell	Village	X	Y	Z	Status	Recommendation (details in appendix 3)	Estimated short term rehabilitation cost (FRW)
144	Kadogo	Rukomo	Mabare	Kanyiramana	511321.77	4824767.52	1794.44	Captured and partially protected	Total rehabilitation	6,000,000
Sub-total (FRW)										**356,500,000**
Training of water users association for springs management and protection every 5 years (FRW)										**100,000,000**
Total (FRW)										**456,500,000**

Explanation	
	Water sources/springs that needs high priority action for their protection
	Water sources/springs that needs medium priority action for their protection
	Water sources/springs in good state or with small requirements for their protection
	High level of fecal coliform observed/ the system need further investigation

9.2.2. Recharge cahcment management measures budget

In addition, for the sustainable spring protection, the protection of the recharge catchment as soil and water conservation measures such as agroforestry, terracing, cut-off drains and trenches, forest plantation and the rehabilitation of natural forest; was considered. Therefore, considering the analysis on the delineated 7 recharge catchments, the area that need to be covered and the local cost for the identified measures; the total cost for the long term interventions is estimated at seventy six billion eight hundred forty five millions, five hundred sixty five thousands and two hundred thirty one and seventy cent Rwandan francs (76,845,565,231.70Rwf).

Table 14: Spring recharge catchment management measures estimated budget.

Spring recharge catchment 1			
Measures	**Area Ha**	**unit cost FRW**	**Budget FRW**
Agroforestry+progressive terraces/cuttoff drains	2,480.16	1,500,000	3,720,233,580.00
Agroforestry+cuttoff drains/horizontal trenches	3,001.79	250,000	750,446,273.50
Agroforestry+radical terraces/gully treatment	4,861.97	2,000,000	9,723,946,680.00
Forest Plantation	711.75	500,000	355,875,582.50
Natural Forest	522.22	1,200,000	626,663,820.00
Total			15,177,165,936.00
Spring recharge catchment 2			
Measures	**Area Ha**	**unit cost FRW**	**budget FRW**
Agroforestry+progressive terraces/cuttoff drains	382.95	1,500,000	574,421,323.50
Agroforestry+cuttoff drains/horizontal trenches	380.86	250,000	95,214,954.50
Agroforestry+radical terraces/gully treatment	757.10	2,000,000	1,514,196,296.00
Forest Plantation	344.06	500,000	172,029,352.00
Natural Forest	147.25	1,200,000	176,697,416.40
Total			2,532,559,342.40
Spring recharge catchment 3			
Measures	**Area Ha**	**unit cost FRW**	**budget FRW**
Agroforestry+progressive terraces/cuttoff drains	2,443.36	1,500,000	3,665,040,568.50
Agroforestry+cuttoff drains/horizontal trenches	2,381.15	250,000	595,287,676.75
Agroforestry+radical terraces/gully treatment	5,731.72	2,000,000	11,463,447,622.00
Forest Plantation	3,298.80	500,000	1,649,401,039.00
Natural Forest	1,107.01	1,200,000	1,328,415,674.40
Total			18,701,592,580.65

Spring recharge catchment 4			
Measures	**Area Ha**	**unit cost FRW**	**budget FRW**
Agroforestry+progressive terraces/cuttoff drains	775.00	1,500,000	1,162,493,739.00
Agroforestry+cuttoff drains/horizontal trenches	669.65	250,000	167,412,532.25
Agroforestry+radical terraces/gully treatment	2,093.90	2,000,000	4,187,790,634.00
Forest Plantation	1,507.98	500,000	753,990,625.50
Natural Forest	467.42	1,200,000	560,898,926.40
Total			6,832,586,457.15
Spring recharge catchment 5			
Measures	**Area Ha**	**unit cost FRW**	**budget FRW**
Agroforestry+progressive terraces/cuttoff drains	1,483.28	1,500,000	2,224,915,209.00
Agroforestry+cuttoff drains/horizontal trenches	1,370.88	250,000	342,720,508.75
Agroforestry+radical terraces/gully treatment	3,958.84	2,000,000	7,917,687,158.00
Forest Plantation	2,846.42	500,000	1,423,208,029.50
Natural Forest	1,175.38	1,200,000	1,410,457,663.20
Total			13,318,988,568.45
Spring recharge catchment 6			
Measures	**Area Ha**	**unit cost FRW**	**budget FRW**
Agroforestry+progressive terraces/cuttoff drains	1,080.31	1,500,000	1,620,471,124.50
Agroforestry+cuttoff drains/horizontal trenches	886.03	250,000	221,506,932.00
Agroforestry+radical terraces/gully treatment	2,976.71	2,000,000	5,953,413,412.00
Forest Plantation	2,305.91	500,000	1,152,954,024.00
Natural Forest	786.93	1,200,000	944,321,050.80
Total			9,892,666,543.30
Spring recharge catchment 7			
Measures	**Area Ha**	**unit cost FRW**	**budget FRW**
Agroforestry+progressive terraces/cuttoff drains	992.84	1,500,000	1,489,257,541.50
Agroforestry+cuttoff drains/horizontal trenches	763.52	250,000	190,879,674.25
Agroforestry+radical terraces/gully treatment	3,352.06	2,000,000	6,704,116,532.00
Forest Plantation	922.23	500,000	461,116,826.00
Natural Forest	1,287.20	1,200,000	1,544,635,230.00
Total			10,390,005,803.75
Total for 7 catchments			**76,845,565,231.70**

10. Conclusions and recommendations

The main objective was to develop the water sources management plan for the water sources and Mwange River located in the sub watersheds of the Gicumbi District. For the current status of the water sources, the main focus was given to the 144 water sources while for the water balance estimation 390 water sources were used and they were selected in conjunction with WFP, including those captured, planned and in the pipeline. To this objective the following specific objectives were associated:

- To quantify and qualify the available water sources on the surface in time and space,
- To assess the hydrology of the Mwange River catchment,
- To quantify water sources use and demand in the study area,
- To identify water surplus and deficit both in time and space in the study area,
- To develop a water sources management plan for optimal and rational utilization of available water sources in the study area,
- To train one stop center staffs on the use of GIS tools

Regarding the water demand, surplus and deficit, it has been found that, the water demands should not meet in 25 years to come if the district continue to rely on water from the existing springs. Under a conservative scenario "A" for water consumption, nearly half of the sectors are non-water deficit, but with a modest surplus. On the other side, under a dynamic water consumption rate scenario "B", the general observations are that the sectors of Byumba, Miyove, Kageyo, Rushaki, Nyamiyaga, Rubaya and Shangasha are currently the only non-water deficit Sector of all. The major driver of the water deficit in Gicumbi District was observed to be the population demand and growth.

The water quality analysis was done for 101 springs taking into account a number of parameters critical for drinking water purposes. This analysis was done in the rainy and dry seasons to ensure capturing the variations of water quality over time and space. In addition to the springs, the Mwange River was also assessed at the point of interest of WASAC Ltd, as a prospective intake location for their future water treatment plant. Therefore, the water quality analysis findings of this study are as follow:

- The hydrogen potential (pH) varies between 3.54 - 7.21 units and 4.12 – 7.61 units in the rainy and dry season respectively. Of all the samples collected, 97.03% in rainy season were observed with acidic pH below the RSB and WHO standards for drinking water, while 96.04% in dry season were also below the standards used.
- The turbidity varies between 0.00-324.00 NTU and 0.09-228 NTU in the rainy and dry seasons respectively. Of all the samples collected, 57.43% in the rainy season were

below the standards, while 42.57% were above the standards. For the case of dry season, 96.04% comply with the standards and only 3.96% were above the standards.

- For iron concentration, in rainy season 72.18% comply with the standards while 17.82% were above the standards. In the dry season, 99.01% of the sources comply with the standards while 0.99%, representing the Mwange River, was above the standards.
- For the manganese concentration, in the rainy season 79.21% of the sources comply with the standards while 20.79% were above standards. In the dry season, 96.04% of the sources comply with the standards while 3.96% were above standards.
- The total nitrogen concentration varied between 0.01 mg/L-10.1 mg/L and 0.00 mg/L-0.45 mg/L in the rainy and dry season respectively. Note that, the highest concentration was observed in the Mwange River.
- The total phosphorus concentration varies between 0.00 mg/L-5.6 mg/L and 0.28 mg/L-1.01 mg/L in the rainy and dry season respectively. Note that, the highest concentration was observed in the Mwange River.
- For total coliform content, in the rainy season it was found that 49.5% were contaminated with coliforms and 50.5% had no coliform content. In the dry season, 19.8% were contaminated with coliforms and 80.2% were free of coliforms.

The increased concentration of fecal coliforms during the rainy season should be associated with the ground water contamination by the pit latrines in the area and the runoff of water in the water catchment which in many places is not well protected and/or captured. It was also noted that farmers in the Gicumbi Districts and in the neighboring Rulindo District regularly empty their pit latrines in their farms as a fertilizer. However, this human waste as a source of fertilizer is probably behind the high level of total coliforms and need to be stopped until the practice is standardized for authorized composting. Besides, the measured concentration in Total Nitrogen and Total Phosphorous indicates a general increasing concentration in rainy season. It should be noted that the latter two parameters could serve as baseline concentrations that should be checked at least every two or three years to assure that significant increases in nitrogen and phosphorous compounds are not occurring due to fertilizer or manure spill.

A catchment management plan and spring protection approach, made of a set of term measures (all in the soil and water conservation package) were proposed. The catchment management plan were made for all the delineated spring recharge catchments and the status of each visited spring and action needed for its protection (provided in appendix 3) were also assessed and proposed. The identified spring protection activities and budget was estimated at Four Hundred Fifty Six Million and Five Hundred Thousand Rwandan Francs, while the spring recharge catchment management measures was estimated at seventy six billion eight hundred forty five millions, five hundred sixty five thousands and two hundred thirty one and seventy cent Rwandan francs.

Due to the fact that Total coliforms have been confirmed to be present in the water sources especially in rain season and considering the bad status of many water sources as described in appendix 3, the following is recommended:

1. There is a need to repair or rehabilitate the existing water springs. Follow the guideline of the distances between water springs and anthropogenic activities;
2. Recapture properly the water spring that are exposed to erosion and provide a water diversion ditch as detailed for each source in appendix 3;
3. To create awareness in the population for the effective management of their water sources especially during the rainy season;
4. Marking the water supply pipelines is an urgent action to avoid water losses that may occur as pipes are damaged by other anthropogenic activities;
5. The water operators should regularly monitor the water quality of the spring and in particular the fecal coliforms;
6. It is urgently needed to add pH regulators and disinfection units to treat the water systems that receives the water from the highly contaminated springs with fecal coliforms;
7. It is recommended to put in place a water users association to manage each water source which will work closely with the hydrographic basin committee already established at the level of Gicumbi District;
8. The water users association, the hydrographic basin committee and water operators should be trained regularly for the spring/catchment management;
9. A wide awareness campaign should also be carried out targeting local communities especially in the neighborhood of the spring infrastructures;
10. A comprehensive study on the sanitation of the Gicumbi District is highly recommended to avoid pollution of the water resources by pit latrines;
11. The district must encourage the population from different centers to harvest the rainwater from the roofs of their houses as one alternative to mitigate the water deficit. This should also be accompanied with encouragement of people to go in agglomeration in order to facilitate the water supply activities;
12. Although the identified 7 recharge catchments correspond to the suspended aquifers, the district need to consider the potential of using wells in the catchment and groundwater for water supply.
13. A study on alternatives water sources should be carried out considering that already many sectors have deficit and that only spring water sources will not be sufficient for the water demand in Gicumbi District in the years to come. The study should focus on water from rivers, groundwater and rainwater harvesting.

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12. Appendix

Appendix 1. Estimated water demand per sector

	Demad ('000 l/day)					
sector	2018	2023	2028	2033	2038	2043
Bukure	1,080	1,487	1,640	2,225	2,480	3,248
Bwisige	998	1,387	1,533	2,093	2,340	3,080
Byumba	2,624	3,486	3,783	5,004	5,491	7,063
Cyumba	893	1,272	1,395	1,929	2,135	2,822
Giti	884	1,241	1,370	1,880	2,098	2,769
Kageyo	1,920	2,700	2,955	4,054	4,472	5,876
Kaniga	1,049	1,417	1,553	2,080	2,307	2,999
Manyagiro	1,220	1,707	1,875	2,567	2,846	3,742
Miyove	1,024	1,442	1,583	2,176	2,410	3,175
Mukarange	1,901	2,336	2,493	3,114	3,378	4,192
Muko	1,090	1,520	1,682	2,301	2,576	3,397
Mutete	1,518	2,120	2,334	3,192	3,551	4,671
Nyamiyaga	1,131	1,579	1,739	2,379	2,649	3,485
Nyankenke	1,221	1,727	1,899	2,617	2,905	3,835
Rubaya	676	940	1,032	1,407	1,560	2,045
Rukomo	1,531	2,139	2,358	3,228	3,597	4,737
Rushaki	848	1,153	1,273	1,714	1,917	2,502
Rutare	1,419	1,995	2,200	3,023	3,371	4,449
Ruvune	1,226	1,699	1,878	2,560	2,865	3,768
Rwamiko	979	1,345	1,558	2,133	2,534	3,409
Shangasha	981	1,381	1,520	2,088	2,322	3,062

Appendix 2. Type of industry and water demand's standard used

	Type of industry	capacity(tons/ha)	Standard used for water demand
Pembe	Milling industry	400	FAO (2009)
Mulindi	Tea factory	800	Kenya (2015)
Gatuna	Milk collection center	100	FAO (1996)

Appendix 3. Characterization of potable water sources and watersheds

<table>
<tr><td>1.Byumba sector</td><td>Source name: Kwa SEHUKU</td><td>Ref number : 015</td><td>Key notes</td></tr>
<tr><td colspan="3">  </td><td>The water catchment is not fenced and there are no diversion ways for the protection of water source catchment.

Required management activities

Establishment of water diversion ditches to deviate the runoff

Introduce fences</td></tr>
<tr><td>2.Byumba sector</td><td>Source name: Kwa NYIRAGICE</td><td>Ref number: 016</td><td>Key notes</td></tr>
<tr><td colspan="3">  </td><td>There are no fences and the catchment is not well protected and there are tree plantation in the catchment area which may disturb the water source.

Required management activities
Establishment of a water diversion ditch around the immediate spring catchment, introduce fences, and protect it.
Total rehabilitation and regular monitoring of this spring is required.</td></tr>
</table>

3.Sector Byumba	Source name :Kwa NDUNGUTSE	Ref number : 017	Key notes
 			The water source catchment is not fencedand it is not protected.There is a path crossing the cathment area. In rainy season ,source water gets dirty as the consequence of the mix of run off water with the source water. **Required management activities** Establishment of immediate spring catchment and fence it. Establishment of a water diversion ditch to catch runoff.

4. Sector :Byumba	Source name : Ku GATARE	Ref number : 018	Key notes
			There are 3 captured sources in this area but the collection chamber is damaged and it is covered by natural vegetation . Source water gets dirty in rainy season. **Required management activities** Immediate rehabilitation and maintenance of the collection chamber. Secure and lock the collection chamber. Maintenance of spring immediate catchment area. Establishment of a water diversion ditch.
5.Sector : Byumba	Source name : KAVURE	Ref number :019	Key notes
			The source is not captured and it is not fenced ,the cathment area is not well protected as the consequence. Source water becomes dirty in the rainy season. **Required management activities** Establishment of immediate spring catchment and fence it. Establishment of a water diversion ditch. Guide :NIYONSABA Jean de Dieu ,SEDO Kivugiza cell Tel:0788996770

6.Sector :Byumba	Source name : GATUKU	Ref number : 020	Key notes
			The source catchment boundary is not clear because it is not fenced to depict it, the cathment area is not also protected properly. The source is not captured. **Required management activities** Capturing of the source spring water. Reestablishment of the spring catchment area. Establishment of water diversion ditch.
7.Sector:Byumba	Source name:NYAMUSANGWA	Ref number : 021	Key notes
			The Source water sometimes becomes dirty in rainy season.. The source catchment area is not protected and it is not fenced. The source catchment area is surrounded by households as it is shown on the picture. **Required management activities** Establishment of immediate spring catchment and fence it with imiyenzi. Establishment of a water diversion ditch.
8. Sector:Byumba	Source name : MIRIKU	Ref number : 022	Key notes

The source is captured and its discharge is transported to NYAMABUYE water treatment plant.
The catchment area is protected but it is not fenced to show its boundaries and to protect life stock grazing.
Required management activities

Establishment of water spring catchment and fence it.

Establishment of a water diversion way as well as the reinforcement of the upstream progressive terraces.

9. Sector :Byumba	Source name : NYAKAGEZI	Ref number :023	Key notes

The source is Captured but distribution pipes are damaged and the distribution line is no longer functioning.
There are no fences to protect the source point area, the water collection chamber is exposed to erosion and runoff water passes over the source catchment area.

Required management activities

Establishment of water spring catchment and fence it.

Establishment of a water diversion ways as well as the reinforcement of the upstream progressive terraces.

10. Sector : Byumba	Source name : KABINGO	Ref number :454	Key notes
			The source is captured but the catchment area is not protected properly and it has no fences. Catchment area boundaries as depicted in the picture, there are life stock grazing activities. **Required management activities** Establishment of a water source immediate protection area with fences. Stop grazing over the spring immediate catchment.
11. Sector:Byumba	Source name :GIHANGA	Ref :455	Key notes
			The source is not captured. The source catchment has no fences and it is not protected properly. **Required management activities** Maintaince of the spring immediate catchment and fence it. Establishment of a water diversion way around the spring immediate catchment.

12.Sector :Byumba	Source name : RUNYENYERI	Ref number :456	Key notes
			The source is not captured. The catchment area has no fences and it is not protected and there is a path way over it as illustrated on the picture. The water tap is exposed to erosion. Guide: TWIZERIMANA Jean Paul Tel :0782352774 **Required management activities** Establishment of water diversion ways. Establishment of water spring catchment and fence it.
13 .Sector :Byumba	Source name : CGM	Ref number: 025	Key notes
			The source is not captured. The source catchment has no fences and it is not protected as well. Guide :KABANDA Felicien,WASAC Technician NYAMABUYE Water treatment plant **Required management activities** Maintaince of the spring immediate catchment and fence it. Establishment of a water diversion way around the spring immediate catchment.

14.Sector :Byumba	Source name: Kwa BYAVU	Ref number :026	Key notes
			The water source is not captured. The source catchment area is not fenced and it is not protected properly. **Required management activities** Maintaince of the spring immediate catchment and fence it. Establishment of a water diversion way around the spring immediate catchment area. Immediate rehabilitation of the spring.
15. Sector : Byumba	Source name :	Ref number : 027	Key notes
			The source is not protected. The catchment area is not protected and it is not fenced. The source water usually gets dirty in the rainy season. **Required management activities** Establishment of the adequate water diversion ditch is required as well as the fences. Establishment of a water diversion ditch.

16.Sector :Byumba	Source name :	Ref number : 028	Key notes
			The source water becomes dirty in rainy season. The source catchment is not protected and it has no fences. The source point is surrounded by natural vegetation and it is polluted by washing activities. **Required management activities** Establishment of fences around the spring catchment area. Establishment of a water diversion ditch and total rehabilitation of the spring. Establishment of terraces upstream of the spring and protect them with grasses.
17 .Sector : Kageyo	Source name:KABAGESHI 2	Ref number :029	Key notes
			The water source is not captured. The source catchment area is not fenced and it is not clear as well. The spring's water pipe is damaged and needs to be rehabilitated. **Required management activities** Recapturing of water source and establishment of fences arround the immediate catchment area. Establishment of water diversion way around the spring immediate catchment. Clearence of immediate catchment area and rehabilitation of the spring.

18. Sector: Kageyo	Source name: KABAGESHI 1	Ref number : 032	Key notes
 			KABAGESHI source is captured but it is damaged as it is shown on both pictures. The distribution system from this source is no longer operating and the water tank which collects water from the source is damaged at a higher extent as it is depicted on the picture. The catchment area is not fenced and it is not protected at all. Water from the source sometimes becomes dirty due to runoff water which easily penetrates in the source point. **Required management activities** Immediate rehabilitation of the entire source and the distribution system as well. Establishment of fences around the catchment area. Establishment of source water diversion ditch around the spring immediate.

19. Sector :Kageyo	Source name: GAHONDO	Ref number : 036	Key notes
 			The source is captured but currently it is damaged as it is shown on the pictures, water is coming from the water collection area. The source catchment area is not protected and there are no clear fences at the catchment boundary. Water of Gahondo source sometimes become dirty in rainy season periods as it is shown on the picture. **Required management activities** Maintaince of the spring immediate catchment and fence it. Establishment of a water diversion way around the spring immediate catchment.

20. Sector : Kageyo	Source name:NYAKABINGO	Ref number :037	Key notes
			The source is not captured and its catchment area is not protected and it is not fenced. **Required management activities** Maintaince of the spring immediate catchment and fence it. Establishment of a water diversion way around the spring immediate catchment. Immediate rehabilitation of the spring.
21.Sector : Kageyo	Source name : KAGWA	Ref number : 038	Key notes
			The source catchment area is not protected and it is not fenced. The source is not captured. **Required management activities** Capturing of the spring water. Establishment of fences around the spring catchment area. Establishment of water diversion ditch.

22. Sector : Kageyo	Source name : MUNINI	Ref number : 039	Key notes
			The source catchment is not well protected and it has no fences. The catchment area is surrounded by natural vegetation. **Required management activities** Capturing of the spring water. Establishment of fences around water catchment area and protect it.
23.Sector:KAGEYO	Source name : RWUNGA	Ref number :040	Key notes
			The source catchment area is protected because it has fences which can show its boundaries. But the catchment area is not protected from a free cross movement of people and animals. Spring's water sometimes becomes dirty especially in rainy season but not at a higher extent. **Required management activities** Reinforce the existing fences and regular maintenances of the spring is required. Establishment of a water diversion way around the spring immediate catchment. Establishment of protection means around the catchment area.

24 . Sector : Kageyo	Source name : Gikuku 1	Ref number : 041	Key notes
			The source catchment area has no fences and consequently, it is not well protected. **Required management activities** Establishment of fences around water spring catchment and protect it.
25. Sector: Kageyo	Source name : Gikuku 2	Ref number : 042	Key notes
			The source catchment area has a clear fence to depict its boundaries but as it is shown on the picture the catchment area is not protected from a free cross movement of animals. The spring's water sometimes become dirty in rainy season. **Required management activities** Reinforce the existing fences and regular maintenances of the spring is required. Establishment of protection means around the catchment area.

26 . Sector : Kageyo	Source name : GIKUKU 3	Ref number : 043	Key notes
			The source catchment area doesn't have fences and it is not protected as well. The surrounding of the water tap and the catchment area is not well maintained and trenches transporting water away from the water tap area are not clean. **Required management activities** Establishment of the adequate water diversion ditch is required as well as the fences and protection. Maintanence of trenches in the catchment area is required as it will enhance the ground water recharge.
27. Sector: Kageyo	Source name: Mwange	Ref number : 044	Key notes
			The surrounding of the water tap and catchment area is not well maintained and trenches transporting water away from the water tap area are not clean. Some of the water from the source is diverted away from the water tap and water from the source sometimes becomes dirty in rainy season The source is not captured and its catchment area doesn't have fences and it is not protected at all. **Required management activities** Capturing of the source water. Establishment of fences around water catchment area and protect it. Maintain the trenches in the catchment area as required.

28.Sector: Kageyo	Source name : NYIRARUZENGA 1	Ref number: 046	Key notes
			The source is not captured with an unprotected catchment area which doesn't have fences. **Required management activities** Capturing of the source water. Establishment of protection means around the catchment area and fence it.
29.Sector :Kageyo	Source name : NYIRARUZENGA 2	Ref number : 047	Key notes
			The source is not captured and its catchment area is not protected and doesn't have fences. The spring is surrounded by lots of shrubs, bushes and natural vegetation. **Required management activities** Capturing of the source water. Protection of the catchment area and fence it. Clean and maintain the catchment area by removing shrubs and bushes around.

30. Sector: Kageyo	Source name : NYIRARUZENGA 3	Ref number : 048	Key notes
			The water fountain is no longer operating. It is preferred to use Nyiraruzenga 1 and 2 although they are too close to Nyiraruzenga 3and have a higher discharge compared to it. As illustrated on the picture, the spring is almost covered by the bushes. The source is not captured and has a water diversion way, its catchment area is not protected and doesn't have fences. **Required management activities** Immediate rehabilitation of the spring. The source needs to be captured and the catchment area needs to be fenced and protected. Clean the spring's surrounding by removing all the bushes.

31 .Sector:Kageyo	Source name: MUGOMERO 1	Ref number : 50	Key notes
			The water source needs to be captured. The catchment area is not protected and doesn't have fences. The source discharges water through the rock and during rainy season, water usually becomes dirty. Guide: GASAGURE Ildephonse Tel : 0722827283 **Required management activities** Capturing of the source water is required. Establishment of a water diversion way, fence and protect the catchment area. Construction of the standard spring's fetching area is required.
32. Sector:Kageyo	Source name: MUGOMERO 2	Ref number : 49	Key notes
			Needs to be rehabilitated Water is always clear and clean. The source is not captured and its catchment area is not protected. The source discharge area is damaged and needs to rehabilitated and maintained. **Required management activities** Capturing of the source water and immediate rehabilitation is needed . Maintenance and fencing of the spring catchment is necessary.

33. Sector:Kaniga	Source name : RUBOROGA 1	Ref number : 054	Key notes
			The source is captured, well maintained and it is in good conditions but its catchment area is not fenced. **Required management activities** Although the source is captured and well maintained, regular and proper cleanig is required. Surround the catchment area by fences.
34 . Sector :Kaniga	Source name : RUBOROGA 2	Ref number : 055	Key notes
			The source is captured, well maintained and it is in good conditions but its catchment area doesn't have fences. **Required management activities** Although the source is captured and well maintained, regular and proper cleanig is required. Surround the catchment area by fences.

35.Sector :Kaniga	Source name: CYASAKU	Ref number : 056	Key notes
			The source is captured, well maintained and it is in good conditions but its catchment area doesn't have fences. **Required management activities** Protection of the catchment area and fence it.
36. Sector :Kaniga	Source name: NYANGOROGORO	Ref number : 058	Key notes
			The source is captured but not in a proper way. Its catchment area doesn't have fences and it is not protected at all. The source point is surrounded by seasonal crops. **Required management activities** Establishment of fences around water catchment area and protect it. Reduce natural vegetation around the source and stop agricultural activities around.

37.Sector: Kaniga	Source name : NYAKEGA	Ref number : 059	Key notes
			The source is captured but not properly and needs total rehabilitation. The source catchment area doesn't have fences and it is not protected. **Required management activities** Re-capture the source to make all water of spring useful. Establishment of fences arround immediate source catchment is required to protect both water quality and quantity of the source.
38.Sector:Kaniga	Source name: RUHITA 2	Ref number : 061	Key notes
			The source is not captured and its catchment area is not protected and doesn't have fences. Water is always clear and clean. **Required management activities** Capturing of the source is required. Establishment of fences around source catchment is required.

39. Sector :Kaniga	Source name: RUHITA 1	Ref number : 063	Key notes
 			The source is captured but not properly. The distribution line is damaged as shown on the sideways picture. The catchment area is not protected and doesn't have fences. **Required management activities** Re-capture the source to make all water of spring useful. Establishment of fences around immediate source catchment is required and rehabilitated the distribution line

40. Sector: Kaniga	Source name:KANYEGA	Ref number:064	Key notes
 			The source is captured but the collection chamber is damaged as you illustrated on the picture below. The source catchment area is not protected. Guide :BIZIMANA Jean Bosco Tel :0784312635 **Required management activities** Surround the catchment area by fences and protect it. Rehabilitation of the collection chamber is required to ensure the quality of source water.
41.Sector : Kaniga	Source name : KINYOGO	Ref number : 066	Key notes
			The source is not captured and the catchment area doesn't have fences but it is partially protected. Water becomes dirty in rainy season. **Required management activities** Capturing of the source is required. Establish a water diversion ditch and surround the catchment area by fences. Immediate rehabilitation of the source is required.

42.Sector : Kaniga	Source name : RUTAHA	Ref number :067	Key notes
			The source is not captured and there is a reserved area for its catchment is not well protected. The water fountain needs a rehabilitation. Water becomes dirty in rainy season. **Required management activities** Capturing of the source is required. Establishment of immediate spring catchment area to protect both water quality and quantity of the spring. Establishment of water diversion ditch and its regular maintenance.
43. Sector: Rushaki	Source name : RURENGERI	Ref number : 69	Key notes
			The source is not captured and its catchment area is not protected. The water fountain is exposed to severe erosion as it is illustrated on the picture and the trenches are no longer able to drive away all water from the fountain. **Required management activities** Reinforce trenches that are located around water fountain and incorporate terraces around catchment area. Pave water diversion path in order to eliminate the interaction between spring water and the runoff. Capturing of the source and fencing the catchment area.

44.Sector: Rushaki	Source name : NYAGAHANGA	Ref number:072	Key notes
			The source is captured but not properly. The catchment doesn't have fences and hence not protected properly. **Required management activities** Re-capture the source to make all water of the source useful. Establishment of fences around immediate spring catchment and protect the source for both water quality and quantity of the source.
45. Sector: Kaniga	Source name : RWABONA	Ref number: 070	Key notes
 			The sources from Rwabona are neither captured nor in use. As it is illustrated, they have higher discharges. The catchment area is protected but without fences. **Required management activities** Capturing sources of Rwabona for future use**.** Suround the catchment area with fences. Pave water diversion paths in order to eliminate the interaction between spring water and the runoff.

46. .Sector : Rushaki	Source name : NYARUHANGA	Ref number : 073	Key notes
			The source has a reserved area for its catchment but has not fences to fully protect it. Water usually becomes dirty in rainy season. **Required management activities** Establishment of immediate spring water catchment and fence it. Establishment and regular maintenance of water diversion ditch.
47.Sector: Rushaki	Source name: NYAGAHANGA	Ref number :074	Key notes
			The source is captured and its catchment area is not protected and is covered by bushes. **Required management activities.** Establishment of fences around the immediate spring catchment area, protect it, and remove bushes.
48. Sector: Rushaki	Source name : NYARURENGA	Ref number : 075	Key notes
			The catchment area is not protected and doesn't have fences. **Required management activities** Protect the catchment area and fence it. Regular maintenance of the spring is required.

49.Sector: Rushaki	Source name : KIVOMO	Ref number :077	Key notes
			The source is captured and its distribution line is under rehabilitation. The catchment area is protected as well. **Required management activities** Reinforcement of distribution line rehabilitation works .
50.Sector: Bungwe / Burera	Source name : NYARUKORE	Ref number : 079	Key notes
			The water fountain is not clean and most of it is diverted. The catchment area is not protected and does not have fences. The source is not captured. **Required management activities** Protect the catchment area and fence it. Capturing of the source is required. Establishment of trenches and diversion ditch around the fountain is required.

51.Sector: Rushaki	Source name: MBANDA	Ref number :080	Key notes
			The source catchment area is neither protected nor captured. Source water is diverted. Guide : MUKAGAKWISI Christine, Nyarukore village Tel : 0787220813 **Required management activities** Introduction of fences and protection of catchment area. Establishment and regular maintenance of water deviation ditch.
52.Sector:Manyagiro	Source name : GITABA	Ref number : 084	Key notes
 			The source is still under work of the recapturing. The source catchment area is protected but not yet fenced. **Required management activities** Reinforcement of recapturing works. Introduce fences around the catchment area and terraces upstream of the source.

53. Sector: Manyagiro	Source name: RWUNGO 1	Ref number :85	Key notes
			The source is captured and is well maintained and the catchment area is protected but without fences. **Required management activities** Introduce fences around the catchment area.
54. Sector: Manyagiro	Source name: Rwungo 2	Ref number:86	Key notes
			The source is captured and is well maintained and the catchment area is protected but without fences. **Required management activities** Introduce fences around the catchment area and maintain the existing terraces.

55. Sector: Manyagiro	Source name:Rwungo 3	Ref number :87	Key notes
			The source is captured and is well maintained and the catchment area is protected but without fences. **Required management activities** Introduce fences around the catchment area and maintain the existing trenches.
56. Sector : Manyagiro	Source name :Rwungo 4	Ref number:88	Key notes
			The source is captured and is well maintained and the catchment area is protected but without fences. **Required management activities** Introduce fences around the catchment area and clear the zone.

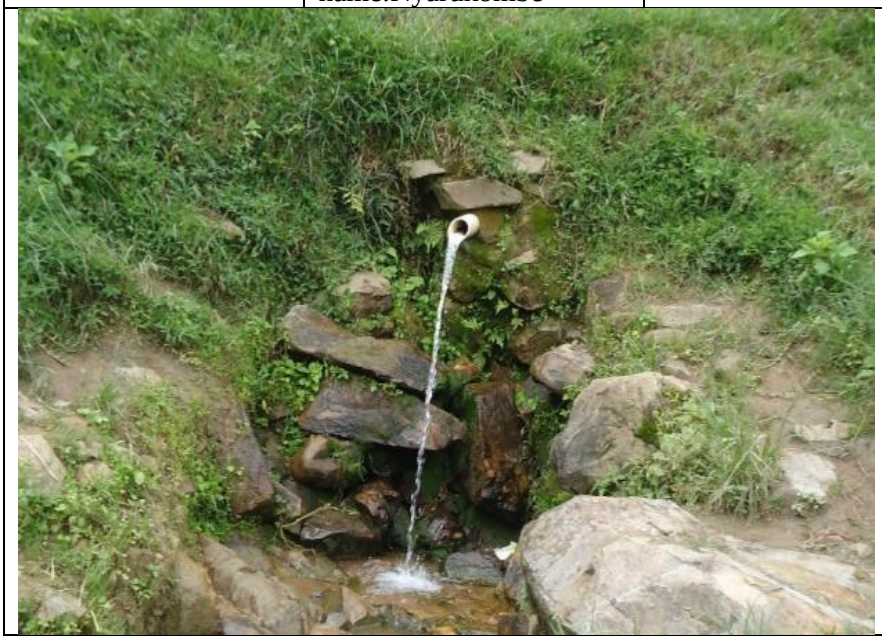
57.Sector: Manyagiro	Source name : Rwungo 5	Ref number:89	Key notes
 			The source is captured and is well maintained and the catchment area is protected but without fences. **Required management activities** Introduce fences around the catchment area.
58. Sector :Manyagiro	Source name :Murehe 1	Ref number :091	Key notes
			The catchment area is neither fenced nor protected. The source is not captured and is exposed to erosion. **Required management activities** Introduce fences and protect the catchment area. Capturing of the source is required and introduces terraces upstream to prevent its exposure to erosion.

59. Sector:Manyagiro	Source name:MUREHE 2	Ref number:090	Key notes
			A good part of the source water is diverted and water sometimes becomes dirty in rainy season. The catchment area is not protected and it is not fenced as well. **Required management activities** Introduce fences and protect the catchment area. Pave the diversion path to eliminate the interaction of spring's water and the runoff. Immediate rehabilitation of the spring.
60. Sector:Miyove	Source name:MUREKO	Ref number :094	Key notes
			The source is captured and demonstrates a high turbidity increment during the rainy season. The catchment is not protected and doesn't have fences. **Required management activities** Introduce fences and protect the catchment area. Introduce diversion paths.

61. Sector:Miyove	Source name:MAYA	Ref number :95	Key notes
			The source is not captured and its catchment area is neither fenced nor protected. Water usually becomes dirty in rainy season. **Required management activities** Capture the source, introduce fences, and protect the catchment area. Introduce diversion paths.
62. Sector:Miyove	Source name: SHONDORI	Ref number:096	Key notes
			The source is not captured and the catchment area is neither fenced nor protected. The source needs a total rehabilitation. Water becomes dirty in rainy season. **Required management activities** Capture the source, introduce fences, and protect the catchment area. Immediate total rehabilitation of the source. Introduce a diversion ditch.

63. Sector:Miyove	Source name:Mu KADOGO	Ref number :097	Key notes
			The source needs Rehabilitation. The source is not captured and its catchment area is not protected. Guide : Duniya Tel : 0783800322 **Required management activities** Capture the source, introduce fences, and protect the catchment area. Immediate rehabilitation and clearance of the source.
64. Sector:Nyankenke	Source name:KABERE	Ref number :099	Key notes
 			The source is captured and there is a reserved area for the catchment but it doesn't have fences. Water becomes dirty in rainy season. Some of the pipes of the distribution line are exposed to erosion. **Required management activities** Establishment of the spring catchment area with fences and protect it. Introduce terraces upstream.

65. Sector:Nyankenke	Source name:Ku ITARE	Ref number :102	Key notes
			The source is captured and it is in good condition. The catchment area is protected and does have fences. The preserved water for population around the source point has a very low discharge as it is shown on the picture. **Required management activities** Regular maintenance of the spring is required. Reinforce the existing fences.
66. Sector :Nyankenke	Source name:RWAMBEHO	Ref number :101	Key notes
			The source is captured and its catchment area is protected and does have fences. **Required management activities** Reinforce the existing fences around the catchment area and regular maintenances of the source is needed.

67. Sector :Nyankenke	Source name:GATARE	Ref number :103	Key notes
			The source is captured and its catchment area is protected but without fences. The source is surrounded by another source which is not in use. **Required management activities** Introduce fences around the catchment area. Explore the feasibility of using another source..
68. Sector :Manyagiro	Source name:Nyarukombe	Ref number :104	Key notes
			The source is not captured and its catchment area doesn't have fences on its boundaries and it is not protected as well. **Required management activities** Capture the source, introduce fences, and protect the catchment area. Introduce diversion paths.

69. Sector:Byumba	Source name:NYARUBANDE	Ref number :105	Key notes
			The source is captured and its catchment area is not protected and doesn't have fences. Guide : SINAYIRAZWE Mathias Tel : 0785080064 **Required management activities** Introduce fences and protect the catchment area. Rehabilitation of the spring is also needed.
70. Sector :Ruvune	Source name:KABINGO	Ref number:106	Key notes
			The source is not captured and doesn't have a water tap. The catchment area is not protected and it is surrounded by a lot of bushes. **Required management activities** Capture the source, and introduce a standard water tap to the source. Introduce fences, clear the surrounding, and protect the catchment area.

71. Sector :Ruvune	Source name :KAGOMERO	Ref number :107	Key notes
			The source is captured but currently, the distribution line is highly damaged and it is no longer in use. The source point is covered by lot of bushes as it is shown on the picture. The source point is damaged and it was not rehabilitated. **Required management activities** Immediate rehabilitation of the distribution line and the source point is required. Immediate clearance of the source point. Establishment of the catchment area, introduces fences, and protects it.
72. Sector:Ruvune	Source name:RWIMILINDI 1	Ref number: 108	Key notes
			The source is not captured and its catchment area is not protected. The source point is too close to banana plantations. **Required management activities** Capture the source, introduces fences, and protect the catchment area Remove banana plantation in direct protection zone and rehabilitate the spring.

73. Sector :Ruvune	Source name:RWIMILINDI 2	Ref number :111	Key notes
			The caption of the source is not assured. Simply it is said to be captured. The source doesn't have a collection chamber; consequently, there is a free flow of water from the source point to the water tap approximately located in 1.5 km away from the source. The catchment area is covered by natural vegetation. **Required management activities** Recapture the source, install a collection chamber and it should be secured and locked. Establish the catchment area, fence it, clear it, and protect it.
74. Sector :Ruvune	Source name:BUTYAZO	Ref number :112	Key notes
			The source is captured and the catchment area is covered by lots of bushes. Some of the spring's pipes are no longer operating. **Required management activities** Establish the catchment area, fence it, and protect it. Clearance of the spring's surrounding is required.

75. Sector : Rukomo	Source name: Kadogo	Ref number: 108	Key notes
			The source is not captured, not fenced, and not protected at all. Water get dirty during the rainy season as it is shown on the picture. **Required management activities** Capture the source, introduces fences, and protect source catchment area. Establish water diversion paths upstream to prevent the interaction of source water and the runoff.
76. Sector : Ruvune	Source name : Karitushi	Ref number :111	Key notes
			The source is not captured and does not have fences and it is not protected. Water becomes dirty during the rainy season. The catchment area is surrounded by uncultivated area. The proper maintenance is required. **Required management activities** Capture the source, introduce fences, and protect the source catchment area. Introduce water diversion ditch around the source.

77. Sector :Rukomo	Source name :KARIBA 1	Ref number :117	Key notes
			The source is captured but it does have a collection chamber, its catchment is protected and covered by the natural vegetation but it is not fenced. **Required management activities.** Install a collection chamber, and it should be secured and locked. Introduce fences around the catchment area.
78. Sector:Rukomo	Source name:KARIBA 2	Ref number :118	Key notes
			The source is Captured but it doesn't have a collection chamber, its catchment area is protected but not fenced. The surrounding area is covered by the bushes and shrubs. **Required management activities** Install a collection chamber, secure it, and lock it. Introduces fences on the catchment area and clear it.

79. Sector :Shangasha	Source name: NYAKABINGO 1	Ref number :119	Key notes
			The source is not captured and its catchment area is not fenced, therefore it is not connected properly. As illustrated on the picture, the spring is surrounded by agricultural activities and has a water diversion path. **Required management activity** Capture the source, introduces fences around the catchment area. Stop agricultural activities near the source.
80. Sector:Shangasha	Source name: NYAKABINGO 2	Ref number:120	Key notes
			The source is captured and the catchment area is not fenced and it is not protected as well. The upstream area of the source is cover by the forest plantation of eucalyptus. And the catchment area is covered by the natural plantation, and too close to small agricultural activities. **Required management activities** Introduces fences, and well protect the catchment area. Clearance of eucalyptus on the vicinity of the source. Establishment of water diversion pathways.

81. Sector:Shangasha	Source name: NYAKABINGO 3	Ref number:121	Key notes
 			The source is captured and the catchment area is not fenced and it is not protected as well. The pumping station illustrated below is no longer in use and needs rehabilitation for the future operations. The upstream area of the pumping station is covered by the banana plantation and forest plantation. **Required management activities** Introduce fences, and well protect the catchment area. Clearance of eucalyptus on the vicinity of the spring. Rehabilitate the pumping station.

82. Sector :Shangasha	Source name : NYAKABINGO 4	Ref number :122	Key notes
			The source catchment area is not protected and most of the catchment area is covered by bushes as illustrated on the picture. The source of water is captured but without a collection chamber, water is conveyed directly to the tank. The upstream area of the source is covered by forest plantation of eucalyptus. **Required management activities** Introduces fences, clear and protect the catchment area. Install a collection, secure it, and lock it. Clearance of eucalyptus on the vicinity of the source.
83. Sector:Shangasha	Source name: KABAYI	Ref number :123	Key notes
			The catchment area of the source is not fenced and it is not also well protected. In addition to that, most of the source water is diverted. As a result, only water with 0.02 l/s flow rate is discharged and it is still talking the normal flow rate. The spring discharges water through two main pipes and some of the spring water leaks. **Required management activities** Introduces fences and well protect the catchment area. Establish a diversion ditch downstream.

84. Sector:Shangasha	Source name: KAZIRANKURWE	Ref number:124	Key notes
			The source is not captured, its catchment area is not protected, and it is not fenced as well. The left part of the spring is surrounded by the shrubs as it is shown on the picture and the spring discharges water through one pipe and some of the spring water leaks. Guide : Dominique Tel : 0728308248 **Required management activities** Capture the source, introduces fences, and protect the catchment area. Clearance and maintenance of the spring's surrounding is required. Establish a water diversion ditch downstream.

85. Sector:Bwisige	Source name: RWANGABO	Ref number :126	Key notes
 			Rwangabo is constituted with lots of sources captured in the area in this picture. The catchment area is not protected and its surrounding is not fenced. Its distribution line is damaged and needs immediate rehabilitation. The pumping station shown in below picture is also damaged and it is no longer operating. The pumping station area is fenced and it is surrounded by the bushes which imply also an immediate maintenance. Guide: NZAKAMWITA Apolinaire **Required management activities** Introduces fences and protect the catchment area. Immediate rehabilitation of the distribution line and pumping station.

86. Sector:Bwisige	Source name: KAGOROGORO	Ref number :127	Key notes
			The source is not captured, its catchment area is not protected, and it is not fenced as well. Water becomes dirty in rainy season. And most of its part area is diverted. The catchment area is surrounded by the shrubs and bushes. Spring discharges water through one pipe and some of the spring water leaks. **Required management activities** Capture the source, introduces fences, and protect the catchment area. Introduce terraces upstream and diversion paths and clear the catchment area. Introduces a water diversion ditch downstream.
87. Sector :Bwisige	Source name : KANYIRABUKI	Ref number :128	Key notes
			The source is captured and its catchment area is not protected, and it is not fenced as well. The Springs catchment area is surrounded by natural vegetation, and the spring discharges water through one pipe and some of the spring water leaks as it is illustrated on the picture. The spring is well constructed and needs proper maintenance around. **Required management activities** Introduces fences and protect the catchment area. Establish a water diversion ditch downstream.

88. Sector:Bwisige	Source name: RYARUGANZU	Ref number:129	Key notes
			The source is captured but not properly. There is a considerable area of the source which is diverted and water goes away from the collection chamber. The catchment area is not protected and it is not fenced. The distribution line is damaged and needs an immediate rehabilitation. Some of spring catchment area is covered by passparum plants. The spring discharges water through two main pipes and some of the spring's water leaks. **Required management activities** Recapture the source and introduces diversion paths. Introduce fences and protect the catchment area. Immediate rehabilitation of the distribution line. Establish a water diversion ditch downstream.

89. Sector :Bwisige	Source name: KIGAGA	Ref number :130	Key notes
			The source is not protected and its catchment area is not protected and it is not fenced as well. Water becomes dirty in rainy season. The immediate spring catchment is not protected and it is sloppy with a possibility of an open runoff. The spring discharges water through one pipe as it is shown on the picture. **Required management activities** Protect both the source and the catchment area, and introduces fences. Introduces water diversion paths to eliminate the interaction of the spring's water and the runoff.
90. Sector:Rukomo	Source name:GAHONDO	Ref number :131	Key notes
			The source is not captured, its catchment area is not fenced and it is not protected as well. Water from the source always becomes dirty in rainy season periods.. The water fountain is too close to the road. The spring discharges water through two main pipes and some of the spring water leaks as it is shown on this picture. **Required management activities** Capture the source, introduces fences, and protect the catchment area. Establish water diversion paths possibly upstream terraces.

91. Sector :Muko	Source name: NYAKABINGO	Ref number:133	Key notes
			The distribution work is still under construction and water becomes dirty in rainy season. The source is characterized by an overflow of water in the catchment area and water leaks in pathways area which seem to be packed with soft soils. **Required management activities** Reinforcement of distribution works and introduces diversion pathways. Establish a catchment area, fence it, and protect it. Introduce a water diversion ditch downstream.
92. Sector:Rutare	Source name: BURERANYANA	Ref number:134	Key notes
			The distribution line from BURERANYANA source is under rehabilitation. Its catchment area is protected and it is fenced. The catchment area is also surrounded by banana plantation and terraces that need a proper improvement. **Required management activities** Reinforce the rehabilitation works. Reinforce the existing fences and terraces.

93. Sector :Rutare	Source name: GATARE	Ref number :135	Key notes
			The source is captured and its catchment area is not protected and it is not fenced as well. Water becomes dirty in rainy season. The catchment area is surrounded by the shrubs and bushes which imply that the source needs a proper maintenance and clearance. The spring discharges water through two main pipes as it is illustrated on the picture. **Required management activities.** Introduce fences and protect the catchment area. Establish diversion pathways upstream.
94. Sector:Rutare	Source name: GAHANGA	Ref number:136	Key notes
			The source is captured and its catchment area is not protected and it is not fenced. Most of the water fountains constituting the distribution line from GAHANGA source are damaged and needs a proper rehabilitation. The catchment area is surrounded by the bushes and the spring has three main pipes for discharging water but only one of them is operating. **Required management activities** Introduces fences and protect the catchment area. Immediate rehabilitation of distribution line is required.

95. Sector: Rutare	Source name: GASHARU	Ref number: 137	Key notes
			Gasharu source is not captured and its catchment area is not protected and it is not fenced. The catchment area is surrounded by few plantations of banana, bushes, and stones. The spring is damaged and discharges water through one pipe. **Required management activities** Fence and protect the catchment area. Rehabilitate the spring and remove the banana plantation in vicinity of the source.
96. Sector:Rutare	Source name:KARANGARA	Ref number :138	Key notes
			The source is not captured and its catchment area is not protected and it is exposed to erosion. A considerable part of the source is diverted and the water fountain needs rehabilitation. The catchment area is mostly surrounded by the bushes of flesh grasses and they are dispatched everywhere within the catchment area. **Required management activities** Capture the source, introduces fences, and protect the catchment area. Introduces diversion pathways, and terraces to prohibit erosion exposure. Immediate rehabilitation of water fountain.

97. Sector:Giti	Source name:KANYAMA	Ref number:139	Key notes
			The source is not captured and its catchment area is not protected and it is not fenced. Water from Kanyama source sometimes becomes dirty in rainy season. . The source point is covered with lots of bushes. **Required management activities** Capture the source, introduces fences, and protect the catchment area. Clear the source, and introduces diversion pathways and terraces upstream.
98. Sector:Giti	Source name:RUHONDO	Ref number :140	Key notes
			The source is newly rehabilitated but it is exposed to erosion. The source is not captured and has a protected catchment with fences. The spring discharges water through two main pipes and some of the spring water leaks. **Required management activities** Introduces terraces upstream to prohibit erosion exposure. Reinforce the existing fences and establish a water diversion ditch downstream.

99. Sector:Muko	Source name :GAHAMA	Ref number:141	Key notes
			The source is captured and its catchment area is not protected and it is not fenced. The source point is surrounded by a lot of bushes and the collection chamber is secured and locked. Water spring over leaked out of the chamber as it is shown on the picture. **Required management activities** Introduces fences, and protect the catchment area. Clear the source point and introduce a standard water pipe. Establish a water diversion ditch.
100. Sector: Muko	Source name :KIDOGO 1	Ref number:142	Key notes
			The source is captured and its catchment area is not protected and it is not fenced as well. The source was hit by a severe landslide and is now highly damaged. Water becomes dirty during the rainy season and the catchment area is located within banana plantation field. **Required management activities** Introduce fences and protect the catchment area. Total rehabilitation of the source is required. Remove all banana plantation surrounding the water source.

101. Sector:Muko	Source name: KIDOGO 2	Ref number :143	Key notes
			The source is captured and its catchment area is not protected and it is not fenced. The source was hit by a severe landslide and is now highly damaged. Water gets dirty during the rainy season. The source is surrounded by a banana plantation field and it really needs an immediate rehabilitation. **Required management activities** Introduce fences and protect the catchment area. Total rehabilitation of the source is required. Remove all banana plantation in the vicinity of water source.
102. Sector:Nyamiyaga	Source name :Gakore	Ref number :144	Key notes
			The source is not captured and its catchment area is not fenced and it is not protected at all. The catchment area is covered by the natural vegetation as illustrated on the picture. The spring discharges water through one pipe and some of the spring water leaks. **Required management activities** Capture the source, introduce fences, and protect the catchment area. Establish a diversion ditch downstream. A rehabilitation of the spring is required.

103. Sector:Rutare	Source name:GAKERI	Ref number:145	Key notes
			The source is captured and its catchment area is not protected and is not fenced. A considerable part of the source is diverted and the water from the source always becomes dirty in rainy season. The pipe at which spring discharges water is almost covered by the bush and it is not well seen as illustrated on the picture. **Required management activities** Introduce fences and protect the catchment area. Establish water diversion pathways to eliminate the interaction of source water and runoff. Introduce a standard water pipe.
104. Sector:Rwamiko	Source name: NYAKAGEZI	Ref number :147	Key notes
			The source is captured and its catchment area is not protected and it is not fenced as well. The source point is exposed to erosion, and covered by the stones. The spring is not constructed and the pipe through which water is discharged is introduced within the rock. **Required management activities** Introduce fences around the catchment area and protect it. Introduce terraces upstream of the source to prohibit its exposure to erosion. Construct and maintain a standardized spring.

105. Sector:Rwamiko	Source name:Gaseke	Ref number :146	Key notes
 			The source is captured and its catchment is not protected and it is not fenced at all. A considerable part of the source is diverted and the water from the source always becomes dirty in rainy season. The catchment area is not clean and diverted water leaks. **Required management activities** Introduce fences and protect the catchment area. Establish water diversion pathways. Establish a diversion ditch downstream.

106. Sector:Bukure	Source name: KIRUHURA	Ref number:149	Key notes
			The source is captured and its catchment is fenced and it is protected. The catchment is surrounded by grazing grasses for domestic animals. **Required management activities** Reinforce and maintain the existing fences.
107. Sector:Bukure	Source name :GAHAMA	Ref number :150	Key notes
			The distribution system from GAHAMA source is now damaged and needs the rehabilitation. The source is captured and its catchment area is not protected and is not fenced. The source point is covered by lot of bushes. **Required management activities.** Immediate rehabilitation of the distribution system from GAHAMA source. Introduce fences around the catchment area and protect it.

108. Sector:Bukure	Source name: NANGURUGOMO	Ref number :151	Key notes
			The source is captured and its catchment is not protected and it is not fenced. The source point was hit by severe erosion and the collection chamber is now covered by soils and can't be easily accessed. The catchment area is surrounded by banana plantation and bushes as it is illustrated on the picture. **Required management activities** Introduce fences around the catchment area and protect it. Introduce terraces and trenches upstream to prohibit the exposure of the source to erosion again. Immediate rehabilitation of the collection chamber and removal of banana trees to the vicinity of the source.

109. Sector:Bukure	Source name: CYAKABARI	Ref number:152	Key notes
			The source is captured and the catchment area is not protected and is not fenced. The upstream area of the source point is cover by agricultural activities. The catchment area is covered by natural vegetation and the spring discharges water through one pipe and some of the spring water leaks. **Required management activities** Introduce fences and protect the catchment area. Remove agricultural activities in the source point vicinity. Introduce a water diversion ditch.
110. Sector :Mutete	Source name: RUSAVE	Ref number :153	Key notes
			The source is not captured and its catchment area is not fenced and it is not protected as well. The water fountain needs to be rehabilitated. The catchment area is covered by the bushes and spring discharges water through one pipe and some spring water leaks. **Required management activities**. Capture the source, introduce fences, and protect the catchment area. Immediate rehabilitation of water fountain and the spring itself. Introduce a water diversion ditch and clean the surrounding area.

111. Sector:Mutete	Source name: MARUMBA	Ref number:154	Key notes
			The source is not captured and its catchment is not fenced and it is not protected. The catchment area is covered by rocks and natural vegetation. **Required management activities**. Capture the source, introduce fences, and protect it. Rehabilitate the source and establish a standardized spring feature.
112. Sector :Mutete	Source name: MAGANGA	Ref number :154	Key notes
			The source is captured and its catchment area is not fenced but it is protected. The distribution system needs to be rehabilitated and it is covered by the bushes. **Required management activities** Introduce fences around the catchment area. Rehabilitate the distribution system and clear the surrounding.

113. Sector:Mutete	Source name: RWIMBOGO	Ref number :155	Key notes
			The water source is captured but now all the collection chambers are damaged. Rwimbogo network is damaged and needs rehabilitation. The catchment area is reserved but it is not fenced. **Required management activities** Immediate rehabilitation of collection chambers, and they should be secured and locked. Establishment of the catchment area and fence it.
114. Sector:Mutete	Source name: NYAMATA	Ref number :156	Key notes
			The source is captured and its catchment area is not protected and it is not fenced. Water becomes dirty in rainy season. The catchment is covered by the natural vegetation and some spring water leaks as illustrated on the picture. **Required management activities** Introduce fences and protect the catchment area. Establish water diversion pathways. Introduce a water diversion ditch downstream.

115. Sector:Nyankenke	Source name: KABAHURA	Ref number :156	Key notes
			The source is captured and its catchment area is not protected and does it is not fenced as well. Water becomes dirty in rainy season. The distribution station area is covered by natural vegetation. **Required management activities** Introduce fences and protect the catchment area. Establish water diversion pathways.
116. Sector:Byumba	Source name: RYARUGANZU	Ref number:157	Key notes
			The source is captured and the catchment area is not protected and it is not fenced at all. The immediate rehabilitation is needed. The source point is within and covered by rocks as it is illustrated on the picture. **Required management activities** Introduce fences and protect the catchment area. The immediate rehabilitation of the source is required.

117. Sector:Rukomo	Source name: Mugomero	Ref number :158	Key notes
			The source is not captured and the catchment area is not protected and it is not fenced. At some part of the source water is diverted. **Required management activities** Capture the source, introduce fences, and protect the catchment area. Establish a diversion ditch downstream.
118. Sector:Rukomo	Source name: NYAMABUYE 1	Ref number :159	Key notes
			The source is captured and the catchment is not protected and it is not fenced at all. The distribution system area is covered by the bushes and it is surrounded by unprogressive terraces. **Required management activities** Introduce fences and protect the catchment area. Reinforcement of the existing terraces.

119. Sector:Nyamiyaga	Source name: NYAMABUYE 2	Ref number :160	Key notes
			The source is captured and the catchment is not protected and it is not fenced at all. The catchment area is surrounded by grazing grasses. **Required management activities** Introduce fences and protect the catchment area. Stop grazing in the vicinity of the source.
120.Sector :Rushaki	Source name: Nyakeru	Ref number :626	Key notes
			The source is not captured and its catchment area is not protected and it is not fenced. The catchment area is covered by the natural vegetation and stones. A proper rehabilitation for the spring is needed. **Required management activities** Capture the source, introduce fences, and protect the catchment area. Immediate and total rehabilitation of the source is required.

121.Sector :Rushaki	Source name: Kamutora	Ref number :625	Key notes
			The source is captured and it is not clean at all. The source catchment area is covered by the shrubs and bushes And needs an immediate rehabilitation. **Required management activities** Recapture the source and clean it properly. Establish again the source catchment area and remove shrubs and bushes. Immediate and total rehabilitation is requested.
122.Sector :Kaniga	Source name: Ku musigiti	Ref number :621	Key notes
			The source catchment area is not fenced and it is not protected. The water source needs to be cleaned and there are season crops in its surroundings. The source area is surrounded by the bushes and it has a low flow rate of spring's water through the pipe as it is shown on the picture. **Required management activities** Introduce fences and protect the catchment area. Stop agricultural activities in the source vicinity. Immediate clearance of the source is required.

123.Sector : Mukarange	Source name: Kiruhura	Ref number: 630	Key notes
			The source is captured, it is not protected and itis not fenced. The source is surrounded by the bushes and rocks and the spring discharges water through a substandard pipe and spring's water leaks as it is illustrated on the picture. **Required management activities** Introduce fences and protect the source catchment area. Rehabilitation of the source is required.
124.Sector: Kaniga	Source name: Ku ibuye	Ref number :620	Key notes
			The water source is captured and it is surrounded by a groundwork made by stones. It needs proper fences and it is clean around though it has some natural vegetation around. **Required management activities** Reinforcement of existing fences with proper fences. Clean and rehabilitate the source.

125.Sector : Kaniga	Source name: Runoni	Ref number :619	Key notes
			The source is not fenced, not protected and it is surrounded by the bushes and shrub. Water doesn't get dirty in rainy season. **Required management activities** Clean and introduce fences around the catchment area and protect it.
126.Sector: Kaniga	Source name:Nyakagezi	Ref number: 624	Key notes
			The catchment area is not protected and it is not fenced. The source is not captured and it is surrounded by the bushes. The source is not clean that is why a proper maintenance is required. **Required management activities** Capture the source, introduce fences, and protect the catchment area. Clean the surrounding of the source.

127.Sector : Kaniga	Source name : Rutare	Ref number :618	Key notes
			The water point source was captured before but its current status shows that it has been damaged. The source is surrounded by the bushes and it not clean at all. The source is not fenced and to be recaptured, it has to be fenced. Guide : NIYIGABA Celestin Tel :0731588326 **Required management activities** Recapture the source, introduce fences, and protect the catchment area. Rehabilitation of the source is required.
128.Sector : Rubaya	Source name: Rwagashyashya	Ref number:632	Key notes
			The source is captured but it has to be well maintained and has to be rehabilitated. The catchment area does not have fences and it is not protected. Guide: BIZIMANA Samuel Tel : 0782300475 **Required management activities** Maintenance and rehabilitation of the source is required. Introduce fences, and protect the catchment area.

129.Sector : Rubaya	Source name: Kirimbi	Ref number : 631	Key notes
			The source is captured, not fenced, and it is not protected. The catchment area seems to be an open place and the spring discharges water through one pipe with low flow arte as illustrated on the picture. **Required management activities** Introduce fences and protect the catchment area. Introduce diversion pathways around the source.
130.Sector : Cyumba	Source name: Bulindi 2	Ref number: 634	Key notes
			The source is captured, it is not fenced, and the catchment area is not protected. The source is surrounded by natural vegetation, elephant grasses, and seasonal crops. **Required management activities** Introduce fences and protect the catchment area. Reinforce the rehabilitation of diversion pathways. Stop the agricultural activities around the source vicinity.

131.Sector: Shangasha	Source name : Gatare	Ref number : 639	Key notes
			The source is not captured, it is not fenced, and it is not protected. It needs an immediate rehabilitation. The source is surrounded by natural vegetation and rocks. **Required management activities** Capture the source, introduce fences, and protect the catchment area. Immediate rehabilitation of the source is required. Introduce water diversion pathways.
132.Sector: Kaniga	Source name: Bikurungu	Ref number : 622	Key notes
			The catchment is not protected and it is not fenced. The source is not clean and it is surrounded by bushes, natural vegetations and needs a proper maintenance. **Required management activities** Recapture the source, introduce fences, and protect the catchment area. Establish a water diversion ditch and rehabilitate the spring.

133.Sector : Giti	Source name : Rwagahunde	Ref number : 640	Key notes
			The source is captured, not fenced and needs to be well protected and well rehabilitated. The spring's surrounding is damaged and it is covered by natural vegetation. **Required management activities** Introduce fences and protect the catchment area. Immediate rehabilitation is required and regular monitoring of the spring.
134.Sector : Mukarange	Source name : Gitoma	Ref number :629	Key notes
			The source is captured and its catchment is not protected and it is not fenced. The source point is surrounded by crops mixed with natural vegetation. **Required management activities** Introduce fences and protect the catchment area. Clean the source point and stop agricultural activities in the source vicinity.
135.Sector : Rushaki	Source name: Rwengwe	Ref number : 628	Key notes
			The source is captured and its catchment area is not fenced and it is not protected as well. The distribution system is surrounded by natural vegetation and stones. **Required management activities** Introduce fences and protect the catchment area. Clean the distribution system surrounding.

136.Sector : Miyove	Source name: Museke	Ref number : 637	Key notes
			The source is not captured and its catchment area is not protected and it is not fenced. It needs to be rehabilitated. The catchment area is covered by natural vegetation and the source discharges water through a substandard pipe and some source water leaks as shown on the picture. **Required management activities** Capture the source, introduce fences, and protect the catchment area. Establish a water diversion ditch and rehabilitate the spring.
137.Sector : RUBAYA	Source name: Kiriba	Ref number : 633	Key notes
			The source is not captured and its catchment area is not protected and it is not fenced. The source's catchment area is surrounded by natural vegetation and there is washing activities within the surrounding. **Required management activities** Capture the source, introduce fences, and protect the catchment area. Establish a water diversion ditch downstream. Stop washing activities in the source vicinity.

138.Sector: Kaniga	Source name : Ku rutare	Ref number : 623	Key notes
			The catchment area is not protected and it is not fenced. The source is not clean and it is covered by the bushes and natural vegetation. **Required management activities** Introduce fences and protect the catchment area. Clean the source properly.
139.Sector: Mutete	Source name : Gahondo	Ref number: 624	Key notes
			The source is not fenced and its surrounding is not clean. The source is not captured and its discharge water is clean. **Required management activities** Recapture the source, establish the catchment area, introduce fences, and protect the catchment area. Maintain and clean the source properly.

Appendix 4. Gicumbi Springs and their discharges

SN	Source name	Discharge (L/S)	Sector	cell	Village	x	y	z	Status
1	Burindi 1	0.15	Cyumba	Muhambo	Centre	500825.94	4834106.52	2047.00	Captured
2	Burindi 2	0.25	Cyumba	Muhambo	Rugerero	501360.57	4834382.82	1950.00	Captured
3	Gashija	0.20	Cyumba	Nyakabungo	Gashija	500931.53	4838569.49	1929.00	Not captured
4	Bulindi 3	2.50	Cyumba	Nyakabungo	Ryamuromba	501177.17	9834372.57	1965.00	Captured
5	Bulindi 4	0.25	Cyumba	Muhambo	Rugerero	501014.38	4834182.83	1946.00	Captured
6	Bulindi 5	0.25	Cyumba	Nyaruka	Burindi	502649.66	4834203.72	1844.00	Not captured
7	Ruboroga (Gatuna) 1	0.41	Kaniga	Nyarwambu	Cyasaku	503386.97	4842668.52	1966.99	Captured
8	Ruboroga (Gatuna) 2	0.20	Kaniga	Nyarwambu	Cyasaku	503407.66	4842668.41	1970.40	Captured
9	Gitaba	1.20	Manyagiro	Remera	Gitaba	497781.86	4829796.68	2189.71	Captured
10	Nyarukombe I	0.73	Manyagiro	Nyarukombe	Ryaruyumba	499945.00	9830527.00	1905.00	Not captured
11	Rusebeya 1	0.40	Manyagiro	Rusebeya	Nyiravuza	500591.00	9830169.00	1859.00	Not captured
12	Nyarukombe II	0.20	Manyagiro	Nyarukombe	Ryaruyumba	500250.00	9830551.00	1909.00	Not captured
13	Rusebeya 2	0.07	Manyagiro	Rusebeya	Nyiravuza	501116.00	9828458.00	1848.00	Not captured
14	Rubindi1	0.15	Manyagiro	Kabuga	Rubindi	50119.00	983054.00	1894.00	Captured
15	Rubindi 2	0.25	Manyagiro	Kabuga	Rubindi	50120.00	983051.00	1889.00	Captured
16	Rwungo 1	0.80	Manyagiro	Remera	Shyigura	497784.20	4829819.01	2173.49	Captured
17	Rwungo 2	1.50	Manyagiro	Remera	Shyigura	497234.30	4830788.54	2159.87	Captured
18	Rwungo 3	1.20	Manyagiro	Remera	Shyigura	497227.74	4830768.53	2156.62	Captured
19	Rwungo 4		Manyagiro	Remera	Shyigura	497362.48	4830687.71	2145.61	Captured
20	Rwungo 5		Manyagiro	Remera	Shyigura	497199.47	4830733.04	2154.78	Captured
21	Murehe 1	0.11	Manyagiro	Kabuga	Murehe	502632.96	4831442.53	1854.96	Not captured
22	Murehe 2	0.03	Manyagiro	Kabuga	Murehe	502632.74	4831440.43	1856.20	Not captured
23	Mubuga 1 (Burera)	0.10	Bungwe	Tumba	Mubuga	496334.00	9832149.00	2241.00	Not captured
24	Mubuga 2 (Burera)	0.10	Bungwe	Tumba	Mubuga	496389.00	9832252.00	2217.00	Not captured
25	Mubuga 3 (Burera)	0.10	Bungwe	Tumba	Mubuga	496378.00	9832234.00	2226.00	Not captured
26	Mubuga 4 (Burera)	0.15	Bungwe	Tumba	Mubuga	496355.00	9832175.00	2234.00	Not captured
27	Nyarukore (Burera)	0.12	Bungwe	Tumba	Mubuga	498144.80	4832789.21	2012.23	Not captured
28	Mbanda	0.17	Bungwe	Tumba	Nyarukore	497761.48	4831795.01	2098.98	Not captured
29	Kwa Sebukangaga (Burera)	0.10	Bungwe	Tumba	Mubuga	496174.78	4832040.45	2278.99	Captured
30	Kwa Bigimbo (Burera)	0.15	Bungwe	Tumba	Mubuga	496190.80	4832285.57	2254.94	Captured
31	Mukoto	0.45	Bungwe	Tumba	Nyarukore	496465.00	9832438.00	2182.00	Not captured
32	Kavure 1	0.09	Manyagiro	Rusekera	Kavure	496571.00	9832365.00	2183.00	Not captured
33	Kavure 2	0.18	Manyagiro	Rusekera	Kavure	496641.00	9832449.00	2167.00	Not captured

SN	Source name	Discharge (L/S)	Sector	cell	Village	x	y	z	Status
34	Kavure 3	0.10	Manyagiro	Rusekera	Kavure	496935.00	9832482.00	2148.00	Not captured
35	Kavure 4	0.40	Manyagiro	Rusekera	Kavure	496961.00	9832471.00	2151.00	Not captured
36	Kagorogoro	0.30	Bungwe	Bungwe	Gatenga	497699.00	9832086.00	2085.00	Not captured
37	Rwambeho 1	0.47	Nyankenke	Butare	Rwambeho	499474.61	4822958.64	2039.69	Captured
38	Rwambeho 2	0.25	Nyankenke	Butare	Rwambeho	499634.00	9823432.00	2020.00	Captured
39	Kigogo		Nyankenke	Butare	Rwambeho	499389.00	9823236.00	2043.00	Not captured
40	Gatare	0.20	Nyankenke	Yaramba	Mwenyi	499907.00	9825851.00	1941.00	Captured
41	Source kwa Fabien	0.16	Manyagiro	Nyiragifumba	Rurambi	500034.00	9826818.00	1886.00	Not captured
42	Gashumba	0.05	Nyankenke	Yaramba	Nyarubuye	500825.00	9827163.00	1855.00	Not captured
43	Gatare	0.43	Nyankenke	Yaramba	Mwenyi	499971.74	4825570.82	1973.08	Captured
44	Kivugiza 1		Byumba	Kivugiza	Kivugiza	502416.00	9827793.00	1889.00	Not captured
45	Kivugiza 2		Byumba	Kivugiza	Kivugiza	502420.00	9827748.00	1886.00	Not captured
46	Sehuku	0.23	Byumba	Kivugiza	Kivugiza	503075.53	4826822.50	1773.33	Not captured
47	Nyiragice	0.20	Byumba	Kivugiza	Kivugiza	502741.07	4827039.50	1836.32	Not captured
48	Ndungutse	0.16	Byumba	Kivugiza	Kivugiza	502479.70	4827108.50	1834.74	Not captured
49	Gatare	0.14	Byumba	Kivugiza	Karambi	502468.13	4827454.00	1875.47	Captured
50	Kavure	0.20	Byumba	Kivugiza	Karambi	501854.39	4827893.00	1846.23	Not captured
51	Gatuku	0.22	Byumba	Kivugiza	Mugando	501566.55	4829327.50	1824.61	Not captured
52	Nyamusangwa	0.32	Byumba	Kivugiza	Mugando	502472.71	4829228.50	1848.19	Not captured
53	Runyenyeri	0.29	Byumba	Kivugiza	Kivugiza	503823.44	4826957.45	1887.00	Not captured
54	Kabere 1	0.60	Nyankenke	Butare	Kabere	500664.70	4821996.84	2106.05	Captured
55	Kabere 2	0.40	Nyankenke	Butare	Kabere	500584.00	4822000.00	2088.00	Captured
56	Ku itare		Nyankenke	Butare	Gikombe	499460.03	4822939.51	2061.73	Captured
57	Museke (Ruhogali)	1.80	Miyove	Gakenke	Museke	500318.00	9819985.00	2005.00	Captured
58	Remera 1	0.30	Miyove	Gakenke	Remera	500029.00	9819889.00	1952.00	Captured
59	Remera 2	0.30	Miyove	Miyove	Remera	500031.00	9819890.00	1958.00	Captured
60	Nyarubande 2	0.60	Miyove	Gakenke	Remera	500136.00	9820228.00	2034.00	Captured
61	Mureko 1	2.20	Miyove	Mubuga	Rutovu	495347.00	4824399.00	2151.00	Not captured
62	Mureko 2	0.05	Miyove	Mubuga	Mubuga	502358.24	4831075.79	2120.46	Not captured
63	Kidogo	1.20	Miyove	Miyove	Mukaka	496953.00	4820731.00	2009.00	Not captured
64	Maya	1.43	Miyove	Miyove	Mukaka	496654.29	4820647.93	1870.41	Not captured
65	Kadogo 1	2.00	Miyove	Miyove	Mukaka	496826.00	9820991.00	2019.00	Not captured
66	Kadogo 2	1.00	Miyove	Miyove	Mukaka	496566.00	9820950.00	1871.00	Not captured
67	Kiryango	0.45	Miyove	Murambo	Miyove	497517.00	9819994.00	1935.00	Not captured
68	Kwa Shondori	0.10	Miyove	Miyove	Mukaka	496485.17	4820751.75	1844.95	Not captured
69	Mukadogo	0.19	Miyove	Miyove	Mukaka	496943.13	4820737.82	1989.61	Not captured
70	Museke	1.09	Miyove	Gakenke	Museke	500431.32	4819694.72	2011.00	Not captured
71	Nyakagera II	0.60	Kaniga	Gatoma	Nyakagera	506159.00	4844901.00	1992.00	Captured

SN	Source name	Discharge (L/S)	Sector	cell	Village	x	y	z	Status
72	Rugarama	1.50	Kaniga	Gatoma	Rugarama	507932.00	4844919.00	1898.00	Captured
73	Gashiru	0.50	Kaniga	Gatoma	Gashiru	507074.00	4842400.00	1960.00	Captured
74	Rwabona / Rukurura	0.50	Kaniga	Rukurura	Ngabira	508471.67	4843274.74	1980.34	Captured
75	Nyakibande	0.30	Kaniga	Nyakibande	Gatoma	507227.00	4844012.00	1828.00	Not captured
76	Cyasaku		Kaniga	Nyarwambu	Cyasaku	503318.64	4842522.91	1949.73	Captured
77	Nyangorogoro	0.80	Kaniga	Nyarwambu	Nyamabare	502922.18	4842987.51	1959.17	Captured
78	Nyakega		Kaniga	Nyarwambu	Kabeza	502983.13	4840743.61	1889.51	Captured
79	Ruhita 1	1.41	Kaniga	Mulindi	Ruhita	503413.97	4839863.74	1892.84	Not captured
80	Ruhita 2	0.20	kaniga	Mulindi	Ruhita	503431.55	4839873.36	1896.99	Captured
81	Kanyega	1.15	Kaniga	Mulindi	Ruhita	503446.23	4839660.52	1877.17	Not captured
82	Kinyogo	0.56	Kaniga	Mulindi	Rukizi	504035.07	4838167.68	1880.66	Not captured
83	Rutaha	0.28	Kaniga	Mulindi	Kagorogoro	504147.56	4837855.55	1876.27	Not captured
84	Rutare	0.13	Kaniga	Gatoma	Nyakagera	506287.17	4844726.68	1984.00	Not captured
85	Runoni	0.17	Kaniga	Gatoma	Nyakagera	506171.51	4844907.76	1990.00	Not captured
86	Ku ibuye/ Rugarama	1.50	Kaniga	Gatoma	Rugarama	507930.56	4844931.43	1895.00	Captured
87	Ku musigiti	0.01	Kaniga	Gatoma	Nyakibande	507534.92	4843690.20	1829.00	Not captured
88	Bikurungu	0.09	Kaniga	Gatoma	Nyakibande	507241.82	4843566.06	1839.00	Not captured
89	Kurutare	0.20	Kaniga	Gatoma	Gashiru	507070.63	4842409.12	1948.00	Captured
90	Nyakagezi	0.32	Kaniga	Kamutora	Mabare	513454.07	4836170.69	2011.00	Not captured
91	Gitoma	1.00	Mukarange	Rugeshi	Mutarama	504895.00	4834582.00	1873.00	Captured
92	Rwengwe	1.60	Mukarange	Mugina	Gatenga	509270.00	4835493.00	1938.00	Captured
93	Kagusa	2.50	Mukarange	Kiyorwa	Gatenga	510532.00	4833935.00	1902.00	Captured
94	Kiruhura	0.45	Mukarange	Kariba	Kiruhura	506851.00	4837943.00	1899.00	Captured
95	Gatare	1.20	Mukarange	Kabungo	Rusambya	507295.00	4836277.00	1882.00	Not captured
96	Kagane 1	0.40	Mukarange	Kagane	Rusambya	508270.00	4838898.00	1955.00	Not captured
97	Kagane 2	0.30	Mukarange	Kagane	Rusambya	507863.00	4838415.00	1941.00	Not captured
98	Kagane 3	0.10	Mukarange	Kagane	Rusambya	507809.00	4838309.00	1941.00	Not captured
99	Burema	0.60	Mukarange	Karambo	Gitega	511853.00	4835061.00	1853.00	Not captured
100	Rwengwe	1.60	Mukarange	Gatenga	Nyange	509312.19	4835206.59	1924.00	Captured
101	Gitoma	1.00	Mukarange	Mutarama	Rugeshi	504992.57	4834280.64	1891.00	Captured
102	Kiruhura	0.45	Mukarange	Kiruhura	Kariba	506429.85	4837835.44	1840.00	Captured
103	Gahama	1.08	Muko	Rwamutembe	Cyamuhinda	523961.00	9809309.00	1701.00	Captured
104	Rudogo 1	0.30	Muko	Kimpongo	Ngange	525312.00	9811658.00	1738.00	Not captured
105	Rudogo 2	0.10	Muko	Kimpongo	Ngange	525318.00	9811628.00	1736.00	Not captured
106	Nyarubande	0.30	Muko	Mayora	Ngange	527059.00	9810504.00	1619.00	Not captured
107	Rugaragara	0.30	Muko	Kigoma	Cyerere	521043.00	9812053.00	1797.00	Not captured
108	Bahene	0.60	Muko	Kigoma	Cyerere	521100.00	9811885.00	1833.00	Not captured
109	Kidogo 1	0.28	Muko	Ngange	Kimpongo	525380.32	4811347.12	1755.08	Not captured
110	Kidogo 2	0.12	Muko	Ngange	Kimpongo	525358.52	4811331.09	1754.45	Not captured

SN	Source name	Discharge (L/S)	Sector	cell	Village	x	y	z	Status
111	Gahama	1.08	Muko	Cyamuhinda	Rwamitembe	522697.81	4809973.32	1708.22	Captured
112	Butyazo	0.70	Ruvune	Kagasha	Gashirira	519432.85	4820927.85	1845.35	Captured
113	Rwimilindi 1	0.19	Ruvune	Cyandaro	Kigarama	520758.74	4818873.32	1685.04	Not captured
114	Rwimilindi 2	0.80	Ruvune	Cyandaro	Kigarama	520769.09	4818867.02	1684.71	Captured
115	Byimana	0.90	Nyamiyaga	Rugarama	Jamba	519249.00	9815990.00	1858.00	Captured
116	Kabingo	0.66	Ruvune	Gashirira	Nyarurama	504807.12	4824074.07	1803.01	Not captured
117	Kagomero	0.60	Ruvune	Cyandaro	Nyankokoma	522495.59	4817945.96	1652.62	Captured
118	Gahondo	0.79	Mutete	Nyarubuye	Gitega	510330.45	4812007.37	1787.00	Captured
119	Gahondo	0.40	Mutete	Karama	Mutandi	507216.00	9815682.00	1886.00	Not captured
120	Marumba	0.22	Mutete	Karama	Mutandi	510369.35	4806251.36	1789.82	Not captured
121	Kagombero	0.34	Mutete	Rugarama	Nyarubuye	510330.00	9812007.00	1787.00	Not captured
122	Nyamutenga 1	0.50	Mutete	Rukondo	Musenyi	510323.00	9811365.00	1706.00	Not captured
123	Nyamutenga 2	2.00	Mutete	Rukondo	Musenyi	510354.00	9811348.00	1716.00	Not captured
124	Nyamutenga 3	1.20	Mutete	Rukondo	Musenyi	510333.00	9811265.00	1706.00	Not captured
125	Rusave	0.34	Mutete	Kabeza	Kagarama	515727.92	4803295.30	1521.09	Not captured
126	Rwimbogo	3.00	Mutete	Kabeza	Kabasega	511756.46	4807487.28	1643.67	Captured
127	Kariku 1	0.29	Mutete	Nyarubuye	Nkenzi	509182.14	4813930.57	1890.00	Not captured
128	Kariku 2	0.20	Mutete	Nyarubuye	Nkenzi	509096.00	9814228.00	1863.00	Captured
129	Nyamata	1.00	Mutete	Gaseke	Runyinya	511925.37	4807932.63	1601.90	Captured
130	Maganga	0.50	Mutete	Mutandi	Kamaganga	507610.56	4817017.67	1805.43	Captured
131	Source Kibingwe		Kisaro	Murama	Kibingwe	501965.00	9821559.00	2059.00	Captured
132	Gasoko		Kisaro	Murama	Kisaro	501647.00	9820957.00	2088.00	Captured
133	Ryamubuga		Kisaro	Murama	Kisaro	502044.00	9821171.00	2042.00	Captured
134	Muyoboke		Kisaro	Murama	Kisaro	502456.00	9821209.00	2046.00	Captured
135	Kibingwe		Kisaro	Murama	Kisaro	502637.00	9820860.00	2063.00	Captured
136	Mwendo / Kabahura	0.02	Nyankenke	Rwagihura	Kabahura	512015.97	4816574.45	1992.70	Not captured
137	Kibingwe2		Kisaro	Murama	Kibingwe	502622.00	9820595.00	2062.00	Captured
138	Source Kabahura		Nyankenke	Rwagihura	Kabahura	501978.00	9821624.00	2046.00	Captured
139	Gahondo	0.23	Rukomo	Kinyami	Gahondo	510632.55	4821508.78	1874.07	Captured
140	Gatare	0.40	Rukomo	cyuru	sabira	513978.00	9818645.00	1948.00	Captured
141	Rwamabuye	0.20	Rukomo	Munyinya	Kabuga	514130.00	9819350.00	1910.00	Captured
142	Karitushi 1	0.30	Rukomo	Mabare	Kanyiramana	511531.73	4824718.53	1794.45	Captured
143	Karitushi 2	0.20	Rukomo	Mabare	Kanyiramana	510758.00	9824393.00	1884.00	Captured
144	Kariba 1		Rukomo	Kinyami	Kariba	513138.08	4820790.31	1789.88	Captured
145	Kariba 2		Rukomo	Kinyami	Kariba	513224.54	4820905.74	1882.32	Captured
146	Kariba 3 source		Rukomo	Kinyami	Kariba	513138.00	9821210.00	1883.00	Not captured
147	Mugomero	0.05	Rukomo	Cyuru	Sabiro	515004.58	4816537.78	1982.51	Not captured
148	Kadogo	0.20	Rukomo	Mabare	Kanyiramana	511321.77	4824767.52	1794.44	Captured
149	Nyakagezi 2	3.13	Rwamiko	Cyeru	Nyagasozi	521676.47	4802684.99	1556.97	Not captured

SN	Source name	Discharge (L/S)	Sector	cell	Village	x	y	z	Status
150	Yogi Source		Rutare	Gasharu	yogi	519828.00	9808215.00	1882.00	Not captured
151	Gakeri 2	1.00	Rutare	Gasharu	yogi	519842.00	9808158.00	1858.00	Not captured
152	Gahama	1.50	Bukure	Rwesero	Nyarubira	521658.87	4800371.75	1615.44	Captured
153	Cyakabari	0.37	Bukure	Kivumu	Butare	526521.57	4797008.33	1498.62	Captured
154	Gatoki source	0.56	Bukure	Kivumu	Butare	526065.00	9797900.00	1566.00	Not captured
155	Nangurugomo	1.00	Bukure	Kivumu	Butare	526048.40	4797743.65	1585.47	Not captured
156	Kanyinya source	0.20	Bukure	Kivumu	Karushya	525702.00	9798409.00	1597.00	Not captured
157	Kareranyana source	0.20	Bukure	Kivumu	Karushya	525668.00	9798489.00	1615.00	Not captured
158	Kiruhura	0.91	Bukure	Karenge	Gasharu	522949.89	4800642.05	1625.26	Captured
159	Mugomero	0.10	Rukomo	Gabiro	Cyuru	514937.00	9816848.00	1996.00	Captured
160	Rwinyege	0.19	Rutare	Bikumba	Nyabisindu	519227.00	4813338.00	1786.00	Captured
161	Karangara	0.34	Rutare	Bikumba	Marembo	518322.00	4812674.00	1810.00	Captured
162	Karangara 2	0.17	Rutare	Bikumba	Nyabisindu	518669.00	4813071.00	1804.00	Captured
163	Kagugu	0.13	Rutare	Bikumba	Nyabisindu	518735.00	4813087.00	1804.00	Captured
164	Byimana 1		Nyamiyaga	Jamba	Byimana	519501.00	4814187.00	1820.00	Captured
165	Byimana 2		Nyamiyaga	Jamba	Byimana	519502.00	4814184.00	1819.00	Captured
166	Byimana 3		Nyamiyaga	Jamba	Byimana	519496.00	4814203.00	1818.00	Captured
167	Karangara	0.24	Rutare	Bikumbu	Marembo	518326.44	4812677.94	1811.12	Not captured
168	Nyamabuye 1	4.17	Nyamiyaga	Cyuru	Karengo	513979.77	4816834.93	1968.55	Not captured
169	Nyamabuye 2	0.60	Nyamiyaga	Cyuru	Karengo	512694.89	4816519.79	1834.80	Captured
170	Nyamabuye 3	3.00	Nyamiyaga	Cyuru	Maya	512338.00	9816685.00	1767.00	Not captured
171	kanyabagabo	1.20	Nyamiyaga	Mataba	Kabeza	515090.00	9814043.00	1919.00	Captured
172	Nyiraruzenga 1	0.31	Kageyo	Kabuga	Gatobotobo	509672.53	4816069.50	1806.77	Captured
173	Nyiraruzenga 2	0.22	Kageyo	Kabuga	Gatobotobo	509715.16	4816084.00	1812.00	Not captured
174	Nyiraruzenga 3	0.05	Kageyo	Kabuga	Gatobotobo	509782.03	4816116.00	1823.64	Captured
175	Nyiraruzenga 4	0.30	Kageyo	Kabuga	Murama	509664.00	9816312.00	1793.00	Captured
176	Nyaruvumu	0.23	Kageyo	Gihembe	Nyaruvumu	509158.00	9823217.00	2021.00	Not captured
177	Munini 1	0.15	Kageyo	Gihembe	Munini	509288.00	9823393.00	1995.00	Not captured
178	Munini 2	0.16	Kageyo	Gihembe	Munini	509287.00	9823384.00	1979.00	Not captured
179	Rwunga	2.00	Kageyo	Kamanyundo	Muhondo	509894.00	9818365.00	1856.00	Not captured
180	Muhondo 1	0.10	Kageyo	Muhondo	Muhondo	509116.00	9818030.00	1814.00	Not captured
181	Kagwa 1	0.20	Kageyo	Muhondo	Kagwa	509328.00	9819292.00	1939.00	Not captured
182	Kagwa 2	0.47	Kageyo	Muhondo	Kagwa	509379.72	4818936.00	1907.12	Not captured
183	Kagwa 3	0.70	Kageyo	Muhondo	Kagwa	509310.00	9819172.00	1898.00	Not captured
184	Muhondo 2	0.15	Kageyo	Kangwa	Muhondo	508256.00	9818605.00	1819.00	Not captured
185	Mugomero 1	2.17	Kageyo	Horezo	Nyirangoga	510988.91	4818851.46	1796.28	Not captured
186	Mugomero 2	0.42	Kageyo	Horezo	Nyirangoga	510982.79	4818860.31	1986.62	Not captured
187	Rutikanga	0.20	Kageyo	Muhondo	Kagwa	508255.00	9818611.00	1823.00	Not captured
188	Gahanda	0.70	Kageyo	Gihembe	Gitaba	508803.00	9822303.00	2017.00	Not captured

SN	Source name	Discharge (L/S)	Sector	cell	Village	x	y	z	Status
189	Kabageshi 1	2.44	Kageyo	Gihembe	Munini	509092.03	4822836.83	2070.69	Not captured
190	Kabageshi 2	0.19	Kageyo	Gihembe	Nyaruvumu	509320.47	4823005.77	2032.91	Not captured
191	Kabageshi 3		Kageyo	Gihembe	Gitaba	508803.00	9822203.00	1980.00	Captured
192	Gahondo	2.08	Kageyo	Gihembe	Gitaba	508862.34	4822174.00	1982.06	Not captured
193	Nyakabingo	0.26	Kageyo	Gihembe	Gitaba	508652.72	4821988.50	1970.23	Not captured
194	Munini 3	0.61	Kageyo	Muhondo	Kamanyundo	509375.25	4818869.50	1899.84	Not captured
195	Rwunga	2.22	Kageyo	Muhondo	Kamanyundo	509969.25	4818048.50	1878.43	Not captured
196	Gikuku 1	0.47	Kageyo	Kabuga	Mukennye	509610.44	4817898.00	1843.06	Not captured
197	Gikuku 2	0.45	Kageyo	Muhondo	Mwange	509395.13	4817956.50	1837.76	Not captured
198	Gikuku 3	0.19	Kageyo	Muhondo	Mwange	509180.16	4817727.50	1825.77	Not captured
199	Mwange source	0.16	Kageyo	Muhondo	Mwange	508932.81	4817407.50	1805.53	Not captured
200	Kabingo		Byumba	Kivugiza	Kabingo	503281.89	4829017.30	1912.00	Not captured
201	Nyamusanga	0.25	Byumba	Kivugiza	Mugando	502398.00	9829537.00	1855.00	Not captured
202	Kivugiza 1	0.30	Byumba	Kivugiza	Kivugiza	503008.00	9827116.00	1875.00	Not captured
203	Kivugiza 2		Byumba	Kivugiza	Kivugiza	504189.00	9827307.00	1921.00	Not captured
204	Kivugiza 3		Byumba	Kivugiza	Kivugiza	504185.00	9827369.00	1926.00	Not captured
205	Runyenyeri		Byumba	Kivugiza	Kivugiza	504224.00	9827331.00	1928.00	Not captured
206	Miriku		Byumba	Kivugiza	Kabingo	503281.07	4829019.50	1904.06	Captured
207	Nyakagezi	0.37	Byumba	Kivugiza	Kabingo	502572.96	4828811.00	1921.57	Not captured
208	Ruramba 1		Manyagiro	Ruramba	Nyiragifumba	499993.00	9826814.00	1898.00	Captured
209	Ruramba 2		Manyagiro	Ruramba	Nyiragifumba	499987.00	9826854.00	1906.00	Captured
210	Gihanga 1	0.40	Byumba	Kivugiza	Kabingo	503304.49	4829452.28	1937.00	Not captured
211	Gihanga 2	1.00	Byumba	Kivugiza	Kabingo	503136.00	9829682.00	1884.00	Not captured
212	Kabingo	0.30	Byumba	Kivugiza	Kabingo	503267.00	9829375.00	1911.00	Not captured
213	Nyangezi	0.35	Byumba	Nyamabuye	Rwabukoko	506247.00	9825773.00	2030.00	Not captured
214	Nkurunziza Anastasie	0.22	Byumba	Nyamabuye	Rwabukoko	506215.00	9825650.00	2040.00	Not captured
215	Nizeyimana	0.35	Byumba	Nyamabuye	Rwabukoko	506151.00	9825696.00	2022.00	Not captured
216	Karake	0.21	Byumba	Nyamabuye	Rwabukoko	505745.00	9825612.00	2003.00	Not captured
217	Muzaribara	0.36	Byumba	Nyamabuye	Rwabukoko	505619.00	9825617.00	1998.00	Not captured
218	Rwabukoko		Byumba	Nyamabuye	Rwabukoko	505519.00	9825622.00	1986.00	Not captured
219	Rwabukoko		Byumba	Nyamabuye	Rwabukoko	505351.00	9825575.00	1969.00	Not captured
220	Mukankusi	0.34	Byumba	Gisuna	Ruhashya	505211.00	9825564.00	1974.00	Not captured
221	Ruhogo	0.41	Byumba	Gisuna	Ruhaskya	505210.00	9825631.00	1962.00	Not captured
222	Nyakagezi	0.90	Byumba	Gisuna	Ruhashya	504713.00	9825900.00	1896.00	Not captured
223	Nyakagezi 2	0.49	Byumba	Gisuna	Ruhashya	504605.00	9825892.00	1888.00	Not captured
224	Nyamabuye 1 & 2	0.44	Byumba	Nyamabuye	Mugomero	506076.00	9826913.00	2020.00	Captured
225	Source 3		Byumba	Murama	Gacaca	506190.00	9826957.00	2024.00	Captured
226	Source 4	0.20	Byumba	Murama	Gacaca	506169.00	9826981.00	2022.00	Captured
227	Source 5	1.00	Byumba	Murama	Gacaca	506162.00	9827019.00	2023.00	Captured

SN	Source name	Discharge (L/S)	Sector	cell	Village	x	y	z	Status
228	Source 6	0.10	Byumba	Nyamabuye	Mugomero	506134.00	9826974.00	2020.00	Captured
229	Source 1	0.20	Byumba	Murama	Gacaca	506145.00	9827012.00	2024.00	Captured
230	Source 7	0.50	Byumba	Murama	Gacaca	506077.00	9827035.00	2019.00	Captured
231	Ryaruganzu 8	4.00	Byumba	Murama	Gacaca	506139.60	4826800.44	1955.12	Captured
232	Source 9	0.35	Byumba	Murama	Gacaca	505978.00	9827042.00	2005.00	Captured
233	Source 10	0.10	Byumba	Murama	Gacaca	505971.00	9827038.00	2003.00	Captured
234	Source 12	0.10	Byumba	Murama	Gacaca	505821.00	9827072.00	2008.00	Proposed
235	Source 13	1.20	Byumba	Murama	Gacaca	505834.00	9827056.00	2006.00	Captured
236	Source 14	1.50	Byumba	Nyamabuye	Mugomero	505682.00	9827128.00	1995.00	Captured
237	Source 15	0.10	Byumba	Nyamabuye	Mugomero	505696.00	9827154.00	1988.00	Captured
238	Source 16	1.70	Byumba	Murama	Gacaca	505694.00	9827160.00	1987.00	Captured
239	Source 17	0.80	Byumba	Nyamabuye	Mugomero	505658.00	9827172.00	1970.00	Captured
240	Source 18	0.50	Byumba	Nyamabuye	Mugomero	505487.00	9827280.00	1972.00	Captured
241	Source 19	0.20	Byumba	Nyamabuye	Mugomero	505481.00	9827283.00	1971.00	Captured
242	Source 20	1.00	Byumba	Nyamabuye	Mugomero	505376.00	9827312.00	1960.00	Proposed
243	CGM	0.11	Byumba	Nyamabuye	Mugomero	504966.52	4827007.66	1950.22	Not captured
244	Byavu	1.00	Byumba	Nyamabuye	Kumana	504782.57	4825600.40	1907.13	Not captured
245	Gasiza 1	0.15	Byumba	Nyamabuye	Gasiza	504111.63	4825830.39	1878.95	Not captured
246	Gasiza 2	0.18	Byumba	Nyamabuye	Gasiza	503129.93	4825959.77	1857.00	Not captured
247	Source 21	0.75	Byumba	Murama	Gacaca	505242.00	9827478.00	1983.00	Not captured
248	Source 22	0.70	Byumba	Murama	Gacaca	505282.00	9827350.00	1963.00	Not captured
249	Source 23		Byumba	Nyamabuye	Mugomero	505243.00	9827333.00	1964.00	Captured
250	Source 26		Byumba	Murama	Gacaca	505069.00	9827374.00	1953.00	Captured
251	Source 24		Byumba	Murama	Gacaca	504974.00	9827549.00	2002.00	Not captured
252	Source 25		Byumba	Nyamabuye	Mugomero	505005.00	9827334.00	1954.00	Not captured
253	Nyagafunzo	1.00	Byumba	Kinishya	Nyagafunzo	499079.00	9826811.00	1943.00	Not captured
254	Karangara	0.50	Gatebe (Burera)	Musenda	Bikumba	499417.00	9826924.00	1924.00	Not captured
255	Nyamutezi 1	0.70	Byumba	Nyarutarama	Nyarubande	504771.00	9824284.00	1975.00	Not captured
256	Nyamutezi 2	0.15	Byumba	Nyarutarama	Nyarubande	505042.00	9824461.00	1975.00	Not captured
257	Nyamutezi 3	0.03	Byumba	Nyarutarama	Nyarubande	505045.00	9824456.00	1983.00	Not captured
258	Mukeri 1	0.16	Byumba	Nyarutarama	Mukeri	505133.00	9824433.00	1997.00	Not captured
259	Mukeri 2	0.13	Byumba	Nyarutarama	Mukeri	505132.00	9824436.00	1993.00	Not captured
260	Mukeri 3	0.50	Byumba	Nyarutarama	Mukeri	505165.00	9824429.00	1998.00	Not captured
261	Mukeri 4	0.20	Byumba	Nyarutarama	Mukeri	505247.00	9824417.00	2004.00	Not captured
262	Mukeri 5	0.12	Byumba	Nyarutarama	Mukeri	505237.00	9824423.00	2001.00	Not captured
263	Mukeri 6	0.33	Byumba	Nyarutarama	Mukeri	505448.00	9824243.00	2019.00	Not captured
264	Gatare	0.50	Byumba	Nyarutarama	Mukeri	505530.00	9824274.00	2048.00	Not captured
265	Nyamutezi 1		Byumba	Nyarubande	Nyarutarama	504782.00	9824304.00	1986.00	Not captured
266	Rudogo 1	0.60	Byumba	Umurara	Nyamabuye	504515.00	9824785.00	1921.00	Not captured

SN	Source name	Discharge (L/S)	Sector	cell	Village	x	y	z	Status
267	Rudogo 2		Byumba	Umurara	Nyamabuye	504510.00	9824859.00	1919.00	Not captured
268	Gate	0.50	Byumba	Gatete	Nyamabuye	504273.00	9825002.00	1900.00	Not captured
269	Nyarukombe	0.59	Manyagiro	Nyarukombe	Ryaruyumba	500025.26	4830235.85	1909.60	Not captured
270	Nyambare 1	0.73	Manyagiro	Nyarukombe	Ryaruyumba	499725.00	9831489.00	2037.00	Not captured
271	Nyambare 2	0.15	Manyagiro	Nyarukombe	Ryaruyumba	499640.00	9831405.00	2014.00	Not captured
272	Nyambare 3	0.20	Manyagiro	Nyarukombe	Ryaruyumba	499639.00	9831410.00	2003.00	Not captured
273	Source 26	0.60	Manyagiro	Rusekera	Gakubo	499037.00	9831212.00	1963.00	Not captured
274	Source 27	1.50	Manyagiro	Rusekera	Gakubo	499039.00	9831166.00	1970.00	Not captured
275	Nyaruvumu	0.23	Kageyo	Gihembe	Nyaruvumu	509158.00	9823217.00	2021.00	Not captured
276	Munini 4	0.15	Kageyo	Gihembe	Munini	509288.00	9823393.00	1995.00	Not captured
277	Munini 5	0.16	Kageyo	Gihembe	Munini	509287.00	9823384.00	1979.00	Not captured
278	Nyarubande	1.00	Byumba	Nyarutarama	Rugandu	504857.08	4824000.43	2027.15	Captured
279	Gatoki	0.80	Cyumba	Nyakabungo	Gashija	500746.00	9838982.00	1880.00	Captured
280	Kirimbi	2.50	Rubaya	Gishambashayo	Gasharu	498115.25	4833991.26	2012.00	Captured
281	Kinyamukana	0.40	Rubaya	Nyamiyaga	Mariba	498279.00	9835332.00	2048.00	Not captured
282	Karambo	0.10	Rubaya	Gishambashayo	Karambo	498913.00	9835109.00	1914.00	Not captured
283	Runaba	0.10	Rubaya	Gihanga	Runaba	499430.00	9835598.00	1904.00	Not captured
284	Ryagashyashya	3.00	Rubaya	Gihanga	Gomba	499550.27	4836957.17	1865.00	Captured
285	Mu Rutare (kwa Cyiza)	0.40	Rubaya	Nyamiyaga	Kabeza	499380.00	9836069.00	1885.00	Not captured
286	Mugote 1 (Gishari cell)	0.30	Rubaya	Gishari	Mugote	500179.00	9838820.00	1827.00	Not captured
287	Mugote 2	0.13	Rubaya	Gishari	Mugote	500278.00	9838959.00	1830.00	Not captured
288	Kiriba	1.50	Rubaya	Muguramo	Mabare	498787.13	4839477.76	1832.00	Captured
289	Mabare	1.20	Rubaya	Mabare	Muguramo	498355.00	9839614.00	1929.00	Not captured
290	Bureranyana	3.50	Rutare	Gatwaro	Bureranyana	520892.50	4809859.07	1803.01	Captured
291	Kanyama 1	0.48	Giti	Murehe	Kababito	527248.00	9803321.00	1685.00	Not captured
292	Kanyama 2	0.16	Giti	Murehe	Butare	507145.36	4790903.38	1665.98	Not captured
293	Rushinya	1.00	Giti	Gatobotobo	Kabacuzi	524432.00	9806102.00	1744.00	Not captured
294	Ruhondo	1.82	Giti	Murehe	Gatare	526109.43	4805178.83	1673.57	Not captured
295	Nyakagezi	0.50	Giti	Gatobotobo	Kababito	525912.00	9805823.00	1674.00	Not captured
296	Karuseke	1.60	Muko	Mwendo	Kirengo	524303.00	9807792.00	1696.00	Not captured
297	Rwagahunde	0.42	Giti	Gatobotobo	Matyazo	521781.27	4807668.63	1894.00	Not captured
298	Rutovu 1	1.00	Shangasha	Kitazigurwa	Rugarama	510386.00	9829619.00	1933.00	Not captured
299	Rutovu 2	0.50	Shangasha	Kitazigurwa	Rugarama	510448.00	9829616.00	1945.00	Not captured
300	Kibumba	0.20	Shangasha	Kitazigurwa	Gacyamo	510028.00	9829680.00	1954.00	Not captured
301	Rutovu 3	0.40	Shangasha	Kitazigurwa	Rugarama	510404.00	9830340.00	1914.00	Not captured
302	Kabayi 3	3.00	Shangasha	Kitazigurwa	Rugarama	510678.00	9830515.00	1936.00	Not captured
303	Bikumba 1	0.25	Shangasha	Nyabubare	Bikumba	510463.00	9830706.00	1906.00	Not captured
304	Harama/Kabayi 2	0.30	Shangasha	Kitazigurwa	Iharama	510540.00	9830843.00	1905.00	Not captured
305	Bikumba 2	0.50	Shangasha	Nyabubare	Bikumba	510526.00	9830887.00	1895.00	Not captured

SN	Source name	Discharge (L/S)	Sector	cell	Village	x	y	z	Status
306	Harama 2	2.00	Shangasha	Kitazigurwa	Iharama	510622.00	9830990.00	1893.00	Not captured
307	Irembo1	1.00	Shangasha	Nyabubare	Nyamiyaga	510643.00	9831080.00	1886.00	Not captured
308	Irembo2	0.30	Shangasha	Nyabubare	Nyamiyaga	510642.00	9831081.00	1886.00	Not captured
309	Nyakagezi 1	0.26	Shangasha	Nyabishambi	Gasiza	508712.00	9829872.00	1971.00	Not captured
310	Kabarungi	0.20	Shangasha	Nyabishambi	Gasiza	508477.00	9830080.00	1932.00	Not captured
311	Nyakagezi 2	0.60	Shangasha	Nyabishambi	Gasiza	508259.00	9830125.00	1923.00	Not captured
312	Mugomero	0.50	Shangasha	Nyabishambi	Gasiza	509197.00	9830110.00	1942.00	Not captured
313	Gatare	0.44	Shangasha	Nyabishambi	Matyazo	509727.49	4827379.75	1902.00	Not captured
314	Kazabagarura	0.10	Shangasha	Nyabishambi	Matyazo	509926.00	9827722.00	1920.00	Not captured
315	Nyirankotsa	0.30	Shangasha	Nyabishambi	Matyazo	510058.00	9827737.00	1922.00	Not captured
316	Nyakabingo 1	0.15	Shangasha	Bushara	Nyakabingo	508541.60	4831867.51	1886.83	Captured
317	Nyakabingo 2	0.10	Shangasha	Bushara	Nyakabingo	508516.56	4831861.88	1903.17	Captured
318	Kinono	0.50	Shangasha	Nyabubare	Karuhanga	509338.00	9832516.00	1911.00	Not captured
319	Bisika	0.30	Shangasha	Nyabubare	Irembo	509333.00	9832055.00	1945.00	Not captured
320	Nyakabingo 3		Shangasha	Bushara	Bushara	508517.57	4831861.32	1889.66	Captured
321	Nyakabingo 4		Shangasha	Bushara	Gasura	508395.62	4831929.21	1938.82	Captured
322	Kabayi 4	0.02	Shangasha	Kitazigurwa	Rugarama	510757.57	4830214.38	1946.99	Not captured
323	Kazirankurwe	0.32	Shangasha	Nyabubare	Nyamiyaga	510518.70	4830760.25	1929.32	Not captured
324	Kagomero	0.51	Bwisige	Bwisige	Rutoma	516247.00	9826372.00	1806.00	Not captured
325	Kanyirabuki 1	0.60	Bwisige	Gihuke	Kuwindege	515447.00	9828098.00	1820.00	Captured
326	Kanyirabuki 2	0.20	Bwisige		Kuwindege	515505.00	9827909.00	1806.00	Not captured
327	Kanyirabuki 3	0.30	Bwisige		Kuwindege	515489.00	9827929.00	1813.00	Captured
328	Kanyirabuki 4	0.20	Bwisige		Murehe	515385.00	9828017.00	1812.00	Not captured
329	Kanyirabuki 5	0.10	Bwisige		Murehe	515427.00	9828104.00	1816.00	Not captured
330	Ruhondo 1	0.50	Shangasha	Kitazigurwa	Mubuga	510308.00	9828284.00	1899.00	Captured
331	Ruhondo 2	0.40	Shangasha		Mubuga	510307.00	9828291.00	1900.00	Captured
332	Ruhondo 3	0.30	Shangasha		Mubuga	510356.00	9828264.00	1889.00	Captured
333	Kigaga	2.00	Bwisige	Mukono	Murambi	510547.49	4795925.62	1818.09	Not captured
334	Rwangabo	4.00	Bwisige	Gihuke	Kumunini	516230.24	4827353.66	1854.25	Captured
335	Nyakabungo	0.10	Bwisige		Nyakabungo	518704.00	9825614.00	1593.00	Not captured
336	Ryaruganzu 1	0.55	Bwisige	Nyabushingitwa	Musayo	512902.00	9831224.00	1880.00	Captured
337	Ryaruganzu 2	0.75	Bwisige	Nyabushingitwa	Musayo	512976.53	4830918.34	1903.52	Captured
338	Kagorogoro	0.09	Bwisige	Bwisige	Rutoma	515896.52	4826916.40	1870.78	Captured
339	Kanyirabuki	0.60	Bwisige	Gihuke	Kuwindege	515511.48	4827788.11	1830.84	Captured
340	Cyarugarama	0.30	Rushaki	Karurama	Nyaruhanga	507676.00	9841677.00	1967.00	Captured
341	Kabakene	0.40	Rushaki	Kamutora	Nkamba	510863.00	9839666.00	1884.00	Captured
342	Nyakene	0.15	Rushaki	Kamutora	Kabuga	512329.87	4838163.35	1933.00	Captured
343	Kamutora	0.30	Rushaki	Kamutora	Kamutora	512182.16	4836650.26	1867.00	Captured
344	Kivomo	2.50	Mukarange	Cyamuganga	Burambira	509224.00	4837233.72	1939.52	Captured

SN	Source name	Discharge (L/S)	Sector	cell	Village	x	y	z	Status
345	Bigerero 1	0.30	Rushaki	Karurama	Rumuri	508918.00	9839481.00	1911.00	Not captured
346	Bigerero 2	0.10	Rushaki	Karurama	Rumuri	508754.00	9839738.00	2047.00	Not captured
347	Bigerero 3	0.15	Rushaki	Karurama	Rumuri	508774.00	9839724.00	2039.00	Captured
348	Rurengeri	3.00	Rushaki	Karurama	Mbuga	503202.72	4835846.40	1768.85	Not captured
349	Ruhanga1	0.15	Rushaki	Karurama	Mbuga	509361.00	9842961.00	1845.00	Not captured
350	Ruhanga2	0.30	Rushaki	Karurama	Mbuga	509092.00	9842973.00	1825.00	Not captured
351	Ruhanga3	0.40	Rushaki	Karurama	Mbuga	509069.00	9843048.00	1829.00	Not captured
352	Gisiza	0.20	Rushaki	Gitega	Gisiza	511981.00	9832056.00	1858.00	Not captured
353	Nyagahanga 1	0.16	Rushaki	Karurama	Nyaruhanga	507740.53	4841376.82	1974.71	Captured
354	Nyakagezi 1	0.70	Rushaki	Kamutora	Mubuga	513357.00	9836443.00	1999.00	Captured
355	Nyakagezi 2	0.20	Rushaki	Kamutora	Mubuga	513096.00	9836278.00	1963.00	Captured
356	Nyakagezi 3	0.50	Rushaki	Gitega	Mubuga	513094.00	9836269.00	1967.00	Captured
357	Nyakare1	0.13	Rushaki	Kamutora	Kabuga	512299.00	9838498.00	1951.00	Captured
358	Nyakare 2 / Nyakene	0.15	Rushaki	Kamutora	Kabuga	512300.00	9838506.00	1954.00	Captured
359	Rurumbira1	0.45	Rushaki	Karurama	Ngabira	510408.00	4840732.00	1858.00	Captured
360	Rurumbira 2	0.30	Rushaki	Karurama	Ngabira	510314.00	9840968.00	1856.00	Not captured
361	Nyaruhanga	0.26	Rushaki	Karurama	Nyaruhanga	508765.56	4840659.12	1886.13	Not captured
362	Nyagahanga 2	0.16	Rushaki	Karurama	Ngabira	509651.99	4841232.58	1874.94	Not captured
363	Nyarurenga	0.14	Rushaki	Nyarurama	Gatonde	510693.61	4840805.76	1930.12	Not captured
364	Gatare	0.13	Rutare	Nkoto	Murehe	517661.79	4804846.25	1622.96	Not captured
365	Gasharu	0.91	Rutare	Gasharu	Kagarama	519194.54	4810626.55	1821.40	Not captured
366	Gahanga		Rutare	Gasharu	Kagarama	519211.97	4810282.03	1847.31	Captured
367	Rwambogo	0.20	Rutare	Rukumba	Karugeyo	519218.00	9811327.00	1799.00	Not captured
368	Karugira	0.50	Muko	Kigoma	Gatobotobo	519799.00	9811554.00	1786.00	Captured
369	Bizi	0.10	Muko	Kigoma	Gatobotobo	519972.00	9812074.00	1788.00	Not captured
370	Nyakabingo	3.85	Muko	Kigoma	Gatobotobo	520889.39	4809862.83	1797.63	Not captured
371	Gatare (Bizi)	0.10	Muko	Kigoma	Cyerere	519891.00	9812311.00	1780.00	Captured
372	Cyerere1	0.30	Muko	Kigoma	Cyerere	519966.00	9812540.00	1776.00	Captured
373	Nyabisindu1	0.17	Rutare	Bikumba	Nyabisindu	518594.00	9813374.00	1804.00	Not captured
374	Karangara	0.34	Rutare	Bikumba	Marembo	518247.00	9812977.00	1810.00	Not captured
375	Kagugu	0.13	Rutare	Bikumba	Nyabisindu	518660.00	9813390.00	1804.00	Not captured
376	Rwinyege	0.19	Rutare	Bikumba	Nyabisindu	519152.00	9813641.00	1786.00	Not captured
377	Nyabisindu 2	0.14	Rutare	Bikumba	Nyabisindu	520244.00	9813120.00	1736.00	Not captured
378	Rukore 1	1.20	Nyamiyaga	Kabeza	Rugari	517253.00	9813474.00	1806.00	Not captured
379	Rukore 2	0.90	Nyamiyaga	Kabeza	Rugari	517295.00	9813356.00	1832.00	Not captured
380	Gakore	0.18	Nyamiyaga	Kabeza	Mugorore	523060.00	4814540.72	1934.61	Not captured
381	Kidahanwa	0.50	Rutare	Rwimbogo	Gashiru	519682.00	9807273.00	1709.00	Not captured
382	Nyakagezi 1	0.45	Rutare	Kigabiro	Mutambiko	519832.00	9807054.00	1715.00	Not captured
383	Nyamirembe1	0.15	Rwamiko	Kigabiro	Mutambiko	520175.00	9807285.00	1753.00	Not captured

SN	Source name	Discharge (L/S)	Sector	cell	Village	x	y	z	Status
384	Nyamirembe 2	0.20	Rwamiko	Kigabiro	Mutambiko	520220.00	9807329.00	1760.00	Not captured
385	Gaseke 1	0.62	Rwamiko	Kigabiro	Mutambiko	520405.15	4807192.52	1788.55	Not captured
386	Gaseke 2	0.20	Rwamiko	Kigabiro	Mutambiko	520349.00	9807567.00	1798.00	Not captured
387	Gaseke 3	0.30	Rutare	Yugi	Gasharu	520235.00	9807874.00	1838.00	Not captured
388	Gakeri	0.31	Rutare	Gasharu	Yogi	515118.83	4814587.85	1883.54	Not captured
389	Nyakagezi 1	0.15	Rwamiko	Karangara	Kigabiro	519831.00	9807012.00	1710.00	Not captured
390	Gakeri 1	1.20	Rwamiko	Karangara	Kigabiro	519846.00	9808156.00	1845.00	Not captured