REPUBLIC OF RWANDA

NORTHERN PROVINCE
RULINDO DISTRICT

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Water sources management plan for the water sources located in Rulindo District

Final Report

Prepared by

Best Associated Consultants

Financed by

water for people

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.

Catchment 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 *catchment basin.* In order to determine the quantity of available water resources in Rwanda, the country was sub-divided into nine Catchments of level one and twenty catchments of level two. (See the 2015 Rwanda National Water Resources Master Plan).

Sub-Catchment: A sub-catchment is usually a smaller area of land draining to a single tributary of a recharger 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 Rulindo district vis a vis the water use that will be in the area in 25 years to come (i.e. from 2016 to 2041).

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 **catchment**.
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

Rwanda has a mountainous relief characterized by a complex topography gradually rising from East to West and North. Also known as a country of thousands hills, Rwanda has a total land area of approximately 26,338 km^2 with an estimate of 24,216 km^2 under land and 2,122 km^2 under water and swamps. Hydrologically, the available water resources in Rwanda are distributed into the Congo basin and the Nile basin. The Congo basin has two main watersheds known as the Lake Kivu watershed and the Rusizi watershed while the Nile basin has seven watersheds namely the Nyabarongo Upstream watershed, the Nyabarongo Downstream watershed, the Akanyaru watershed, the Akagera Upstream watershed, the Akagera Downstream watershed, the Muvumba watershed and the Mukungwa watershed.

The Water Resource 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 achievement of the country's 2020 vision. Meeting the above challenges requires a comprehensive planning.

The country has a lot of rainfall and countless mountain springs. But these springs are very difficult to access due to the complex topography of the country. Up to now many people in rural areas in Rwanda still spend hours every day to fetch water. In addition, in some areas these water sources are brimming with contaminants/pollutants inducing subsistent health threat. However, according to Rwanda Vision 2020, the country will continue to invest in protection and efficient management of water resources, as well as water infrastructure development to ensure that by 2020 all Rwandans have access to clean water[3]. To do this, the country must first grow its economy, and that means the people of the country must be healthy and productive. For that to happen, everyone needs to have clean and safe water.

With that intention, Water For People (WFP) contribute to the GoR's development agenda and in particular for Rulindo 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 Water for People, driven by its Rwanda Program derived from the Rwanda Vision 2020, the Economic Development and Poverty Reduction Strategy (EDPRS I &

[3] Republic of Rwanda, 2012. Rwanda Vision 2020 Revised 2012

II) and the Sustainable Development Goals, under the framework of the National Policy & Strategy for Water Supply and Sanitation Services, has adopted a number of objectives contributing to the increase of rural and urban water supply up to 100%; and in this particular case, has been financing Rulindo District water supply with the aim of reaching 100% by 2017.

Since 2009, Water for People works with numerous partners (private sector, civil society and local government) to provide sustainable safe drinking water, sustainable sanitation facilities and hygiene education to communities, health centers and schools of Kicukiro and Rulindo Districts. The main partners are Kicukiro and Rulindo Districts, Ministry of Health (MoH), Ministry of Infrastructure (MININFRA), Ministry of Natural Resources (MINIRENA), Ministry of Education (MINEDUC), Water and Sanitation Corporation (WASAC) Ltd, and "Organisation Rwandaise pour la Solidarite et le Development"- Rwandan Organization for Solidarity and Development (ORSD).

In Rwanda, WFP, the District of Rulindo which is part of Nyabarongo downstream and Muvumba watersheds and the Ministry of Infrastructure through WASAC are implementing a program known as "Rulindo Challenge" that aimed to bring the whole district to full water coverage by December 2018. After successful initiation in Rulindo in 2012, Water For People scaled up this approach globally under the name *Everyone Forever*.

In this target of reaching everyone, it is planned to Increase sustainable water infrastructure by increasing the level of water service by 11% through the construction of eight piped water systems in five sectors and the installation of rainwater harvesting tanks at 13 schools and one health centre. Toilet blocks will also be constructed in 14 schools, and household sanitation marketing will be promoted in 10 sectors[4].

In this framework, different water supply systems were installed in the Rulindo District where they use a combination of electric pumps and gravity to move the water through a network of pipes to the villages, health centers, and schools that need it. These seven systems feed 106 public tap serving almost 26,000 people. At the end of the project, the beneficiary population are supposed to have the access to clean and safe water.

To have water available Forever, it is planned to increase sustainability to 100% by building the technical and financial capacity of two private operators and district water board members and staff; building a customer feedback system; establishing and training water user committees; increasing the district WASH budget; and training the households on water safety[5]. It is again in this context of insuring the sustainability and the efficiency of water availability, that a study aiming at Developing a Water Resources Management Plan for the water sources located in the

[4] http://eftracker.waterforpeople.org/rulindo
[5] http://eftracker.waterforpeople.org/rulindo

Rulindo District was organized. The study put out the capability of the current water sources vis a vis the water use that will be in the area in 25 years to come.

1.2. Objectives of the assignment

1.2.1. General objective

To develop a water sources management plan for sustainable water sources development, utilization and management in the sub Watersheds of the Rulindo District.

1.2.2. Specific objectives

1. To quantify and qualify the available water sources on the surface in time and space
2. To quantify water sources use and demand in the study area
3. To identify water surplus and deficit both in time and space in the study area
4. To develop a water sources management plan for optimal and rational utilization of available water sources in the study area
5. To train one stop center staffs on the use of GIS tools

1.2.3. Scope of the assignment

The study geographical and temporal scope is briefly described in this section.

1.2.4. Geographical coverage

The study covered the Rulindo District, consisting of 17 administrative sectors, for the water uses and demand analysis. The study was conducted on the basis of hydrological boundaries at sub- Watershed level for surface water within the Rulindo District. The water sources mapping and management plan was limited to 87 spring sources that considered the previously 50 sources that WFP identified and also the quality assessment was conducted on the later 50 spring sources based on the ToR, limited to measuring nitrate, total phosphorus, iron, manganese and total coliforms. The spring flow and the water quality analysis was conducted first in the rainy season, i.e. April and the second analysis in the dry season, i.e. July.

1.2.5. Temporal horizon and resolution

The study was conducted on a 25 years horizon with a temporal resolution aggregated on a monthly basis in order to enable the detection of possible deficit and surplus of water per month. The basis of all analysis was daily based but the results were monthly displayed for better understanding and results presentation.

2. STUDY AREA

2.1. Administrative entities in the study area

Rulindo District is one of the 30 districts in Rwanda which is located in the Northern Province as illustrated on figure 1. The surface area of the district of Rulindo is estimated to be 567 square kilometers.

Figure 1: Administrative location of Rulindo District.

The District administrative entities are composed of 17 Sectors, 71 cells and 494 villages. The following is illustrated in figure 2.

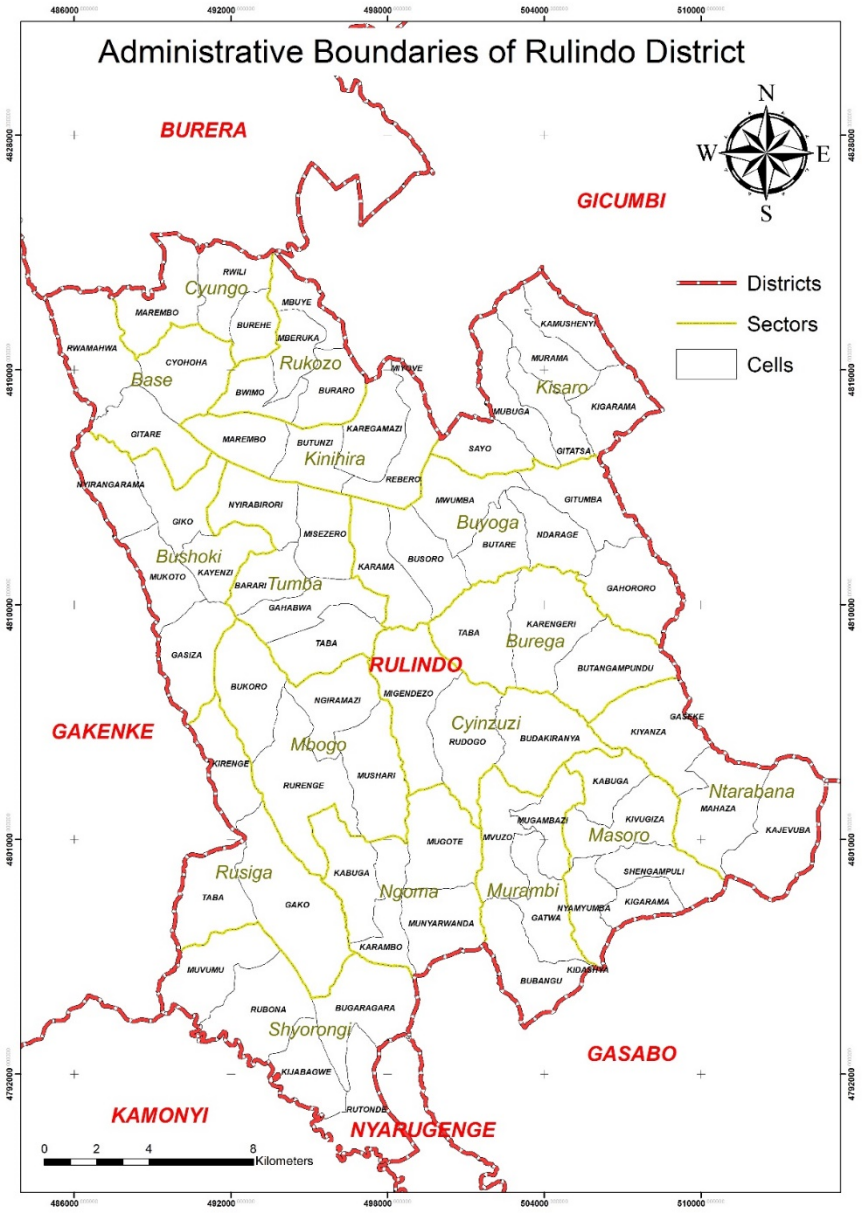


Figure 2: Administrative entities in Rulindo District.

2.2. Topography of the study area

Rulindo District is mostly characterized by many hills like for example the Tare, Tumba and Cyungo hills with altitude rising up to 2,300 m a.s.l. These hills are interspaced by valleys and swamps bordering major rivers such as the Nyabarongo and the Nyabugogo Rivers among others. A topographical illustration of the Rulindo District is provided in figure 3. A complex topography made of abrupt changes of elevation in relatively short distances resulting into steep slopes are observed in the entire Rulindo District.

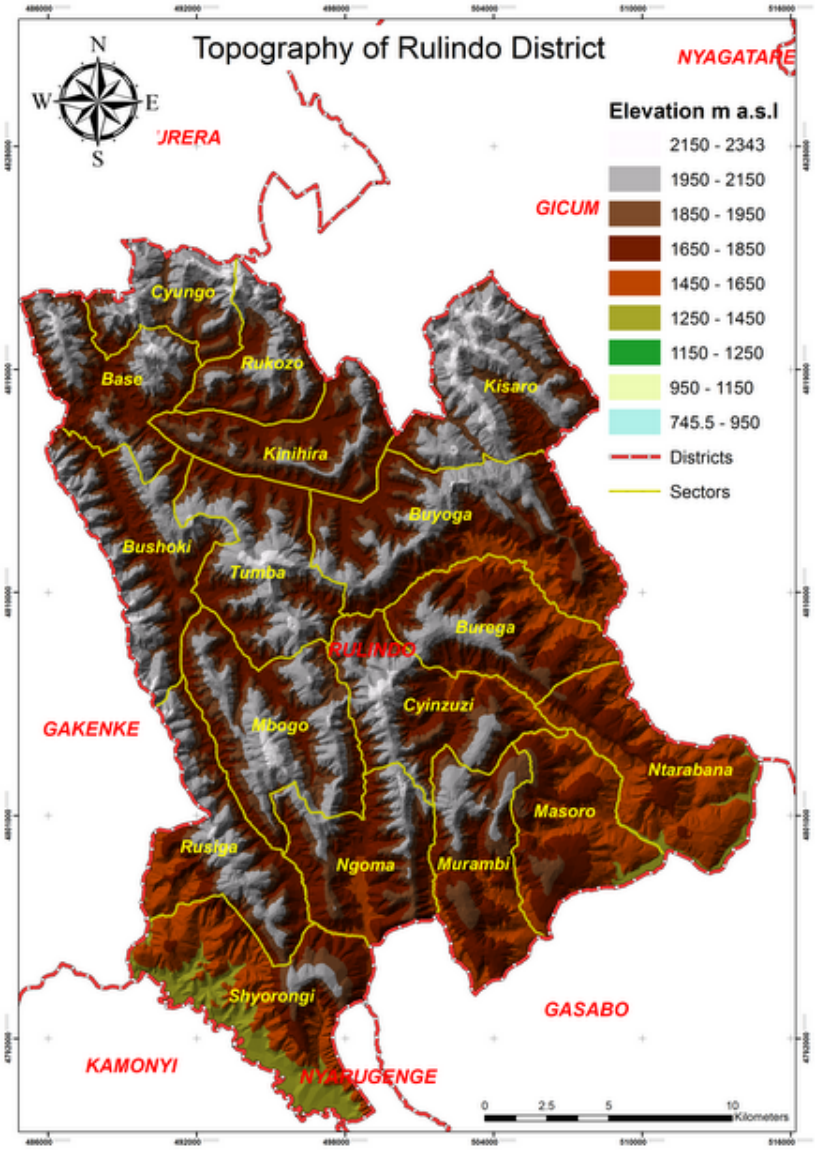


Figure 3: Topographical illustration of Rulindo District.

2.3. Climatology of the study area

Like other parts of Rwanda, the rainfall in the region distribution is bimodal with 2 rainy periods, the first being from March to May and the less intensive from October to December. In fact the region experiences four "seasons" annually:

- **A small dry season** starting from mid-December to February: characterized by occasional light rainfall. This period can vary from dry to moderately wet with the rainfall accounting for 18% of the annual total.
- **A heavy rainy season** starting from March to May: This is the wettest season of the year delivering 40% of the annual rainfall. Recently, this season was observed with a tendency to end around mid-May.

- **The heavy dry season** starting from June to mid-September: This season is characterized by little to no rain particularly in highlands. The rain that is received accounts for less than 12% of annual total. In recent times this period has often begun in mid-May.
- **A small rainy season** starting from mid-September (early October) to mid- December: This season is characterized by 30% of the annual rainfall.

The Annual Rainfall normally reaches up to 1,200mm as illustrated on figure 4.

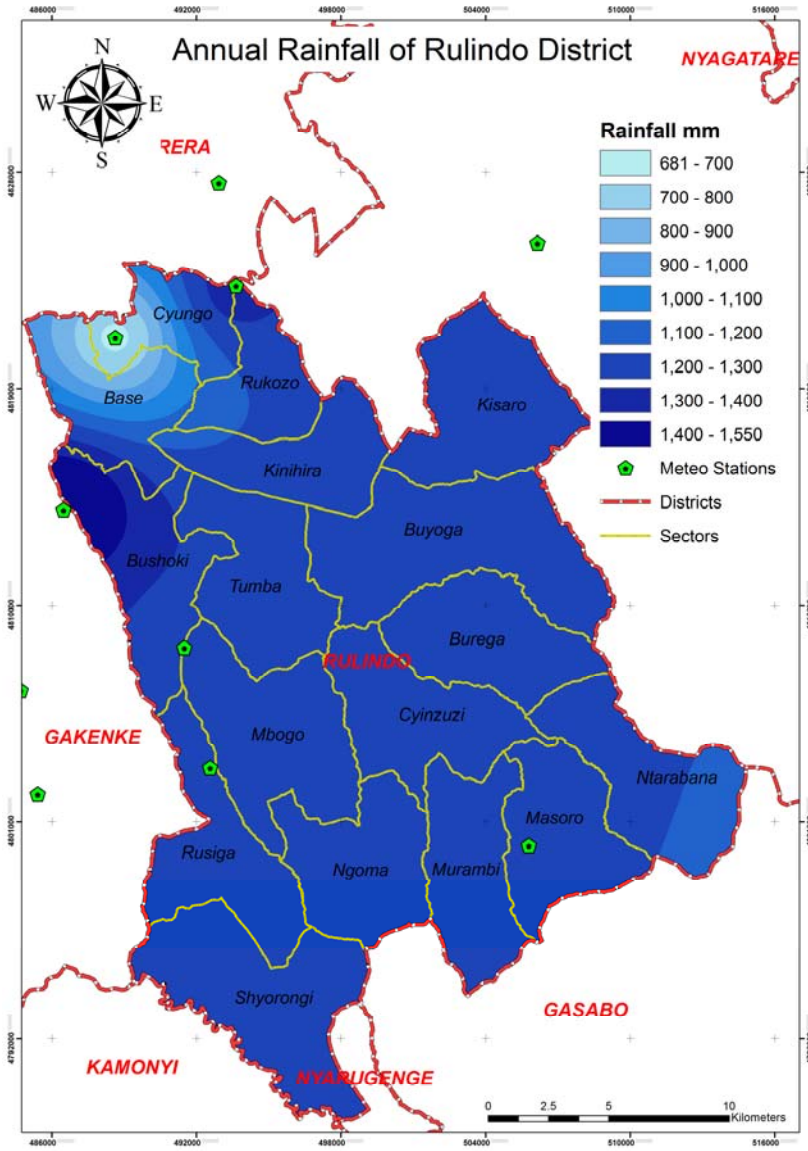


Figure 4: Annual Rainfall distribution of Rulindo District.

2.4. Land Use/Land Cover of the study area

In Rulindo District, similarly to Rwanda in general, agricultural activities is the dominant land use. Based to the Rwanda poverty profile report of 2013/2014 indicate that agricultural sector is

the second economically contributing sector with an estimated total amount of 1,785 billion of Rwf in 2014. In the Rulindo District the major land uses and cover observed, as illustrated in figure 4, are open and closed agriculture, irrigation and a scattered forest cover.

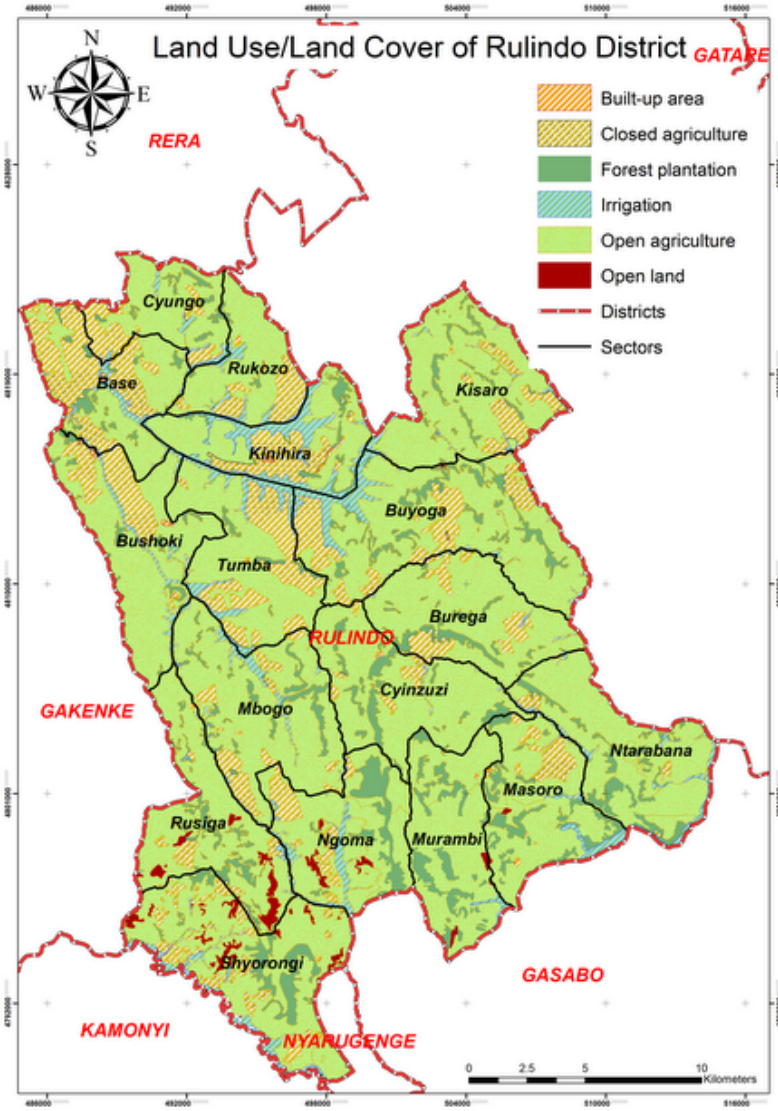


Figure 5: LULC map of Rulindo District.

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 favourable conditions for groundwater development. Some sedimentary rocks may extend many miles as aquifers of fairly uniform permeability. Other types of rocks may be cracked and broken and contain openings recharge enough to carry water. The types of groundwater, as represented through their aquifer types, is very much dependent on the area landscape.

In Rulindo District, many investigations of these kinds were done during the National Water Resources Masterplan indicated a high groundwater development in the District. Mostly, in Rulindo District the existing aquifers contains a number of recharge 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 the Rulindo District.

A majority of fractured aquifers is located in the Rulindo 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 Southern-Western part of the District on its border with the Kamonyi District, an organo-sedimentary alluvial aquifer made of clay base with a low permeability is observed.

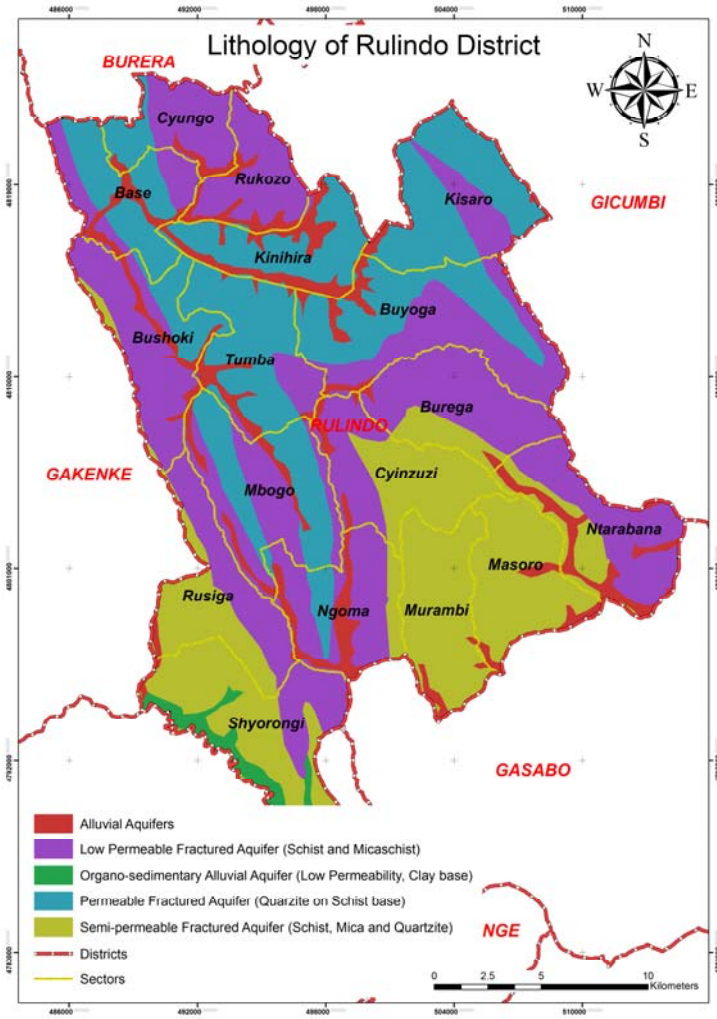


Figure 6: Aquifers in Rulindo District.

2.6. Socio-economic characteristics of the study area

The EICV3 survey results show that the total population of Rulindo district in 2010–11 was 294,000, with females making up 52.7% of the population. The population of Rulindo district represents 16% of the total population of Northern Province and 2.7% of the total population of Rwanda. The majority is young, with 82% of the population under 40 years old. The percentage of the poor and extremely poor in Rulindo is 42.9%, which is slightly below the national average of 45%.

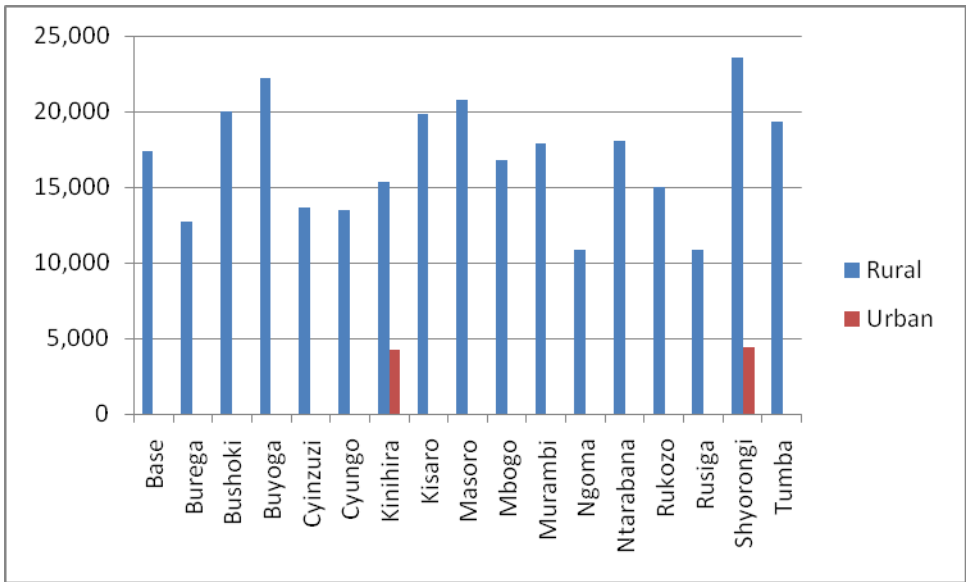


Figure 7: Distribution of the population in Rulindo distict

Source: *Rwanda 4th Population and Housing Census, 2012 (NISR).*

Compared with other districts in Northern Province, Rulindo district has the second highest percentage of extreme-poor after Gakenke.

The percentage of households in Rulindo district with access to an improved drinking water source is 74.6%, which is below the EDPRS target of 85% by 2012. All the other districts in the Northern Province are similarly below the national target, except for Gicumbi with 89.4% of its households having access to an improved water source. Under 50% of households in Rulindo district are within 15 minutes' walking distance of an improved water source.

Table 1**:** Access to main sources of water in Rulindo district

Sectors	Total number of Private Households	Main source of water										
		Total number of Private Households	Internal pipe-born water	Pipe-born water in the compound	Public tap out of the compound	Protected spring/well	Unprotected spring/well	Rain water	River	Lake/Stream/ Pond/Surface water	Other	Not stated
			Improved source of water				Unimproved source of water					
Rwanda	**2,424,898**	**100**	**0.5**	**7.1**	**27.7**	**37**	**13**	**0.7**	**6.4**	**6.4**	**0.2**	**1.1**
Northern Province	**391,668**	**100**	**0.2**	**3.3**	**28.8**	**44.5**	**12.4**	**1.2**	**6.5**	**1.8**	**0.2**	**1.1**
Rulindo district	**67,453**	100	0.1	1.7	21.8	53.8	13.3	0.1	7.3	0.8	0.2	0.9
Base	4,049	100	0.1	2.4	21	43.3	25.2	0	4.4	0	2.6	0.9
Burega	3,045	100	0	0.4	17.1	67.9	3.7	0.1	10.3	0.1	0	0.2
Bushoki	4,702	100	0.4	4.5	21.1	49.4	22.1	0.1	0.9	0.7	0	0.9
Buyoga	5,070	100	0	0.2	4.4	69.8	12.9	0.1	11.4	0.5	0	0.6
Cyinzuzi	3,261	100	0	0.9	17.5	43.4	18.7	0.1	18.1	0.4	0.2	0.7
Cyungo	3,017	100	0	0.9	10.3	82.1	5.4	0.1	0.1	0	0	1.1
Kinihira	3,473	100	0.5	2.7	22.5	62.6	8.5	0	2.1	0.3	0	0.8
Kisaro	4,452	100	0.1	0.5	14.8	65.7	13.8	0.4	3.3	0	0	1.4
Masoro	5,068	100	0.1	1.9	35.6	38.2	22.4	0.1	0.6	0	0	1.1
Mbogo	3,834	100	0.1	1.4	20.6	52.9	16.6	0.2	4.8	2.9	0.2	0.3
Murambi	4,312	100	0	2.3	31.3	56.1	5.3	0.1	3.2	0.8	0	0.8
Ngoma	2,605	100	0.1	0.9	5.8	51.1	22.3	0.2	15.2	3.3	0.4	0.7
Ntarabana	4,383	100	0	1.7	58.8	28.1	4	0	5.4	0.7	0	1.3
Rukozo	3,421	100	0	0.1	0.3	85	8.7	0	4	0	0.1	1.8
Rusiga	2,596	100	0	1	19.1	49.5	12.4	0.9	16.6	0	0	0.3
Shyorongi	5,774	100	0.2	3.7	38.6	20.6	8.1	0.1	24.7	3	0	0.9
Tumba	4,391	100	0.1	1.2	8.2	74.6	14.1	0	0.9	0.1	0	0.7

Source: Rwanda 4th Population and Housing Census, 2012 (NISR).

The percentage of households that use electricity as the main source of lighting in Rulindo district is only 2.6%, which is below the rural, urban and national averages. In Rulindo district, 67.9% of households own a radio; the district is fourth at national level on this indicator and first within Northern Province. The national average of households owning a radio is 46.7% while in urban areas it is 50.7% and in rural areas 45.9%. Rulindo district is one of the districts with a longer mean walking distance to a health centre (65.8 minutes, compared to 35 minutes in urban areas and 64.4 minutes in rural areas). Rulindo district is ranked fourth at the national level by employment rate; the overall employment rate is 88.5% of the resident population aged 16 years and above and the unemployment rate is 0.1%. The industry of usual main jobs in Rulindo district is agriculture, involving 77% of the working population aged 16 and above. In addition, the access to improved toilet facility throught the Rulindo district range from 96 to 98%.

Table 2**:** Main type of toilet facility per sector in Rulindo district

Sector	Total number of Private Households	Total	Main type of toilet facility		
			Improved sanitation facilities	Unimproved sanitation facilities	Not stated
Rwanda	2,424,898	100	95.6	2.6	1.7
Northern Province	391,668	100	95.5	2.9	1.6
Rulindo district	67,453	100	96.4	2.3	1.3
Base	4,049	100	90.8	7.7	1.6
Burega	3,045	100	98	1.4	0.7
Bushoki	4,702	100	95.9	1	3
Buyoga	5,070	100	97.5	1.7	0.8
Cyinzuzi	3,261	100	97.1	1.9	1
Cyungo	3,017	100	95.5	3.6	0.9
Kinihira	3,473	100	96.9	1.3	1.9
Kisaro	4,452	100	93.8	2.3	3.8
Masoro	5,068	100	96.1	2.7	1.2
Mbogo	3,834	100	98.3	0.9	0.8
Murambi	4,312	100	98.2	1.1	0.5
Ngoma	2,605	100	97.9	1.6	0.5
Ntarabana	4,383	100	97.4	2.1	0.5
Rukozo	3,421	100	94.8	3.9	1.2
Rusiga	2,596	100	98.9	0.8	0.3
Shyorongi	5,774	100	97.4	1.6	1
Tumba	4,391	100	96.1	2.3	1.6

Source: Rwanda 4th Population and Housing Census, 2012 (NISR).

Agriculture is the main source of income for 52% of households. The literacy rate among the population aged 15 years and above in Rulindo district is 82.6%, which is above the national average of 69.7% and is the highest in the Northern Province. However, ICT education is still

low in Rulindo district; the percentage of the population aged six and above that has used a computer before and would feel confident about using one again is only 1.5%, compared to the national average of 4%. The percentage of orphans in Rulindo among the population aged 0–20 is relatively low at 2.2% for both parents deceased and 11% for one parent deceased. The distribution of heads of household by gender in Rulindo district shows that 26.4% of households are headed by females and 2.8% are de facto female-headed households.

3. METHODOLOGY

As this study covered many environmental aspects, the methodology included different approaches. The next sections of this chapter provide a descriptive summary of the applied methodology so far.

3.1. Field visits

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

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 Rulindo sub watersheds. The data were sourced from different governmental and private institutions such as MINIRENA, MININFRA, MINECOFIN, RNRA, WASAC, WFP, as well as Rulindo District and its Sectors. This review focused mainly on the available technical reports, official and institutional documents. A detailed list of documents that were used in this regards can be found in references.

3.3. Estimating spring flow

A spring yield was measured in litres per second (l/s). The measurement process involved two personnel. One personnel collecting water with a container of a known volume while the other measures the time needed to fill the container. The container was chosen such that the water outflow will not fill the measuring container in less than five seconds. Three readings were taken during the measurement and the averages were made and expressed in l/s/spring.

3.4. Watershed mapping

To illustrate the key physical characteristics of the Rulindo District sub-catchment for each source, 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 Rulindo District sub-catchment. Data that were stored in the geodatabase were but not limited to administrative boundaries of the study area, sub-catchment 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 catchment mapping during

this study. The geodatabase was designed using Arc Catalog as an ArcGIS application dedicated for spatial database creation and management. Topology was also created for controlling consistency between features sharing common boundaries and for avoiding gaps and overlaps between different units and sub-units. During the design of the geodatabase the spatial referencing system that was used is the customised WGS84 known as TM Rwanda for easy harmonization and integration of all datasets to be used.

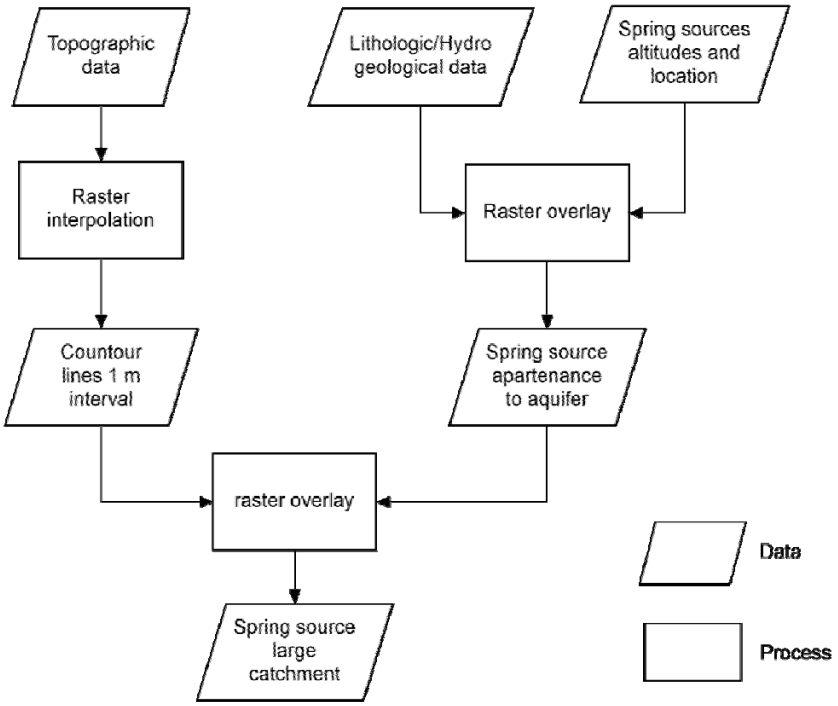


Figure 8: Method for delineating the recharge spring sources catchment

The ArcGIS 10.2.2 software was used as a tool for sub catchment delineation, Hydroprocessing, topographical analysis that was required in this study using its geo-processing functionalities and tools. Land cover was extracted on aerial photographs with 25cm spatial resolution which was supplemented by the existing topographic map (at 1:50000) as well as field trips to validate the mapping using ground truth and ground control points.

Statistics on population density variation and on other socio-economic indicators were collected and joined to spatial data layers for producing different thematic maps in line with the feasibility of sub-catchment management plan including the sub-catchment rehabilitation plan.

Table 3: Needed data and their applications

Required data	Application/analysis
Administration boundaries (cells, Sectors and District)	Administrative delineation of the study area
Digital Elevation Model (DEM)	Catchment 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	Catchment 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

The spatial based analysis related to catchment and sub-catchment produced the following outputs:

- Geographic location: latitude, longitude and altitude for each corner of the catchment and sub-catchment
- Area and Perimeter covered by the entire catchment and each sub-catchment
- Land use and land cover characteristics
- Slope and topography characteristics
- Drainage networks

These maps were complemented using the data that were collected during the field visits in the sub- catchment of the Rulindo District.

3.5. Watershed management measures

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 applied 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 project.

3.5.1. Soil resilience units

To identify the land resilience units in the project area, a comprehensive approach consisting of combining the slope classes and soil depth classes spatially in the project area based on the land unit matrix provided in table 4, 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 4: Land Resilience Unit 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 land units identified were classified into 4 categories of land resilience units as illustrated in table 5 (note that the colour 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 destabilising influences (this is a subset of a notion of environmental resilience). The meaning behind the classification provided in table 5 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 5: Land Resilience Unit.

#	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 maps below with additional tables.

3.5.2. 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 categorised into agro-climatic zones where the Rulindo District falls in the Northern part the Buberuka Highlands and in the Southern part the central plateau. Additionally, the altitude and annual rainfall distribution were considered in the study area to complement its agro-climatic parameterisation. 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 low land (M. L. L) in the study area.

Table 6: Recharge Catchment Management Measures

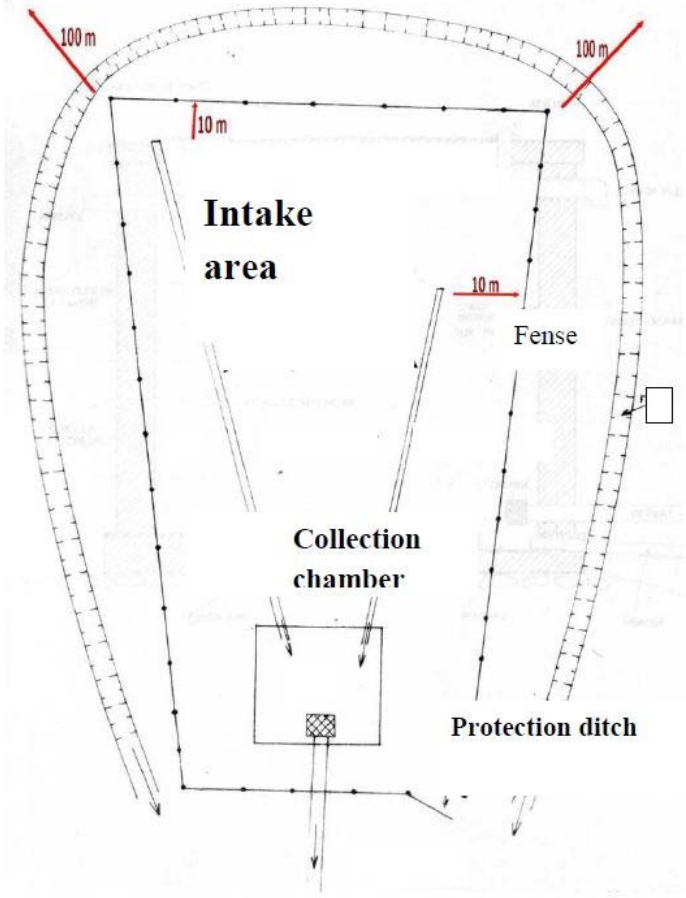
		Land Resilience Units			
		Croplands	Rangelands	Forest plantation	Natural forest
Agro climatic zones	**M. L. L**	Agro forestry + simple management	Agroforestry + average management (Progressive terraces)	Forest plantation	Natural forest
	M. M. H. L	Agroforestry + average management (Progressive terraces)	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 6 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 as illustrated in figure 9, additional maps with extra information are provided.

3.5.3. 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.



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.

Figure 9: Spring immediate catchment area standard management measures
Source: WASAC Ltd

3.5.4. Data analysis

Both qualitative and quantitative techniques were used to analyse data. The quantitative technique included descriptive statistics. The qualitative analysis included the description of the use of knowledge acquired, the GIS tools and the modelling software for specific format designed. This phase of data processing and analysis mainly consisted of the following:

- Data compilation
- Data editing and cleaning of data
- Data analysis and interpretation using local and international standards

4. INSTITUTIONAL AND LEGAL FRAMEWORK FOR THE MANAGEMENT OF WATER SOURCES IN RULINDO DISTRICT

The institutional and legal framework for managing water sources are 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 environmental protection.

In analysing the institutional and legal framework for the management of water sources, some key questions that need to be clarified are: who is in charge of managing water sources? Who is the owner of water sources? How to protect water sources? Etc.

The answers for these questions are found in the above mentioned policy and legal documents.

4.1 Review of the main policies and other legal documents related to water sources management

Some policies and laws have statements or provisions related to the management of water sources and these include mainly the national Policy for water resources management as well as the national policy for water supply and sanitation.

4.1.1 National Policy for water supply and sanitation, 2010

One of the policy statements of the policy for water supply and sanitation is to strengthen community based maintenance system for rural point water sources

Under that statement, it is anticipated that community management will continue to be the most common approach to ensure the operation and maintenance of point water sources, such as protected springs and boreholes equipped with hand pumps. Communities and user committees shall be supported and supervised by the Districts, with technical assistance from the water supply and sanitation Authority if required, and shall have access to capacity building programmes.

4.1.2 National Policy for water resources management, 2011

One of the guiding principles under the national policy for water resources management is related to catchment based water resources management but the policy highlights that in the Rwanda context with the drive of achieving efficiency and taking advantage of the established administrative set-up, water resources management processes will be effected within local government administrative entities in terms of planning, programme implementation and water users' organizations.

Also, one of the policy statements on the institutional framework emphasizes on the need for supporting and promoting water users associations and ensures their participation in water resources protection and conservation.

4.1.3 Environment policy

One of the strategic actions under the policy statement related water resources protection in the environment policy provides for putting in place measures aiming at preventing the degradation of the environment around water points.

The other action is related to taking the necessary measures for maintaining the hydro-ecological processes.

4.1.4 Rwanda Water law, 2008

The 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"*.

4.1.5 Organic law on environmental protection

As far as the management of water sources is concerned, the organic law on environmental protection provides the boundaries for the public domain that need protection around water bodies. This law provides that the public domain is 50 m width for lakes, 10 m width for big rivers, 5 m width for small rivers and 2 m width for streams.

4.2 Regulations related to the management of water sources

The management of water sources is governed by the water law n° 62/2008 of 10/09/2008 putting in place the use, conservation, protection and management of water resources as well as various ministerial orders affiliated to this law.

Article 3 of the water law states 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"* whereas 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"*.

Under the general principles provided for by the same 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".

Concerning the boundary of the area around a water source that is considered to be part of the public domain and therefore requiring protection, the water law in its article 13 provides for a ten meters width for streams, rivers as well as for lakes and ponds to be included in the public domain. However, this article contradicts with the provisions of the 2005 organic law on environmental protection under which the public domain is 50 m width for lakes, 10 m width for big rivers, 5 m width for small rivers and 2 m width for streams. In such a case, the provisions of the organic law prevail over those of an ordinary law. ***Therefore, the public domain for water***

sources is a 2 m radius around the water source and 2 m width all along the stream. This area needs protection.

In addition to the protection of the water sources buffer zone, the Ministerial Order nº 007/16.01 of 24/05/2013 determining the main management vision of water resources in the main hydrographic basins in Rwanda stipulates that every person who carries out activities on the land shall be required to control soil erosion taking into account the nature of the land.

Therefore, it is important that the water users associations in collaboration with water resources management committees at both Sector and District levels make sure that the upstream parts of the water sources are well protected so more that there is a legal back up.

5. SPRING SOURCES CHARACTERIZATION

The following section provides a landscape and geomorphological characterization of the spring sources catchment in the Rulindo District. A technical analysis using the existing GIS data, fieldwork data and standard methodologies is provided with the aim of technically describe how the landscape management measures and technologies proposed were obtained. Different landscape management practices for spring sources are normally distinguished for the immediate catchment of the source as well as its recharge catchment. This distinction was maintained in this section for clarity purpose.

The following chapter is structured in the following way. Firstly, a location of the spring sources and their characterization are provided as well as few fieldwork observations. Secondly, the spring sources catchment delineation methodology is provided with the resulting delineated catchments. Finally, a technical management's scheme is proposed for each delineated catchment following a general technical management scheme of the immediate catchment of spring sources.

5.1. Spring sources localization

Many sources were localized in the Rulindo District were studied based on the springs that were captured by WFP or other springs planned to be captured. As figure 10 illustrates, a concentration of these spring sources is observed in the western axis of the Rulindo District. A few spring sources are also observed in the Northern-Eastern part of the Rulindo District on the border as well as in the Gicumbi District. These are the spring sources which serves the Kinihira sector. Few other spring sources are located in the Buyoga sector in the Central-Eastern part of the Rulindo District and an isolated spring source is located in the Murambi sector in the Southern part of the Rulindo District. A total number of 87 spring sources were localized in the Rulindo District. Within the localized spring sources, it was observed that among them, 19 spring sources are already captured for water supply purposes. Within the remaining not captured spring sources, 54 spring sources have already been identified and utilization studies carried out or being carried out by Water for People. During the fieldwork of this project, 14 new spring sources were localized in the Rulindo District. An illustration of these spring sources is provided in figure 10.

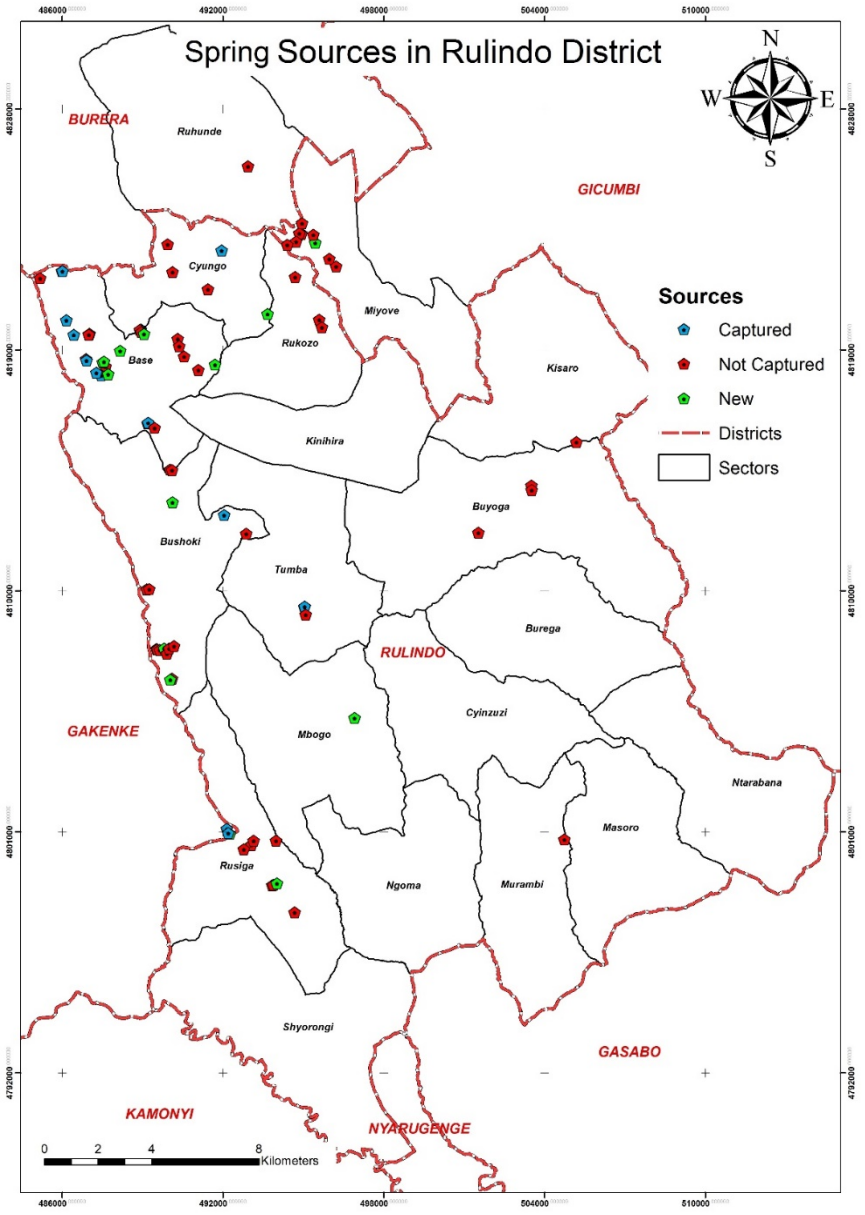


Figure 10: Location of studied spring sources in Rulindo District.

Note: *The above mapped spring sources in Rulindo district were selected based on the list of the springs captured or planned to be captured by WFP, and other existing sources in use by the local population. A detailed list of all the spring sources in Rulindo district is annexed to this report.*

Table 7: Administrative localization and description of the studied spring sources

Id	Source name	X	Y	Z	District	Sector	Cellule	Village	System name	Status	Recommendation	Estimated short term rehabilitation cost in Frw
1	Rugaragara 1	487616	4818383	1768	Rulindo	Base	Rwamahwa	Kiruli	Base center water supply system	Captured & protected	Well managed	
2	Rugaragara 2	487619	4818378	1776	Rulindo	Base	Rwamahwa	Kiruli	Base center water supply system	Not captured & not protected	To provide fences	300,000
3	Rutembe 1	487461	4818050	1810	Rulindo	Base	Rwamahwa	Kiruli	Base center water supply system	Captured & not protected	Old system that need full intake structure rehabilitation	6,000,000
4	Rutembe 2	487277	4818156	1803	Rulindo	Base	Rwamahwa	Kiruli	Base center water supply system	Captured & protected	Need to be planted with passparum and a water diversion ditch	600,000
5	Rutare 1	486162	4820117	1974	Rulindo	Base	Rwamahwa	Kabeza	Base center water supply system	Captured & fairly protected	Need a water diversion ditch and clean up the eucalyptus up to 20 m from the catchment. In addition, maintain the old trenches in the juxtaposed forest	600,000
6	Rutare 2	486887	4818653	1897	Rulindo	Base	Rwamahwa	Kabeza	Base center water supply system	Not captured & fairly protected	Need a water diversion ditch and clean up the eucalyptus up to 20 m from the catchment and reinforcement of trenches in upstream forest	600,000
7	Rutare 3	486913	4818612	1934	Rulindo	Base	Rwamahwa	Kabeza	Base center water supply system	Captured & protected	Well managed	
8	Ruho	486436	4819562	1942	Rulindo	Base	Rwamahwa	Kabeza	Base center water supply system	Not captured & not protected	Establishment of : immediate spring catchment, fences, a water diversion ditch and progressive terraces in upstream part	1,400,000
9	Gihanga 1	490307	4819421	1997	Rulindo	Base	Cyohoha	Gitwa	Gihinga network	Captured & protected	To provide at least two additional stands of water taps along the distribution line Gihanga-Ruhozo.	
10	Gihanga 2	491076	4818256	1828	Rulindo	Base	Cyohoha	Buramba	Gihinga network	Not captured & not protected	Establishment of immediate spring catchment, a water diversion ditch and fences	1,300,000

11	Nyirakagorogoro	490546	4818754	1937	Rulindo	Base	Cyohoha	Buramba	Gihinga network	Not captured & not protected	Full intake structure	6,000,000
12	Migogo1	488935	4819762	1812	Rulindo	Cyungo	Marembo	Kidomo	Rwamahwa migogo	Captured & fairly protected	To remove banana plantation in the catchment, establishment of immediate spring catchment and fences. Also introduce the runoff water diversion	1,300,000
13	Migogo 2	488903	4819748	1799	Rulindo	Cyungo	Marembo	Kidomo	Rwamahwa migogo	Not captured & not protected	Full intake structure rehabilitation	6,000,000
14	Migogo 3	488951	4819667	1842	Rulindo	Base	Cyohoha	Bukanganono	Rwamahwa migogo	Not captured & not protected (high level of FC in Rain season)	Full intake structure rehabilitation	6,000,000
15	Kidogo1	487514	4818539	1815	Rulindo	Base	Rwamahwa	Kiruli	Rwamahwa migogo	New, not captured & not protected	To set up a water diversion way, the spring immediate catchment area and rehabilitation of trenches in the forested areas	1,800,000
16	Kidogo2	487563	4818567	1810	Rulindo	Base	Rwamahwa	Kiruli	Rwamahwa migogo	New, not captured & not protected	To set up a water diversion way and the spring immediate catchment area	1,000,000
17	Migogo 4	489055	4819601	1816	Rulindo	Base	Cyohoha	Bukanganono	Rwamahwa migogo	New, not captured & not protected	Full intake structure rehabilitation	6,000,000
18	Rwamahwa 1	487000	4819592	1987	Rulindo	Base	Rwamahwa	Kabeza	Rwamahwa migogo	Not captured & not protected (high level of FC in Rain season)	Full intake structure rehabilitation	6,000,000
19	Rwamahwa 2	487016	4819599	1984	Rulindo	Base	Rwamahwa	Kabeza	Rwamahwa migogo	Not captured & not protected	Full intake structure rehabilitation	6,000,000
20	Rwamahwa 3	486995	4819575	1993	Rulindo	Base	Rwamahwa	Kabeza	Rwamahwa migogo	Captured & fairly protected (high level of FC in Rain season)	Old system that need total rehabilitation, including the water tank	6,000,000
21	Rwamahwa 4	486995	4819575	1993	Rulindo	Base	Rwamahwa	Kabeza	Rwamahwa migogo	Not captured & not protected	Full intake structure rehabilitation	6,000,000

22	Rwicanyoni 1	489191	4816259	1925	Rulindo	Base	Gitare	Gatete	Rwicanyoni network	Captured & protected	Well protected but need a proper water capturing as the water is turbid during the rainy season. Establishment of terraces upstream	400,000
23	Rwicanyoni 2	489214	4816283	1919	Rulindo	Base	Gitare	Gatete	Rwicanyoni network	Captured & protected	Well protected	
24	Mutoyi 1	489447	4816091	1895	Rulindo	Base	Gitare	Kirwa	N/a	Captured & protected	Well protected but the upstream need terraces to reduce the soil erosion.	100,000
25	Rujeneri	488169	4818968	1762	Rulindo	Base	Rwamahwa	Kiruli	N/a	New, not captured & not protected	Full intake structure rehabilitation	6,000,000
26	Kabingo 1	487714	4818093	1795	Rulindo	Base	Rwamahwa	Kiruli	N/a	New, captured & protected	Clean the neighbouring forest at 10 m of distance from the direct catchment area	100,000
27	Kabingo 2 (mukabeza)	491703	4818451	1804	Rulindo	Base	Cyohoha	Kabingo	N/a	New, captured & protected	Delineate the spring catchment area & establishment of a water diversion ditch	1,000,000
28	Ruramba	485180	4821678	1906	Rulindo	Base	Rwamahwa	Cyondo	N/a	Not captured & not protected	Establishment of immediate spring catchment and fences	800,000
29	Rwankende1	485993	4821944	1973	Rulindo	Base	Rwamahwa	Karambi	N/a	Captured & protected	Establishment of a water diversion ditch	500,000
30	Rwankende2	486011	4821951	1964	Rulindo	Base	Rwamahwa	Karambi	N/a	Captured & protected	Establishment of a water diversion ditch	500,000
31	Rwankende3	486012	4821947	1957	Rulindo	Base	Rwamahwa	Karambi	N/a	Captured & protected	Establishment of a water diversion ditch	500,000
32	Mugomero	490363	4819140	2014	Rulindo	Cyungo	Cyohoha	Gitwa	Mugomero marembo	Captured & protected	Well protected	
33	Nyabirama	489936	4822945	1988	Rulindo	Cyungo	Marembo	Buyaga	Mugomero marembo	Not captured & not protected	Establishment of immediate spring catchment and fences	800,000
34	Nyangoyi	490122	4821908	1954	Rulindo	Cyungo	Marembo	Gahinga	Mugomero marembo	Not captured & not protected	Establishment of immediate spring catchment and fences	800,000
35	Gatobero	491438	4821265	1877	Rulindo	Cyungo	Rwili	Nturo	Mugomero marembo	Not captured & not protected	Establishment of immediate spring catchment and fences	800,000
36	Ruseke	491951	4822712	1925	Rulindo	Cyungo	Rwili	Karambi	Mugomero marembo	Captured & protected	Well protected	

37	Cyasure ruhunde	492928	4825862	2156	Burera	Ruhunde	Rusekera	Bugambanyoni	Mugomero marembo	Not captured & not protected	Establishment of immediate spring catchment and fences	800,000
38	Mukagono	493663	4820344	1835	Rulindo	Cyungo	Burehe	Gitandi	N/a	New, not captured & not protected	Full intake structure rehabilitation	6,000,000
39	Kivure 1	490027	4814529	1828	Rulindo	Base	Gitare	Rugerero	Buramira network	Captured & protected	Well managed	
40	Kivure 2	490104	4814516	1972	Rulindo	Bushoki	Giko	Buramira	Buramira network	Captured & protected	Well managed	
41	Nkore	490117	4813311	1968	Rulindo	Bushoki	Giko	Kigamba	N/a	New, not captured & not protected	Full intake structure rehabilitation	6,000,000
42	Buhande 1	490100	4806721	2024	Rulindo	Bushoki	Gasiza	Ruhanga	Tare network	Captured & protected (high faecal coliforms in dry season), need further investigation	Reinforce the existing fences and a proper water capturing as the water is turbid during the rainy season	700,000
43	Buhande 2	490036	4806686	2025	Rulindo	Bushoki	Gasiza	Ruhanga	Tare network	Captured & protected (high faecal coliforms in dry season), need further investigation	Reinforce the existing fences and a proper water capturing as the water is turbid during the rainy season	700,000
44	Muhanga 1	489526	4807829	2065	Rulindo	Bushoki	Gasiza	Ruhanga	Tare network	Captured & protected	Well managed	
45	Muhanga 2	489546	4807812	2055	Rulindo	Bushoki	Gasiza	Ruhanga	Tare network	Captured & protected	Need to mark the water supply pipeline location and reinforce the existing fences	300,000
46	Muhanga 3	489644	4807791	2049	Rulindo	Bushoki	Gasiza	Ruhanga	Tare network	Captured & protected	Need to mark the water supply pipeline location and reinforce the existing fences	300,000
47	Muhanga 4	489807	4807846	2040	Rulindo	Bushoki	Gasiza	Ruhanga	Tare network	New, Captured & protected	Need to mark the water supply pipeline location and reinforce the existing fences	300,000
48	Nyamwijima	489911	4807656	1991	Rulindo	Bushoki	Gasiza	Ruhanga	Tare network	Captured & protected	Need to mark the water supply pipeline location	

49	Nyakabingo 1	489985	4807848	1992	Rulindo	Bushoki	Gasiza	Remera	Tare network	Captured & protected	Need to mark the water supply pipeline location	
50	Nyakabingo 2	490174	4807938	2001	Rulindo	Bushoki	Gasiza	Remera	Tare network	Captured & protected	Need to mark the water supply pipeline location	
51	Rukungeri 1	489157	4810054	2009	Rulindo	Bushoki	Mukoto	Gatare	Tare network	Captured & protected	Establishment of a water diversion ditch and fences. There is a need of progressive terraces with the embankments made of stone	600,000
52	Rukungeri 2	489246	4810066	1971	Rulindo	Bushoki	Mukoto	Gatare	Tare network	Captured & protected	Establishment of a water diversion ditch and fences	800,000
53	Gahondo 1	503510	4813935	1960	Rulindo	Buyoga	Ndarage	Gahondo	Gahondo network	Not captured but protected	Establishment of trenches in the upstream forest is required for the sustainability of the spring	800,000
54	Gahondo 2	503522	4813770	1949	Rulindo	Buyoga	Ndarage	Gahondo	Gahondo network	Not captured & not protected	Full intake structure rehabilitation	6,000,000
55	Kiruruma (4 springs in one)	505188	4815561	1786	Rulindo	Buyoga	Gitatsa	Ndago	Kiruruma network	Captured & protected (high faecal coliforms observed in rain season)	Establishment of trenches in the upstream forest to slow the rainfall. Proper water capturing as the water is turbid during the rainy season	1,200,000
56	Nyagahera source	501527	4812173	1922	Rulindo	Buyoga	Butare	Ryanyira kayobe	Nyagahera network	Not captured & not protected (high turbidity observed in Rain season)	Full intake structure rehabilitation	6,000,000
57	Nyirantarengwa	496910	4805259	1847	Rulindo	Mbogo	Mushari	Buraro	N/a	New, captured & fairly protected	Establishment of spring immediate catchment, fences and a water diversion way	1,300,000
58	Mutagata	504735	4800721	1722	Rulindo	Murambi	Mugambazi	Ruri	Mutagata network	Captured & fairly protected	Maintain the fences surrounding the spring and establishment of the water diversion way	800,000
59	Mubuga 1	494914	4823357	2167	Gicumbi	Miyove	Mubuga	Murambo	Kinihira rehabilitation extension	Captured & protected (high faecal coliforms observed in rain season)	Stop the illegal gold washing activities next to the catchment area	6,000,000

60	Mubuga 2	494921	4823323	2177	Gicumbi	Miyove	Mubuga	Murambo	Kinihira rehabilitation extension	Captured & protected (high faecal coliforms observed in rain season)	Stop the illegal gold washing activities next to the catchment area	6,000,000
61	Mubuga 3	494844	4823358	2183	Gicumbi	Miyove	Mubuga	Murambo	Kinihira rehabilitation extension	Captured & protected (high faecal coliforms observed in rain season)	Stop the illegal gold washing activities next to the catchment area	6,000,000
62	Cyogo	495442	4823001	2161	Gicumbi	Miyove	Mubuga	Kirwa	Kinihira rehabilitation extension	New, captured & fairly protected	Old system that need maintenance and/or total rehabilitation	6,000,000
63	Baradega	494944	4823734	2169	Gicumbi	Miyove	Mubuga	Murambo	Kinihira rehabilitation extension	Not captured & not protected	Need of full intake structure rehabilitation	6,000,000
64	Kirwa	495368	4823301	2154	Gicumbi	Miyove	Mubuga	Kirwa	Kinihira rehabilitation extension	Not captured & not protected	Need of full intake structure rehabilitation	6,000,000
65	Nyakagezi	495962	4822402	2082	Gicumbi	Miyove	Mubuga	Kivumu	Kinihira rehabilitation extension	Captured & protected	Maintain the spring leakages, full intake structure rehabilitation	6,000,000
66	Kacyiriba	496225	4822117	2088	Gicumbi	Miyove	Mubuga	Kacyiru	Kinihira rehabilitation extension	Captured & protected	Reinforce the existing fences and a proper water capturing as the water is turbid during the rainy season	6,000,000
67	Nyarubuye 1	494731	4823050	2082	Gicumbi	Miyove	Mubuga	Tetero	Kabonanyoni network	Captured & protected	Introduce a water diversion ditch	500,000
68	Nyarubuye 2	494402	4822923	2041	Gicumbi	Miyove	Mubuga	Tetero	Kabonanyoni network	Captured & protected	Stabilization of bench terraces embankments on top of the spring and establishment of a water diversion ditch	600,000
69	Nyaruganzu	494687	4821725	2023	Rulindo	Rukozo	Mbuye	Musave	Kabonanyoni network	Captured & protected	Clearance of eucalyptus up to 10 m from the spring and establishment of water percolation pit along the gully that passes next to the spring	200,000
70	Kibare 1	495590	4820133	1904	Rulindo	Rukozo	Mbuye	Kibare	Kabonanyoni network	Captured & protected	Maintenance of trenches in the top forest to reduce the runoff of water	800,000

71	Kibare 2	495688	4819852	1920	Rulindo	Rukozo	Buraro	Kamiyo ve	Kabonanyoni network	Captured & protected	Maintenance of trenches in the top forest to reduce the runoff of water	800,000
72	Nyakabizi 1	492141	4801112	1918	Gakenke	Muhondo	Busake	Kibirizi	Nyakabizi	Captured & fairly protected (high level of FC in Rain season)	Maintenance of the spring catchment, slow the runoff and a proper water capturing as the water is turbid during the rainy season	900,000
73	Nyakabizi 2	492249	4800929	2008	Gakenke	Muhondo	Busake	Kibirizi	Nyakabizi	Captured & fairly protected	Maintenance of the spring catchment, slow the runoff and a proper water capturing as the water is turbid during the rainy season	900,000
74	Nyakabizi 3	492197	4800954	1943	Gakenke	Muhondo	Busake	Kibirizi	Nyakabizi	Not captured & fairly protected	Establishment of immediate spring catchment and fences	800,000
75	Nyaboga 1	493056	4800512	2001	Rulindo	Rusiga	Gako	Kabuye	Nyakabizi	Captured & not protected	Establishment of immediate spring catchment with fences and a water diversion way	800,000
76	Nyaboga 2	493146	4800668	1961	Rulindo	Rusiga	Gako	Kabuye	Nyakabizi	Not captured & not protected	Establishment of immediate spring catchment with fences and a water diversion way	800,000
77	Agatare	492777	4800352	2060	Rulindo	Rusiga	Gako	Kabuye	Tare rusiga	Not captured & not protected	To capture the spring and put in place the immediate spring catchment and fences	6,000,000
78	Ntakara	494676	4797993	1874	Rulindo	Rusiga	Gako	Kabunig u	Tare rusiga	Captured & protected	Cover the manhole, maintain the spring catchment and rehabilitation of trenches in the forest	1,040,000
79	Nyagatovu 1	493835	4799004	1952	Rulindo	Rusiga	Gako	Kabunig u	Tare rusiga	Not captured & not protected	Establishment of immediate spring catchment with fences and a water diversion way	1,300,000
80	Nyagatovu 2	493883	4799023	1944	Rulindo	Rusiga	Gako	Kabunig u	Tare rusiga	Not captured & not protected	Establishment of immediate spring catchment with fences and a water diversion way	1,300,000

81	Nyagatovu 3	494010	4799079	1904	Rulindo	Rusiga	Gako	Kabunigu	Tare rusiga	Not captured & not protected	Establishment of immediate spring catchment with fences and a water diversion way	1,300,000
82	Nyagatovu 4	493977	4800670	1743	Rulindo	Rusiga	Gako	Nkanga	Tare rusiga	New_Not captured & not protected	Establishment of immediate spring catchment with fences and a water diversion way	1,300,000
83	Matonyanga 1	492942	4912409	1885	Rulindo	Bushoki	Kayenzi	Muduha	Matonyanga	Captured & fairly protected	Re-capture the leaking water of the spring, introduce a definite immediate spring catchment with fences and a water diversion way	1,700,000
84	Matonyanga 2	492871	4812138	1855	Rulindo	Bushoki	Kayenzi	Muduha	Matonyanga	Not captured fairly protected	Establishment of immediate spring catchment with fences and re-capture the leaking water of the spring,	1,200,000
85	Nyirambuga 1	495038	4809391	1950	Rulindo	Tumba	Gahabwa	Mafene	Nyirambuga extensions	Captured & protected (high FC obsereved in Rain season)	Regular maintenance of the water diversion ditch and introduce radical terraces for soil erosion control	600,000
86	Nyirambuga 2	495045	4809418	1951	Rulindo	Tumba	Gahabwa	Mafene	Nyirambuga extensions	Captured & protected	Cover the manhole and regular maintenance of the water diversion ditch	240,000
87	Nyirambuga 3	495086	4809115	1946	Rulindo	Tumba	Gahabwa	Nyiramb uga	Nyirambuga extensions	New_Not captured	Can be captured and conveyed downstream to Nyirambuga 2.	

Definition

	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

5.1.1 Priority in terms of protection and the source capacity

Table 8 below set the priority in terms of protection based on the discharge of the water source as well as the number of fecal coliforms identified in some sources. In fact, table 8 complement table 7 and both tables provide to the decision makers priority options in terms of spring protection. This classification provides 35 springs that need more priority for protection relative to other spring sources. The priority number 1 was given to 14 springs with the water discharge ranging from 2.6 to 0.5 L/s, while the second priority was given to 21 springs with a water discharge ranging between 0.45 and 0.1 L/s. For the planning purpose, other springs fall in the third category of springs that need regular maintenance and protection based on table 7 recommendation.

Table 8: Priority in terms of importance of source protection based on the source capacity and the status

SN	Source name	Q (L/S)	FC (high level of fecal coliform)	Priority number
1	Nyirambuga 1	2.66	FC	1
2	Kiruruma	1.67	FC	1
3	Migogo1	1.50	-	1
4	Rutare 1	1.27	-	1
5	Gihanga 2	1.27	-	1
6	Mubuga 2	1.24	FC	1
7	Migogo 2	1.00	-	1
8	Mutagata	1.00	-	1
9	Cyogo	1.00	-	1
10	Nyakabizi 1	1.00	FC	1
11	Rukungeri 1	0.83	-	1
12	Nyaboga 1	0.63	-	1
13	Baradega	0.55	-	1
14	Kacyiriba	0.50	-	1
15	Nyakabizi 2	0.45	-	2
16	Nyarubuye 2	0.41	-	2
17	Rutembe 1	0.38	-	2
18	Kivure 1	0.33	-	2
19	Rukungeri 2	0.32	-	2
20	Nyakagezi	0.29	-	2
21	Matonyanga 1	0.28	-	2
22	Mubuga 1	0.26	FC	2
23	Ntakara	0.26	-	2
24	Nyagatovu 1	0.26	-	2
25	Kivure 2	0.22	-	2

26	Mubuga 3	0.22	FC	2
27	Nyirakagorogoro	0.20	-	2
28	Rwamahwa 2	0.20	-	2
29	Nyagahera source	0.20	-	2
30	Kirwa	0.19	-	2
31	Migogo 3	0.17	FC	2
32	Migogo 4	0.15	-	2
33	Rwamahwa 1	0.15	FC	2
34	Buhande 1	0.12	-	2
35	Buhande 2	0.10	-	2

5.2. Surface and Recharge catchments in Rulindo District

Surface catchment and recharge catchment are different hydrological entities and their delineation approach is totally different. Surface catchment delineation are based on the surface topography and flow direction while recharge catchment delineation are based on the lithology and soil structure. Contour lines were also considered in this study because recharge catchment for a spring is commonly known as a suspended aquifer, this implying to some extent consideration of topography. In this study, the surface catchments and identified spring catchments were delineated. The result of this exercise is illustrated in figure 11 and 12.

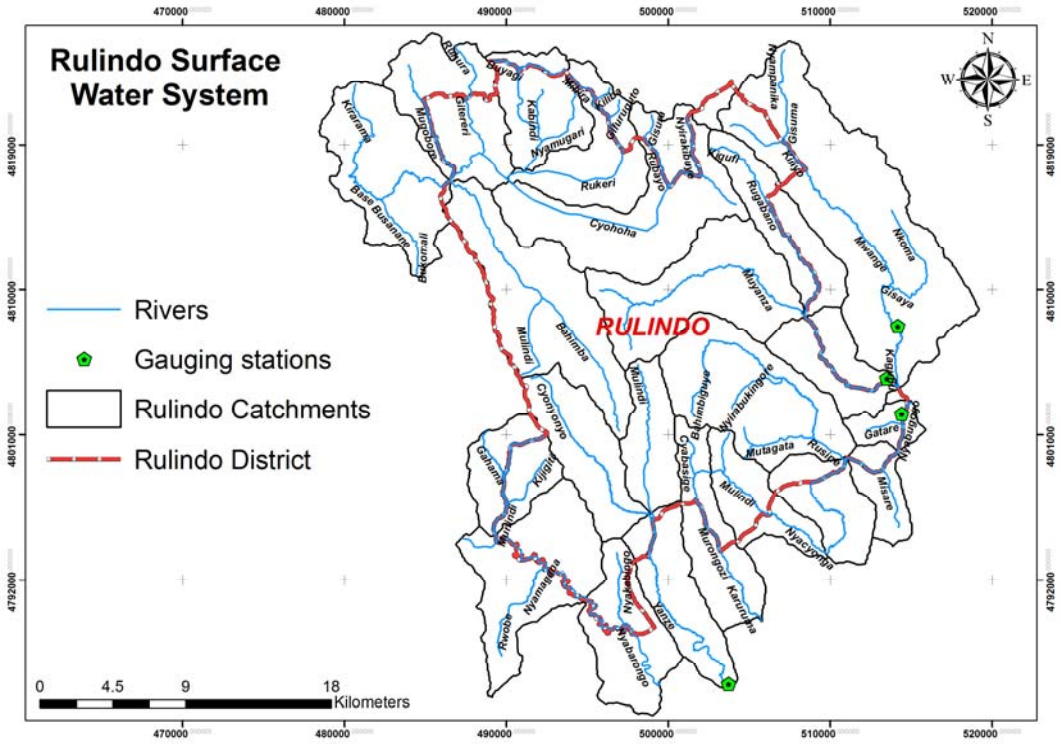


Figure 11: Rulindo surface water system.

On figure 11, the main rivers and surface catchment of Rulindo are illustrated. 22 surface catchments were identified in Rulindo District and these were named after the main rivers in them. Table 7 provides the list of the delineated surface catchments in Rulindo District.

Table 7: Rulindo District Surface Catchment List.

#	Name	Area ha
1	Mugobore	4,873.06
2	Mwange	12,899.16
3	Nyamugendamporo	3,220.19
4	Rukeri	3,750.04
5	Busanane	5,656.10
6	Cyohoha	7,573.53
7	Rugabano	3,334.89
8	Bahimba	7,245.96
9	Muyanza	6,521.98
10	Muyanza downstream	2,811.06
11	Rusine	6,707.33
12	Mulindi	2,571.63
13	Cyonyonyo	3,666.70
14	Gatare	971.13
15	Mulindi 2	2,866.65
16	Nyakagezi	3,555.23
17	Nyacyonga	2,594.31
18	Misare	1,501.01
19	Nyabugogo	2,711.59
20	Nyamagana	5,874.75
21	Yanze	3,432.16
22	Nyakabingo	3,909.24

On figure 12, the delineated recharge catchment are illustrated. A total number of 14 recharge catchment were delineated. It was also observed that many springs originate from the same recharge catchment.

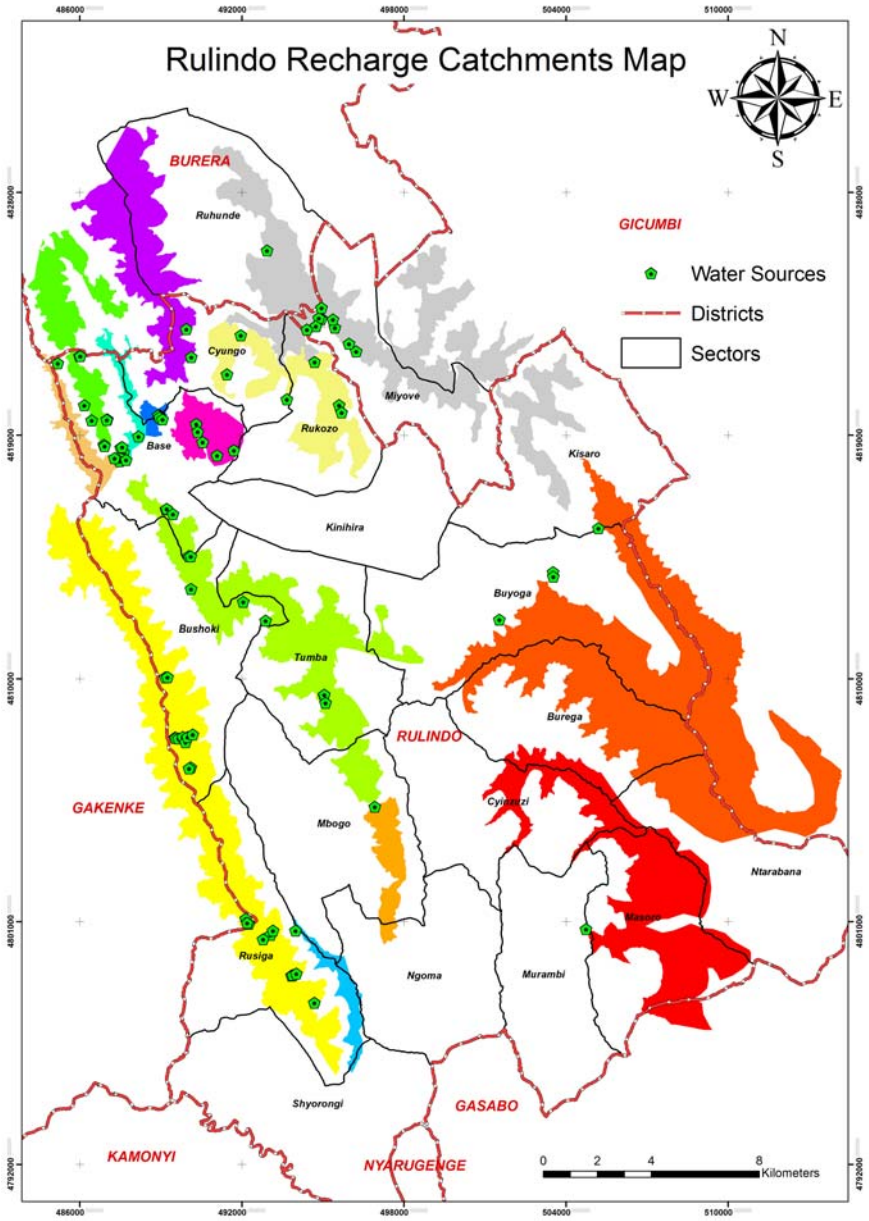


Figure 12:Spring Sources Recharge catchments in Rulindo.

For the purpose of watershed management and spring protection, the relation between the surface and recharge catchments were analyzed. It is practically better to management surface catchment rather than recharge catchment since a lot of consideration are to be taken into account. This relation is better illustrated on figure 13. A practical relationship between these two types of system was obtained where clearly some surface catchments include recharge catchment entirely. A translation of management measures for recharge catchment protection to surface catchment was found feasible.

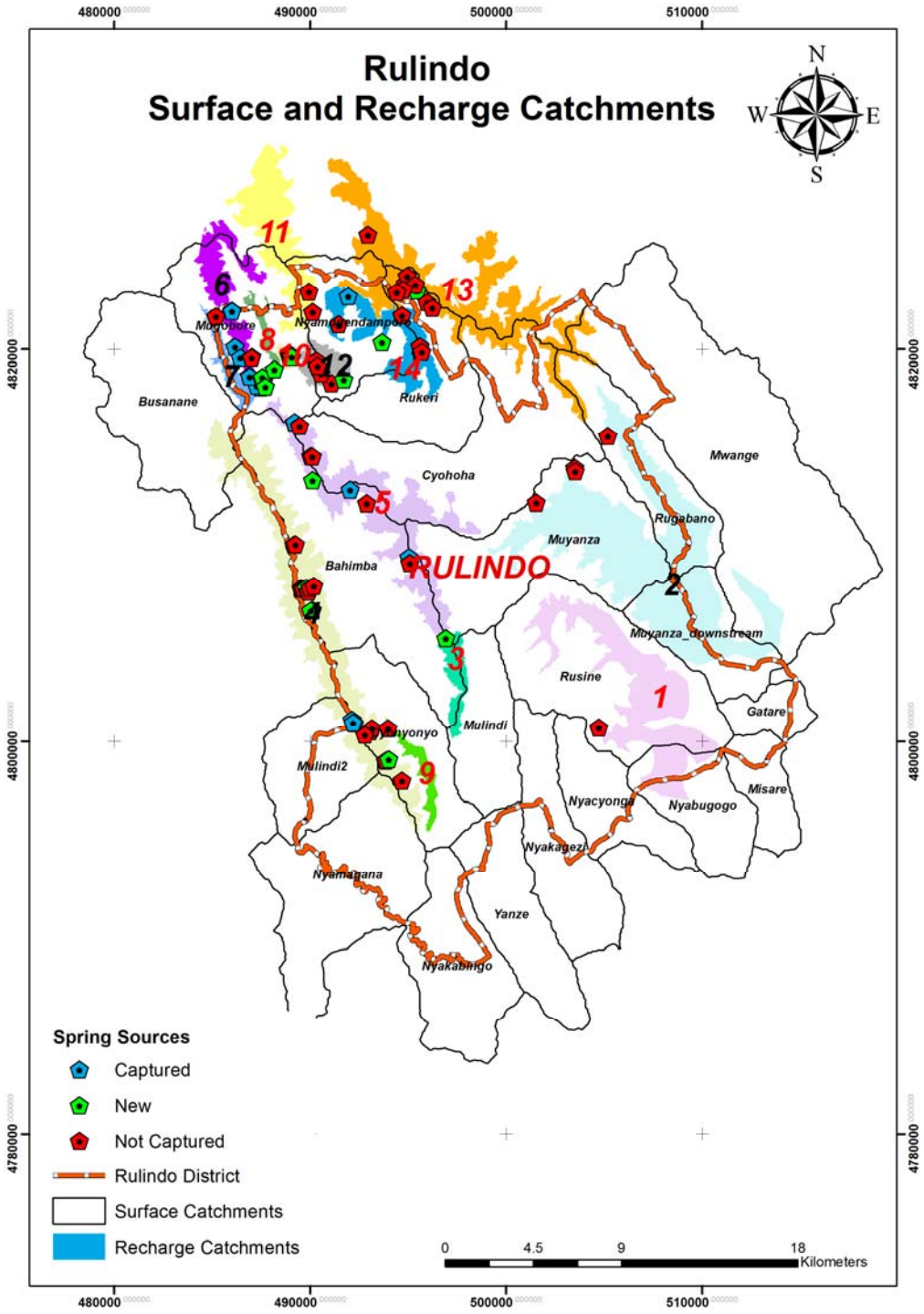


Figure 13: Rulindo Surface and Recharge Catchments map.

Table 8 below provides a descriptive summary of all the spring recharge catchment.

Table 8: Descriptive summary of the Spring recharge catchments in the study area.

#	Spring recharge catchment	Area sq.km	Administrative location		Nbr. of springs	Status of springs
			Districts	Sectors		
1	Recharge catchment 1	2,857.90	Gasabo, Rulindo	Burega, Cyinuzi, Jabana, Masoro, Murambi, Nduba, Ntarabana	1	not captured
2	recharge catchment 2	6,138.10	Gicumbi, Rulindo	Burega, Buyoga, Kisaro, Mutete, Ntarabana, Rutare	5	not captured
3	Recharge catchment 3	409.90	Rulindo	Mbogo, Ngoma	1	newly identified
4	Recharge catchment 4	3,856.50	Rulindo, Gakenke	Bushoki, Gashenyi, Muhondo, Muyongwe, Rushashi, Rusiga	21	5 newly identified, 14 not captured and 2 captured
5	Recharge catchment 5	2,469.80	Rulindo	Base, Bushoki, Buyoga, Mbogo, Tumba	10	5 not captured and 5 captured
6	Recharge catchment 6	901.80	Rulindo, Burera	Base, Nemba	10	4 not captured and 6 captured
7	Recharge catchment 7	361.90	Rulindo, Gakenke, Burera	Base, Gashenyi, Nemba	1	not captured
8	Recharge catchment 8	240.30	Rulindo, Burera	Base, Cyungo, Nemba	8	1 not cpatured, 3 captured and 4 newly identified
9	Recharge catchment 9	282.20	Rulindo	Mbogo, Ngoma, Rusiga, Shyorongi	1	not captured
10	Recharge catchment 10	84.90	Rulindo	Base, Cyungo	4	2 not captured, 1 captured and 1 newly identified
11	Recharge catchment 11	1,631.00	Rulindo, Burera	Cyungo, Nemba, Ruhende, Rwerere	3	not cpatured
12	Recharge catchment 12	466.50	Rulindo	Base, Cyungo, Rukozo	5	3 not captured, 1 captured and 1 newly identified
13	Recharge catchment 13	3,611.40	Rulindo Burera Gicumbi	Cyungo, Kisaro, Rukozo, Ruhunde, Miyove,	12	11 not cpatured, 1 newly identified

				Nyankenke		
14	Recharge catchment 14	1,105.00	Rulindo	Cyungo, Rukozo	5	3 not captured, 1 captured and 1 newly identified

5.2.1. Spring recharge catchment 1

The spring recharge catchment 1 has an area of 2857.89 hectares. It has 1 studied spring source which was found not captured. The spring recharge catchment is located in the southern part of the District. This recharge catchment lies within the 2 Districts known as Rulindo and Gasabo and at the same time lying within 7 Sectors known as Burega, Cyinyuzi, Jabana, Masoro, Murambi, Nduba, Ntarabana.

A common classification of slope is done into 5 classes. These are set as varying from 0-6%, 6-16%, 16-40%, 40-60% and <60%. The following classification was done for every spring recharge catchment as illustrated in the following maps and tables.

Table 9: Spring recharge catchment 1 slope coverage

Spring recharge catchment 1		
Slope classes	**Area Ha**	**% of Area Covered**
0-6%	153.28	5.36
6-16%	459.72	16.09
16-40%	1358.76	47.54
40-60%	677.05	23.69
>60%	209.07	7.32

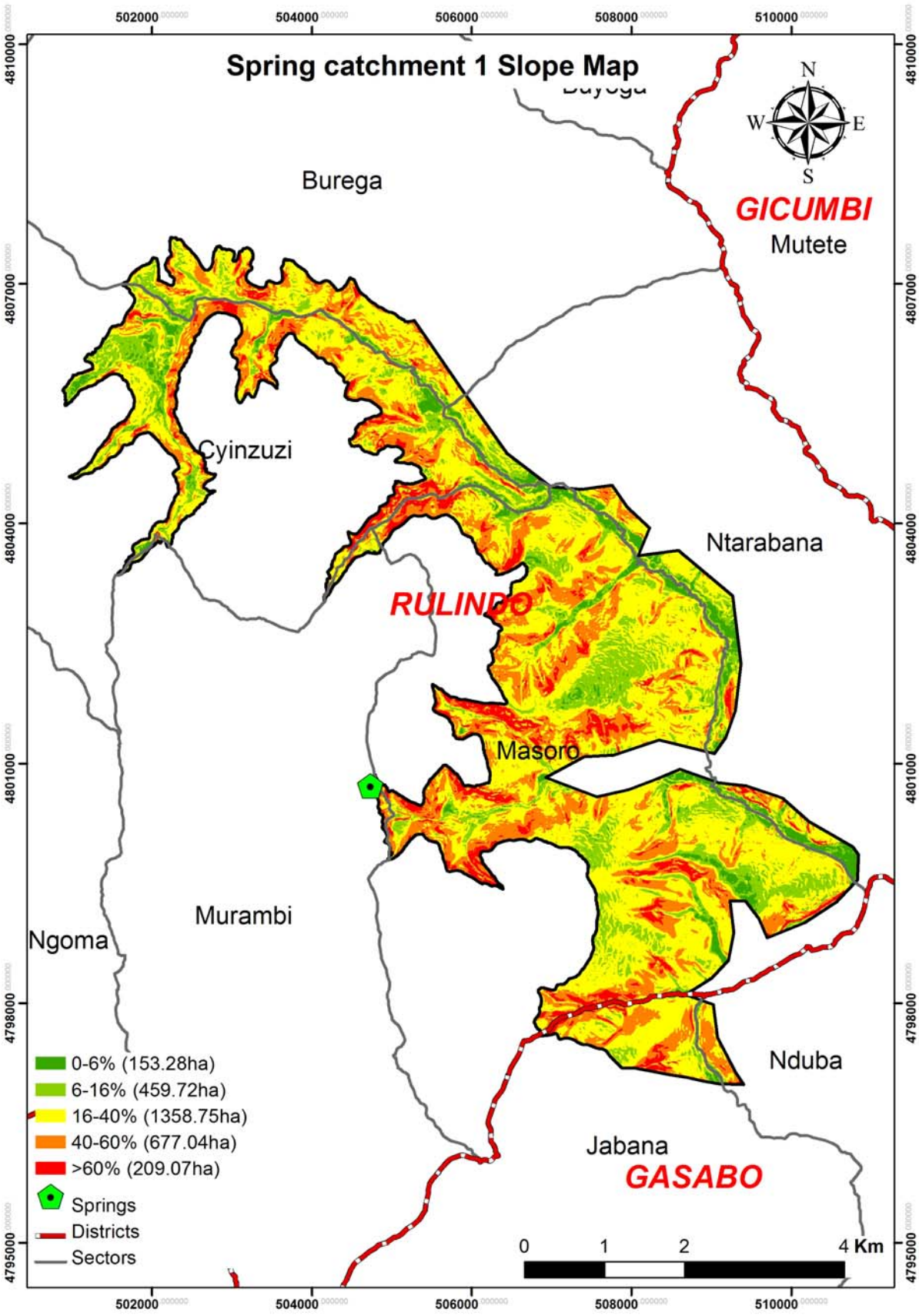

Spring catchment 1 Slope Map
N
W
E
S
Burega
GICUMBI
Mutete
Cyinzuzi
Ntarabana
RULINDO
Masoro
Murambi
Ngoma
Nduba
Jabana
GASABO
0-6% (153.28ha)
6-16% (459.72ha)
16-40% (1358.75ha)
40-60% (677.04ha)
>60% (209.07ha)
Springs
Districts
Sectors
0
1
2
4 Km
502000
504000
506000
508000
510000
4810000
4807000
4804000
4801000
4798000
4795000

Figure 14: Spring recharge catchment 1 slope map.

A common classification of soil depth is done into 3 classes. These are set as varying being <50 cm deep, varying between 50-100 cm deep and >100 cm deep. The following was also done for every spring recharge catchment as illustrated below.

Table 10: Spring recharge catchment 1 soil depth coverage

Spring recharge catchment 1		
soil depth	**Area Ha**	**% of Area Covered**
<0.5m	1440.52	50.41
0.5 - 1.0m	90.92	3.18
>1.0m	1326.45	46.41

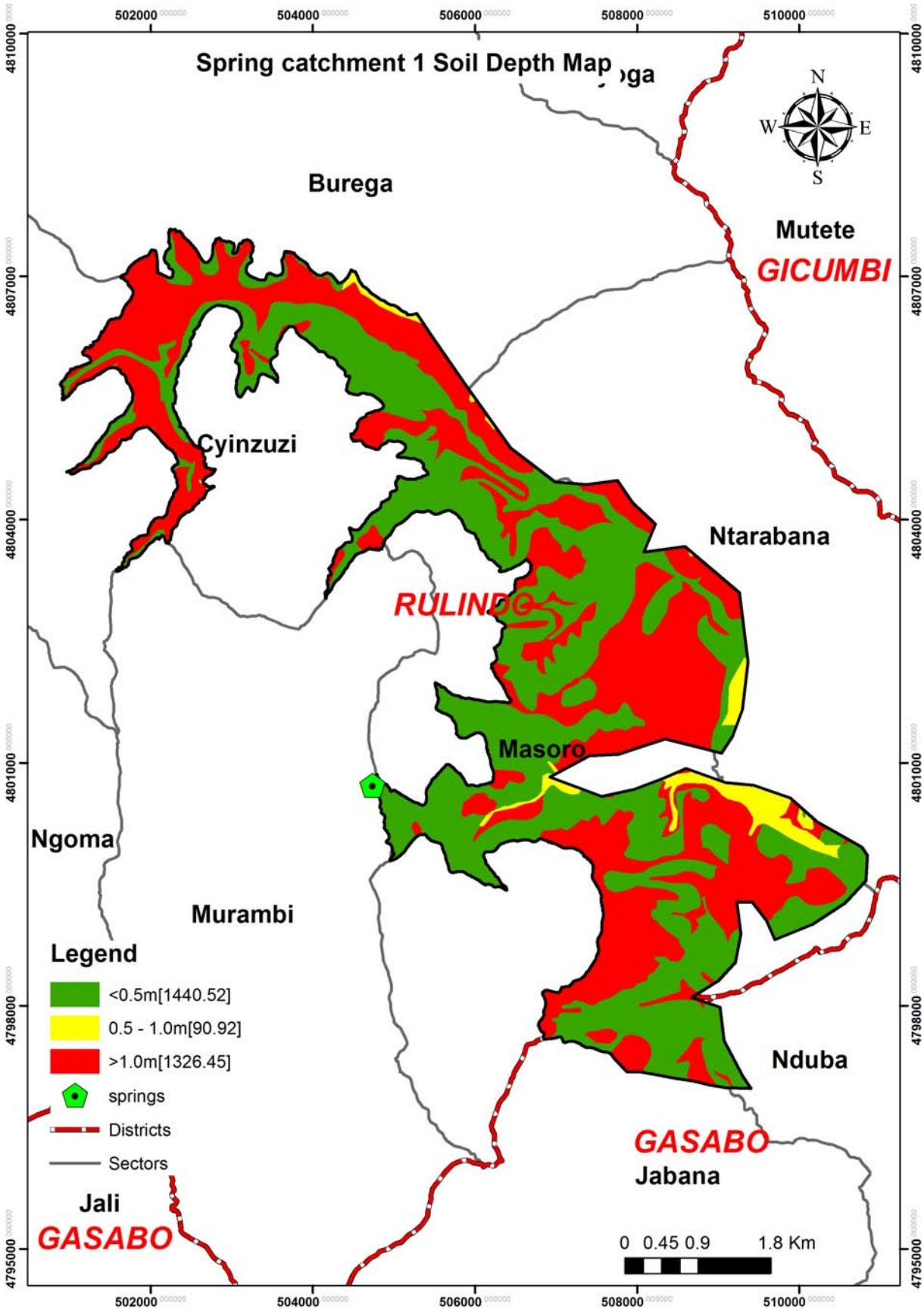

Spring catchment 1 Soil Depth Map
N
W
E
S
Buregа
Mutete
GICUMBI
Cyinzuzi
Ntarabana
RULINDO
Masoro
Ngoma
Murambi
Nduba
GASABO
Jabana
Jali
GASABO
Legend
<0.5m[1440.52]
0.5 - 1.0m[90.92]
>1.0m[1326.45]
springs
Districts
Sectors
0 0.45 0.9 1.8 Km
502000
504000
506000
508000
510000
4810000
4807000
4804000
4801000
4798000
4795000

Figure 15: Spring recharge catchment 1 soil depth map.

Table 11: Spring recharge catchment 1 resilience unit coverage

Spring recharge catchment 1		
resilience	**Area Ha**	**% of Area Covered**
cropland	1165.75	40.79
forest plantation	206.31	7.22
natural forest	207.96	7.28
rangeland	1277.86	44.71

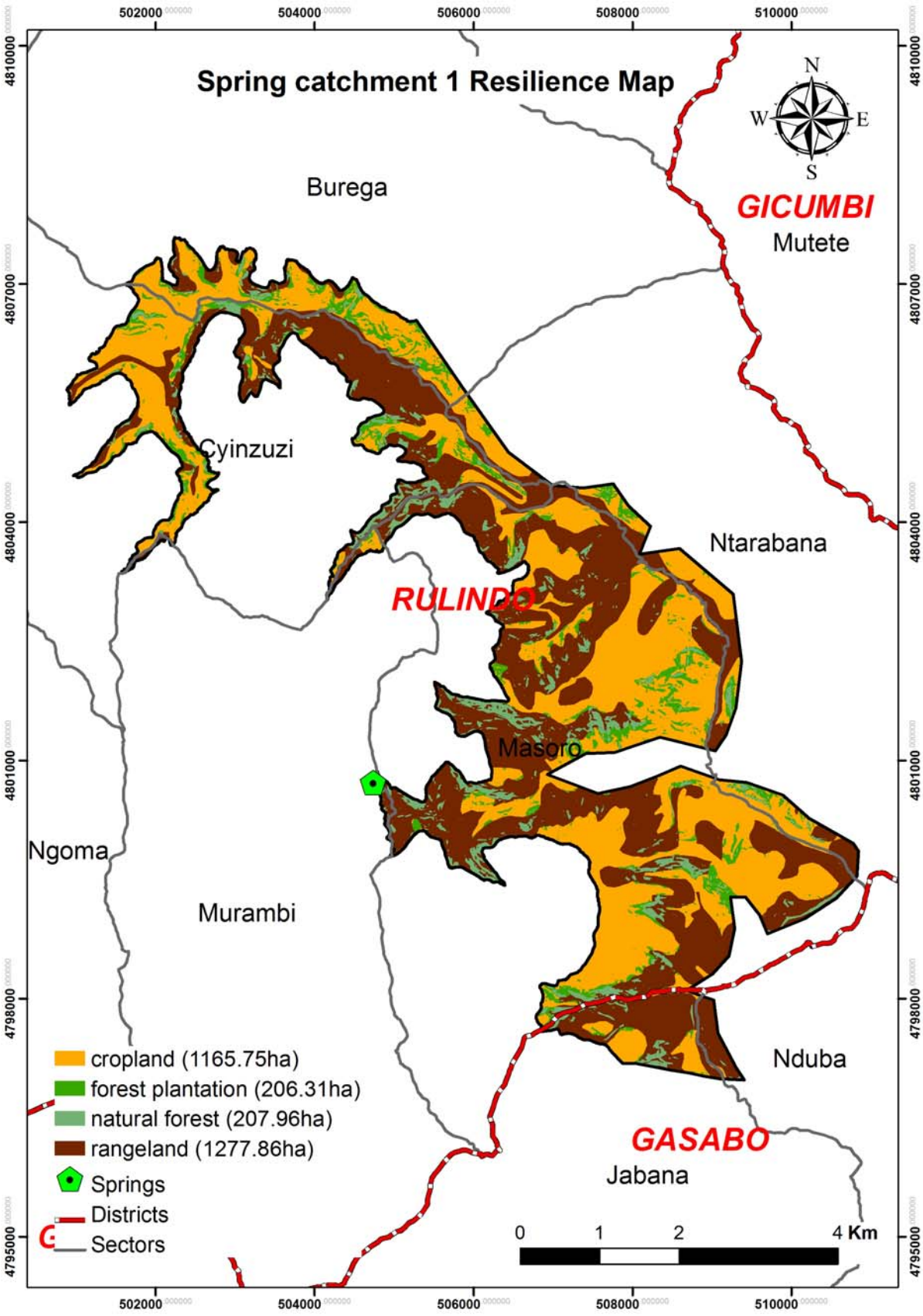

Spring catchment 1 Resilience Map
N
W
E
S
Burega
GICUMBI
Mutete
Cyinzuzi
Ntarabana
RULINDO
Masoro
Ngoma
Murambi
Nduba
GASABO
Jabana
cropland (1165.75ha)
forest plantation (206.31ha)
natural forest (207.96ha)
rangeland (1277.86ha)
Springs
Districts
Sectors
0 1 2 4 Km
502000
504000
506000
508000
510000
4810000
4807000
4804000
4801000
4798000
4795000

Figure 16: Spring recharge catchment 1 soil resilience map

Table 12: Spring recharge catchment 1 management measures coverage

Spring recharge catchment 1		
Measures	**Area Ha**	**% Area Covered**
Agroforestry+progressive terraces/cuttoff drains	1355.36	47.43
Agroforestry+cuttoff drains/horizontal trenches	616.98	21.59
Agroforestry+radical terraces/gully treatment	469.21	16.42
Forest Plantation	206.91	7.24
Natural Forest	209.43	7.33

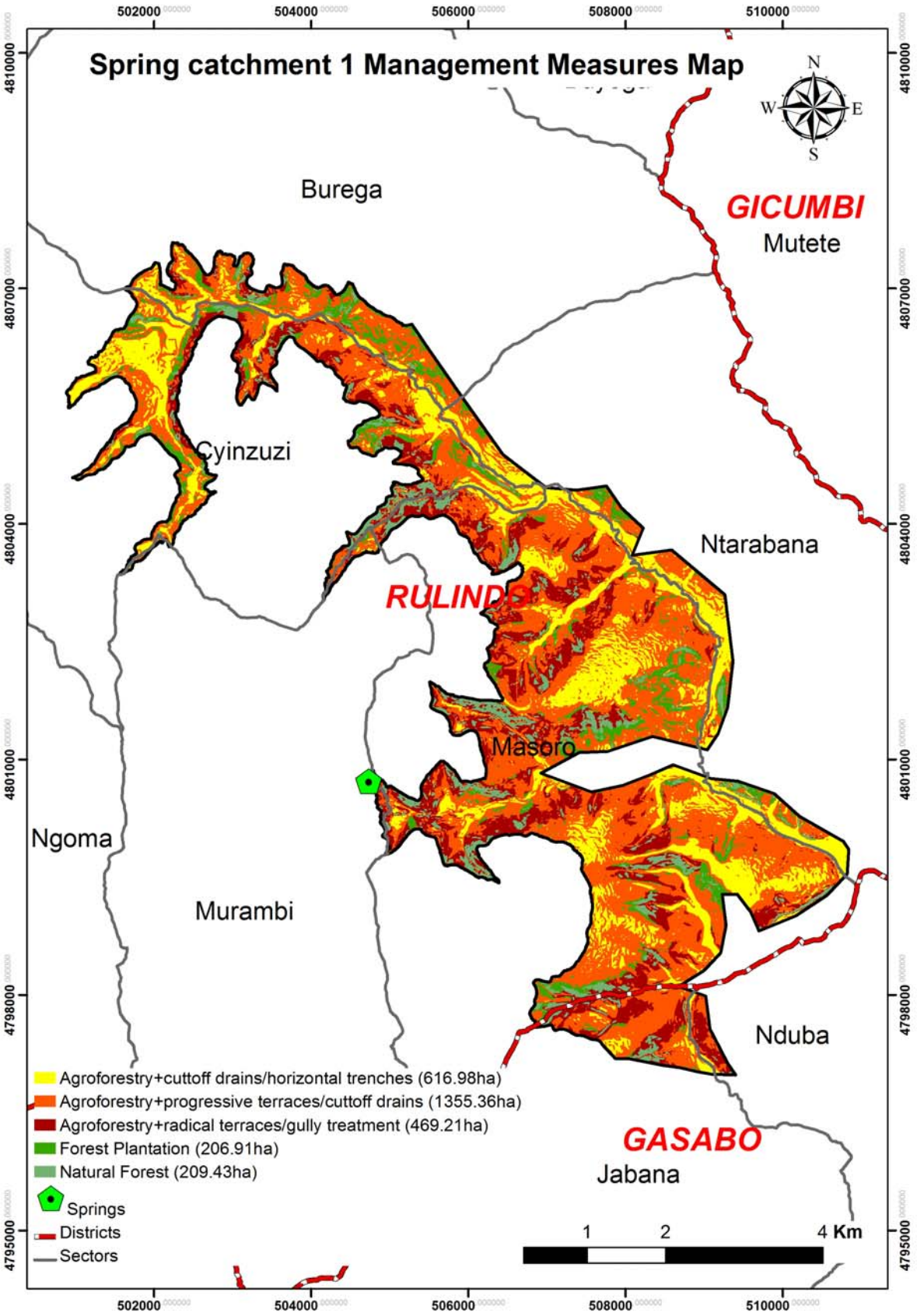

Spring catchment 1 Management Measures Map
N
W
E
S
502000
504000
506000
508000
510000
4810000
4807000
4804000
4801000
4798000
4795000
Burega
GICUMBI
Mutete
Cyinzuzi
Ntarabana
RULINDO
Masoro
Ngoma
Murambi
Nduba
GASABO
Jabana
Agroforestry+cuttoff drains/horizontal trenches (616.98ha)
Agroforestry+progressive terraces/cuttoff drains (1355.36ha)
Agroforestry+radical terraces/gully treatment (469.21ha)
Forest Plantation (206.91ha)
Natural Forest (209.43ha)
Springs
Districts
Sectors
1
2
4 Km

Figure 17: Spring recharge catchment 1 management measures map

Mutagata

Mutagata is an existing spring that is being improved to increase its efficiency and the coverage area by installing a pumping system in its water distribution network. The spring has an immediate spring catchment that is not regularly maintained as illustrated on the figure above. On the left part toward the upstream part, the immediate spring catchment shares the border with a banana plantation. The upstream part of the spring is protected by progressive terraces with embankments stabilized by elephant grasses.

Required activities

- Maintaince of the spring immediate catchment fence
- Establishment of a water diversion way around the spring immediate catchment
- Stop grazing over the spring immediate catchment.

5.2.2. Spring recharge catchment 2

The spring recharge catchment 2 is the biggest recharge catchment in all the delineated recharge catchment with an area of 6,138.05 ha. It is located in two districts known as Gicumbi and Rulindo as well as in six sectors known as Burega, Buyoga, Kisaro, Mutete, Ntarabana and Rutare. The recharge catchment 2 has five spring sources that were studied and which are all not captured yet. The resulting maps based on the above classification are presented below.

Table 13: Spring recharge catchment 2 slope coverage

Spring recharge catchment 2		
Slope classes	**Area Ha**	**% of Area Covered**
0-6%	307.61	5.01
6-16%	884.77	14.41
16-40%	2634.00	42.91
40-60%	1556.56	25.36

>60%	755.09	12.30

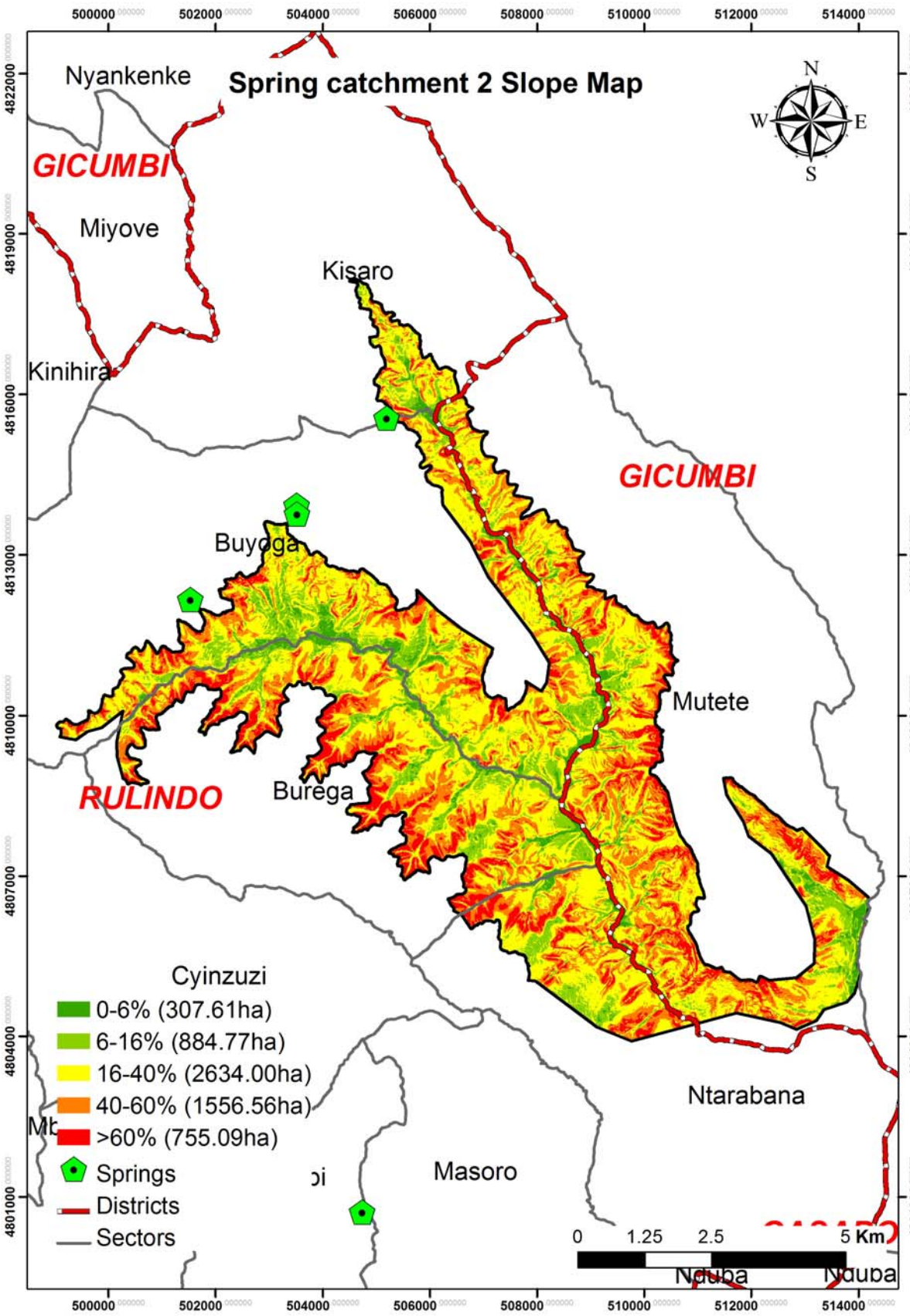

Spring catchment 2 Slope Map
Nyankenke
GICUMBI
Miyove
Kisaro
Kinihira
GICUMBI
Buyoga
Mutete
RULINDO
Burega
Ntarabana
Masoro
Nduba
Cyinzuzi
0-6% (307.61ha)
6-16% (884.77ha)
16-40% (2634.00ha)
40-60% (1556.56ha)
>60% (755.09ha)
Springs
Districts
Sectors
0 1.25 2.5 5 Km
N
W
E
S
500000
502000
504000
506000
508000
510000
512000
514000
4822000
4819000
4816000
4813000
4810000
4807000
4804000
4801000

Figure 18: Spring recharge catchment 2 slope map.

Table 14: Spring recharge catchment 2 slope depth coverage

Spring recharge catchment 2		
soil depth	**Area Ha**	**%Of Area Covered**
<0.5m	1934.67	31.52
0.5 - 1.0m	1300.45	21.19
>1.0m	2902.93	47.29

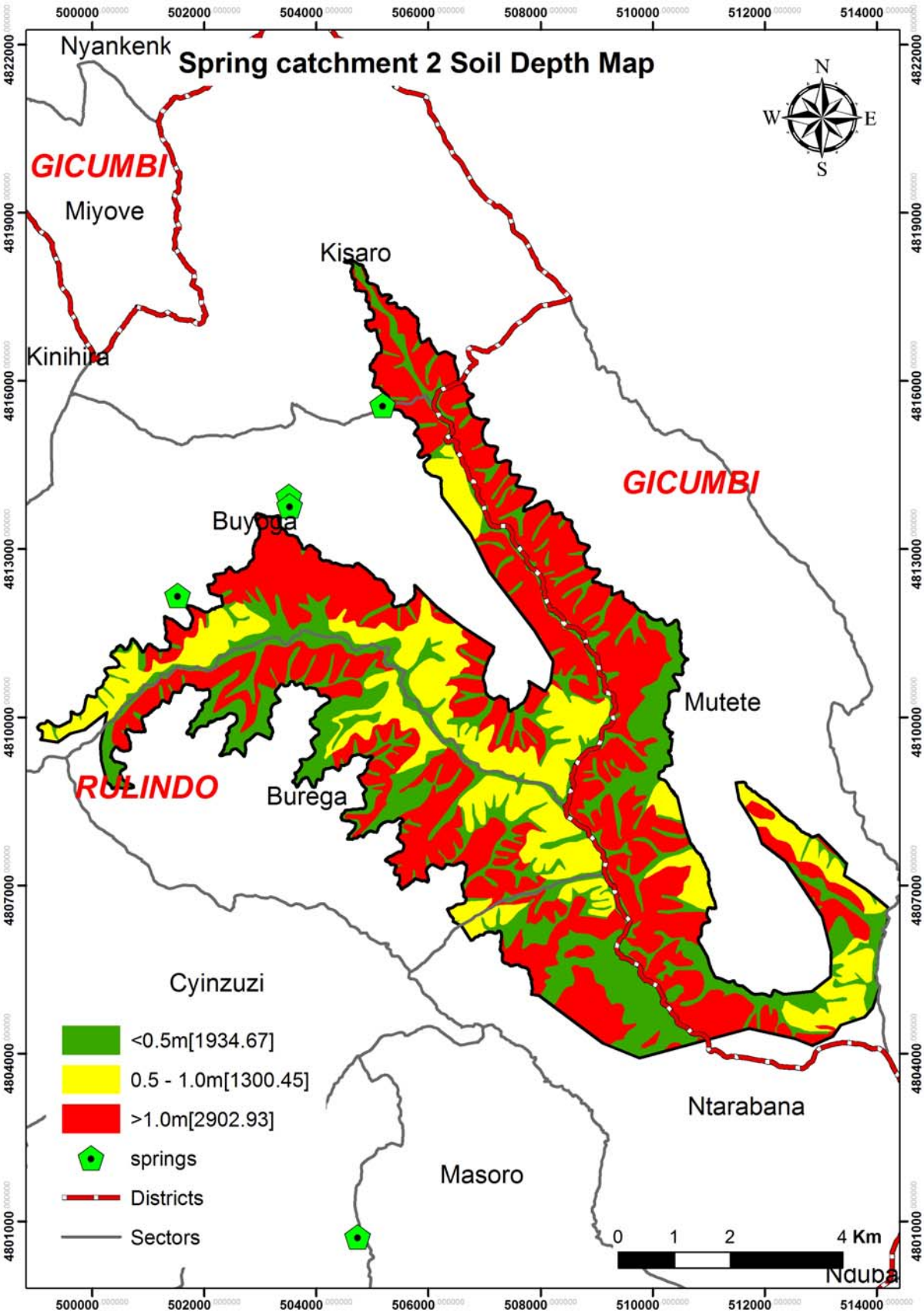

Spring catchment 2 Soil Depth Map
N
W
E
S
Nyankenk
GICUMBI
Miyove
Kisaro
Kinihira
GICUMBI
Buyoga
Mutete
RULINDO
Burega
Cyinzuzi
Ntarabana
Masoro
Nduba
<0.5m[1934.67]
0.5 - 1.0m[1300.45]
>1.0m[2902.93]
springs
Districts
Sectors
0 1 2 4 Km
500000
502000
504000
506000
508000
510000
512000
514000
4822000
4819000
4816000
4813000
4810000
4807000
4804000
4801000

Figure 19: Spring recharge catchment 2 soil depth map

Table 15: Spring recharge catchment 2 resilience unit coverage

Spring recharge catchment 2		
resilience	**Area Ha**	**% of Area Covered**
cropland	2661.41	43.36
forest plantation	1086.09	17.69
natural forest	756.12	12.32
rangeland	1634.39	26.63

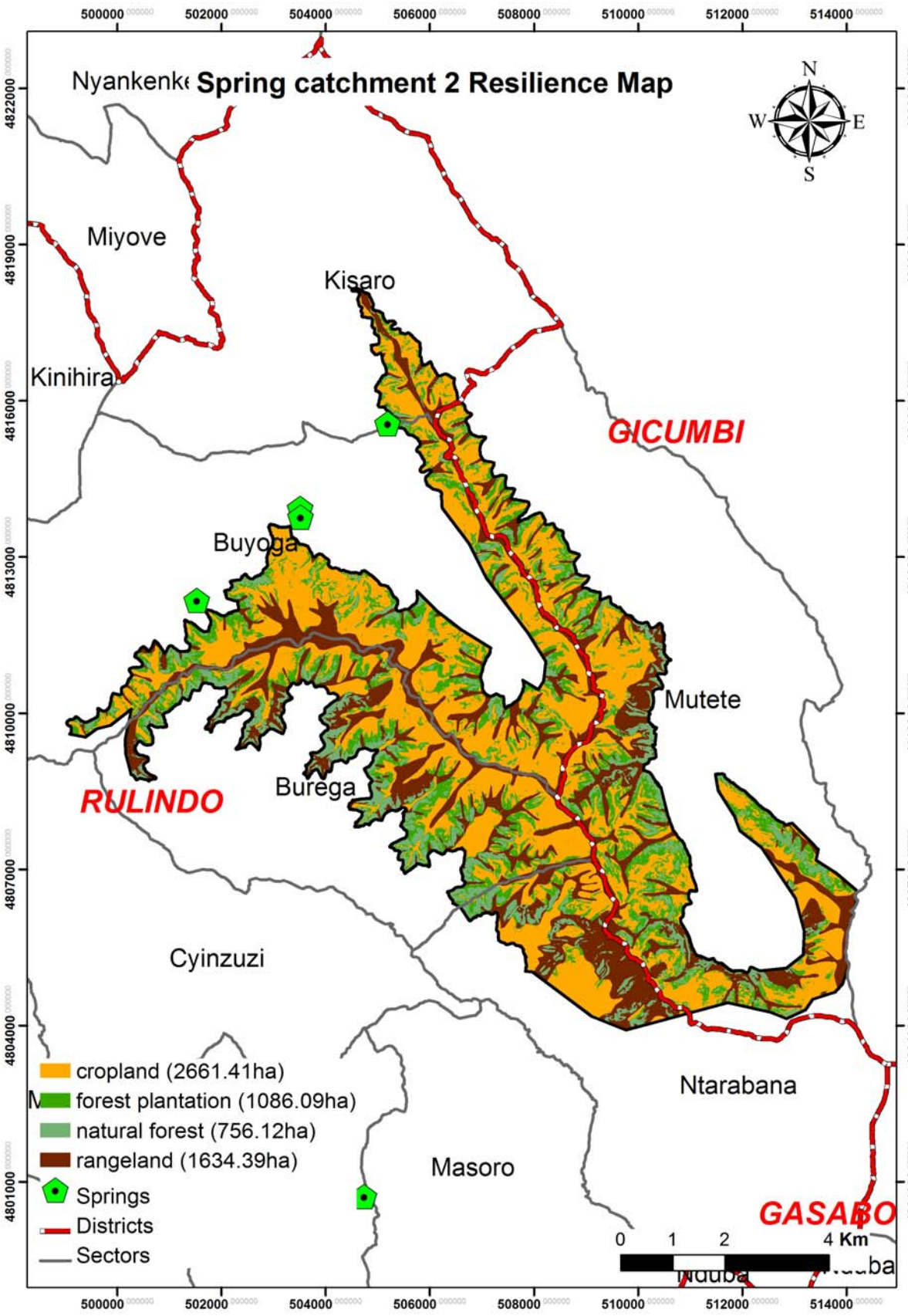

Nyankenke Spring catchment 2 Resilience Map
N
W
E
S
Miyove
Kisaro
Kinihira
GICUMBI
Buyoga
Mutete
Burega
RULINDO
Cyinzuzi
Ntarabana
Masoro
GASABO
cropland (2661.41ha)
forest plantation (1086.09ha)
natural forest (756.12ha)
rangeland (1634.39ha)
Springs
Districts
Sectors
0 1 2 4 Km
500000
502000
504000
506000
508000
510000
512000
514000
4822000
4819000
4816000
4813000
4810000
4807000
4804000
4801000

Figure 20: Spring recharge catchment 2 soil resilience map.

Table 16: Spring recharge catchment 2 management measures coverage

Spring recharge catchment 2		
Measures	**Area Ha**	**% Area Covered**
Agroforestry+progressive terraces/cuttoff drains	2628.72	61.21
Agroforestry+cuttoff drains/horizontal trenches	1200.12	27.95
Agroforestry+radical terraces/gully treatment	465.53	10.84
Forest Plantation	1087.11	25.31
Natural Forest	756.48	17.62

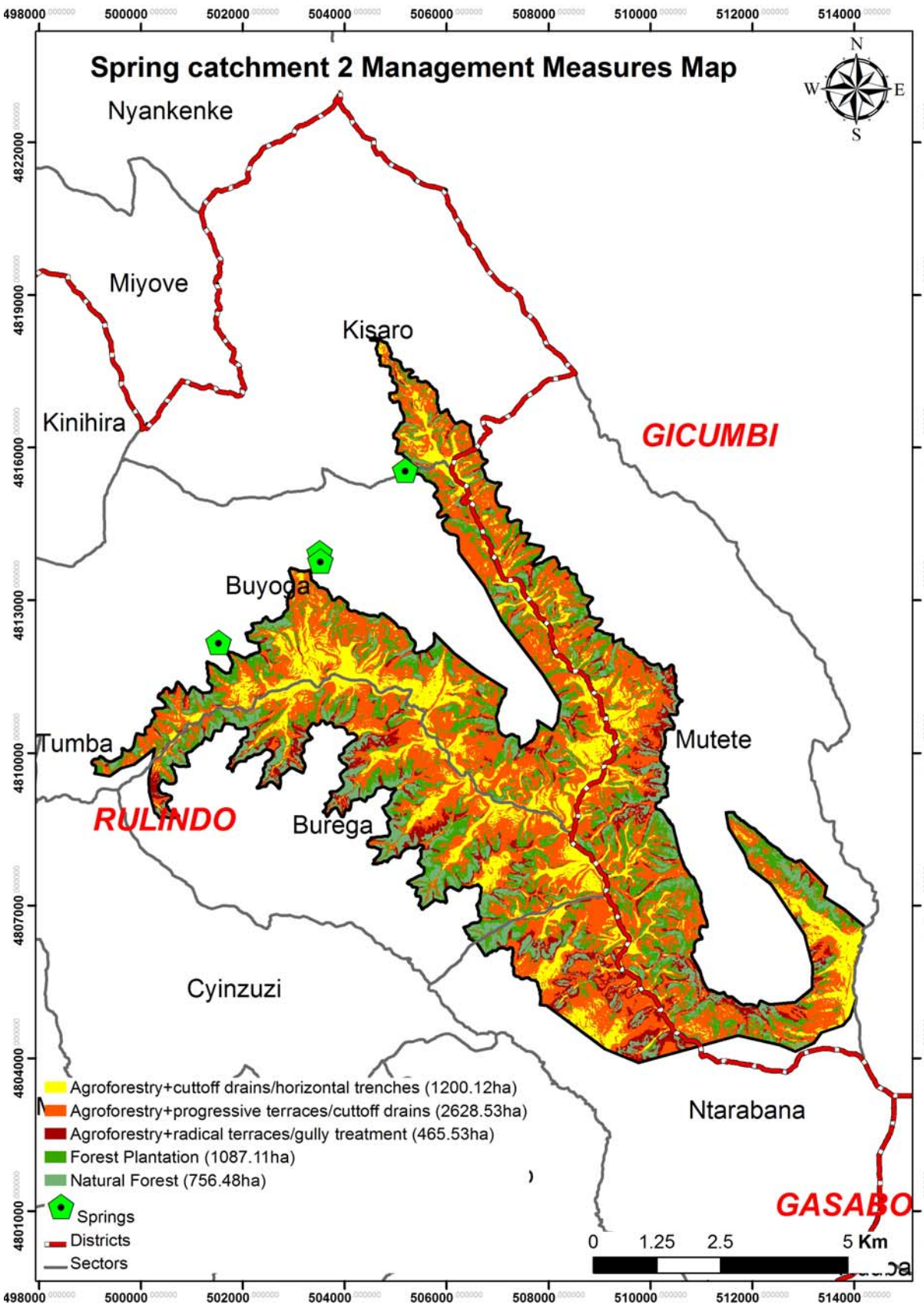

Spring catchment 2 Management Measures Map
N
W
E
S
Nyankenke
Miyove
Kisaro
Kinihira
GICUMBI
Buyoga
Tumba
Mutete
RULINDO
Burega
Cyinzuzi
Ntarabana
GASABO
Agroforestry+cuttoff drains/horizontal trenches (1200.12ha)
Agroforestry+progressive terraces/cuttoff drains (2628.53ha)
Agroforestry+radical terraces/gully treatment (465.53ha)
Forest Plantation (1087.11ha)
Natural Forest (756.48ha)
Springs
Districts
Sectors
0 1.25 2.5 5 Km
498000
500000
502000
504000
506000
508000
510000
512000
514000
4822000
4819000
4816000
4813000
4810000
4807000
4804000
4801000

Figure 21: Spring recharge catchment 2 management measures map

RUKUNGERI 2

Although it is required to fence and surround the spring immediate catchment by the water diversion ditch (also called water diversion way or cut-off drain) that deviates the runoff, the two important practices are not adequate for these particular springs. In fact; around the springs immediate catchment there are no fence that limit humans from conducting activities over the intakes. The picture below (left) shows the boundary of one of the intakes but if a fence is not established, in few months the signs of its limit will disappear. For another one it is not easy to retrieve the real location of the intake.

Regarding the enrecharged catchment area, it is almost protected with stable and effective progressive terraces with embankment stabilized by elephant grasses. However, the area around the spring does not have a defined watershed management practices. In addition the water supply pipeline is unmarked; therefore there is a worry that in the coming years people may forget their location and break them while cultivating or establishing other necessary infrastructure.

Furthermore the manhole for the spring boxes are not fixed with crew and children flew different kinds of wastes that may lead to a permanent pollution of the supplied water.

Required measures

- Establishment of progressive terraces with the embankments made of stone bunds as the area is rich in stones
- Establishment of the adequate water diversion ditch is required as well as the fence that should be made with imiyenzi (Euphorbia tirucalli). In fact, Euphorbia tirucalli is a local plant that was found in that area and has been used for the other springs protection.

GAHONDO

This spring originate from a rock. Up stream of its intake there are forest plantations with shrubs. Although the area does not have an immediate spring catchment, the water quality and quantity are not apparently threatened. However establishment of trenches in the upstream forest is required for the sustainability of the spring.


Required activities

- Rehabilitation of the spring used by local community
- Establishment of trenches in upstream forest to increase the ground water recharge.

GAHONDO 2 (New Spring)

This spring is located on the right wing of Gahondo 1 in few meters of its pipeline. As the picture below the stream is uncaptured and water is collected from a banana leave petiole installed by the local community. This spring is surrounded by the banana plantation of the local community and the upstream is predominated by unmaintained progressive terraces.


Required management activities

- Capture the spring and link its system to the pipeline from the prvious spring
- Establishment of an immediate spring catchment
- Reinforcement of the existing progressive terraces and establishment of the new in upstream areas.

NYAGAHERA

This spring is located in the area without the agricultural activities that can interfere either with the water quality and quantity. The spring does not have a market spring catchment as well as the water diversion way which is necessary because the spring seem to be located in a talwage.

Upstream as well as on the left and right part of the spring, there are forest of eucalyptus with natural grasses and shrubs. The field observation revealed that the trenches in the forest need maintenance. They would reduce the organic matter as well as the biological contaminant to run toward the spring.

Required catchment management activities

- Establishment of spring catchment and remove the neighboring eucalyptus
- Establishment of water diversion ditches to deviate the runoff
- Maintenance of trenches in upstream forest

KIRURUMA

Like many other springs, these springs are located at the foot of the hill. The springs have an immediate spring catchment fenced with imiyenzi. On the left part of the immediate spring catchment, there is young roseau that is growing. According to the local community as well as the spring care hired by WFP, the water from these springs is affected by the rainfall as its colour changes when a heavy rain occurs.

The enrecharged catchment area is protected by the forest plantation of eucalyptus containing many shrubs. This particular forest does not have trenches to slow the runoff. Although the springs have a considerable discharge, the water collection tank seems to be leaking as illustrated in the photo above. This is not only a problem to the distribution network but also to the local community as the tank has the potential of causing serious damage to the local environment as well to the local community.

Required catchment management practices

- Establishment of trenches in the upstream forest to slow the impact of rainfall to the springs
- Total removal of Roseau that is growing in the immediate spring catchment area and on its left part toward the top of the hill.
- Regular maintenance of runoff water diversion ditch

Note: The spring recharge catchments 1 to 2 were presented in the above chapter 5 as an illustration of high level observation noted for each spring. However, to easy the reading of this document other spring recharge catchment from 3 to 14 were included in the appendix 1.

6. HYDROLOGY

6.1. Rainfall

The average daily rainfall pattern of a typical hydrological year in Rulindo exhibit the 4 seasonal rainfall supplies typical experienced in Rwanda. Heavy rainfall up to approximately 9 mm a day is experienced in the beginning of the year followed by a heavy dry season with rainfall of approximately 1 mm per day and less in the middle of the year and medium rainfall depths of up to approximately 5 mm in the last part of the year. Figure 22 illustrates the above mentioned rainfall pattern.

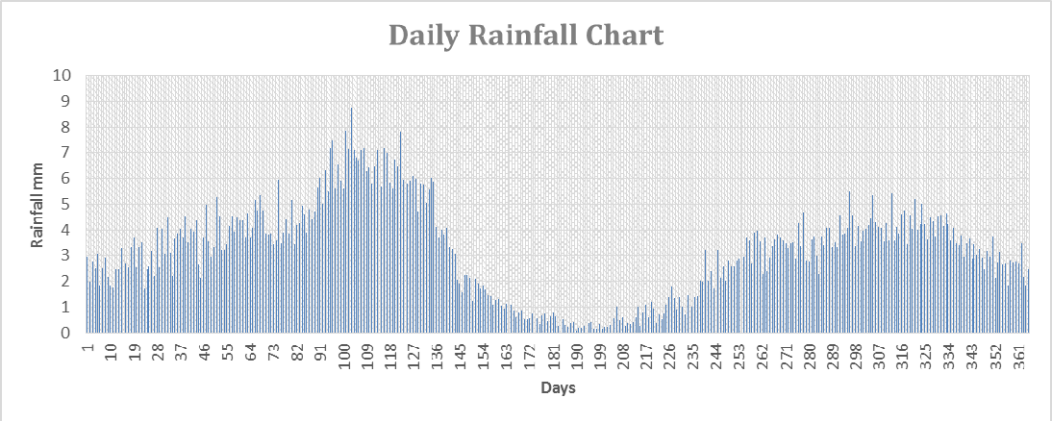


Figure 22: Hydrologic daily rainfall pattern of Rulindo district.

The same pattern is clearly observed in terms of monthly figures as illustrated on figure 23. This clearly shows that the months of March, April and May constitute the biggest supply of rainfall water and therefore aquifer recharge. This is immediately followed by the heavy dry period representing the biggest water consumption 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.

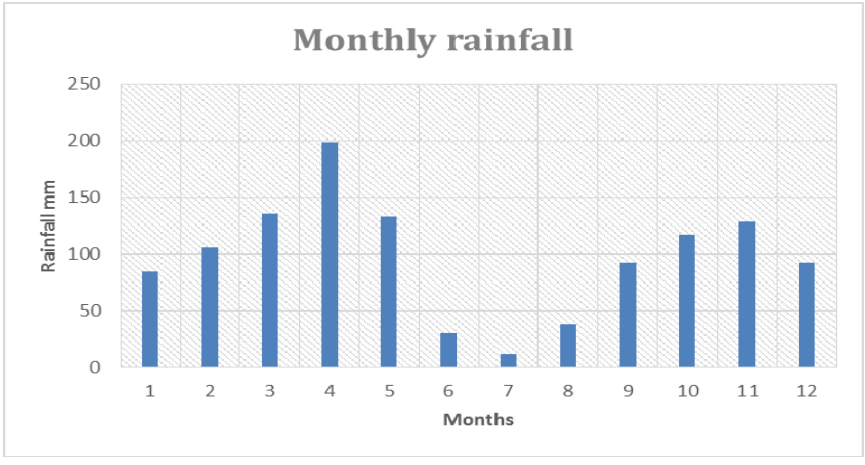


Figure 23: Monthly rainfall of Rulindo.

6.2. Temperature

The temperature variation pattern of Rulindo varies between 20^0 and 23^0 Celsius as illustrated on figure 24. On average Rulindo is observed to be a warm area. The pattern of temperature indicate normally the sun energy supply of Rulindo which consequently provides indication on how much water losses are to be expected through evapotranspiration in the area.

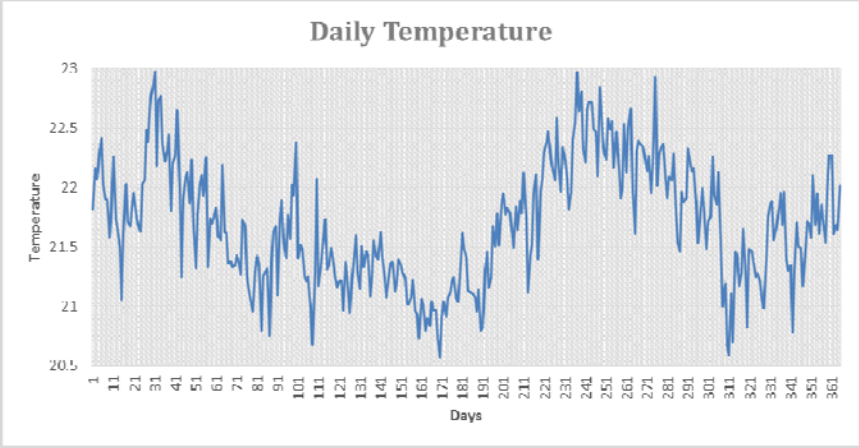


Figure 24: Rulindo daily temperature.

The pattern is clearly shown on the monthly figures illustrated in figure 25. Two pattern 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).

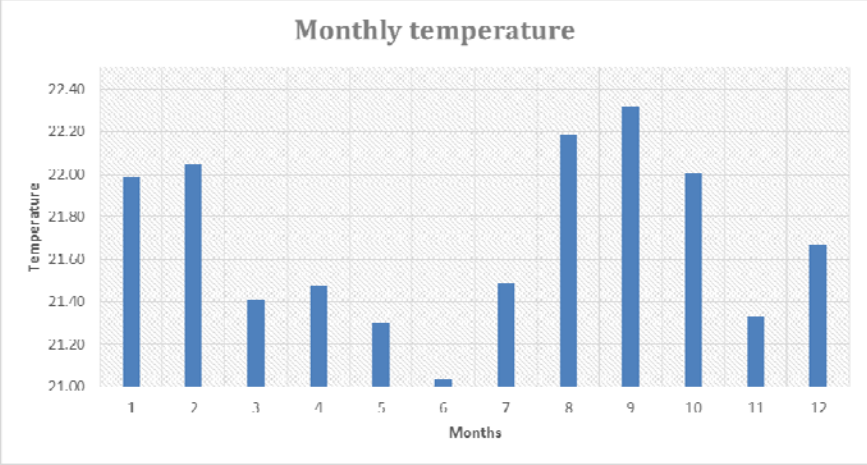


Figure 25: Monthly Temperature of Rulindo.

6.3. Evapotranspiration

The evapotranspiration constitutes the biggest natural water loss of Rulindo District. 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 a water loss because it cannot be harvested and/or used. Its pattern differ from the rainfall. It can be observed from figure 26 that heavy daily evapotranspiration occurs in August. The reason of this trend is scientifically 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.

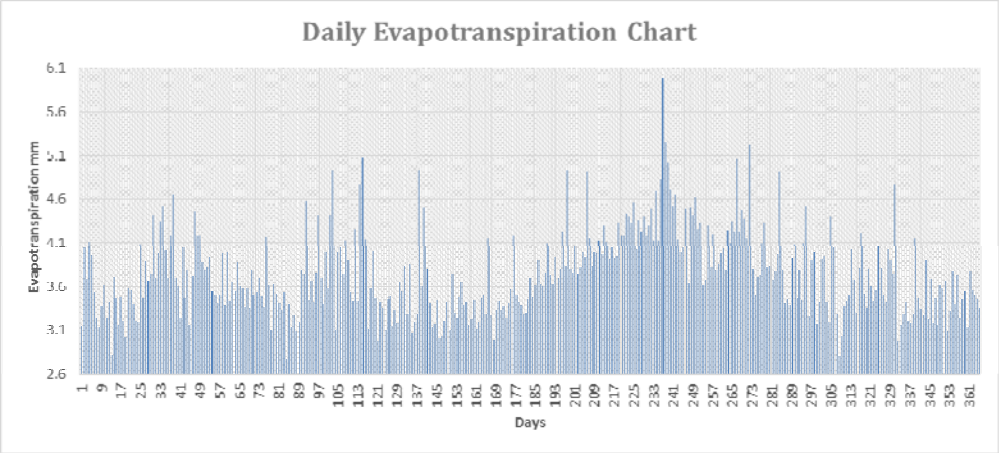


Figure 26: Rulindo daily evapotranspiration.

The pattern is clearly shown on the monthly figures illustrated in figure 27. The last part of the year has high evapotranspiration, considering the medium rainfall contribution; this will constitutes a limited recharge period for the Rulindo water resources system in general.

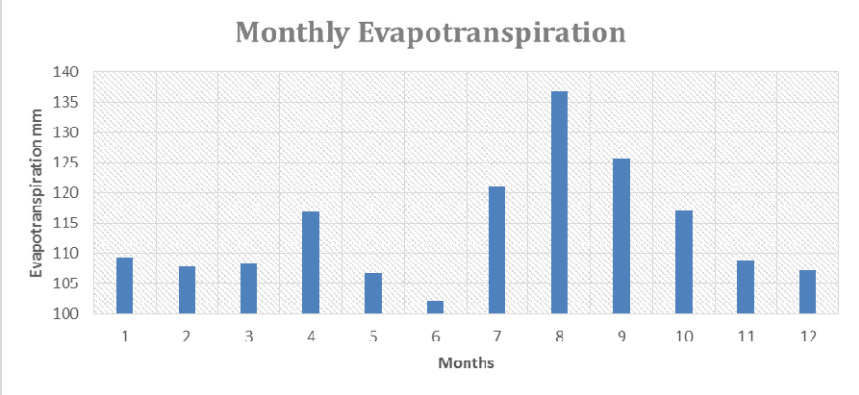


Figure 27: Monthly evapotranspiration of Rulindo.

6.4. Existing flow data

The illustrated catchments in figure 11 are the entire river system considered with either the whole catchment included in the Rulindo District or a portion of it but which can be easily accessed from within the District. Figure 11 also indicate few existing gauging stations on some of the rivers in Rulindo District. The gauging stations are the Yanze, Gaseke and Rusumo

gauging stations respectively on Yanze, Muyanza and Mwange Rivers. The flow data from these stations were 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 Natural Resources Authority. The available data were limited but they served to estimate an average daily flow at each gauging station. Note that, flow data are a result of water level data that were converted into flow data using what is known as a rating curve developed at the gauging station section. The following was obtained:

The Yanze River located in the southern part of the Rulindo District exhibit flows varying between 1 to 8 cubic meters per second on daily average within its hydrological year. This particular river is however not completely open to extraction since it is among the major water supply source of the city of Kigali. Heavy conflict of water uses are commonly experienced in this catchment during dry seasons. An alternative to use this river would be to invest in heavy hydraulic infrastructures as one of the solutions.

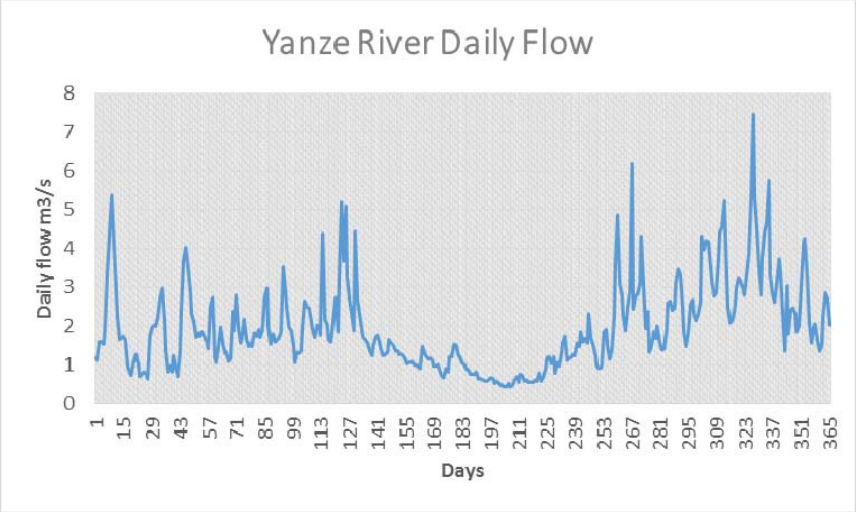


Figure 28:Yanze River daily flow.

The Muyanza River is a second monitored water course in Rulindo District located in the northern part of the District. Its exhibit flow a variation between 0.4 to 2.2 cubic meters per second on daily average within its hydrological year. The exploitation of the resources of this river would in principle require investment in hydraulic infrastructures to ensure a fruitful and sustainable use of its resources.

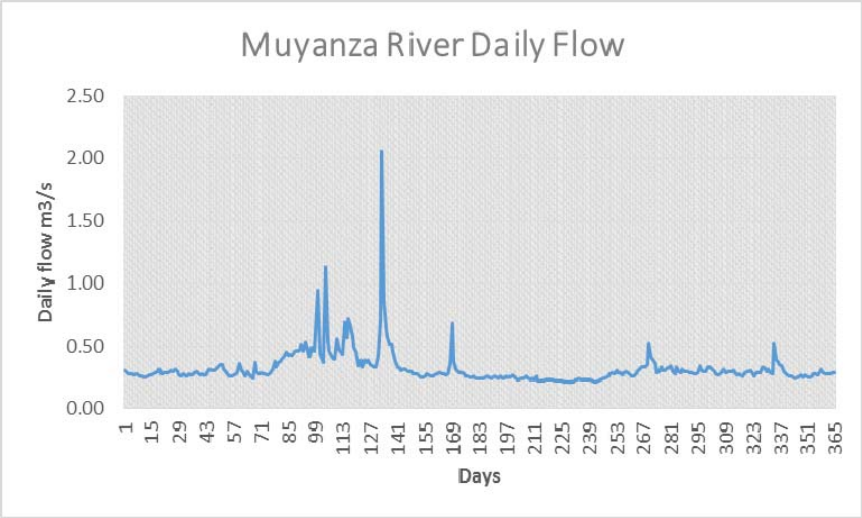


Figure 29: Muyanza River daily flow.

The Mwange River is another monitored water course in Rulindo. It has a flow variation between 0.01 and 0.4 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.

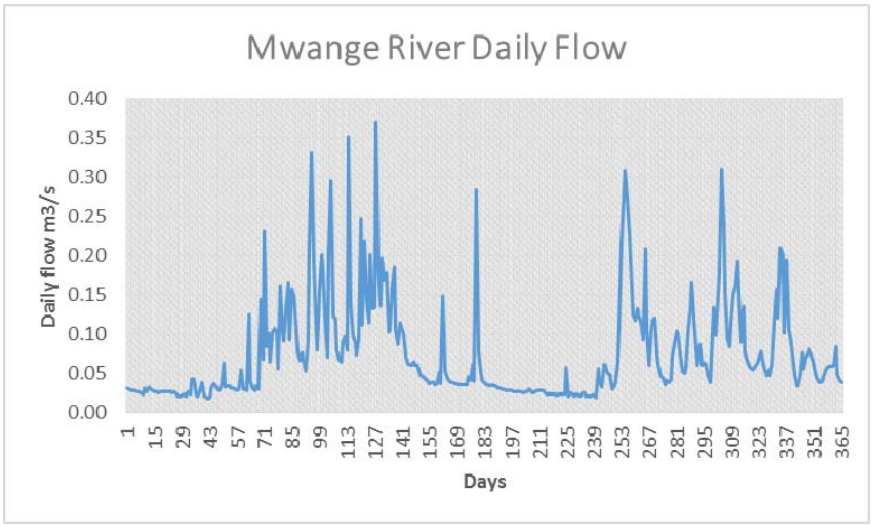


Figure 30: Mwange River Daily Flow.

6.5. Infiltration estimation

Infiltration data in Rulindo District were missing, however with the existing soil data an estimation of the potential for infiltration within the Rulindo District was possible. Using the available soil data, the saturated hydraulic conductivity variation within the Rulindo District 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 Rulindo District aquifers. The same can be related to the management measures proposed as these aim at ensuring maximum infiltration to ensure the sustainability of the spring sources. Figure 31 provides the variation of the saturated hydraulic conductivity obtained for the Rulindo District.

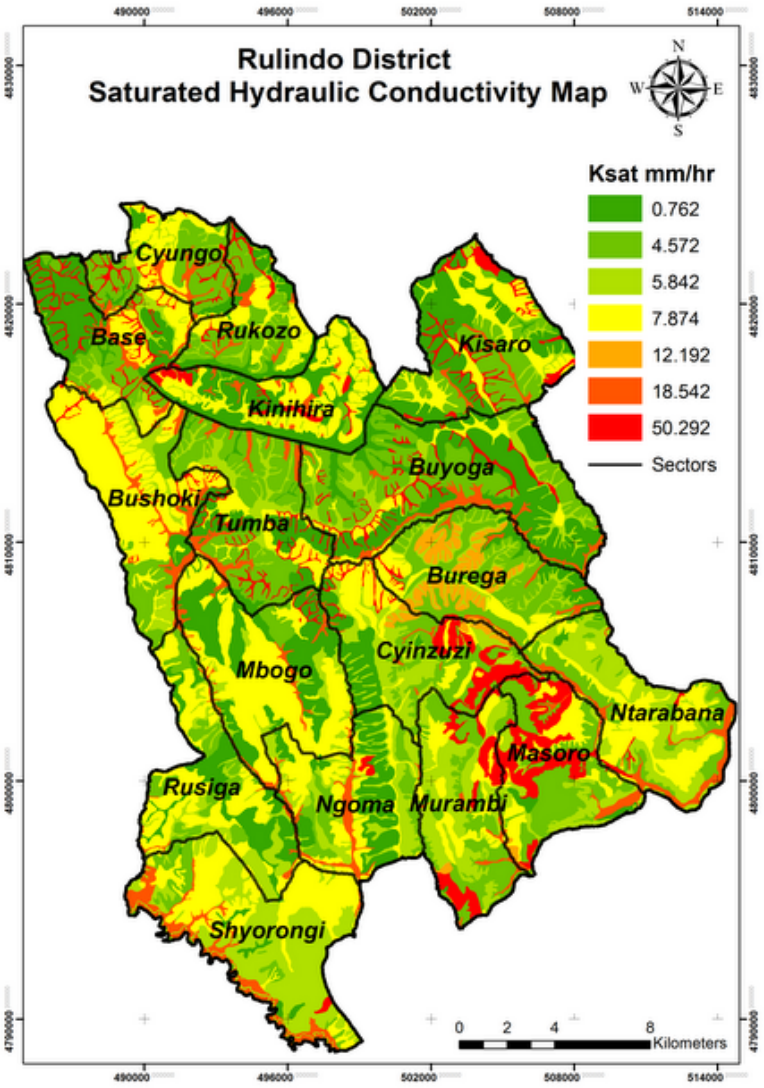


Figure 31: Saturated Hydraulic Conductivity map.

A general picture of Rulindo's hydraulic conductivity indicates that it varies mostly from low to medium hydraulic conductivity during saturated conditions. The southern part of the district indicates very high saturated hydraulic conductivity probably due to sandy soil located there. Saturated conditions represent maximum water flow within the water, at this stage all the pore space in the soil are filled with water and water can move easily within the soil, the following implies 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 hydraulic conductivity of the soil in the area, therefore positively affecting the infiltration capacity of the soil and ultimately the recharge rate of the aquifers in Rulindo District. Note that, attention has to be taken when implementing such measures since aquifers become more vulnerable to pollution from the surface, especially for the case of Rulindo with suspended aquifers.

7. WATER DEMAND AND BALANCE ESTIMATION

The water demand and water balance are analysis performed to assess the sustainability of a proposed development in a certain region as far as its available water resource is concerned. This analysis for Rulindo District was done per sector per each 5 years up to 2040 (a horizon of 25 years).

7.1. Available water

During the field work, a good number of water springs were identified. These identified springs were combined with previously identified water sources during the elaboration of hydraulic plan of the Rulindo district. The following table shows the number of springs recorded for each sector and the average discharge per sector. In addition, an excel sheet presenting in detail each spring is annexed to this report.

Table 17: Number of springs and total discharge in dry season per sector

Sector	No. of springs	Discharge (l/s)
Base	53	10.65
Burega	36	11.78
Bushoki	74	19.2
Buyoga	53	11.65
Cyinzuzi	13	4.16
Cyungo	36	11.78
Kinihira	42	18.34
Kisaro	46	11.84
Masoro	20	7.98
Mbogo	52	19.36
Murambi	48	9.48
Ngoma	8	3.61
Ntarabana	18	7.64
Rukozo	57	7.37
Rusiga	55	11.74
Shorongi	22	8.35
Tumba	72	12.59

Source: *Adapted from the Rulindo district hydraulic plan (2013) and other data collected during the elaboration of this report*

7.2. Estimation on water demand

According to Rwanda National Water Resources Master Plan, the water demand per capita will be changing as follows following gradually improving living standards and gradually converges between rural and urban population will be around 100liters/capita/day.

Year	*2012*	*2020*	*2030*	*2040*
L/day	40	60	80	100

Therefore for the future plan different scenario considering the above demand were made for 40, 60, 80 and 100 litres/capita/day w. According to the ToR, water demand should be estimated in 25 years from 2015. The current demographic statistics were gathered in 2012, population were projected taking the time horizon of 29 years (from 2012-2040) as illustrated in the next table

Table 18: Estimated population per sector

Sector	**Total Population/sector in 2012**	**Average Annual Growth Rate (2002-2012) (%)**	**Population Density (sq.km)**	**(1+r)**	**Population 2020**	**Population 2025**	**Population 2030**	**Population 2035**	**Population 2040**
					$P_{20}=P_{2012}(1+r)^8$	**$P_{25}=P_{2020}(1+r)^5$**	**$P_{30}=P_{2025}(1+r)^5$**	**$P_{35}=P_{2030}(1+r)^5$**	**$P_{40}=P_{2035}(1+r)^5$**
BASE	17,378	1.70	612.00	1.02	19,887	21,636	23,538	25,608	27,860
BUREGA	12,780	1.25	395.00	1.01	14,119	15,026	15,992	17,019	18,113
BUSHOKI	20,045	0.90	571.00	1.01	21,535	22,521	23,553	24,632	25,761
BUYOGA	22,264	1.00	417.00	1.01	24,109	25,339	26,631	27,989	29,417
CYINZUZI	13,653	1.10	408.00	1.01	14,902	15,740	16,625	17,559	18,546
CYUNGO	13,428	0.60	679.00	1.01	14,086	14,514	14,955	15,409	15,877
KINIHIRA	15,401	0.70	562.00	1.01	16,285	16,863	17,461	18,081	18,723
KISARO	19,957	0.90	522.00	1.01	21,440	22,422	23,450	24,524	25,648
MASORO	20,826	2.30	702.00	1.02	24,981	27,989	31,359	35,135	39,366
MBOGO	17,010	0.90	416.00	1.01	18,274	19,111	19,987	20,903	21,860
MURAMBI	17,918	2.30	607.00	1.02	21,493	24,081	26,981	30,229	33,869
NGOMA	11,043	1.20	351.00	1.01	12,149	12,895	13,688	14,529	15,422
NTARABANA	18,018	4.00	515.00	1.04	24,659	30,001	36,501	44,409	54,031
RUKOZO	14,996	0.70	741.00	1.01	15,857	16,419	17,002	17,606	18,231
RUSIGA	10,904	1.20	348.00	1.01	11,996	12,733	13,516	14,346	15,228
SHYORONGI	23,633	2.60	506.00	1.03	29,020	32,994	37,512	42,649	48,489
TUMBA	19,198	0.70	559.00	1.01	20,300	21,020	21,766	22,539	23,339
Total	**288,452**				**325,090**	**351,305**	**380,517**	**413,168**	**449,780**

Note: *the district average value of 1.25 for growth rate was used in Burega sector. The average calculation excluded Ntarabana sector as an outlier value.*

Regarding public institutions, the water needs of centres and health posts were established at the rate of 100 while for educational institutions was considered 50 litres per pupil per day as the average because in non-boarding school the water consumption is generally law.

7.2.1 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 follows.

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. As we couldn't obtain data on the number of cows of improved race for milk production, we took into we assumed that in 2040 all cows will be of an improved race. Considering the availability of grazing and fodder land we assume that the number of cattle remains more or less constant over the life time of this projection; the assumption also used in Rwanda National Water Resources Master Plan. The excel sheets annexed to the report are detailing calculation and data used during the water demand estimation while the next table and figure sums up the situation 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 Rulindo District Development Plan, the Rulindo District Master Plan as well as the Rulindo district hydraulic plan. The appendix 2 provides the detail of 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 2040 considering the population growth and the increase of other water demand activities such as livestock and industrial consumption.

7.3 Water demand and balance in Rulindo district

Figure 32 illustrates the findings from the water demand and balance analysis for each Sector of Rulindo 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 unit. The deficit and surplus (or in other words the water balance) of water were calculated as the difference of water available (from existing spring sources) and water demand. 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 in this analysis was obtained from the population census and also from the District Development Plan as well as the Rulindo District Master Plan. These demands were estimated per each five years until 2040 and compared to the available water resources.

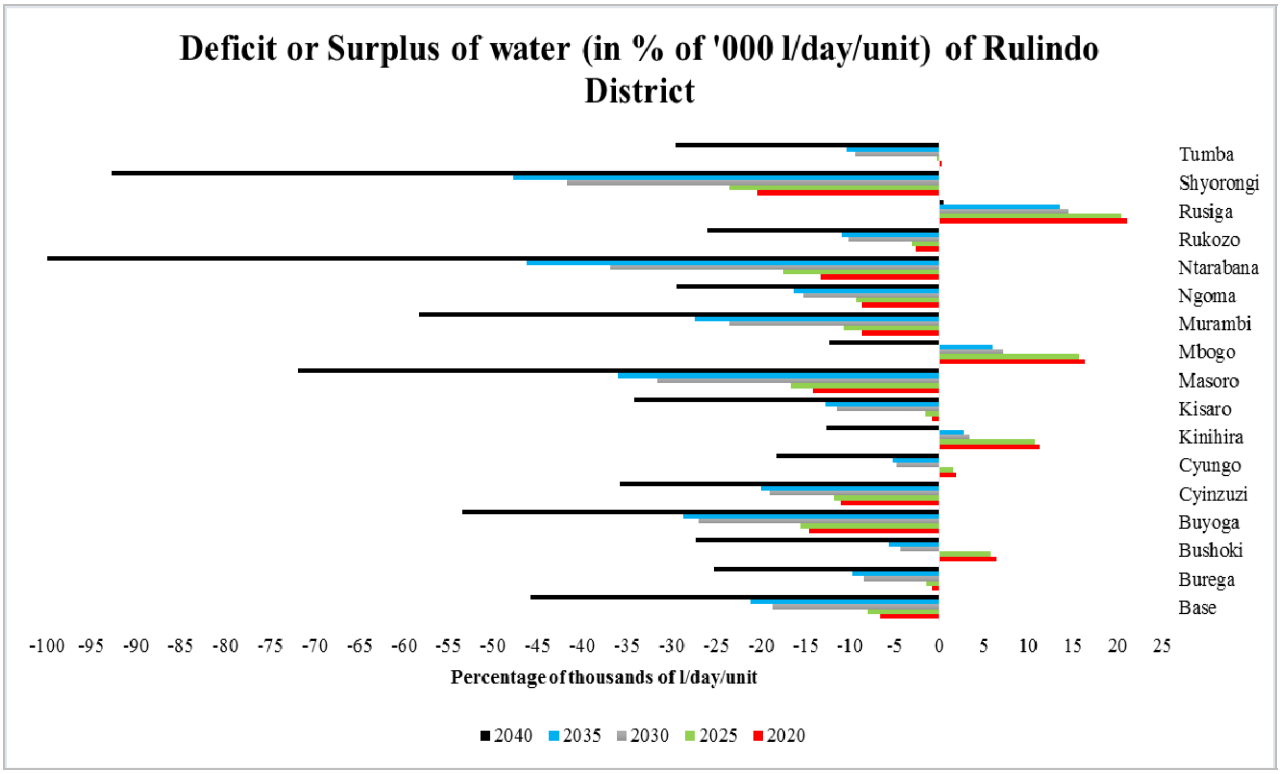


Figure 32: Deficit vs Surplus of water in Rulindo District.

Note: *x-axis is expressed in percentage of thousands of l/day/unit. This means that the values obtained were divided by 1000, and then these were converted in percentage on the basis of the highest absolute value obtained within the entire value set for all the Sectors. The following was done to allow a proper and visible illustration of the figures obtained for Rulindo. The real values are provided in the annexed tables representing each Sector.*

The general observations are that the Sectors of Rusiga is the only non-water deficit Sector of all. Tumba Sector is slightly non-water deficit up to the year 2020. Mbogo and Kinihira Sectors are non-water deficit up to 2035. Bushoki and Cyungo Sectors are non-water deficit up to 2025. The major driver of the water deficit aspect with time in Rulindo District was observed to be the population growth. The Sectors of Shyorongi, Ntarabana and Masoro have been observed to face heavy water deficits in the near future. These Sectors have a high population and heavy water consumer activities planned in the near future based on the Rulindo District Master plan.

On the other hand, the sectors of Cyungo, Kinihira and Mbogo were predicted with the lowest water deficit in all the Sectors. An indication like that maybe used as a guidance of where should the efforts be concentrated in the short and medium term to avoid an unbalanced development of the Rulindo District. It is also important to observe the unusual trend of the Ntarabana Sector compared to the Shyorongi Sector. The 2035 water deficit in Shyorongi is heavier than the one of Ntarabana Sector but if you look at 2040, the water deficit is suddenly the other way around. This is actually impacted by the high growth rate of the population in Ntarabana sector and the district should reflect on the family planning specifically in that sector for the 25 years to come.

An additional assessment was done to assess the surplus and deficit of water based on the management of the human water specific consumption per day. The assessment assumes a constant specific demand over the 25 years for each value specified in the master plan. The result is illustrated in the table below.

Sectors	Scenario	Surplus/Deficit				
		2020	2025	2030	2035	2040
Base	1 (20 l/c/d)	58960.70	23923.77	-14129.01	-55528.13	-100567.88
	2 (40 l/c/d)	-338777.60	-408791.45	-484897.01	-567695.27	-657774.76
	3 (60 l/c/d)	-736515.90	-841506.68	-955665.02	-1079862.40	-1214981.64
	4 (80 l/c/d)	-1134254.20	-1274221.90	-1426433.03	-1592029.53	-1772188.52
	5 (100 l/c/d)	-1531992.49	-1706937.13	-1897201.04	-2104196.67	-2329395.40
Burega	1 (20 l/c/d)	244349.99	226204.94	206893.94	186342.07	164469.59
	2 (40 l/c/d)	-38031.02	-74321.11	-112943.11	-154046.86	-197791.82
	3 (60 l/c/d)	-320412.03	-374847.17	-432780.17	-494435.79	-560053.23
	4 (80 l/c/d)	-602793.03	-675373.22	-752617.22	-834824.71	-922314.64
	5 (100 l/c/d)	-885174.04	-975899.28	-1072454.28	-1175213.64	-1284576.05
Bushoki	1 (20 l/c/d)	-137684.18	-157417.27	-178054.48	-199637.23	-222208.84
	2 (40 l/c/d)	-568374.78	-607840.96	-649115.37	-692280.87	-737424.09
	3 (60 l/c/d)	-999065.37	-1058264.64	-1120176.26	-1184924.51	-1252639.35
	4 (80 l/c/d)	-1429755.96	-1508688.32	-1591237.15	-1677568.15	-1767854.60
	5 (100 l/c/d)	-1860446.55	-1959112.00	-2062298.04	-2170211.79	-2283069.85
Buyoga	1 (20 l/c/d)	-260528.93	-285124.68	-310975.05	-338144.05	-366698.94
	2 (40 l/c/d)	-742703.37	-791894.85	-843595.60	-897933.60	-955043.38
	3 (60 l/c/d)	-1224877.80	-1298665.03	-1376216.14	-1457723.15	-1543387.83
	4 (80 l/c/d)	-1707052.24	-1805435.20	-1908836.69	-2017512.70	-2131732.27
	5 (100 l/c/d)	-2189226.67	-2312205.38	-2441457.24	-2577302.24	-2720076.71
Cyinzuzi	1 (20 l/c/d)	-264327.54	-281084.08	-298782.73	-317476.45	-337221.20
	2 (40 l/c/d)	-562362.58	-595875.66	-631272.96	-668660.41	-708149.91
	3 (60 l/c/d)	-860397.63	-910667.24	-963763.19	-1019844.36	-1079078.61
	4 (80 l/c/d)	-1158432.67	-1225458.82	-1296253.41	-1371028.32	-1450007.32
	5 (100 l/c/d)	-1456467.71	-1540250.40	-1628743.64	-1722212.27	-1820936.02
Cyungo	1 (20 l/c/d)	375830.64	367276.86	358463.37	349382.29	340025.48

	2 (40 l/c/d)	94105.78	76998.22	59371.25	41209.08	22495.46
	3 (60 l/c/d)	-187619.08	-213280.42	-239720.88	-266964.14	-295034.55
	4 (80 l/c/d)	-469343.95	-503559.05	-538813.01	-575137.35	-612564.57
	5 (100 l/c/d)	-751068.81	-793837.69	-837905.13	-883310.56	-930094.59
Kinihira	1 (20 l/c/d)	898741.81	886981.68	875011.23	862615.92	849780.66
	2 (40 l/c/d)	573044.12	549723.85	525782.97	500992.34	475321.81
	3 (60 l/c/d)	247346.42	212466.03	176554.70	139368.77	100862.97
	4 (80 l/c/d)	-78351.27	-124791.80	-172673.56	-222254.81	-273595.88
	5 (100 l/c/d)	-404048.96	-462049.62	-521901.83	-583878.39	-648054.72
Kisaro	1 (20 l/c/d)	389594.19	369947.73	349401.12	327913.13	305440.61
	2 (40 l/c/d)	-39205.62	-78498.54	-119591.75	-162567.75	-207512.79
	3 (60 l/c/d)	-468005.43	-526944.80	-588584.63	-653048.62	-720466.18
	4 (80 l/c/d)	-896805.23	-975391.07	-1057577.50	-1143529.49	-1233419.58
	5 (100 l/c/d)	-1325605.04	-1423837.34	-1526570.38	-1634010.37	-1746372.97
Masoro	1 (20 l/c/d)	-225009.78	-285170.72	-352575.82	-428097.37	-512712.71
	2 (40 l/c/d)	-724631.06	-844952.93	-979763.13	-1130806.24	-1300036.91
	3 (60 l/c/d)	-1224252.35	-1404735.15	-1606950.45	-1833515.11	-2087361.12
	4 (80 l/c/d)	-1723873.63	-1964517.37	-2234137.76	-2536223.98	-2874685.32
	5 (100 l/c/d)	-2223494.91	-2524299.59	-2861325.08	-3238932.85	-3662009.53
Mbogo	1 (20 l/c/d)	1196022.48	1179277.16	1161764.62	1143449.70	1124295.64
	2 (40 l/c/d)	830542.46	797051.83	762026.75	725396.91	687088.79
	3 (60 l/c/d)	465062.44	414826.49	362288.87	307344.11	249881.93
	4 (80 l/c/d)	99582.42	32601.16	-37449.01	-110708.69	-187324.93
	5 (100 l/c/d)	-265897.60	-349624.18	-437186.88	-528761.48	-624531.78
Murambi	1 (20 l/c/d)	-10642.09	-62402.56	-120395.67	-185371.92	-258172.15
	2 (40 l/c/d)	-440499.68	-544020.62	-660006.85	-789959.33	-935559.79
	3 (60 l/c/d)	-870357.26	-1025638.69	-1199618.02	-1394546.75	-1612947.44
	4 (80 l/c/d)	-1300214.85	-1507256.75	-1739229.20	-1999134.16	-2290335.08
	5 (100 l/c/d)	-1730072.44	-1988874.81	-2278840.37	-2603721.58	-2967722.73
Ngoma	1 (20 l/c/d)	-198427.26	-213359.86	-229210.17	-246034.60	-263893.01
	2 (40 l/c/d)	-441402.03	-471267.21	-502967.84	-536616.70	-572333.53
	3 (60 l/c/d)	-684376.79	-729174.57	-776725.50	-827198.79	-880774.04
	4 (80 l/c/d)	-927351.55	-987081.93	-1050483.17	-1117780.89	-1189214.56
	5 (100 l/c/d)	-1170326.32	-1244989.28	-1324240.84	-1408362.99	-1497655.07
Ntarabana	1 (20 l/c/d)	-182795.04	-289643.39	-419640.74	-577802.39	-770230.23
	2 (40 l/c/d)	-675972.59	-889669.28	-1149663.98	-1465987.29	-1850842.96
	3 (60 l/c/d)	-1169150.13	-1489695.17	-1879687.22	-2354172.18	-2931455.68
	4 (80 l/c/d)	-1662327.67	-2089721.06	-2609710.46	-3242357.07	-4012068.41
	5 (100 l/c/d)	-2155505.22	-2689746.95	-3339733.70	-4130541.97	-5092681.14
Rukozo	1 (20 l/c/d)	183677.68	172421.54	160765.89	148696.53	136198.80
	2 (40 l/c/d)	-133455.14	-155967.41	-179278.72	-203417.43	-228412.90
	3 (60 l/c/d)	-450587.97	-484356.37	-519323.33	-555531.40	-593024.61
	4 (80 l/c/d)	-767720.79	-812745.33	-859367.95	-907645.36	-957636.31

	5 (100 l/c/d)	-1084853.61	-1141134.29	-1199412.56	-1259759.33	-1322248.01
Rusiga	1 (20 l/c/d)	1311143.10	1296398.46	1280747.66	1264135.00	1246501.38
	2 (40 l/c/d)	1071226.70	1041737.43	1010435.83	977210.51	941943.25
	3 (60 l/c/d)	831310.30	787076.39	740123.99	690286.01	637385.13
	4 (80 l/c/d)	591393.89	532415.36	469812.15	403361.52	332827.00
	5 (100 l/c/d)	351477.49	277754.32	199500.32	116437.02	28268.88
Shyorongi	1 (20 l/c/d)	-456038.45	-535517.35	-625879.95	-728616.63	-845421.86
	2 (40 l/c/d)	-1036438.89	-1195396.71	-1376121.90	-1581595.25	-1815205.72
	3 (60 l/c/d)	-1616839.34	-1855276.06	-2126363.85	-2434573.88	-2784989.58
	4 (80 l/c/d)	-2197239.78	-2515155.42	-2876605.80	-3287552.50	-3754773.44
	5 (100 l/c/d)	-2777640.23	-3175034.77	-3626847.75	-4140531.13	-4724557.30
Tumba	1 (20 l/c/d)	421380.51	406970.31	392048.65	376597.37	360597.66
	2 (40 l/c/d)	15384.51	-13435.88	-43279.20	-74181.77	-106181.18
	3 (60 l/c/d)	-390611.48	-433842.07	-478607.05	-524960.90	-572960.01
	4 (80 l/c/d)	-796607.47	-854248.25	-913934.90	-975740.04	-1039738.85
	5 (100 l/c/d)	-1202603.47	-1274654.44	-1349262.76	-1426519.17	-1506517.69

8. WATER QUALITY

Water samples were collected in the starting tank for captured springs and and at the outlet of pipe for non-captured springs. It should be noted that for all the samples collected there were no pretreatment by human intervention. After the sampling, samples were stored in a 600 ml plastic bottles and placed in a cooler box with ice pending. The plastic bottles were rinsed before with HCl (1M) and then with distilled water at laboratory level to insure that they are cleaned perfectly. Furthermore, sampling bottles were rinsed twice with sample water before final collection.

For Mn and Fe samples, few drops of concentrate nitric were added while sampling of total coliforms samples were preceded by the sterilization of both sampling bottles and spring site.

The analysis of the collected samples was done following the already developed standards operating procedures for faecal coliforms, Total Nitrogen (TN), Total Phosphorous (TP), Iron (Fe) and Manganese (Mn) as these samples will be analysed by UR laboratories specialized in water quality control.

The results from the analysis were compared to Rwanda standards and WHO guideline standards for drinking water.

8.1. Presentation of results

Sampling dates		Sampling location	Iron (mg/l)		Manganese (mg/l)		Total Nitrogen (mg/l)		Total Phosphorus (mg/l)		Fecal Coliforms (Cfu/100ml	
Rain Season (RS)	Dry season (DS)	Sector/Cell/Village/name	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS
4/15/2016	18-7-16	Base/Cyohoha/Kabingo/Gihanga 1	0.07	0.04	0.046	0.036	1.33	1.747	0.03	0.170	0	0
4/15/2016	18-7-16	Base/Cyohoha/Gitwa/Gihanga 2	0.02	0.05	0.069	0.114	0.92	1.154	0.05	0.097	2	0
4/15/2016	18-7-16	Base/Cyohoha/Gitwa/Nyirakagorogoro	0.29	0.08	0.179	0.216	0.79	0.050	0.02	0.077	6	1
4/15/2016	18-7-16	Base/Gitare/Kirwa/Mutoyi	0.01	0.17	0.187	0.151	1.04	0.276	0.03	0.142	0	3
4/15/2016	18-7-17	Base/Gitare/Kirwa/Rwicanyoni	0.01	0.06	0.205	0.191	0.78	2.918	0.57	0.277	4	0
4/15/2016	18-7-16	Base/Rwamahwa/Kiruri/Kabingo	0.08	0.06	0.172	0.108	1.87	0.477	0.02	0.167	0	0
4/15/2016	18-7-16	Base/Rwamahwa/Base/Rutembe 2	0.03	0.08	0.154	0.101	0.63	0.017	0.04	0.090	0	0
4/15/2016	25-7-16	Base/Rwamahwa/Base/Rutembe 1	0.07	0.01	0.165	0.194	0.87	0.945	0.01	0.387	0	0
4/16/2016	22-7-16	Base/Cyohoha/Bukangano/Migogo 2	0.06	0.06	0.040	0.259	0.81	0.276	0.02	0.147	4	0
4/16/2016	22-7-16	Base/Cyohoha/Bukangano/Migogo 1	0.02	0.03	0.130	0.109	1.13	nd	0.06	0.102	60	0
4/16/2016	22-7-16	Base/Cyohoha/Bukangano/Migogo 3	0.02	0.00	0.130	0.084	1.08	nd	0.02	0.091	200	0
4/16/2016	18-7-16	Base/Rwamahwa/Kiruri/Rwamahwa 1	0.01	0.14	0.042	0.177	0.95	0.360	0.03	0.501	700	0
4/16/2016	18-7-16	Base/Rwamahwa/Kiruri/Rwamahwa 2	0.06	0.06	0.124	0.205	0.90	6.806	0.03	0.345	2	8
4/16/2016	18-7-16	Base/Rwamahwa/Kiruri/Rwamahwa 3	0.24	0.24	0.218	0.130	0.93	0.142	0.045	0.132	8000	0
4/16/2016	22-7-17	Base/Gitare/Rugaragara/Rugaragara	0.00	0.06	0.143	0.140	0.86	0.334	1.09	0.188	4	0
4/16/2016	25-7-16	Rulindo/Base/Rwamahwa/Base/Rutare 2	0.00	0.02	0.149	0.189	0.97	0.385	0.019	0.118	0	0
4/16/2016	23-7-16	Base/Rwamahwa/Mutima/Rutare 1	0.02	0.01	0.129	0.106	0.75	3.821	0.033	0.130	0	0
4/16/2016	22-7-16	Base/Rwamahwa/Mutima/Ruho	0.03	0.01	0.104	0.156	0.88	0.98	0.43	0.154	10	0
4/22/2016	19-7-16	Bushoki/Gako/Buramira/Kivure 1	0.02	0.14	0.270	0.209	0.72	0.192	0.23	0.109	0	0
4/22/2016	19-7-16	Bushoki/Gako/Buramira/Kivure 2	0.00	0.04	0.322	0.397	0.85	0.134	0.012	0.224	0	2
4/22/2016	19-7-16	Tumba/Taba/Nyirambuga/Nyirambuga 1	0.04	0.06	0.175	0.104	0.96	0.761	0.041	0.445	100	0
4/22/2016	19-7-16	Tumba/Taba/Nyirambuga/Nyirambuga 3	0.05	0.02	0.154	0.121	0.58	0.326	0.043	0.072	20	0
4/22/2016	19-7-16	Tumba/Taba/Nyirambuga/Nyirambuga 2	0.04	0.02	0.117	0.084	0.67	0.401	0.025	0.118	0	0
4/22/2016	23-7-16	Tumba/Kayenzi/Muduha/Matonyanga 1	0.01	0.01	0.185	0.189	0.71	1.472	0.33	0.154	40	0
4/22/2016	23-7-16	Tumba/Kayenzi/Rebero/Matonyanga 2	0.07	0.01	0.329	0.404	0.78	5.318	ND	0.634	0	0

4/23/2016	19-7-16	Bushoki/gasiza/Ruhanga/Buhande 1	0.07	0.06	0.139	0.205	0.94	0.226	0.012	0.062	90	12
4/23/2016	19-7-16	Bushoki/gasiza/Ruhanga/Muhanga 1	0.12	0.04	0.238	0.247	0.65	0.117	0.078	0.032	80	0
4/23/2016	19-7-16	Bushoki/gasiza/Ruhanga/Muhanga 2	0.04	0.04	0.191	0.156	0.88	0.167	0.023	0.041	30	0
4/23/2016	19-7-16	Bushoki/gasiza/Ruhanga/Muhanga 3	0.08	0.09	0.193	0.159	0.95	0.201	0.023	0.051	7	0
4/23/2016	19-7-16	Bushoki/gasiza/Ruhanga/Nyamwijima	0.23	0.08	0.07	0.284	1.34	0.217	0.03	0.165	80	0
4/23/2016	19-7-16	Bushoki/gasiza/Ruhanga/Nyakabingo 1	0.04	0.04	0.169	0.201	1.30	0.192	0.01	0.356	20	0
4/23/2016	19-7-16	Bushoki/gasiza/Ruhanga/Nyakabingo 2	0.01	0.07	0.243	0.244	0.94	0.167	0.014	0.265	0	0
4/23/2016	19-7-16	Bushoki/Mukoto/Marembo/Rukungeri 1	0.03	0.02	0.235	0.255	0.90	nd	0.035	0.121	0	3
5/6/2016	19-7-16	Bushoki/Mukoto/Marembo/Rukungeri 2	0.04	0.17	0.345	0.348	0.89	0.075	0.035	0.324	10	0
5/6/2016	22-7-16	Kinihira/Mubuga/Kacyiru/Kacyiriba	0.34	0.08	0.194	0.262	0.79	2.433	0.046	0.139	0	0
5/6/2016	22-7-16	Kinihira/Mubuga/Murambo/Mubuga 1	0.10	0.07	0.191	0.137	1.02	0.217	0.057	0.188	60,000	0
5/6/2016	22-7-16	Kinihira/Mubuga/Murambo/Mubuga 2	0.04	0.05	0.057	0.224	1.17	1.940	0.044	0.748	900	0
5/6/2016	22-7-16	Kinihira/Mubuga/Murambo/Mubuga 3	0.06	0.26	0.223	0.212	1.16	5.753	0.081	0.198	90,000	5
5/6/2016	22-7-16	Rukzo/Mbuye/Musave/Nyaruganzu	0,04	0.06	0,383	0.259	7.45	0.042	0.063	0.224	30	0
5/7/2016	23-7-16	Buyoga/Butare/Ryanyiranyonga/Nyagahera	0.07	0.08	0.103	0.105	0.95	1.05	0.29	0.34	400	0
5/7/2016	23-7-16	Buyoga/Ndarage/Gahondo/Gahondo 1	0.08	0.06	0.209	0.160	0.88	3.587	0.27	0.401	40	0
5/7/2016	23-7-16	Buyoga/Ndarage/Gahondo/Gahondo 2	0.13	0.01	0.211	0.167	0.79	3.679	0.34	0.203	90	0
5/7/2016	23-7-16	Buyoga/Gitumba/Rutabo/Kiruruma	0.01	0.01	0.060	0.142	0.90	2.575	0.34	0.132	70,000	0
5/14/2016	22-7-16	Rukzo/Mbuye/Nyarusebeya/Nyarubuye 1	0.03	0.10	0.370	0.419	1.27	0.452	0.03	0.408	2	0
5/14/2016	22-7-16	Rukzo/Mbuye/Nyarusebeya/Nyarubuye 2	0.05	0.08	0.186	0.189	1.07	0.318	0.017	0.203	1	0
5/14/2016	23-7-18	Rusiga/Gako/Kabuniga/Nyaboga 1	0.02	0.05	0.178	0.217	0.99	0.059	0.012	0.198	2	0
5/14/2016	23-7-19	Rusiga/Gako/Kabuniga/Nyaboga 2	0.05	0.10	0.284	0.172	0.74	0.334	0.11	0.135	0	6
5/14/2016	23-7-20	Rusiga/Gako/Kabuniga/Agatare	0.29	0.28	0.148	0.104	0.99	0.100	0.024	nd	0	0
5/14/2016	23-7-21	Rusiga/Taba/Kingazi/Nyakabizi 1	0.15	0.02	0.165	0.130	0.70	0.677	0.21	0.277	600	0
5/14/2016	23-7-22	Rusiga/Taba/Kingazi/Nyakabizi 2	0.08	0.02	0.119	0.068	1.24	0.435	0.039	0.238	8	0
		Rwanda Standards (RSB)	0.3	0.3	0.1	0.1					0	0
		WHO guide line	0.3	0.3	0.4	0.4					0	0

Note: The gray colour shading in the results indicate that the standard has been exceeded.

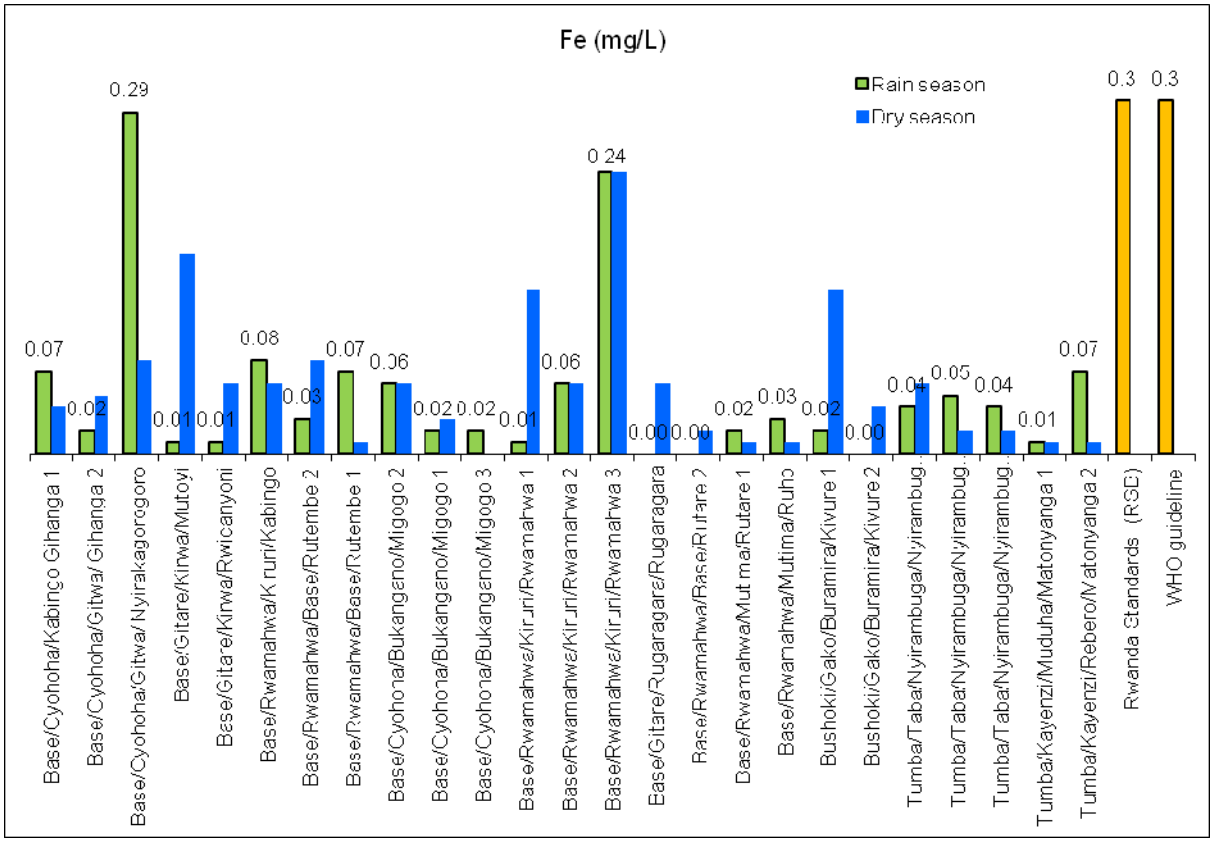
8.2 Interpretation of results

8.2.1. Iron (Fe)

The Iron element is found in earth's crust and is essential cellular constituents but is required in low concentrations in relation to their availability in fresh waters (UNEP/GEMS, 2008). The occurrence of iron in aqueous solution is dependent on environmental conditions, especially oxidation and reduction (Mark, 2000).

Anaerobic groundwater may contain ferrous iron at concentration up to several mg/l without discoloration or turbidity in the water when directly pumped from a well. Iron also promotes the growth of iron bacteria which derive their energy from the oxidation of ferrous iron to ferric iron and in process deposit a slimy coating on the pumping. At level above 0.3mg/l the impact of iron in water is staining laundry and plumbing fixtures. A turbidity and colour may develop at the concentration of iron above 0.3mg/l (WHO, 4th ed).

In both seasons, except one spring of Kacyiriba in Kinihira sector, the concentration of Iron was lower when compared to Rwanda standards and World Health Organization Guideline for Drinking water (see the figure 33 below).



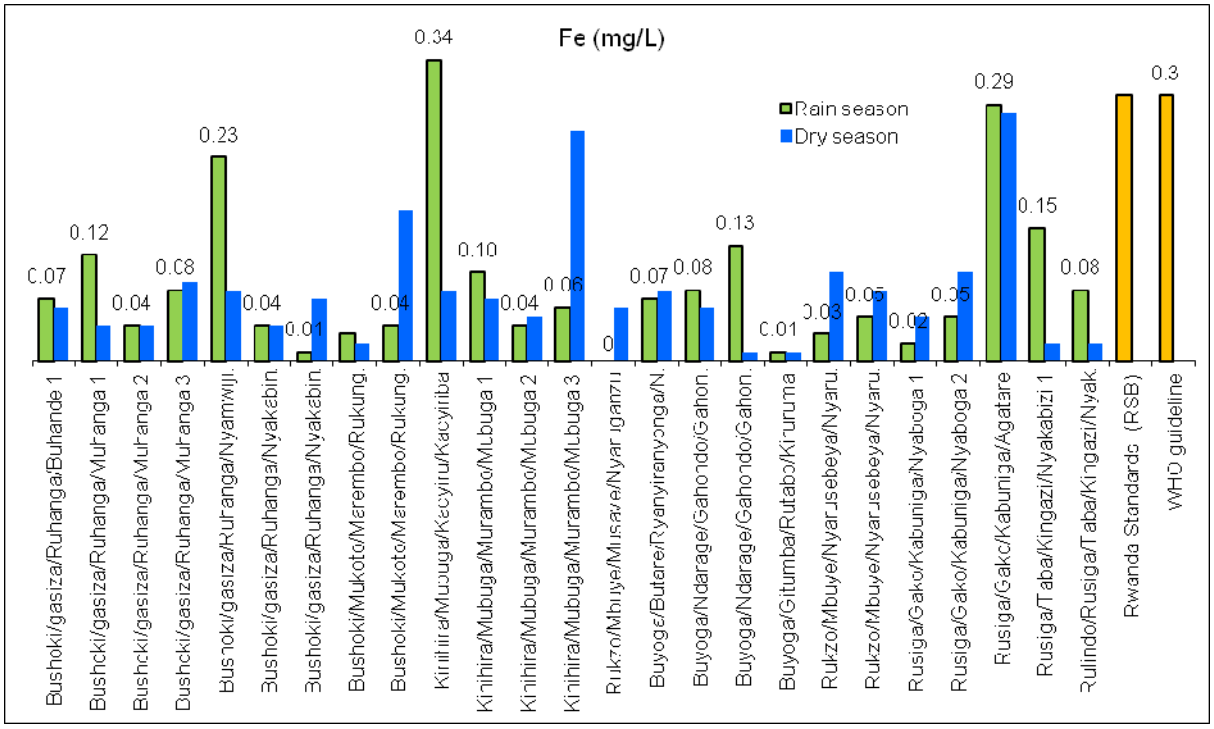


Figure 33: *Variation of Iron on different water springs. The green and blue colours show values in rain and dry seasons below the accepted limit, and the yellow colour shows the standard limit value of RSB and WHO respectively*.

8.2.2. Manganese (Mn)

Manganese like Iron is also found in earth's crust and it is also essential cellular constituents; it is also required in low concentrations in relation to their availability in fresh waters (UNEP/GEMS, 2008).

The concentration of manganese below the acceptable limit is representing 12% in the two season's rain and dry seasons while 88% of water spring have higher concentration compared to Rwanda standards. It should be noted that the presence of manganese in drinking-water will be objectionable to consumers if the manganese is deposited in water mains and causes water discoloration. At level exceeding 0.1mg/l, manganese in water supplies causes an undesirable taste in beverages and stain sanitary water and laundry. The concentration of manganese below 0.1 mg/l is usually acceptable to consumers. It should also be mentioned that the World Health Organization (WHO) has established a health based value of 0.4 mg/l in drinking water, based on an upper tolerable intake (WHO, 2011) while the standards in Rwanda is based on water discolouration and deposition in mains rather than human health.

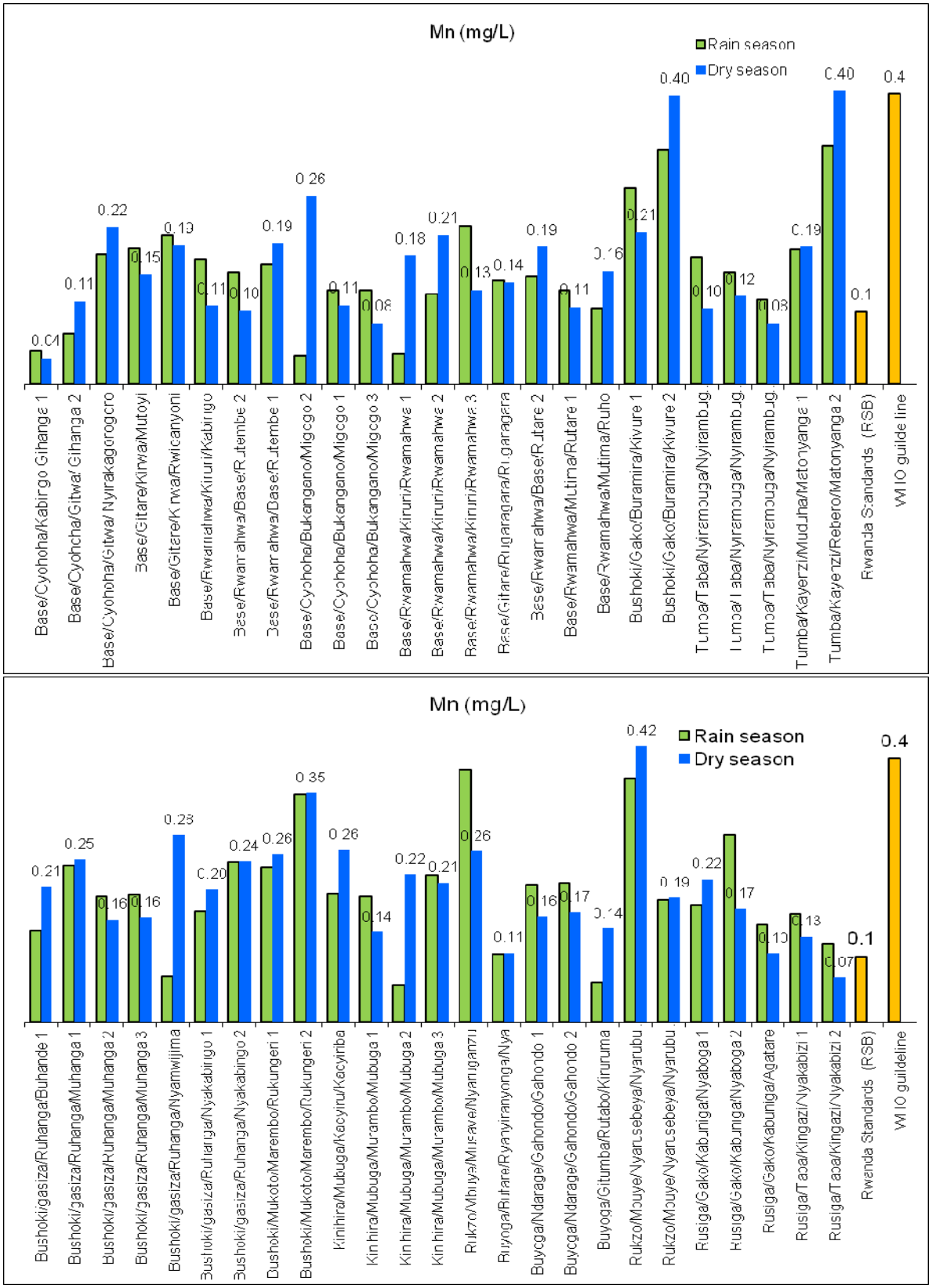


Figure 34: *Variation of Manganese on different water springs. The green color shows concentration values in rain while blue color shows values in dry seasons and the yellow color shows the standards RSB and WHO.*

8.2.3. Total Nitrogen

Total Nitrogen is total of all compound of nitrogen such ammonia, nitrates and nitrites. The term Ammonia includes non-ionized (NH_3) and ionized (NH_4^+) species. Ammonia in the environment originates from metabolic, agriculture and industrial processes. Natural level of ammonia in surface and groundwater are usually 0.2mg/l. Ammonia in drinking water is not of immediate health relevance and therefore no health based guideline value (WHO, 4th ed). Nitrate is found naturally in the environment and it is important plant nutrient. Nitrate can reach both surface and groundwater as a consequence of agriculture activities (including excess of application of inorganic fertilizer and manures), from industrial wastewater disposal and from oxidation of nitrogenous waste products in human and animal excreta, including septic tank (WHO, 4th ed). Nitrite is not usually present in significant concentration except in a reducing environment, as nitrate is the more stable oxidation state (WHO, 4th ed).

Activities near the well can potentially contaminate the water supply. Domestic wells near potential point sources of contamination, such as livestock facilities or sewage disposal areas, should be tested at least once a year to monitor changes in nitrate concentration. Depending on the location of the well relative to areas where nitrogen fertilizer is applied, follow-up testing to monitor changes from non-point sources may be conducted less often. All drinking water supplies should be checked at least every two or three years to assure that significant increases in nitrogen compounds (nitrate, nitrite, ammonia, and TKN) are not occurring. If a fertilizer or manure spill occurs, the spill should be cleaned up immediately and any wells near the spill should be tested. Unfortunately, any nitrate from the spill may not move through the soil profile quickly and annual testing is recommended to monitor the effects of the spill. The Total Nitrogen does not have a standard value for drinking water as shown above; it is a total of all compound of nitrogen. Each species has own standards value for drinking water.

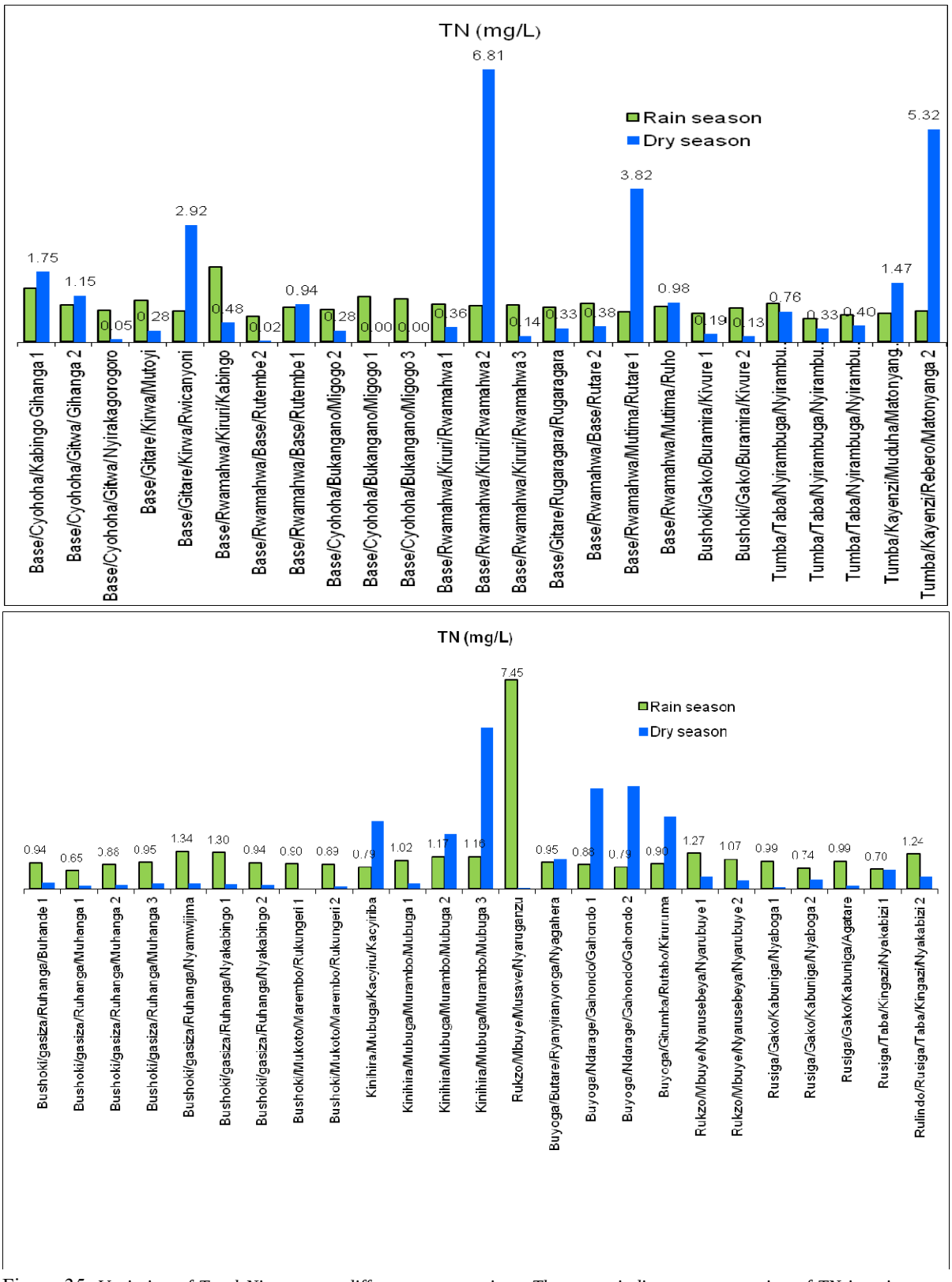
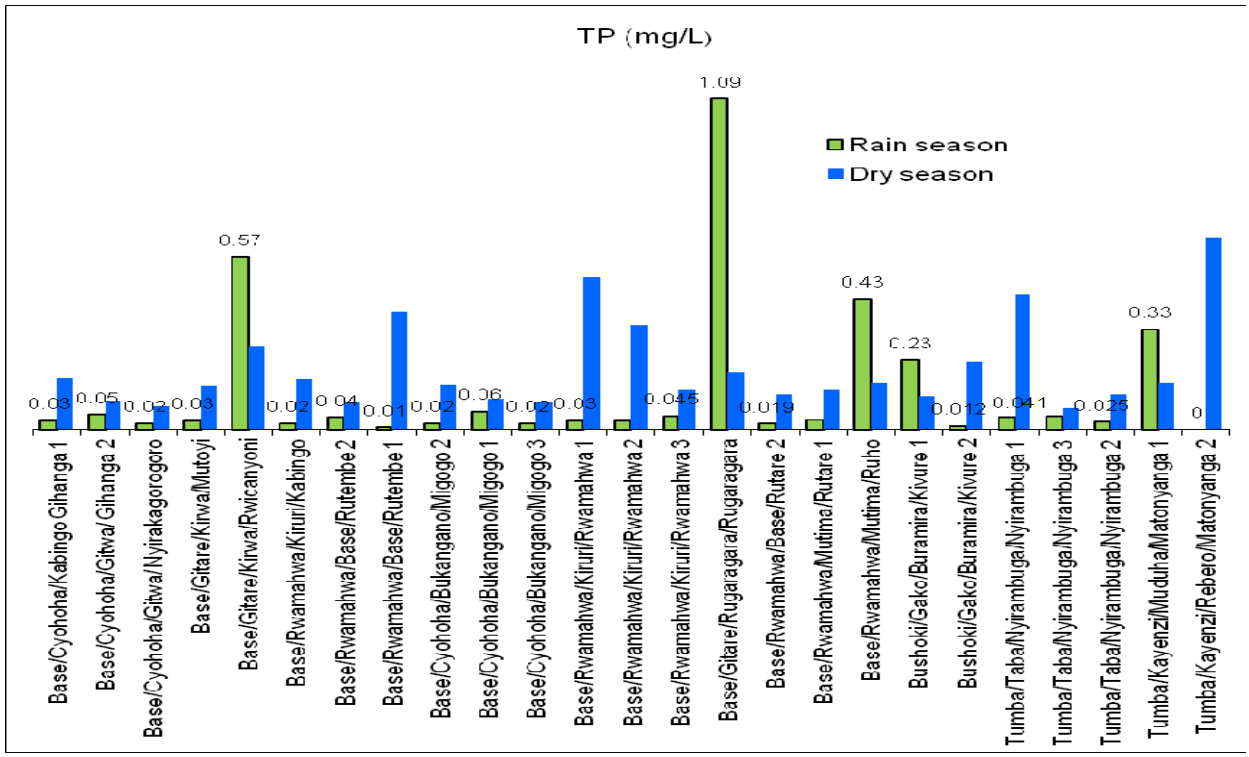


Figure 35: *Variation of Total Nitrogen on different water springs. The green indicate concentration of TN in rain season while blue color shows the concentration of TN in dry season.*

8.2.4. Total Phosphorus

Phosphorus is an essential nutrient for living organisms and exists in water bodies as both dissolved and particulate species. It is generally the limiting nutrient for algal growth and, therefore, controls the primary productivity of a water body. Natural sources of phosphorus are mainly the weathering of phosphorus-bearing rocks and the decomposition of organic matter. Domestic wastewaters (particularly those containing detergents), industrial effluents, fertilizer and run-off contribute to elevated levels phosphorus in waters.

The Total Phosphorus does not also have a standard value for drinking water as shown above; it is a total of all compounds of phosphates. It is the last compound which has a standards value for drinking water.



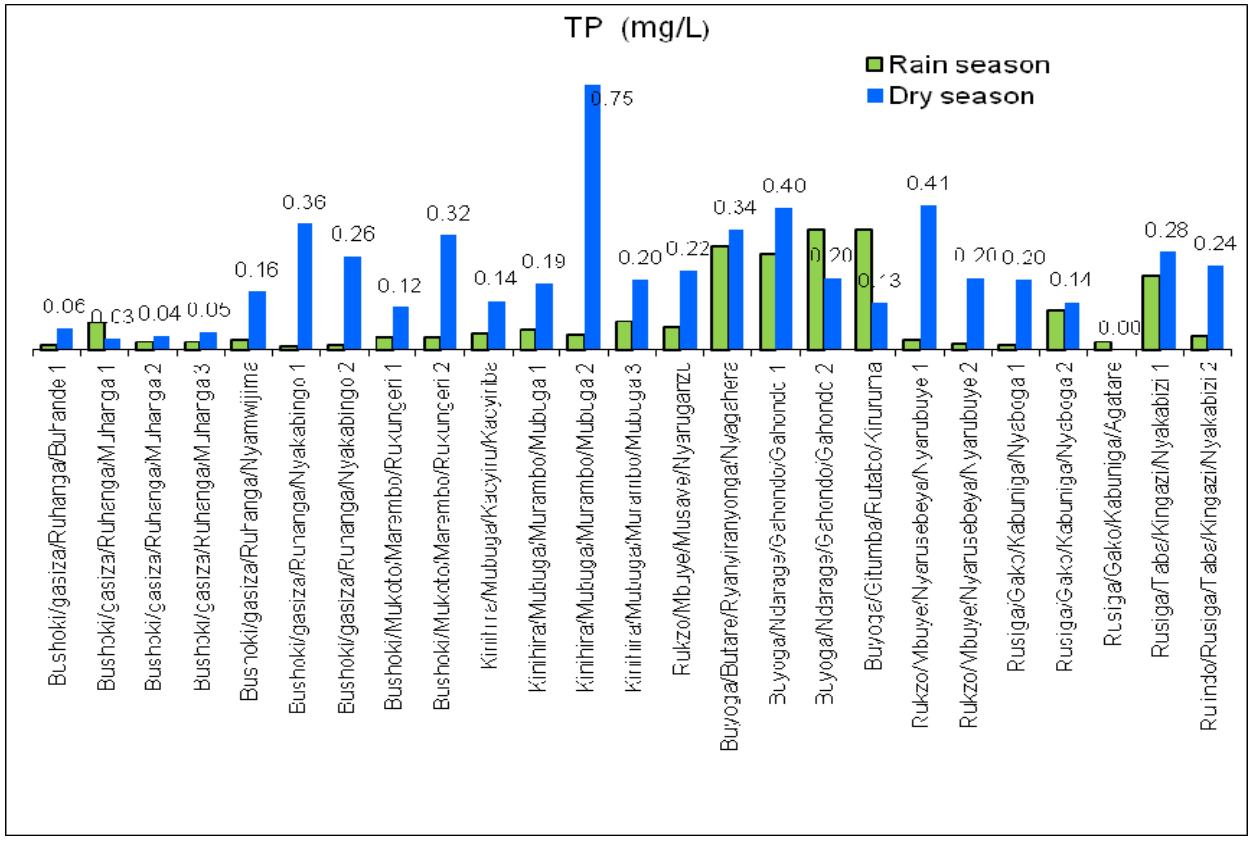


Figure 36*: Variation of Total Phosphorus on different water springs. The green indicate concentration of TP in rain season while blue color shows the content of TP in dry season.*

7.2.5. Fecal Coliforms

The coliforms bacteria that are able to ferment lactose at 44ºC are known as Fecal Coliforms (Thermotolerant coliforms). In most water, the predominance specie of fecal coliforms is Escherichia Coli. The source of fecal coliforms is highly from human and animals feces and sewage. The water temperature and nutrient conditions present in drinking water distribution system are highly unlikely to support the growth of these organisms (WHO 4th ed). The presence of fecal coliforms or E. Coli in drinking water should lead to consideration of further actions which could include a water treatment (disinfection).

The high contamination of fecal coliforms was found in rain season where 34/50 springs representing 68% of all sampled springs while in dry season 8/50 springs representing 16% have colony between 1 - 12 Cfu/100ml the remained have none colony of fecal coliforms.(see the fig 37 below).

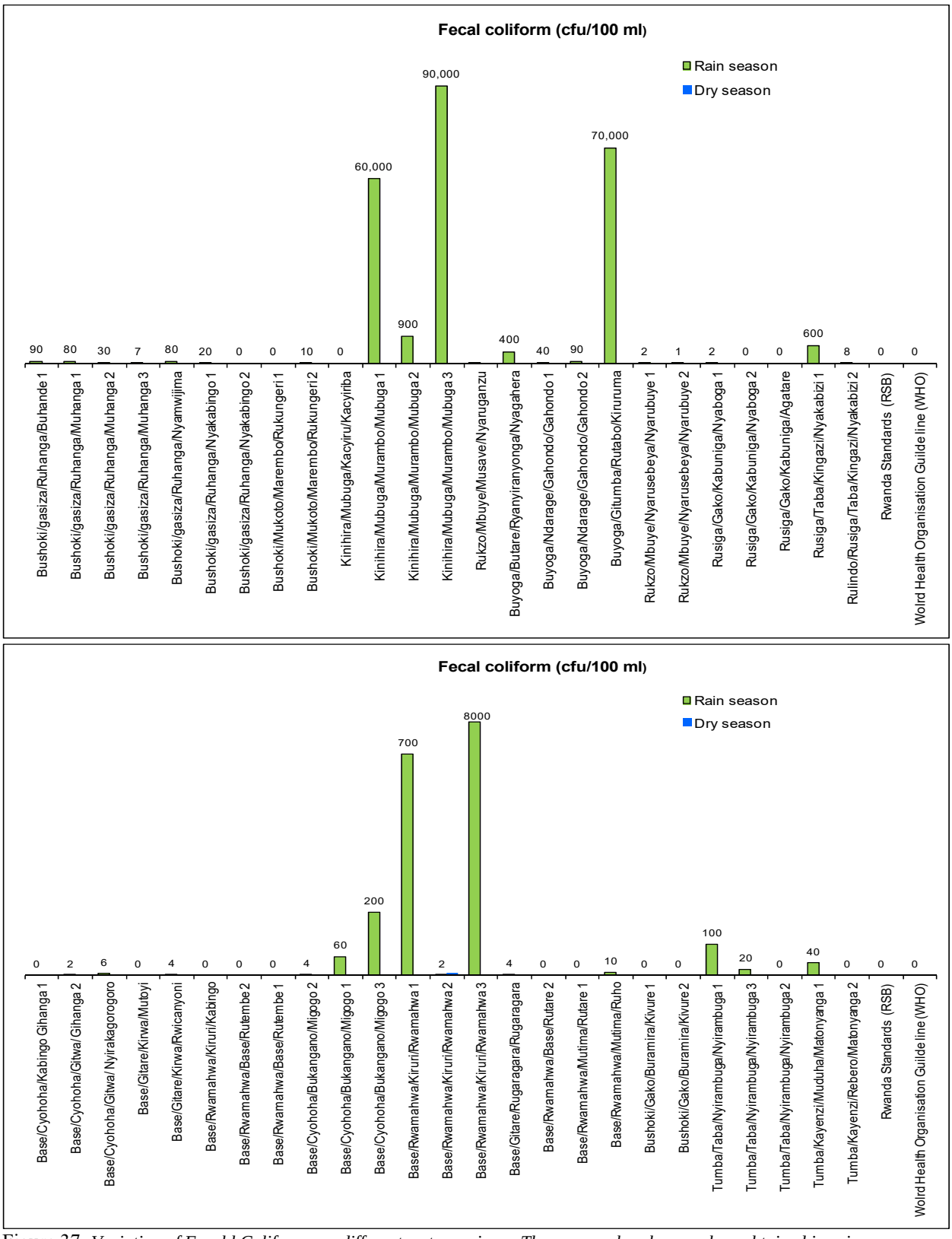


Figure 37*: Variation of Fecal l Coliforms on different water springs. The green color shows values obtained in rain season while blue color shows value obtained in dry season and none color shows the absence of coliforms according to the standard of RSB and WHO respectively.*

9. Management Plan for Springs Captured or Rehabilitated by WFP and other Selected Springs

To insure a sustainable sufficiency of the springs as well as the sustainability of the infrastructure of constructed water supply systems, different activities are required. These activities vary from one spring to another as discussed in the table 8. 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 organisations 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 organisations 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 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 Rulindo district, this one will be part of the water users association as an observer. This meaning 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:

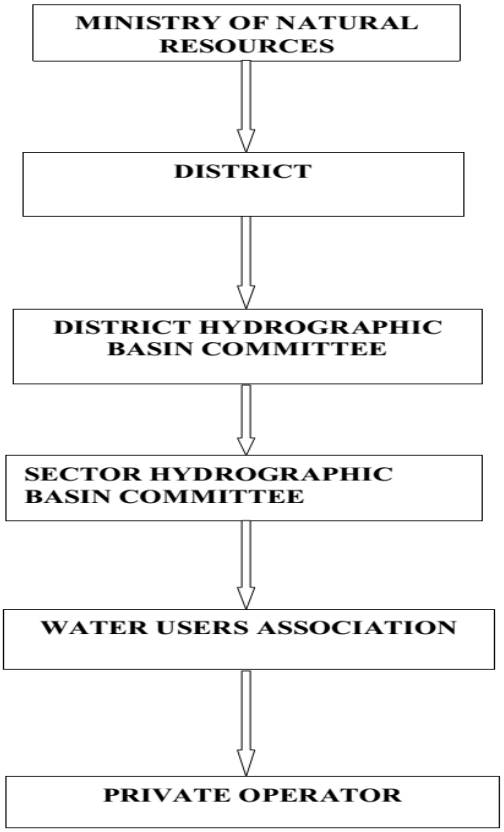
Main obligations of the private operator:

- To manage domestic water supply infrastructures in a sustainable manner and at the satisfaction of the water users;
- To carry out a regular maintenance of the infrastructures so as to meet their fixed lifespan at the beginning of the contract;
- To manage waste water generated from water treatment plants and water points in collaboration with water users associations;
- To ensure that the quality of water supplied is in accordance with the applicable drinking water standards in Rwanda;
- To make sure that water is always supplied to the users except in case of force majeure;
- To ensure a good collaboration with the water users association;
- 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:

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

The below table provide estimate budget computed based on 87 spring sources of Rulindo district as detailed in table 7, chapter 5. These springs will serve as a reference project for the water sources management plan in Rulindo district given that most of the springs were recently captured or under rehabilitation by Water for People, while others has not been captured but are being used by the neighbouring population. Table 19 below; provide an estimate of the budget that is needed for short term intervention for the urgent rehabilitation protection of the water sources studied. The total budget for the short term intervention is estimated at one hundred fifty one millions and six hundred Rwandan francs (151,600,000 Rwf). It should be noted that another short term approach for the urgent protection of the springs is to consider the springs by its capacity in terms of discharge capacity and the current water quality. Hence, for that option, table 8 provide 35 priority springs that need urgent protection and the cost for each spring is provided in table 7.

In addition, for the sustainable spring protection, a long term approach was considered in this study and it considers the protection of the recharge catchment by considering the agroforest plantation, progressive terraces, and use of cut-off drains, forest plantation and the rehabilitation of natural forest. Therefore, considering the analysis on the delineated 14 recharge catchment, the surface that need to be covered and the local cost for the identified measures the total cost for the long term intervention is estimated at twenty six billion eight

hundred and eighty five millions, three hundreds ten thousands and five hundred Rwandan francs (26,885,310,500 Rwf). The appendix 3 explains in details how this long term intervention cost was calculated.

Table 19: Budget estimated for short term intervention for the protection of the springs already captured by WFP and others in pipeline

SN	Description of the intervention	Concerned water sources	Cost per source (Rwf)	Total budget (Rwf)
1	Provision of water diversion ditch at the catchment area	23	500,000	11,500,000
2	Provision of fences for spring catchment protection	25	300,000	7,500,000
3	Passparum plantation in the direct spring catchment area	15	100,000	1,500,000
4	Clean up the eucalyptus up to 20 m from the catchment	5	100,000	500,000
5	Establishment of immediate spring catchment	20	500,000	10,000,000
6	Proper water capturing	10	400,000	4,000,000
7	Progressive terraces in upstream part of the spring catchment	6	100,000	600,000
8	Maintain/establish trenches in upstream part	13	800,000	10,400,000
9	Total rehabilitation of the intake structure	18	5,000,000	90,000,000
10	Manhole covers	15	40,000	600,000
11	Marking the pipelines	all	-	5,000,000
12	Training of water users association for springs management and protection	All sectors once every 5 years	-	10,000,0000
	Total budget for the intervention	-		**151,600,000**

*The total rehabilitation cost do not include the supply cost

9.3: Sequence of activities

The sequencing of activities is very important in order to achieve smoothly the results expected from the spring management measures, therefore, it is recommended to do the sequencing of the proposed measures as follow:

1. Establishment (reinforcement) of water diversion ditches and spring catchment: this will help in reducing the interaction between the runoff and spring water which is suspected to be the most probable cause of turbidity of some springs and pathogens.
2. Mark all water supply pipelines. This will allow stakeholders to conduct other activities in the area without damaging the water supply infrastructure.
3. Implement all the sustainable land management measures (bench terraces, progressive terraces and forestation) but starting from the upstream of the of the spring meaning at the top of the hill/mountain.
4. Remove the eucalyptus in the vicinity of the spring as they may clog pipes and therefore lead to the leakage of water at intake level.
5. Establishment of narrow fences with local plants/materials at each spring catchment

10. Conclusions and recommendations

The main objective was to develop the water sources management plan for sustainable water sources development, utilization and management in the sub Watersheds of the Rulindo District. However, as agreed the main focus was given to the water sources already captured by WFP and others 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 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 that, the water demands should not meet in 25 years to come if the district continue to rely on water from the existing springs. Considering the five years water demand and deficit calculation up to 2040, only Rusiga sector will not experience deficit till 2040, Mbogo and Kinihira Sectors will not have deficit up to 2035, Bushoki and Cyungo Sectors have water surplus up to 2025 and Tumba Sector will not have deficit up to the year 2020. The remaining sector will have water deficit in the mention periods if other water sources alternatives are not considered. The major driver of the water deficit aspect with time in Rulindo District was observed to be the population demand and growth.

The analysis of the water quality for iron (Fe) concentration in both rainy and dry seasons has shown the concentration in range of RSB and WHO limits. On the other hand, the results have shown concentration above standard limits of 0.1 mg/L for Manganese in 88% of the studied water sources but almost all the sources are in the range of the health based concentration of 0.4 mg/L of manganese established by WHO. The analysis of fecal coliforms counts has shown increased fecal coliforms concentrations during the rainy season in 34 out of 50 springs while in the dry season 8 out of 50 springs were positively counted. In fact, Coliform bacteria of any kind are not to be tolerated in a supplied drinking water. However, it should be noted that around 10 springs are in the range of 100 to 90,000 cfu/100 ml which are severe deviations from the RSB and WHO drinking water standards.

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. Besides, the measured concentration in Total Nitrogen and Total Phosphorous indicates a general increasing concentration in rainy season. It should be noted that the later 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.

In addition, based on the provisions of the water law, this report highlight the management of the springs by considering the key contribution of the water users association in addition to the existing water operators in the district. Thus, the best practices for the spring protection were proposed and the total budget for the short term intervention was estimated at one hundred fifty one millions and six hundred Rwandan francs (151,600,000 Rwf). Furthermore, for the sustainable spring protection, catchment protection as a long term approach was estimated at a cost of 26,885,310,500 Rwf by considering different actions for soil retentions and to improve the spring recharge.

Therefore, considering the study findings, the following are recommend:

1. An emphasis can be made in maintaining and protecting the water supply system built in Rulindo district as many of them have been damaged;
2. Marking the water supply pipeline is an urgent action to avoid the water loss that may occur to the breakage of pipes by other human activities;
3. The water quantity from springs cannot help the district to meet the water demand target by Rwanda government in 2040 which correspond to the time horizon that was set for this study;
4. The water operators should regularly monitor the water quality of the spring and in particular the fecal coliforms;
5. It is urgently needed to add a disinfection unity to disinfect the water systems that receives the water from the highly contaminated springs with fecal coliforms;
6. It is recommended to put in place a water users association to manage each water source which will work closely with the hydro-graphic basin committee already established at the level of Rulindo District;
7. The water users association, the hydro-graphic basin committee and water operators should regularly be trained for the spring/catchment best management approaches such as the flow quantity regulation;
8. A wide awareness campaign should also be carried out targeting local communities especially in the neighbourhood of the spring infrastructures;
9. The district must encourage the population from different centres 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;
10. Although the identified 14 large catchment correspond to the suspended aquifers, the district need to consider the potential of using wells in the catchment and groundwater for water supply.
11. A study on alternatives water sources should be carried out considering that by 2040 only spring water sources will not be sufficient for the water demand in Rulindo district. The study should focus on water from rivers, groundwater and rainwater harvesting.

11. References

1. APHA, AWWA, WEF, 1998. Standard methods for the examination of water and wastewater, 30 edn. American Public Health Association, Washington, D.C.
2. District de Rulindo, 2013. Plan directeur d'hydraulique et d'assainissement du District de Rulindo.
3. Republic of Rwanda, 2020. Rwanda Vision 2020 Revised 2012.
4. Rulindo District, 2013. District Development plan 2013-2018.
5. Rulindo District, 2014. Situation Analysis for Rulindo District.
6. MINAGRI, 2011. Illustrated supervision checklist for the Assessment of the Quality of Comprehensive land-husbandry works at LWH project Sites.
7. MINICOFIN (2013): Economic Development and Poverty Reduction Strategy II (2013-2018)
8. MINIRENA, 2011. National Policy for Water Resources Management.
9. MINIRENA. 2012. Feasibility study for Yanze Watershed Rehabilitation.
10. MINIRENA, 2013. Guidelines for Watershed Management.
11. MINIRENA, 2014. Rwanda National Water Resources Master Plan
12. NISR, 2014. Main indicators report. Fourth Population and Housing Census in Rwanda for 2012
13. NISR, 2015. Results of Integrated Household Living Conditions Survey, EICV 2013-2014
14. Water and Sanitation Coorporation , MIS- Rulindo, 2010-2014
15. Water for People –Rwanda 2015. Rulindo Challenge Program: Our Journey.
16. http://eftracker.waterforpeople.org/rulindo
17. REMA, 2013.Baseline study on socio-economic and ecological impact of watershed management (Yanze).
18. MINIRENA, 2012. Rwanda National Policy for Water Resources Management.
19. MINITERE, 2005.Organic Law n^0 4/2005 determining the modalities of protection, conservation and promotion of environment in Rwanda.
20. Organic law n° 08/2005 of 14/07/2005 determining the use and management of Land in Rwanda.
21. National human Settlement policy in Rwanda, May 2009, National water and sanitation policy, 2011.
22. WHO (2011) Guidelines for Drinking-water, Fourth Edition, Manganese pp 386-387. World Health Organization.

12. Appendixes

Appendix 1: Spring recharge catchment 3 to 14

The following recharge catchments complement the previous two recharge catchments discussed in chapter 5.

A.1.1 Spring recharge catchment 3

The spring recharge catchment 3 has an area of 409.91 ha and it is completely located into the Rulindo District and it is also located in the Sectors of Mbogo and Ngoma. The recharge catchment 3 has 1 newly identified spring which is unprotected. The resulting maps based on the above classification are presented below.

Table 20: Spring recharge catchment 3 slope coverage.

Spring recharge catchment 3		
Slope class	**Area Ha**	**% of Area Covered**
0-6%	2.73	0.67
6-16%	17.54	4.28
16-40%	120.93	29.50
40-60%	163.18	39.81
>60%	105.53	25.74

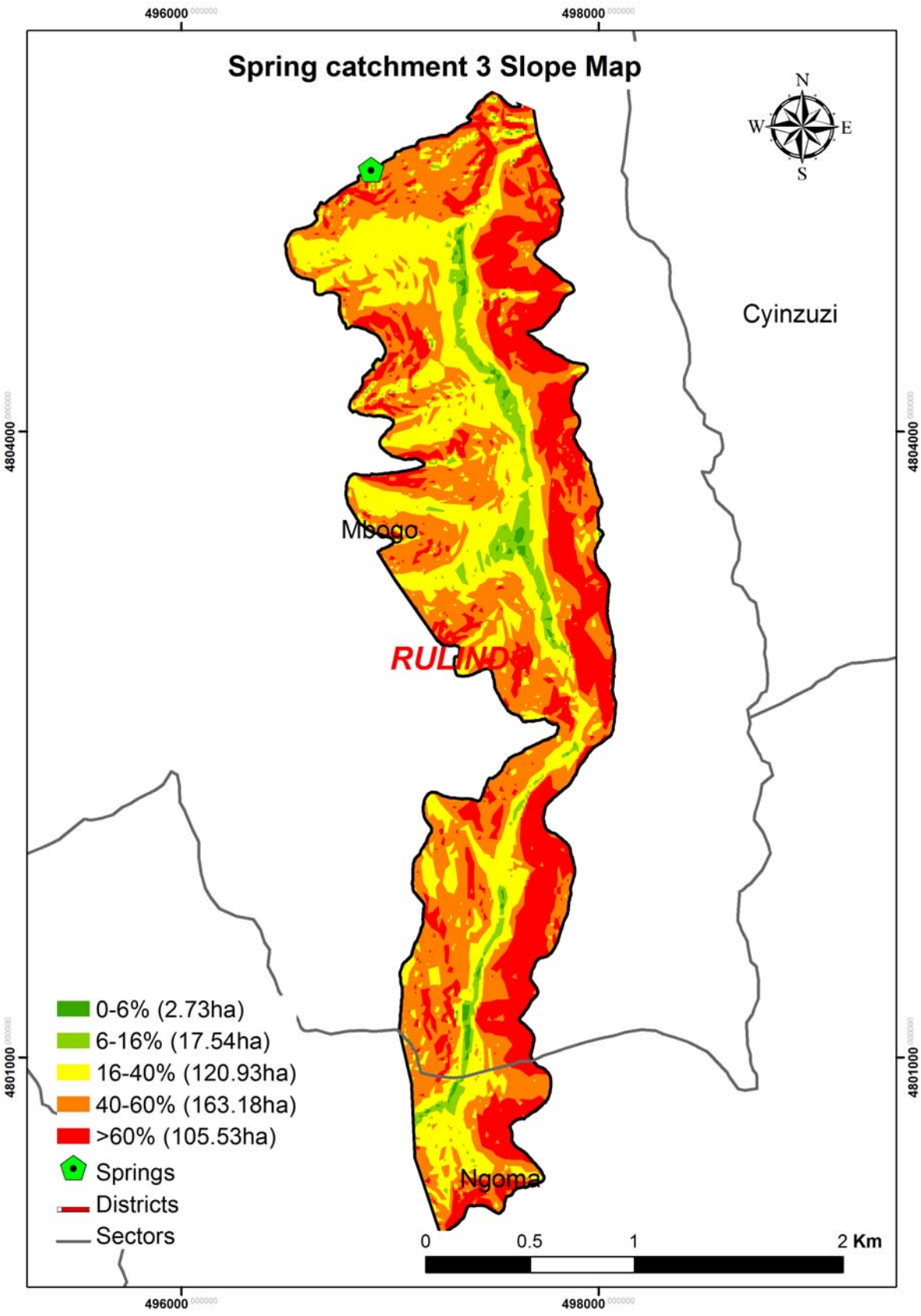

Spring catchment 3 Slope Map
N
W
E
S
496000
498000
4804000
4801000
Cyinzuzi
Mbogo
RULINDO
Ngoma
0-6% (2.73ha)
6-16% (17.54ha)
16-40% (120.93ha)
40-60% (163.18ha)
>60% (105.53ha)
Springs
Districts
Sectors
0
0.5
1
2 Km

Figure 38: Spring recharge catchment 3 slope map.

Table 21: Spring recharge catchment 3 soil depth coverage

Spring recharge catchment 3		
soil depth	**Area Ha**	**% of Area Covered**
<0.5m	85.08	20.76
0.5 - 1.0m	6.67	1.63
>1.0m	318.16	77.62

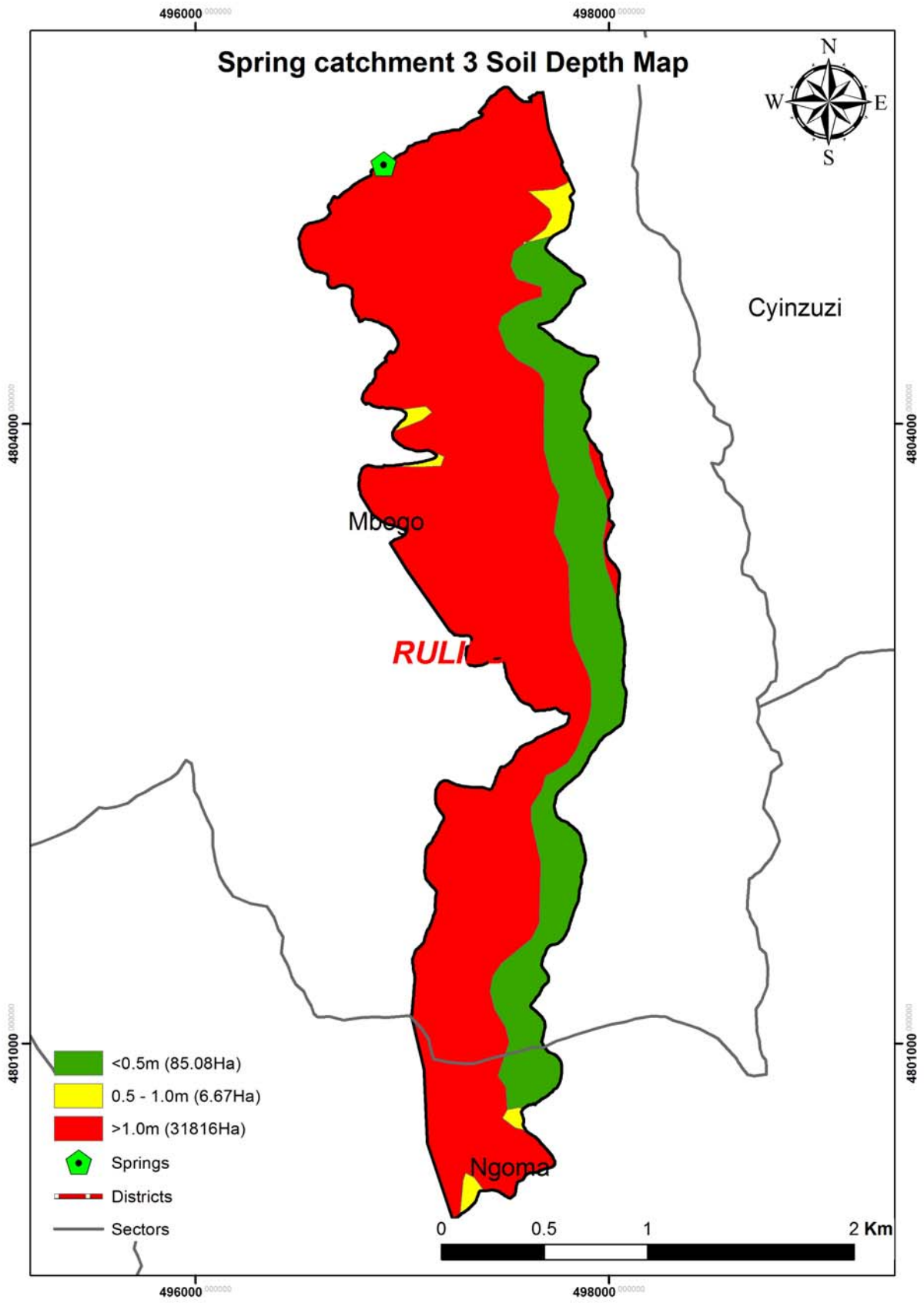

Spring catchment 3 Soil Depth Map
N
W
E
S
496000
498000
4804000
4801000
Cyinzuzi
Mbego
RULI
Ngoma
<0.5m (85.08Ha)
0.5 - 1.0m (6.67Ha)
>1.0m (31816Ha)
Springs
Districts
Sectors
0
0.5
1
2 Km

Figure 39: Spring recharge catchment 3 soil depth map.

Table 22: Spring recharge catchment 3 resilience unit coverage

Spring recharge catchment 3		
resilience	**Area Ha**	**% of Area Covered**
cropland	137.08	33.44
forest plantation	137.94	33.65
natural forest	105.55	25.75
rangeland	29.33	7.16

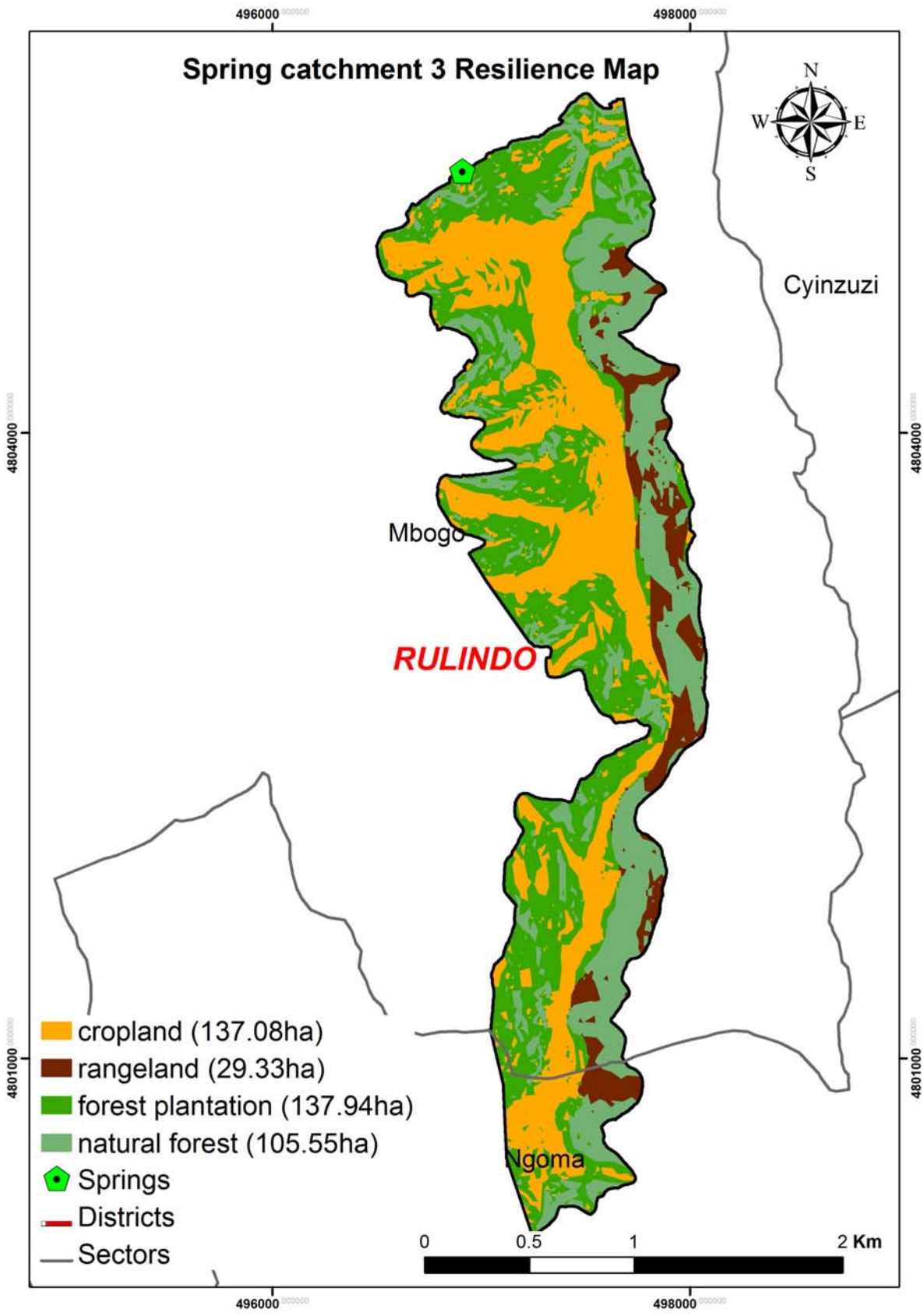

Spring catchment 3 Resilience Map
N
W
E
S
496000
498000
4804000
4801000
Cyinzuzi
Mbogo
RULINDO
Ngoma
cropland (137.08ha)
rangeland (29.33ha)
forest plantation (137.94ha)
natural forest (105.55ha)
Springs
Districts
Sectors
0
0.5
1
2 Km

Figure 40: Spring recharge catchment 3 soil resilience map

Table 23: Spring recharge catchment 3 management measures coverage

Spring recharge catchment 3		
Measures	**Area Ha**	**% Area Covered**
Agroforestry+progressive terraces/cuttoff drains	120.97	72.75
Agroforestry+cuttoff drains/horizontal trenches	20.33	12.23
Agroforestry+radical terraces/gully treatment	24.98	15.02
Forest Plantation	138.04	83.01
Natural Forest	105.60	63.50

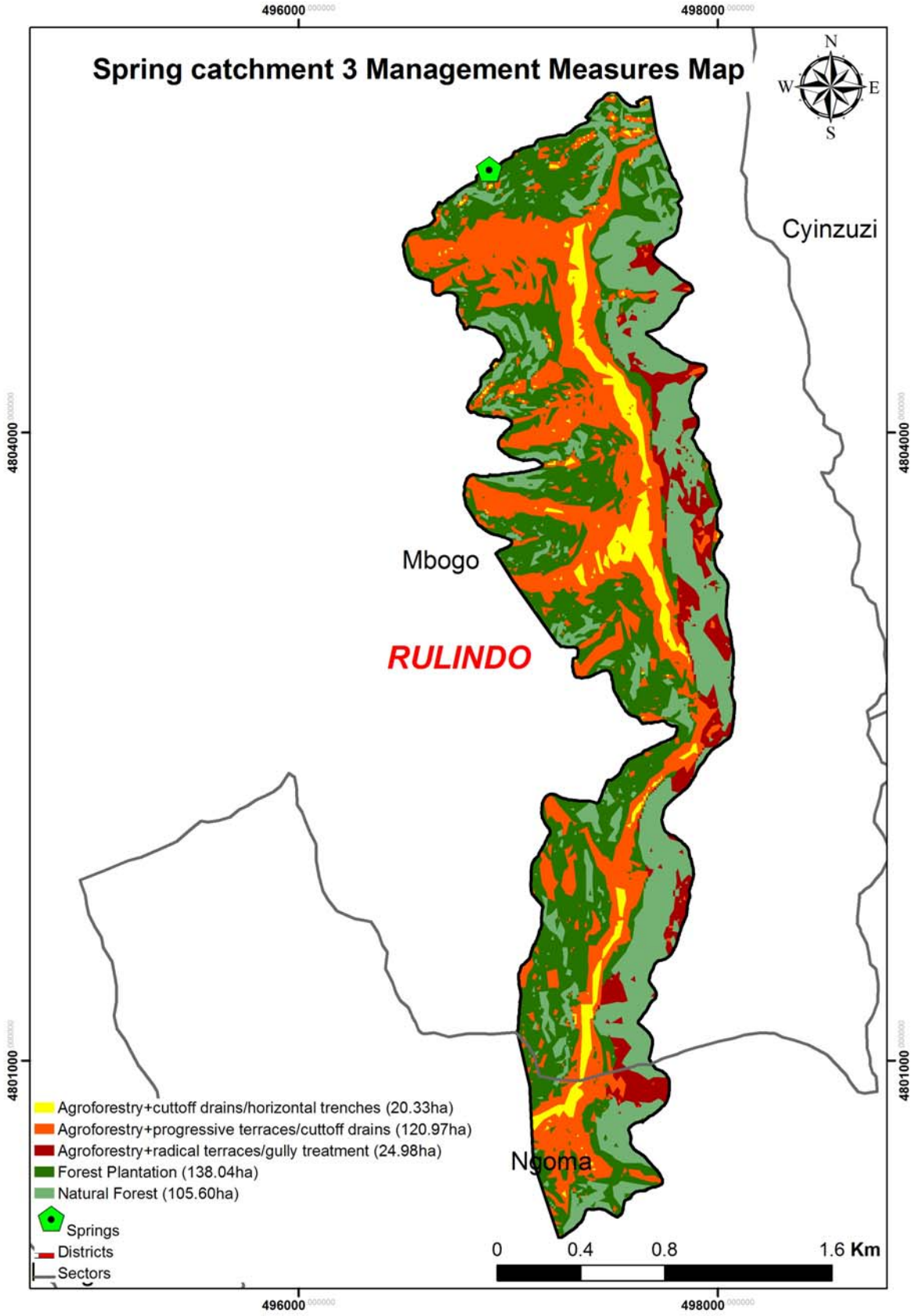

Spring catchment 3 Management Measures Map
N
W
E
S
496000
498000
4804000
4801000
Cyinzuzi
Mbogo
RULINDO
Ngoma
Agroforestry+cuttoff drains/horizontal trenches (20.33ha)
Agroforestry+progressive terraces/cuttoff drains (120.97ha)
Agroforestry+radical terraces/gully treatment (24.98ha)
Forest Plantation (138.04ha)
Natural Forest (105.60ha)
Springs
Districts
Sectors
0
0.4
0.8
1.6 Km

Figure 41: Spring recharge catchment 3 management measures map

NYIRANTARENGWA

Nyirantarengwa spring is a spring located upstream of the road that links Cyinzuzi and Mbogo sectors. The spring id located in a forested area of eucalyptus and does not have an immediate spring catchment limiting the location of the intake. The eucalyptus forest that surrounds the spring has trenches that are not maintained.

Required measures

- Maintenance of trenches in the forest
- Establishment of spring immediate catchment
- Clearance of eucalyptus on the vicinity of the spring
- Establishment of water diversion way

A.1.2 Spring recharge catchment 4

The spring recharge catcment 4 has an area of 3,856.45 ha. It is located in two districts known as Rulindo and Gakenke and also in six sectors known as Bushoki, Gashenyi, Muhondo, Muyongwe, Rushashi and Rusiga. This recharge catchment was observed to have the highest number of spring sources. Among the two springs identified on this recharge catchment, five were newly identified, fourteen are not captured and only two are captured. The resulting maps based on the above classification are presented below.

Table 24: Spring recharge catchment 4 slope coverage.

Spring recharge catchment 4		
slope class	**Area Ha**	**% of Area Covered**
0-6%	27.10	0.70
6-16%	167.59	4.35
16-40%	993.41	25.76
40-60%	1396.15	36.20
>60%	1272.20	32.99

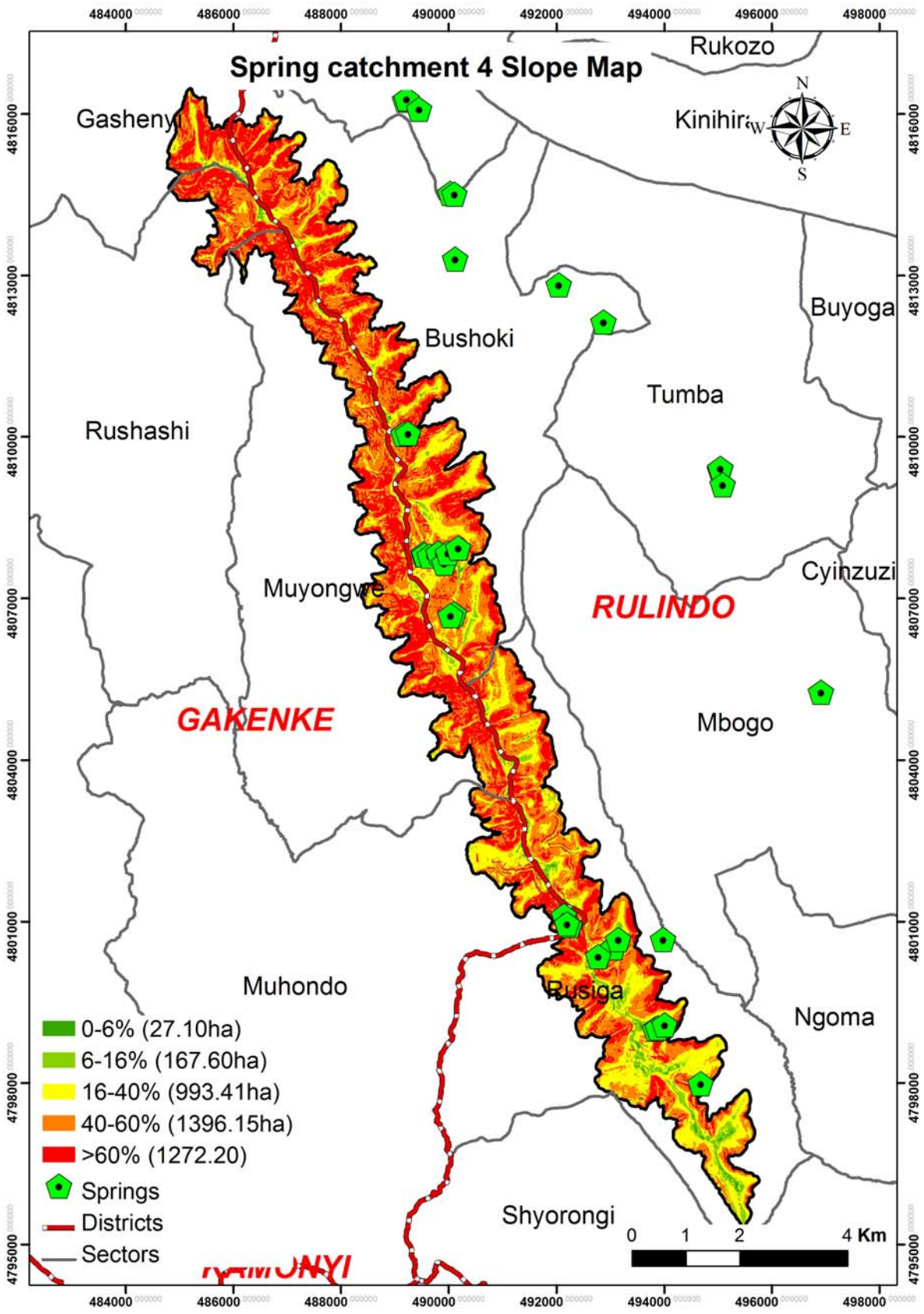

Spring catchment 4 Slope Map
Rukozo
Gashenyi
Kinihira
N
W
E
S
Buyoga
Bushoki
Tumba
Rushashi
Cyinzuzi
Muyongwe
RULINDO
GAKENKE
Mbogo
Muhondo
Rusiga
Ngoma
Shyorongi
0-6% (27.10ha)
6-16% (167.60ha)
16-40% (993.41ha)
40-60% (1396.15ha)
>60% (1272.20)
Springs
Districts
Sectors
0 1 2 4 Km
484000
486000
488000
490000
492000
494000
496000
498000
4816000
4813000
4810000
4807000
4804000
4801000
4798000
4795000

Figure 42: Spring recharge catchment 4 slope map.

Table 25: Spring recharge catchment 4 soil depth coverage.

Spring recharge catchment 4		
soil depth	**Area Ha**	**% of Area covered**
<0.5m	612.01	15.87
0.5 - 1.0m	1106.56	28.69
>1.0m	2137.88	55.44

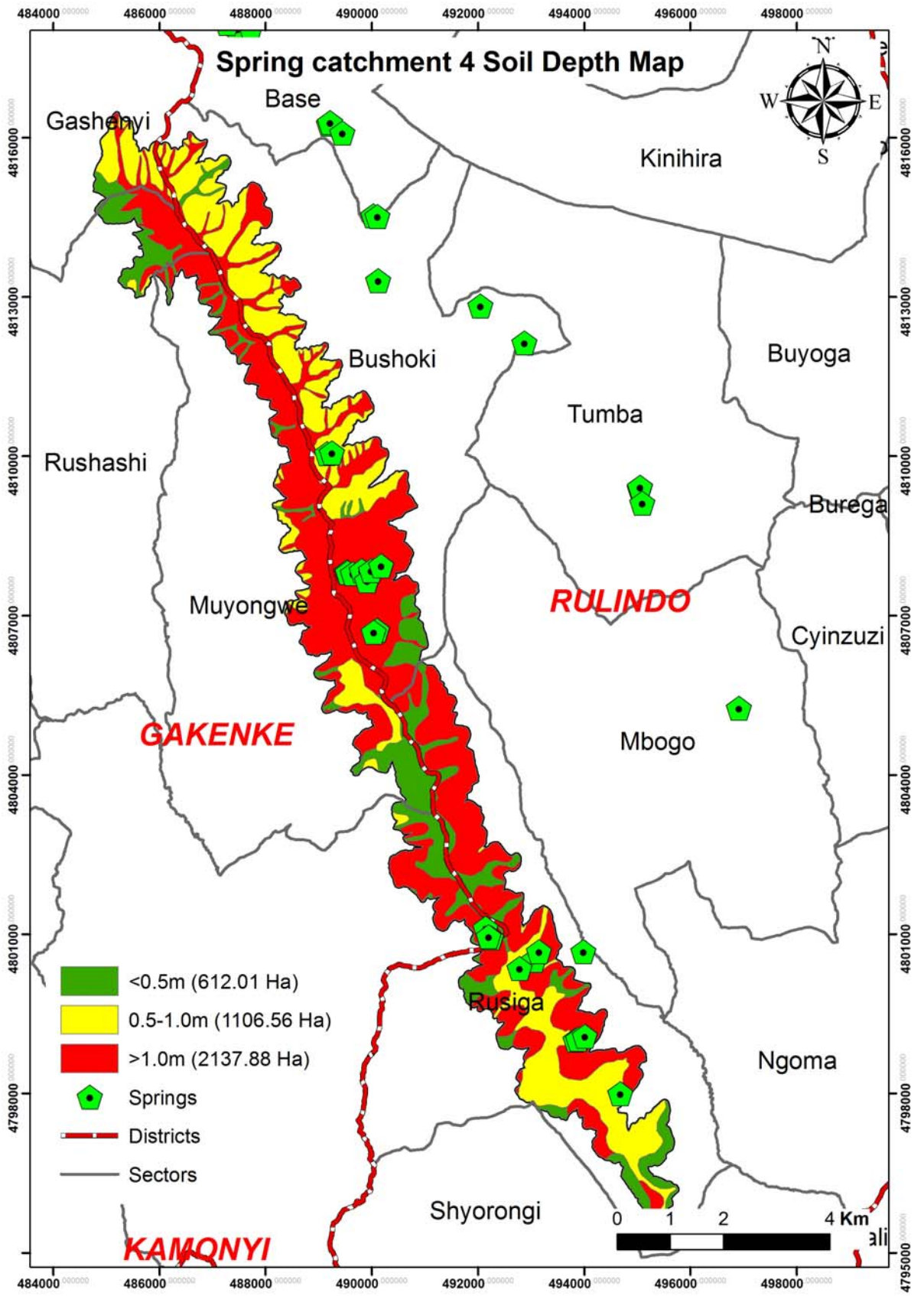

Spring catchment 4 Soil Depth Map
N
W
E
S
Base
Gashenyi
Kinihira
Bushoki
Buyoga
Tumba
Rushashi
Burega
Muyongwe
RULINDO
Cyinzuzi
GAKENKE
Mbogo
Rusiga
Ngoma
Shyorongi
KAMONYI
<0.5m (612.01 Ha)
0.5-1.0m (1106.56 Ha)
>1.0m (2137.88 Ha)
Springs
Districts
Sectors
0 1 2 4 Km
484000
486000
488000
490000
492000
494000
496000
498000
4816000
4813000
4810000
4807000
4804000
4801000
4798000
4795000

Figure 43: Spring recharge catchment 4 soil depth map.

Table 26: Spring recharge catchment 4 resilience unit coverage

Spring recharge catchment 4		
resilience	**Area Ha**	**% of Area Covered**
cropland	969.75	25.15
forest plantation	1173.85	30.44
natural forest	1271.19	32.96
rangeland	441.67	11.45

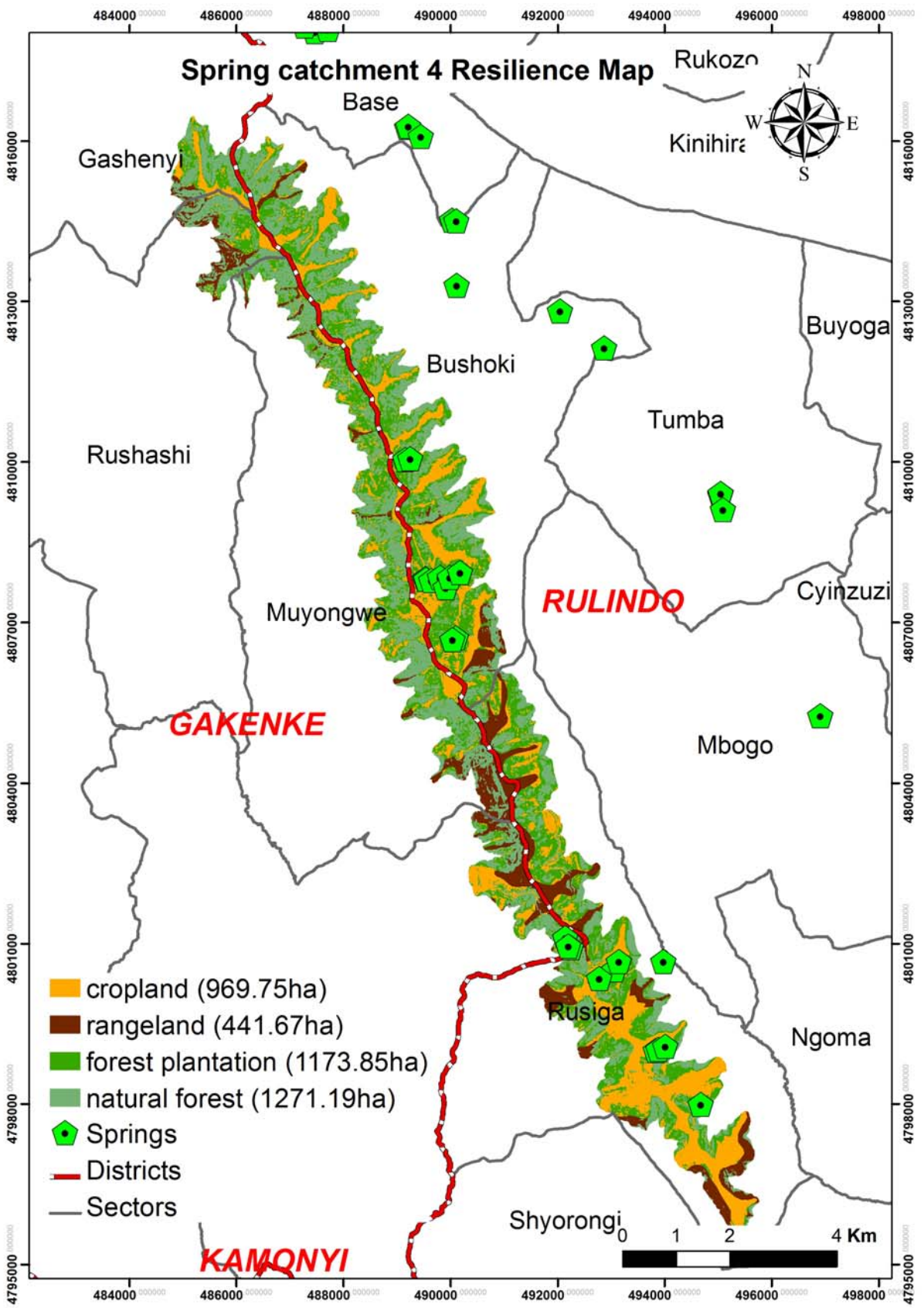

Spring catchment 4 Resilience Map
Rukozo
Base
Gashenyi
Kinihira
N
W
E
S
Buyoga
Bushoki
Tumba
Rushashi
RULINDO
Cyinzuzi
Muyongwe
GAKENKE
Mbogo
Rusiga
Ngoma
Shyorongi
KAMONYI
cropland (969.75ha)
rangeland (441.67ha)
forest plantation (1173.85ha)
natural forest (1271.19ha)
Springs
Districts
Sectors
0 1 2 4 Km
484000
486000
488000
490000
492000
494000
496000
498000
4816000
4813000
4810000
4807000
4804000
4801000
4798000
4795000

Figure 44: Spring recharge catchment 4 soil resilience map.

Table 27: Spring recharge catchment 4 management measures coverage.

Spring recharge catchment 4		
Measures	**Area Ha**	**% Area Covered**
Agroforestry+progressive terraces/cuttoff drains	992.66	70.43
Agroforestry+cuttoff drains/horizontal trenches	195.88	13.90
Agroforestry+radical terraces/gully treatment	220.89	15.67
Forest Plantation	1174.34	83.32
Natural Forest	1272.68	90.30

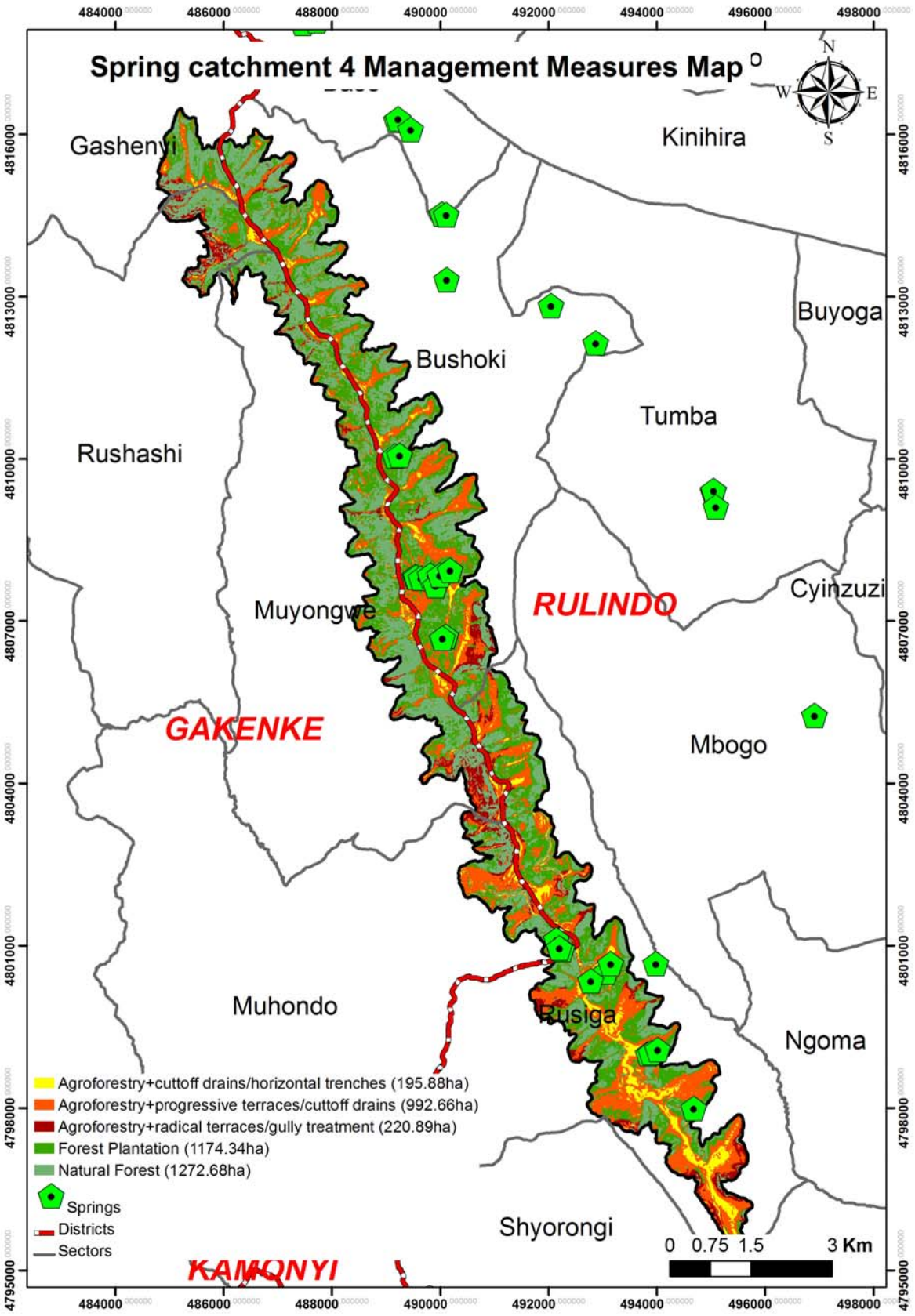

Spring catchment 4 Management Measures Map
N
W
E
S
Gashenyi
Kinihira
Buyoga
Bushoki
Tumba
Rushashi
Muyongwe
RULINDO
Cyinzuzi
GAKENKE
Mbogo
Muhondo
Rusiga
Ngoma
Shyorongi
KAMONYI
Agroforestry+cuttoff drains/horizontal trenches (195.88ha)
Agroforestry+progressive terraces/cuttoff drains (992.66ha)
Agroforestry+radical terraces/gully treatment (220.89ha)
Forest Plantation (1174.34ha)
Natural Forest (1272.68ha)
Springs
Districts
Sectors
0 0.75 1.5 3 Km
484000
486000
488000
490000
492000
494000
496000
498000
4816000
4813000
4810000
4807000
4804000
4801000
4798000
4795000

Figure 45: Spring recharge catchment 4 management measures map.

RUKUNGERI 1

Although it is required to fence and surround the spring immediate catchment by the water diversion ditch (also called water diversion way or cut-off drain) that deviates the runoff, the two important practices are not adequate for these particular springs. In fact, around the spring's immediate catchment there are no fence that limit humans from conducting activities over the intakes. The picture below (left) shows the boundary of one of the intakes but if a fence is not established, in few months the signs of its limit will disappear. For the other intake (middle), it is not easy to retrieve the real location of the immediate catchment.

Regarding the enrecharged catchment area, it is almost protected with stable and effective progressive terraces with embankment stabilized by elephant grasses. However, the area around the spring does not have a defined watershed management practices. In addition, the water supply pipeline is unmarked; therefore there is a worry that in the coming year's people may forget their location and break them while cultivating or establishing other necessary infrastructure. Furthermore the manhole for the spring boxes are not fixed with crew and children flew different kinds of wastes that may lead to a permanent pollution of the supplied water.

Required measures

- Establishment of progressive terraces with the embankments made of stone bunds as the area is rich in stones.
- Establishment of the adequate water diversion ditch is required as well as the fence that should be made with imiyenzi (Euphorbia tirucalli). In fact, Euphorbia tirucalli is a local plant that was found in that area and has been used for the other springs protection.

MUHANGA 1, 2 and 3

For all three springs the immediate spring catchment is fenced and surface water diversion ditches are present. However the growth of the natural trees used to make fence was hindered by goats as they ate their leaves.

The enrecharged catchment area is adequately protected with stable and effective progressive terraces with embankment stabilized with elephant grasses. Like in the previous case, the water supply pipeline is unmarked.

Required measures

- Reinforce the existing fences and regular maintenances of the surface water diversion ditches is required.

BUHANDE 1 and 2

The immediate spring catchment is fenced and surface water diversion ditches are present. However, the water of this spring becomes very turbid when a heavy rain occurred or when consecutive rains occur as reported by the local community.

The enrecharged catchment area is adequately protected with stable and effective progressive terraces with embankment stabilized by elephant grasses. Like in the previous case, the water supply pipeline is unmarked.

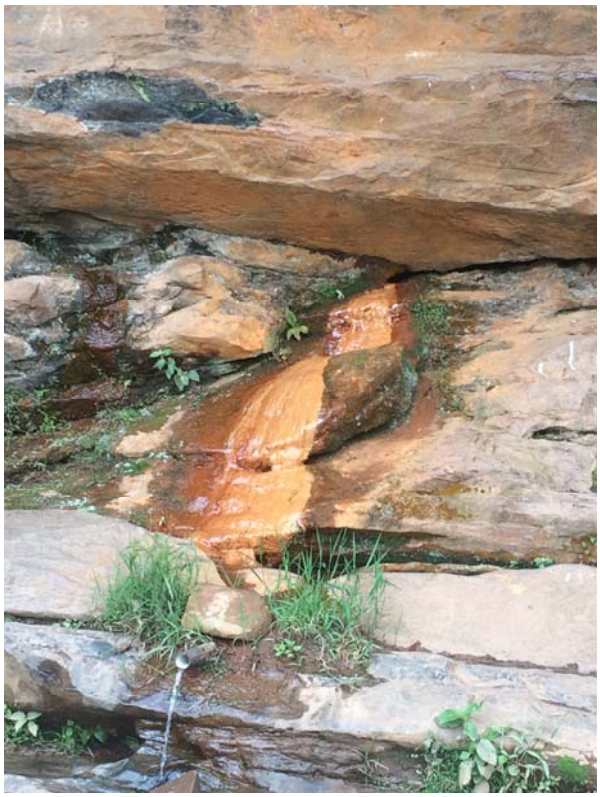
Regarding the other infrastructure, the manholes are not covered and debris and other wastes were flown inside and plants are growing inside as illustrated in the picture above. Also, the picture above (right) shows the effects of human activities on the foundation of the spring box. In fact, for this spring box, the human activities combined with the rainfall runoff washed out of the soil that was protecting the foundation.

Required measures

- Reinforce the existing fences and regular maintenances of the surface water diversion ditches is required.

AGATARE

This spring discharges water from a rock. The upper stream part is covered by forest mixed with shrubs of natural vegetation. The spring is uncaptured and therefore does not have the spring catchment.



Required measures

- Establishment of trenches in the upstream forest is required as it will enhance the ground water recharge.
- Establishment of the spring catchment is required and eucalyptus should be cleared up to 50 m from the spring catchment.
- Establishment of the adequate water diversion ditch is required as well as the fence that should be made with imiyenzi.

NYABOGA 1

This is a captured spring but the location of its intake is unknown as it does not have the fence or any other sign that can help to retrieve it. In fact the area where local population consider as the location of the Nyaboga 1 intake is covered by banana plantation mixed with season crops including sorghum and beans. These crops are extended up to the spring collection chamber which is not covered.

Required measures

- Establishment of water spring catchment and fence it.
- Establishment of a water diversion way as well as the reinforcement of the upstream progressive terraces.

NYABOGA 2

Unlike Nyaboga 1, Nyaboga 2 is not captured. The spring discharges water through a pipe and some of the spring water leaks. In the left wing part toward the top of the hill, there is a household family surrounded by the field of banana plantation mixed with season crops.
The right wing is occupied by uncultivated areas protected by trenches.

Required measures

- Establishment of water spring catchment and fence it;

- Establishment of a water diversion way;
- Replace the trenches located upstream by bench terraces.

NYAKABIZI 1

This is a captured spring with the intake located downstream of a non-active gully that was deviated via a water diversion way. This gully originates from a forest without trenches. Upstream toward the right part of the mountain there are two households with substandard toilets. In the spring immediate catchment there are two young eucalyptus trees and other shrubs that are growing there.

According to the local community, the water of this spring becomes dirty during the rainy season. In addition, its discharge change dramatically and this led to the overflow of spring collection tank that is located downstream. This was found to be due to the runoff from upstream.

Required measures

- Maintenance of the spring catchment is necessary as there are eucalyptus trees and shrubs that are growing insides;
- The water diversion path can be paved in order to eliminate the interaction between that spring water and the runoff;
- The boundary of the fence are not also well marked and therefore its rehabilitation is necessary;

- Establishment of water percolation pit along the gully may slow the runoff, contribute to the ground water recharge and therefore to the reduction of the effect of rainfall runoff to the water quality of the spring.

NYAKABIZI 2

Nyakabizi 2 is a captured spring with a good immediate spring catchment of Imiyenzi surrounded by a water diversion way that deviate the runoff from upstream that is conveyed by a stable gully. In some of its parts, shrubs developed and need to be cleared. The upstream part is protected by stable progressive terraces with the embankments stabilized by elephant grasses. These progressive terraces are used by local population for agricultural activities predominated by seasonal crops that include maize, sorghum, beans, cassava, etc.

Like the previous spring this spring becomes muddy during the rainy season and its discharge also changes suddenly and this lead to the overflow of water in the spring collection tank. This is caused by the direct interaction between the runoff and the spring water.

Required measures

- Establishment of water percolation pits along the gully
- Reinforce trenches in the forest that is located upstream of the cultivated area

NYAKABIZI 3

This is a new source located upstream of Nyakabizi 2 in Kibirizi village, Busake cell, Muhondo sector, Gakenke district. Alhgouh it is located in Gakenke district, it is precisely located at the boundary of Gakenke and Rulindo sector. This spring is used during the whole year but it becomes more useful during the rainy season when other springs are discharging dirty water.

Like other springs, the surrounding areas are used for agricultural activities that include banana plantation mixed with seasonal crops.

NYAGATOVU 1 (Mugera)

The water of this spring is drained by a pipe installed by the local community. It has a small immediate catchment which probably does not reach the spring intake (according to the local people) while the surrounding and upstream areas are used for agriculture activities. The total area is protected with progressive terraces that seem to be effective.

Required activities

- Establishment of immediate spring catchment and fence it with imiyenzi.
- Establishment of a water diversion ditch

NYAGATOVU 2

This spring is not well maintained as illustrated in the picture below. It is surrounded by area used for agriculture purposes. The area where it originates is covered by elephant grasses mixed with avocado tree plantation.

The enrecharged catchment of this spring is protect with progressive terraces used by the local community for agricultural activities of both seasonal and perennial plantation predominated by banana plantation.

Required activities

- Capturing of the spring water
- Establishment of the spring catchment area
- Establishment of water diversion ditch

NYAGATOVU 3

Like the previous spring, Nyagatovu 3 is uncaptured spring with a volume of water that leaks. As illustrated in the picture below, the upstream part of the spring is used for agriculture activities stabilized by progressive terraces with embankments protect by elephant grasses.

Required activities:

- Establishment of a water spring immediate catchment with a fence
- Establishment of a water diversion ditch
- Reinforcement of trenches for the progressive terraces

NTAKARA

Ntakara spring is located at the foot of the hill covered by the forest plantation of eucalyptus with trenches that need maintenances. The spring immediate catchment is not fenced and shrubs are about to cover the entire space. Downstream of the catchment there are agricultural activities that are developed up to the water collection tank. Like other pipelines, its location is not marked.


Required activities

- Maintenance of spring immediate catchment
- Rehabilitation of trenches in the forest
- Covering the manhole

NKORE

The Nkore spring is an identified new spring, uncaptured and located in Bushoki sector, Giko cell and Kigamba village. This source could be captured to increase the water at Nyirambuga system which was reported to be insufficient currently to the increase demand in that area. The Nkore spring is located downhill with the water outlet from a rock which is surrounded by bush plantation and with juvenile eucalyptus upslope. Next to the spring, a group of settlement has captured part of the water at around 500 meters for their household activities and the other part of the spring is used by the local community, but still the spring has a lot of leakages.

Required activities

- The spring at Nkore need a total rehabilitation and it could also be used to increase the water at Nyirambuga system.

A.1.3 Spring recharge catchment 5

The spring recharge catchment 5 has an area of 2,469.76 ha and is totally located in the District of Rulindo. The recharge catchment 5 lies in 5 sectors known as Base, Bushoki, Buyoga, Mbogo and Tumba. The recharge catchment 5 has ten spring sources of which five are not captured and the other five are captured. The resulting maps based on the above classification are presented below.

Table 28: Spring recharge catchment 5 slope coverage

Spring recharge catchment 5		
slope class	**Area Ha**	**% of Area Covered**
0-6%	44.67	1.81
6-16%	263.81	10.68
16-40%	938.66	38.01
40-60%	726.10	29.40
>60%	496.52	20.10

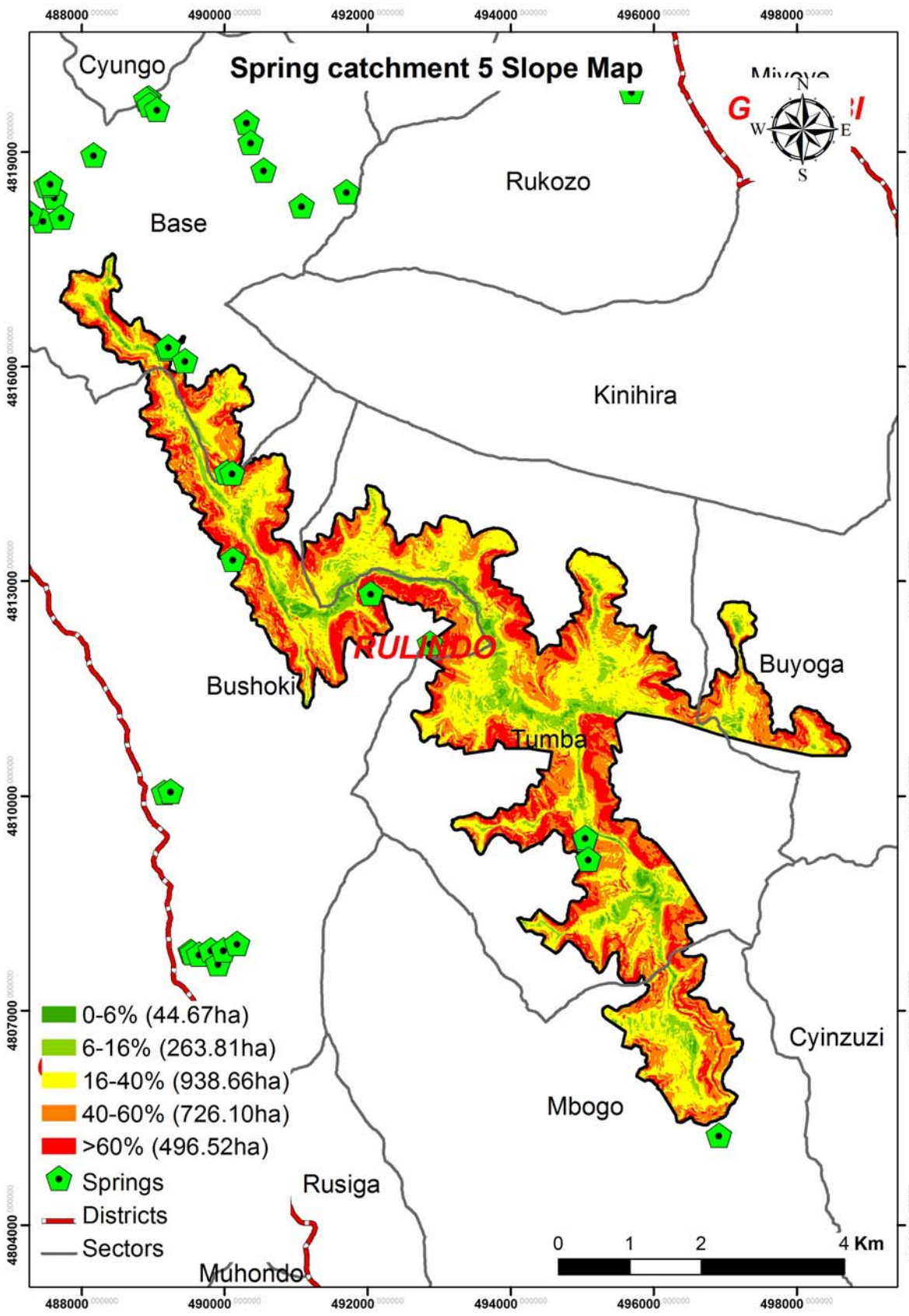

Spring catchment 5 Slope Map
Cyungo
Rukozo
Base
Kinihira
RULINDO
Bushoki
Buyoga
Tumba
Cyinzuzi
Mbogo
Rusiga
Muhondo
N
W
E
S
0-6% (44.67ha)
6-16% (263.81ha)
16-40% (938.66ha)
40-60% (726.10ha)
>60% (496.52ha)
Springs
Districts
Sectors
0 1 2 4 Km
488000
490000
492000
494000
496000
498000
4819000
4816000
4813000
4810000
4807000
4804000

Figure 46: Spring recharge catchment 5 slope map

Table 29: Spring recharge catchment 5 soil depth coverage

Spring recharge catchment 5		
soil depth	**Area Ha**	**% of Area covered**
<0.5m	624.12	25.27
0.5 - 1.0m	208.44	8.44
>1.0m	1637.20	66.29

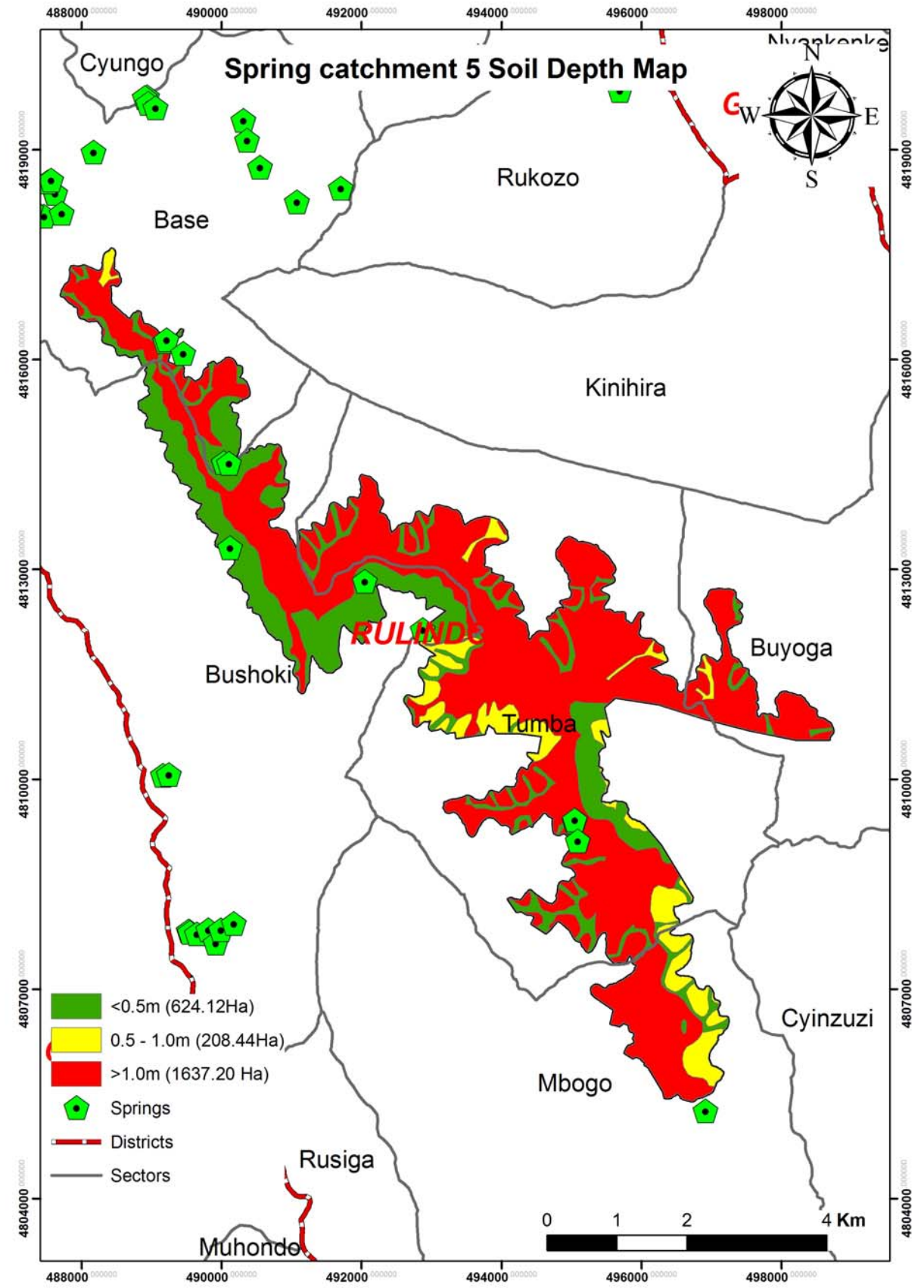

Spring catchment 5 Soil Depth Map
N
W
E
S
Cyungo
Rukozo
Base
Kinihira
RULINDO
Bushoki
Buyoga
Tumba
Cyinzuzi
Mbogo
Rusiga
Muhondo
<0.5m (624.12Ha)
0.5 - 1.0m (208.44Ha)
>1.0m (1637.20 Ha)
Springs
Districts
Sectors
0 1 2 4 Km
488000
490000
492000
494000
496000
498000
4819000
4816000
4813000
4810000
4807000
4804000

Figure 47: Spring recharge catchment 5 soil depth map

Table 30: Spring recharge catchment 5 resilience unit coverage

Spring recharge catchment 5		
resilience	**Area Ha**	**% of Area Covered**
cropland	1079.97	43.73
forest plantation	477.55	19.34
natural forest	495.14	20.05
rangeland	417.09	16.89

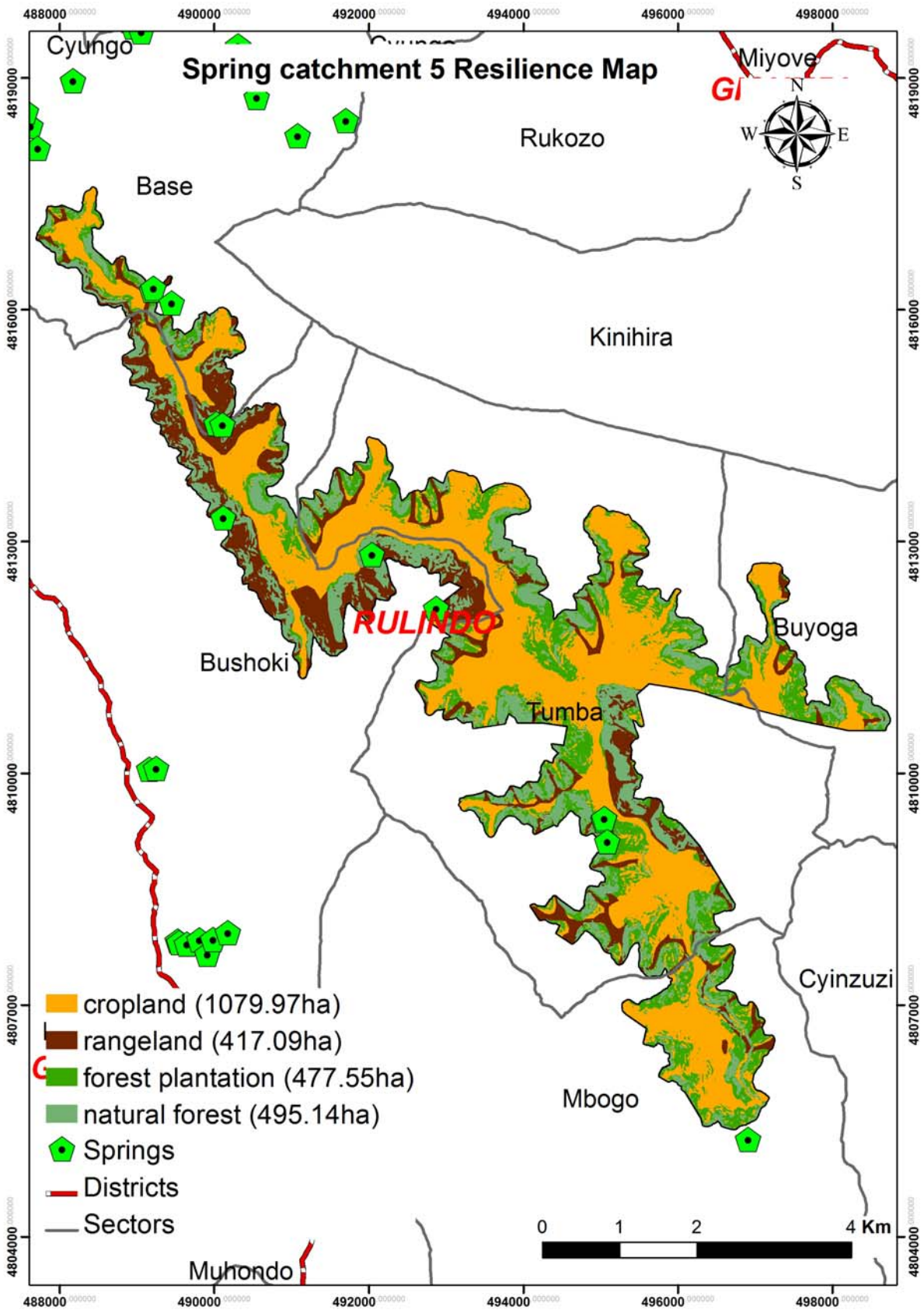

Spring catchment 5 Resilience Map
Cyungo
Miyove
Rukozo
Base
Kinihira
RULINDO
Bushoki
Buyoga
Tumba
Cyinzuzi
Mbogo
Muhondo
N
W
E
S
cropland (1079.97ha)
rangeland (417.09ha)
forest plantation (477.55ha)
natural forest (495.14ha)
Springs
Districts
Sectors
0
1
2
4 Km
488000
490000
492000
494000
496000
498000
4819000
4816000
4813000
4810000
4807000
4804000

Figure 48: Spring recharge catchment 5 soil resilience map

Table 31: Spring recharge catchment 5 management measures coverage

Spring recharge catchment 5		
Measures	**Area Ha**	**% Area Covered**
Agroforestry+progressive terraces/cuttoff drains	938.51	62.76
Agroforestry+cuttoff drains/horizontal trenches	309.74	20.71
Agroforestry+radical terraces/gully treatment	247.22	16.53
Forest Plantation	477.29	31.92
Natural Forest	497.00	33.23

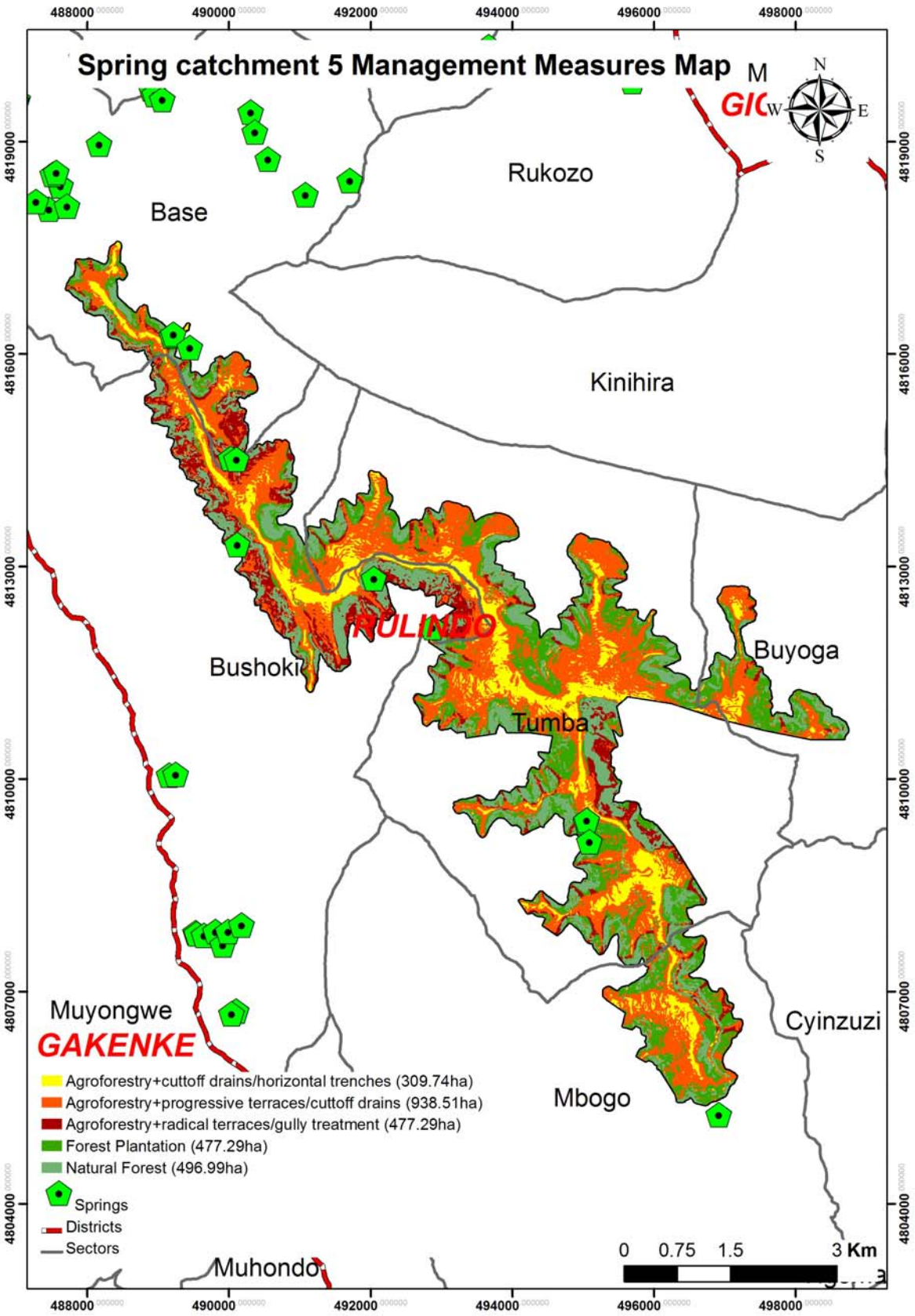

Spring catchment 5 Management Measures Map
N
W
E
S
488000
490000
492000
494000
496000
498000
4819000
4816000
4813000
4810000
4807000
4804000
Base
Rukozo
Kinihira
RULINDO
Bushoki
Buyoga
Tumba
Muyongwe
GAKENKE
Cyinzuzi
Mbogo
Muhondo
Agroforestry+cuttoff drains/horizontal trenches (309.74ha)
Agroforestry+progressive terraces/cuttoff drains (938.51ha)
Agroforestry+radical terraces/gully treatment (477.29ha)
Forest Plantation (477.29ha)
Natural Forest (496.99ha)
Springs
Districts
Sectors
0 0.75 1.5 3 Km

Figure 49: Spring recharge catchment 5 management measures map.

NYIRAMBUGA 1

This is a combination of eight intakes collected in the same water collection chamber. Despite being a collection point of many intakes, this water collection chamber is not covered and debris of vegetation were flown inside and this can be a source of organic matter as well as pathogenic micro-organisms in the water supply system branched to these sources. Furthermore, among the eight intakes, there is one that its water is affected by the rainfall as its colour changes dramatically during the rainy season.

While the water pumps of other systems are operated by the fuel, the pumps of this system are operated by the electricity.

The springs have a stable immediate spring catchment fenced using imiyenzi. Upstream of the immediate spring catchment there is stable gully conveying water from upstream to a water diversion ditch.

The manhole of the spring box is opened and some wastes were thrown inside and can be a source of organic matter as well as micro-organism is the water supply system branched to these sources.

The enrecharged catchment areas of these springs are sloppy and are almost occupied by the agriculture activities with season crops the most abundant.

In around 50m from the fence of the immediate spring catchment, there is a household with banana plantation arriving at the fence.

Required activities

- Althouth the enrecharged catchment seem to be stabilised by the progressive terraces the installation of radical terraces should help in soil erosion control as well as in ground water recharge.
- Regular maintenance of the water diversion ditch.

NEW SPRING

Downstream of the above springs, there is an uncaptured spring located in the Roseau. Once that spring is captured, its water can be conveyed downstream to be combined with the water from the spring described in the next paragraphs which are located in reasonable distance from it.

The activities indicated above should help also this spring to work effectively.

NYIRAMBUGA 2

MATONGANYA 1

The intake of the spring of this catchment is located in the field of one of the local community that was occupied by potatoes plantation during the field visit as illustrated by the picture below. Therefore, the spring does not have a defined immediate spring catchment. Around the spring pipe supplying water to the local community there is small of water that leaks which can increase the spring yield once captured.

The enrecharged catchment is occupied by steep land occupied by perineal crops mainly banana plantation mixed with the season plantation.

Upstream there is a small inactive gully that conveys a small volume that passes next to the intake. In addition to that, there is a forest plantation of eucalyptus that outsources water from the spring.

Required management activities

- Establishment of immediate spring catchment is required to protect both water quality and quantity of the spring.
- Removal of eucalyptus up to 50m from the intake is also required in order to eliminate any problem that may be caused by eucalyptus such as the pipes clogging by roots of eucalyptus or water quantity depletion.
- Re-capture the spring to make all water of spring useful.

MATONYANGA 2 (New)

This spring is located downstream of Matonyanga in the banana plantation. The spring has a very small immediate spring catchment covered by passparum. Upstream there is a banana plantation followed by the forest of eucalyptus with trenches that are not regularly maintained. The location of this new spring allows its water to be combined with the water from the Matonyanga 1spring by gravity.


Required management activities

- Establishment of immediate spring water catchment and fence it
- Capture the spring to make its entire discharge useful
- Rehabilitation of trenches in forest located upstream of enrecharged catchment spring

RWICANYONI


This spring is located downstream of Rutare 2 spring. The upstream part of the spring is used for agricultural activities as well as other surroundings. These cultivated areas are protected by progressive terraces with embankment stabilized by elephant grasses. The spring has an immediate spring catchment protected by Imihati and planted with passparum. Beside, according to the local community, the water of this spring becomes turbid in rainy season.

MUTOYI

As shown in the figure below, Mutoyi is a captured spring with a developing spring immediate catchment fenced by Imihati. This fence is surrounded by a water diversion ditch that deviate the runoff from the upstream areas which are generally steep. The upstream part of the spring is occasionally used for agricultural activities although it is not adequately protected from the soil erosion.

Required activities

- Regular maintenance of water diversion ditch
- Establishment of terraces upstream of the spring and protect them with elephant grasses

KIVURE 1 AND KIVURE 2

The Kivure 1 and Kivure 2 springs are two closest springs located in Bushoki sector and in Giko cell and supplying the Buramira network. The sources are supplying two villages of Kivomo and Karambo as well as the Buramira primary school. The water catchment area for the two sources is well protected with Imiyenzi fences with passparum plantations in the direct spring catchment and with clear water diversion ditches. The Kivure 1 catchment is captured downhill from a rock with an upstream part of the rock covered with a juvenile forest plantation. The Kivure 2 source located downhill is surrounded by agriculture activities of seasonal crops.

According to the Giko cell representative and the local population, the population of Kivomo and Karambo village do not use the water that is supplied to them claiming that the cost is too high and prefer to use the water fountain that is next to the two Kivure sources or sometime use the water that overflow the storage tank. Consequently, the water line supplying the two villages was closed during the March 2016 field trip and only the Buramira primary school network was in operation. It could be considered, however, that closing the network in the

area for long-time will result in a lot of damages to the water system and a lack of ownership of the system by the local community.

Required activities

Involve the local population in the management of the water system and discuss the best scenario that can be used for the population to use the water that is supplied to them. In fact, some people in the area mentioned that they prefer to pay the water per year or per trimester instead of 20 rwf per 20 Liters, however he didn't' mention the price for that proposition.

Kivure 1 (left) and Kivure 2 (right)

A.1.4 Spring recharge catchment 6

The spring recharge catchment 6 has an area of 901.8 ha. The recharge catchment is located in the Districts of Rulindo and Burera. It lies in the Sectors of Base and Nemba. The recharge catchment has ten spring sources of which four are not captured and six are captured. The resulting maps based on the above classification are presented below.

Table 32: Spring recharge catchment 6 slope coverage

Spring recharge catchment 6		
slope class	**Area Ha**	**% of Area Covered**
0-6%	7.96	0.88
6-16%	54.03	5.99
16-40%	251.76	27.92
40-60%	313.91	34.81
>60%	274.14	30.40

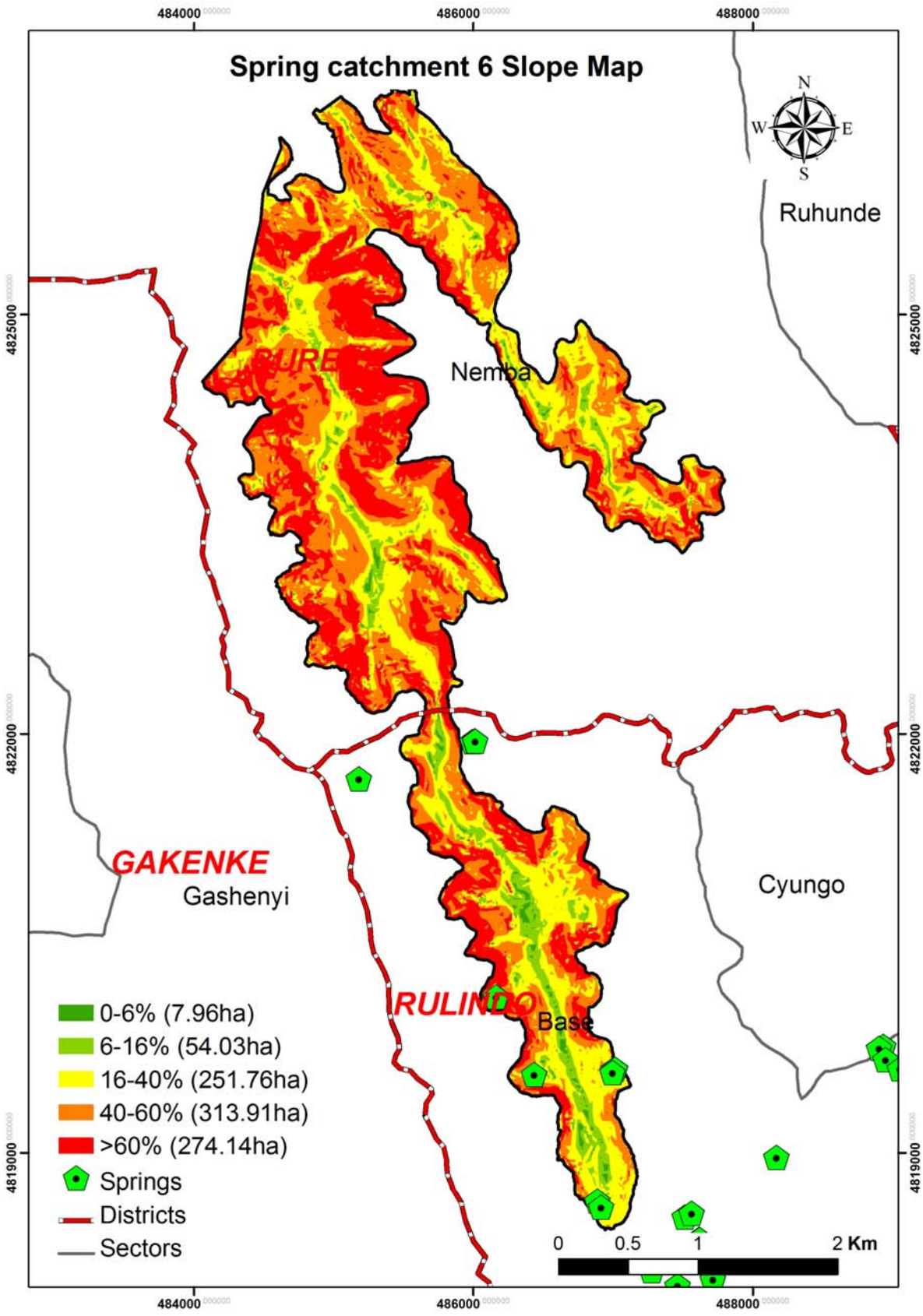

Spring catchment 6 Slope Map
N
W
E
S
Ruhunde
Nemba
PURE
GAKENKE
Gashenyi
Cyungo
RULINDO
Base
0-6% (7.96ha)
6-16% (54.03ha)
16-40% (251.76ha)
40-60% (313.91ha)
>60% (274.14ha)
Springs
Districts
Sectors
0
0.5
1
2 Km
484000
486000
488000
4825000
4822000
4819000

Figure 50: Spring recharge catchment 6 slope map

Table 33: Spring recharge catchment 6 soil depth coverage

Spring recharge catchment 6		
soil depth	**Area Ha**	**% of Area covered**
<0.5m	206.89	22.94
0.5 - 1.0m	351.82	39.01
>1.0m	343.09	38.04

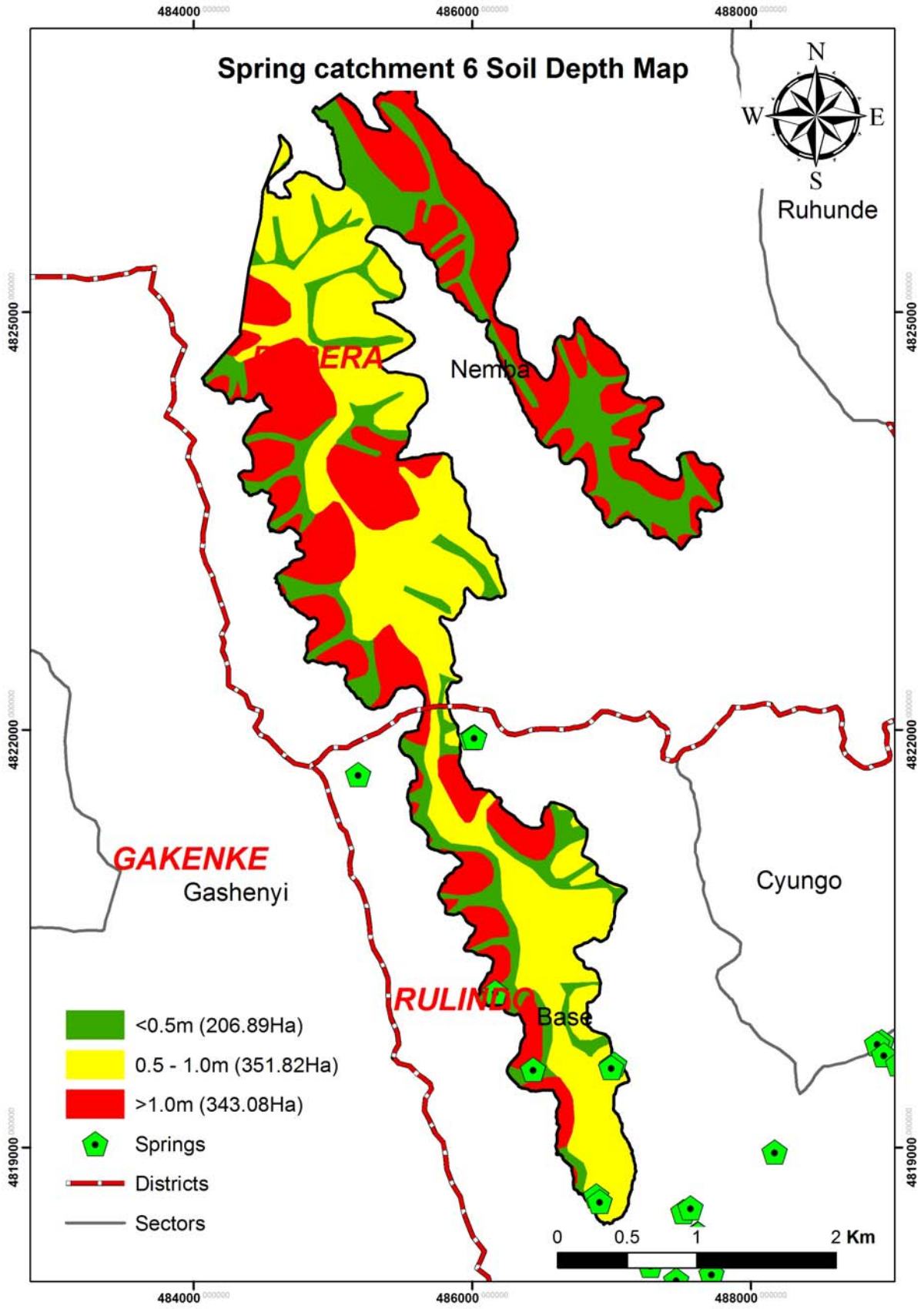

Spring catchment 6 Soil Depth Map
N
W
E
S
Ruhunde
Nemba
GAKENKE
Gashenyi
Cyungo
RULINDO
Base
<0.5m (206.89Ha)
0.5 - 1.0m (351.82Ha)
>1.0m (343.08Ha)
Springs
Districts
Sectors
0
0.5
1
2 Km
484000
486000
488000
4825000
4822000
4819000

Figure 51: Spring recharge catchment 6 soil depth map.

Table 34: Spring recharge catchment 6 resilience unit coverage

Spring recharge catchment 6		
resilience	**Area Ha**	**% of Area Covered**
cropland	227.47	25.22
forest plantation	238.88	26.49
natural forest	273.28	30.30
rangeland	162.17	17.98

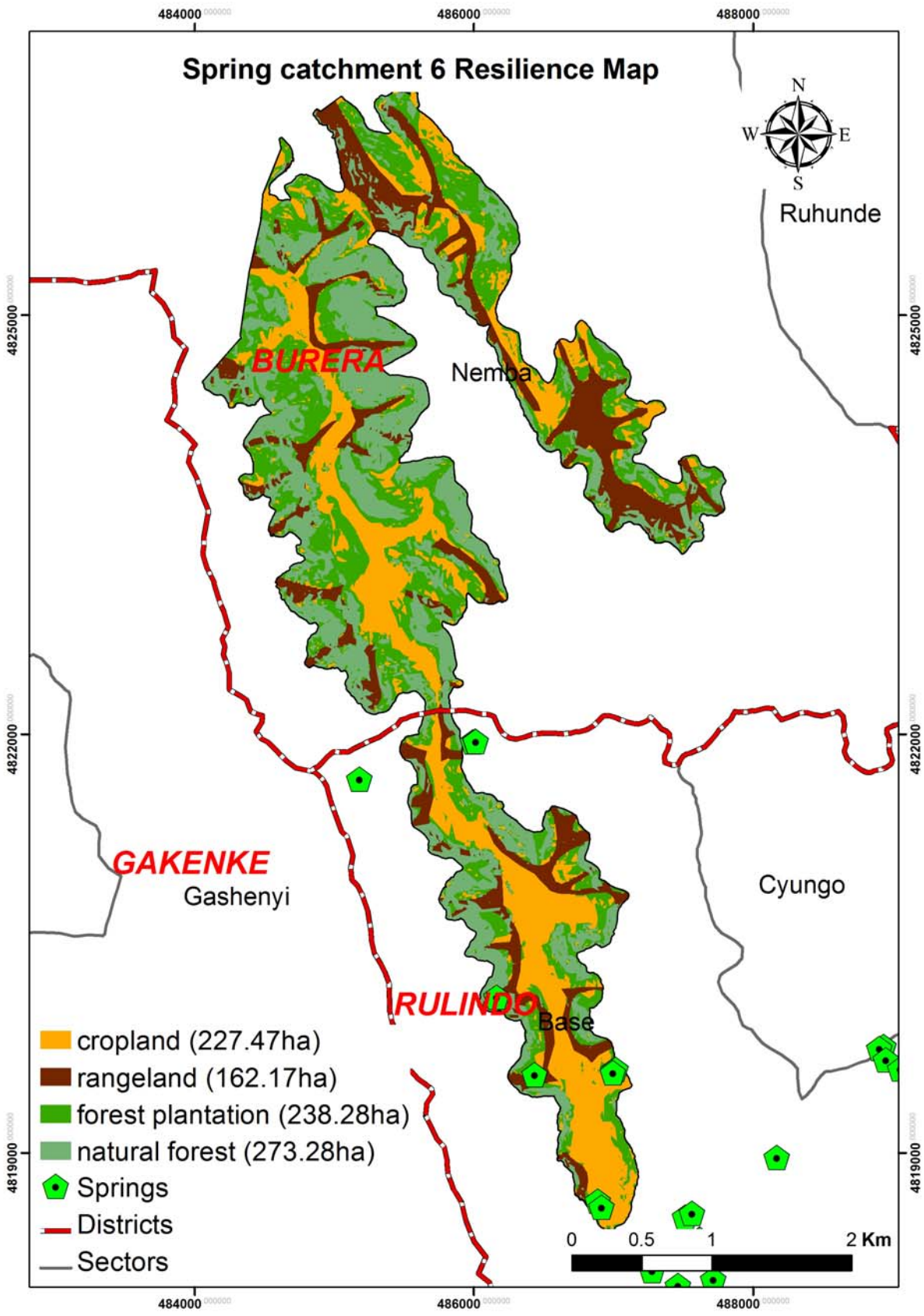

Spring catchment 6 Resilience Map
N
W
E
S
Ruhunde
BURERA
Nemba
GAKENKE
Gashenyi
Cyungo
RULINDO
Base
cropland (227.47ha)
rangeland (162.17ha)
forest plantation (238.28ha)
natural forest (273.28ha)
Springs
Districts
Sectors
0
0.5
1
2 Km
484000
486000
488000
4825000
4822000
4819000

Figure 52: Spring recharge catchment 6 soil resilience map

Table 35: Spring recharge catchment 6 management measures coverage

Spring recharge catchment 6		
Measures	**Area Ha**	**% Area Covered**
Agroforestry+progressive terraces/cuttoff drains	251.81	64.81
Agroforestry+cuttoff drains/horizontal trenches	62.45	16.07
Agroforestry+radical terraces/gully treatment	74.29	19.12
Forest Plantation	238.66	61.42
Natural Forest	274.59	70.67

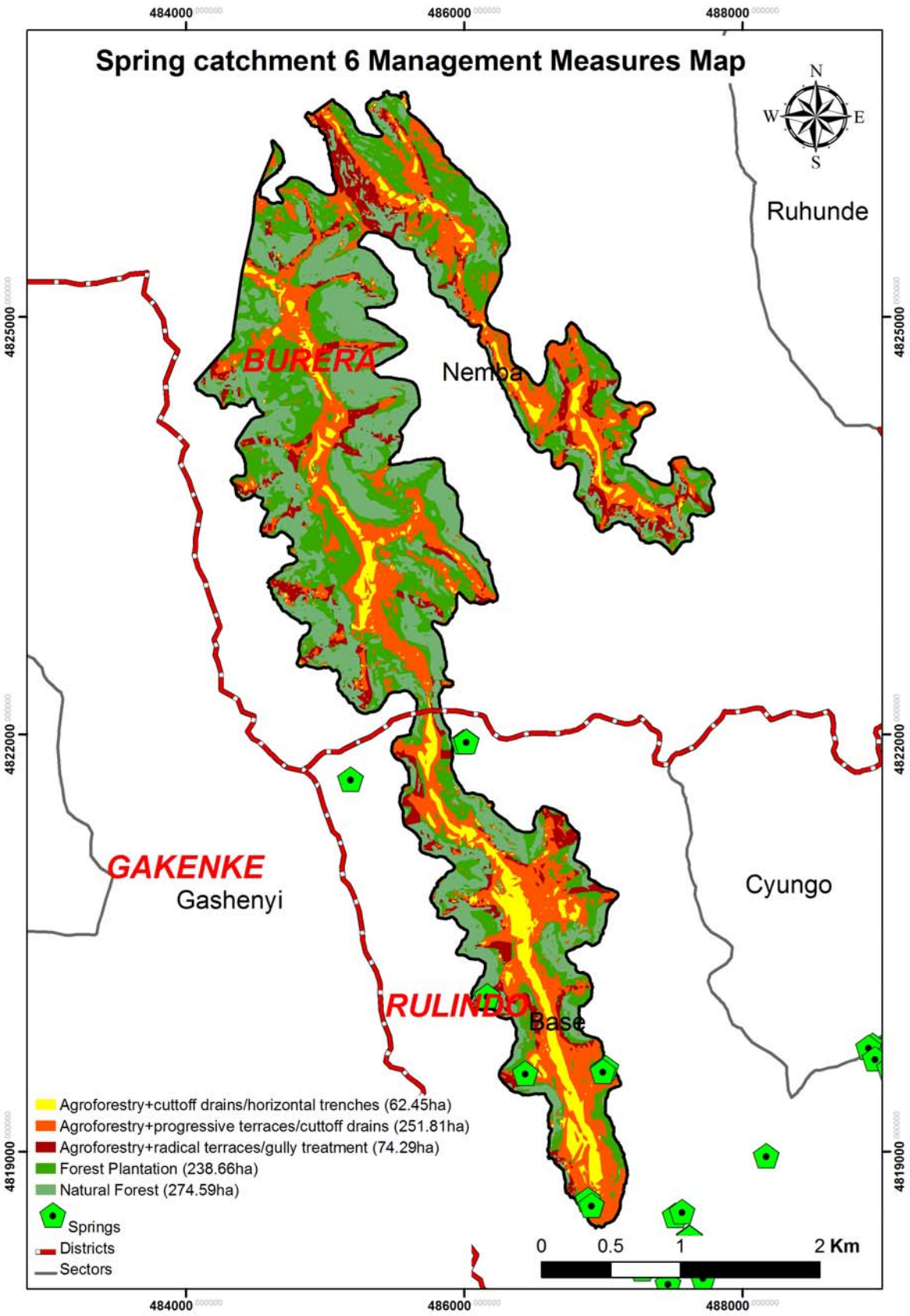

Spring catchment 6 Management Measures Map
N
W
E
S
Ruhunde
BURERA
Nemba
GAKENKE
Gashenyi
Cyungo
RULINDO
Base
484000
486000
488000
4825000
4822000
4819000
Agroforestry+cuttoff drains/horizontal trenches (62.45ha)
Agroforestry+progressive terraces/cuttoff drains (251.81ha)
Agroforestry+radical terraces/gully treatment (74.29ha)
Forest Plantation (238.66ha)
Natural Forest (274.59ha)
Springs
Districts
Sectors
0
0.5
1
2 Km

Figure 53: Spring recharge catchment 6 management measures map.

RWAMAHWA 1, 2 AND 3

The Rwamahwa water supply system was built in 1996 and was urgently used to supply the water to the nearby refugee camp that was located in the region by that time. For the three sources of Rwamahwa, there are no clear existences of spring catchment protection structures or delineation. Upslope of the two springs of Rwamahwa 1 and 2, there are a lot of Eucaryptus plantations which are located in the immediate catchment areas of the springs. However, these eucaryptus plantations are not recommended for use and neither suitable when planted in the immediate catchment area. Therefore, there is potential for these trees to uptake the spring water and may also destroy the water supply pipelines.

In addition, trenches are located along the hill of Rwamahwa sources with the main objective to conserve the soil and water which support vegetative growth upstream of Rwamahwa sources. There is however a need to rehabilitate the trenches as many of them are filled with the soil and increasing the trenches will be another option to protect the pipeline. In addition, to protect the existing pipelines, there is a need to install protection tube next to the pipe to prevent the fall of miscellaneous objects during the rainy season. In particular for Rwamahwa source 2 and 3, there is a need to slow the rainwater runoff which is too high and for that a water percolation pit in addition to trenches can be used. In brief, the three springs of Rwamahwa has a lot of water and needs a total rehabilitation for an adequate water supply.

Rwamahwa 1

Rwamahwa 2

Rwamahwa 3

Required activivties

- Maintenance of the existing trenches upstream of the spring catchment and establishment of water percolation pits.
- Total rehabilitation of the Rwamahwa spring water sources including the water tank

RUTARE 1

Rutare 1 is composed by two intakes originating from a rock. The upstream part is covered by a young forest plantation while the downstream part is used for agriculture activities. The immediate spring catchment is protected by Imihati. However it lacks the water diversion ditch.

Required activities

- The old trenches that in the forest need maintenance
- Water diversion ditch around the spring is necessary
- Upstream of the spring immediate catchment eucalyptus need to be cleared up to 20m

RUHO

Ruho spring is uncaptured spring that is used only by the local community. The upstream part from the location of the spring is used for agriculture activity and during the visit it was occupied by sorghum while the downstream part as well as the left part and right part of the spring are occupied by forest of eucalyptus. It is very important to document that the cultivated area is protected by progressive terraces with embankment stabilized by elephant grasses.

Required measures

- Capturing the spring
- Establishment of immediate spring catchment and fence it
- Establishment of water diversion ditch around the established spring immediate catchment
- Establishment of progressive terraces in upstream part where agricultural activities are taking place

RUTARE 2

This spring originate from a rock. Upstream of the spring is occupied by forest of eucalyptus. Like in Rutare 1 area, the downstream part of the spring is used for agriculture activities dominated by seasonal crops. As the water comes from the rock, the immediate spring catchment is small.

Required activities

- Clearance of upstream forest up to 20m
- Reinforcement of trenches in upstream forest
- Water diversion ditch around the immediate spring catchment

RUTARE 3

A.1.5 Spring recharge catchment 7

The spring recharge catchment 7 has an area of 361.85 ha and it is located in the districts of Rulindo, Gakenke and Burera. The recharge catchment lies in the sectors of Base, Gashenyi and Nemba. The recharge catchment has only 1 spring source which is not captured. The resulting maps based on the above classification are presented below.

Table 36: Spring recharge catchment 7 slope coverage

Spring recharge catchment 7		
slope class	**Area Ha**	**% of Area Covered**
0-6%	16.46	4.55
6-16%	35.36	9.77
16-40%	129.92	35.90
40-60%	115.29	31.86
>60%	64.82	17.91

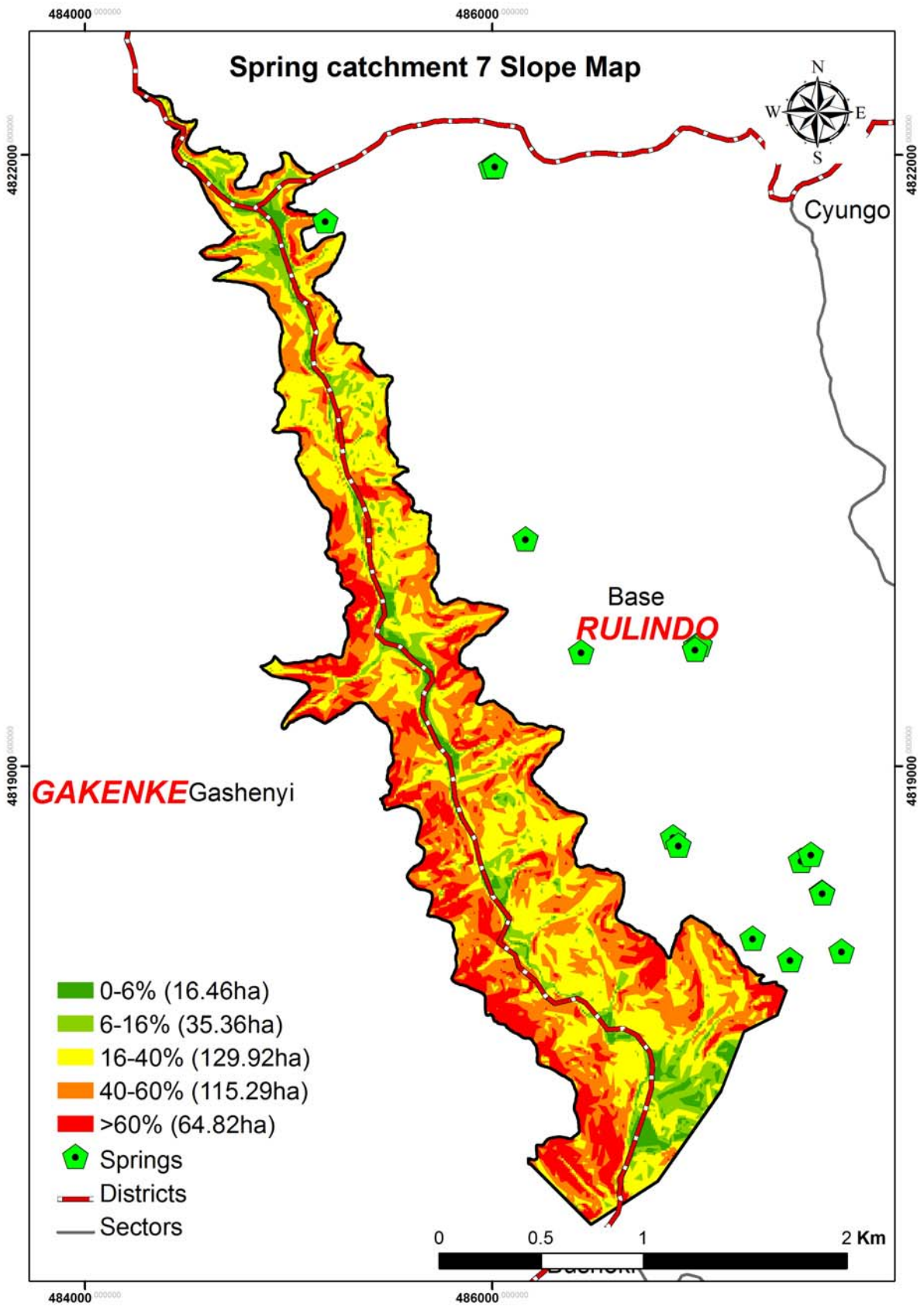

Spring catchment 7 Slope Map
N
W
E
S
484000
486000
4822000
4819000
Cyungo
Base
RULINDO
GAKENKE
Gashenyi
0-6% (16.46ha)
6-16% (35.36ha)
16-40% (129.92ha)
40-60% (115.29ha)
>60% (64.82ha)
Springs
Districts
Sectors
0
0.5
1
2 Km

Figure 54: Spring recharge catchment 7 slope map

Table 37: Spring recharge catchment 7 soil depth coverage

Spring recharge catchment 7		
soil depth	**Area Ha**	**% of Area covered**
<0.5m	42.41	11.72
0.5-1.0m	0.00	0.00
>1.0m	319.44	88.28

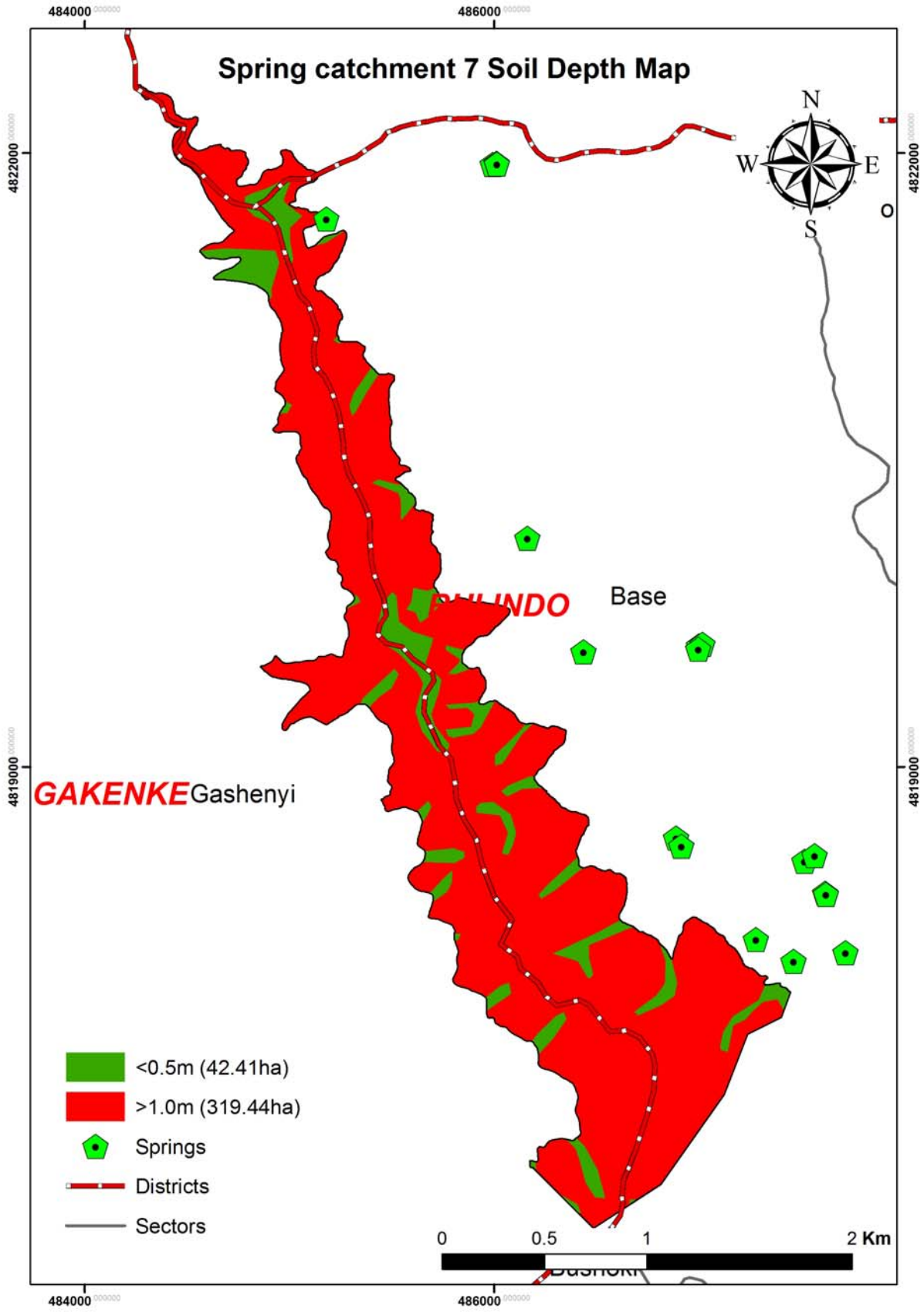

Spring catchment 7 Soil Depth Map
484000
486000
4822000
4819000
N
W
E
S
Base
GAKENKE Gashenyi
<0.5m (42.41ha)
>1.0m (319.44ha)
Springs
Districts
Sectors
0
0.5
1
2 Km

Figure 55: Spring recharge catchment 7 soil depth map

Table 38: Spring recharge catchment 7 resilience unit coverage

Spring recharge catchment 7		
resilience	**Area Ha**	**% of Area Covered**
cropland	157.94	43.65
forest plantation	102.22	28.25
natural forest	64.83	17.92
rangeland	36.87	10.19

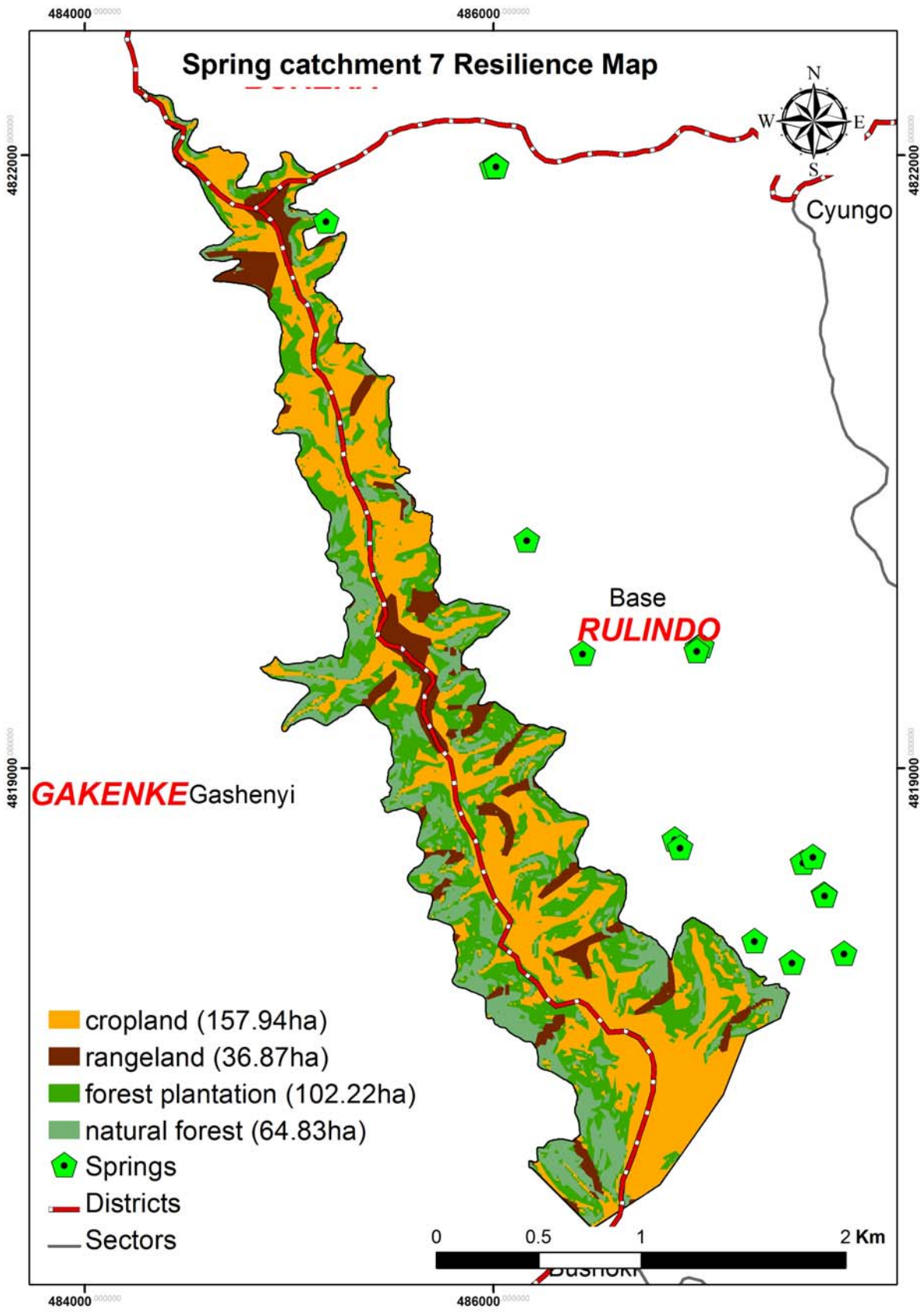

Spring catchment 7 Resilience Map
484000
486000
4822000
4819000
N
W
E
S
Cyungo
Base
RULINDO
GAKENKE
Gashenyi
cropland (157.94ha)
rangeland (36.87ha)
forest plantation (102.22ha)
natural forest (64.83ha)
Springs
Districts
Sectors
0
0.5
1
2 Km

Figure 56: Spring recharge catchment 7 soil resilience map

Table 39: Spring recharge catchment 7 management measures coverage

Spring recharge catchment 7		
Measures	**Area Ha**	**% Area Covered**
Agroforestry+progressive terraces/cuttoff drains	129.74	66.76
Agroforestry+cuttoff drains/horizontal trenches	52.20	26.86
Agroforestry+radical terraces/gully treatment	12.41	6.39
Forest Plantation	102.54	52.76
Natural Forest	64.96	33.43

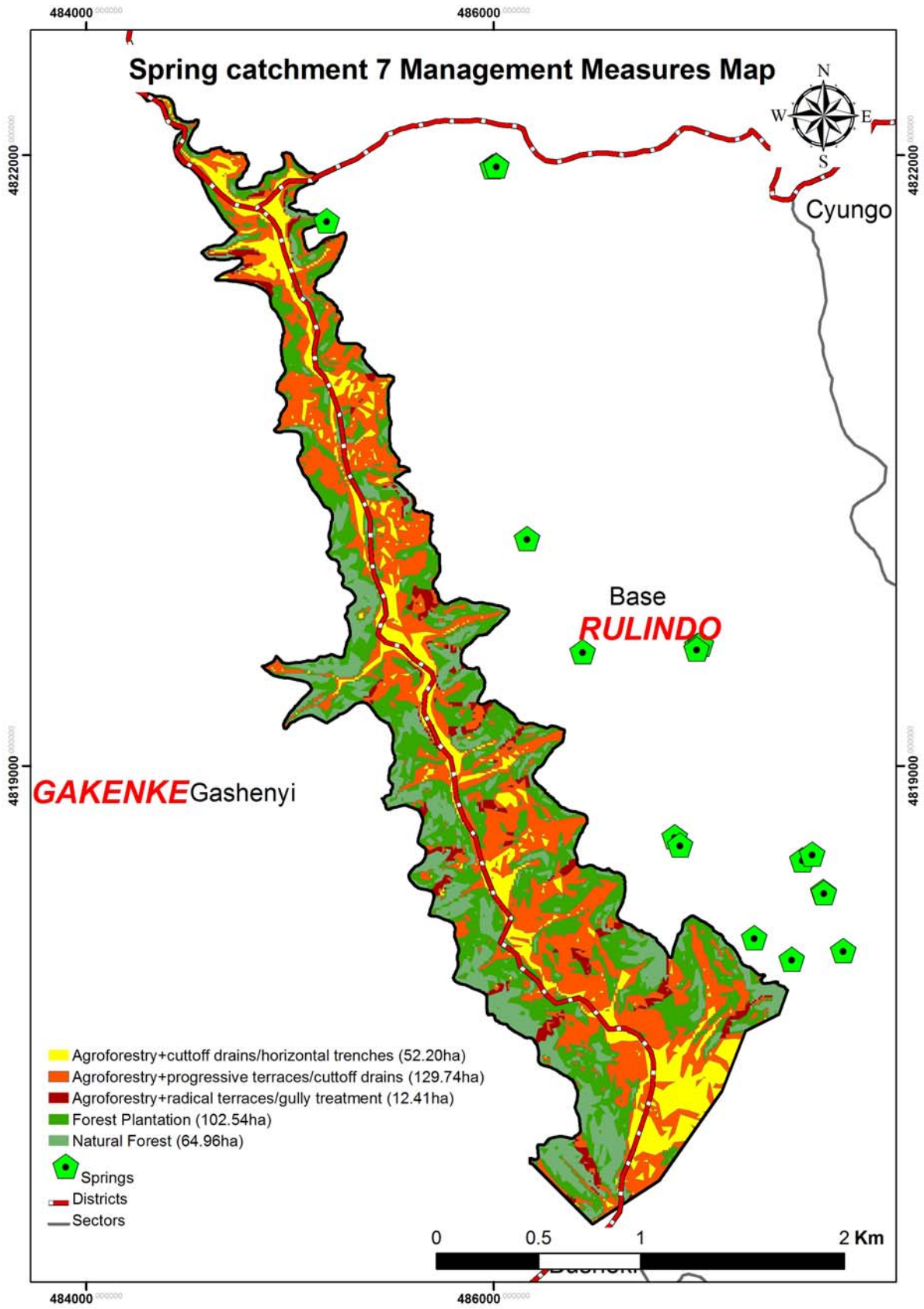

Spring catchment 7 Management Measures Map
N
W
E
S
484000
486000
4822000
4819000
Cyungo
Base
RULINDO
GAKENKE
Gashenyi
Agroforestry+cuttoff drains/horizontal trenches (52.20ha)
Agroforestry+progressive terraces/cuttoff drains (129.74ha)
Agroforestry+radical terraces/gully treatment (12.41ha)
Forest Plantation (102.54ha)
Natural Forest (64.96ha)
Springs
Districts
Sectors
0
0.5
1
2 Km

Figure 57: Spring recharge catchment 7 management measures map

RURAMBA

Table 40: Spring recharge catchment 8 slope coverage

Spring recharge catchment 8		
slope class	**Area Ha**	**% of Area Covered**
0-6%	36.49	15.18
6-16%	52.10	21.68
16-40%	82.76	34.43
40-60%	43.64	18.16
>60%	25.35	10.55

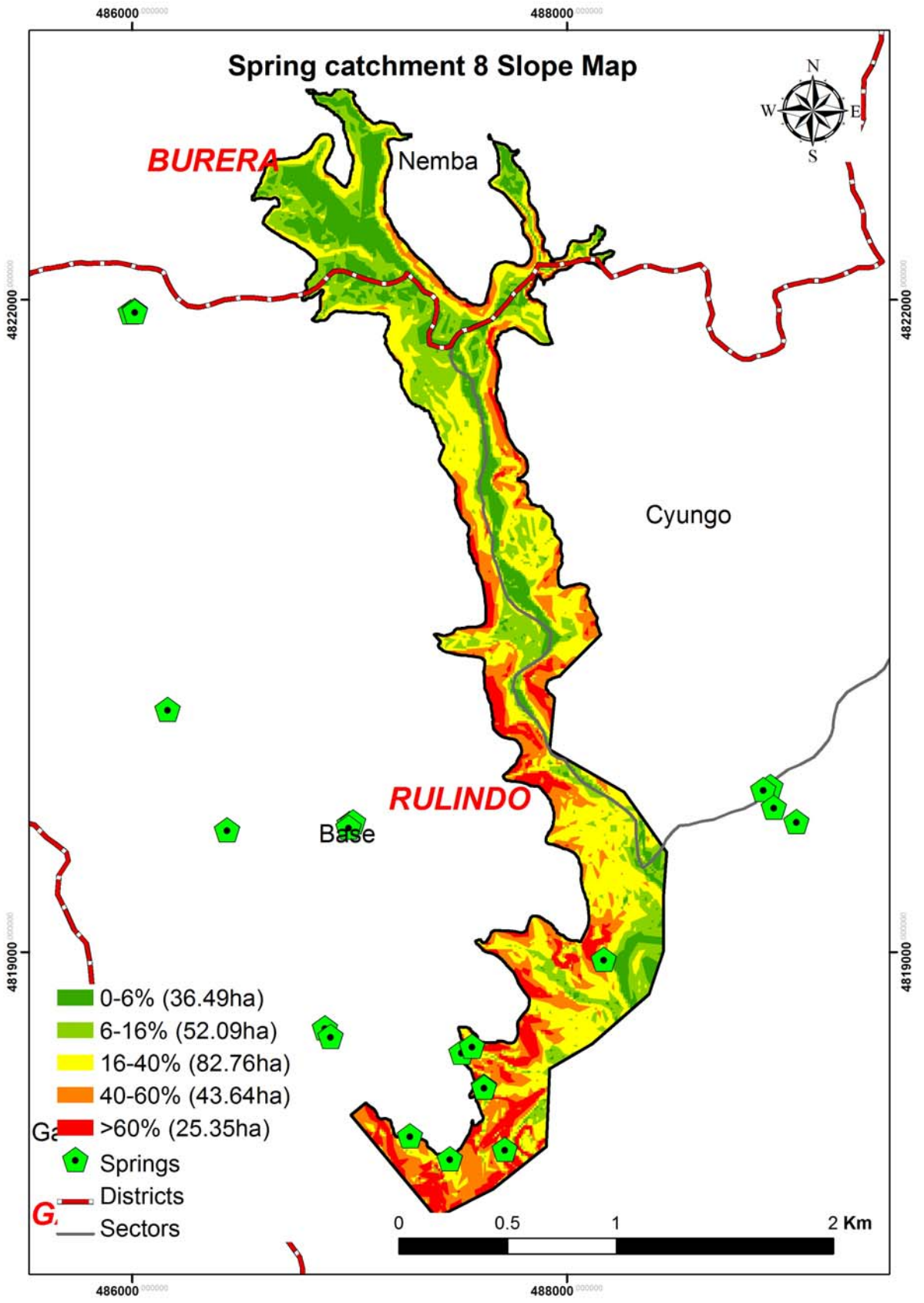

Spring catchment 8 Slope Map
N
W
E
S
BURERA
Nemba
Cyungo
RULINDO
Base
486000
488000
4822000
4819000
0-6% (36.49ha)
6-16% (52.09ha)
16-40% (82.76ha)
40-60% (43.64ha)
>60% (25.35ha)
Springs
Districts
Sectors
0
0.5
1
2 Km

Figure 58: Spring recharge catchment 8 slope map

A.1.6 Spring recharge catchment 8

The spring recharge catchment 8 has an area of 240.34 ha. The recharge catchment is located within the Districts of Rulindo and Burera. It lies within the Sectors of Base, Cyungo and Nemba. The recharge catchment has eight spring sources of which one is not captured, three are captured and four are newly identified, i.e. added to the existing list of WFP. The resulting maps based on the above classification are presented below.

Table 41: Spring recharge catchment 8 soil depth coverage

Spring recharge catchment 8		
soil depth	**Area Ha**	**% of Area covered**
<0.5m	93.06	38.72
0.5 - 1.0m	79.55	33.10
>1.0m	67.73	28.18

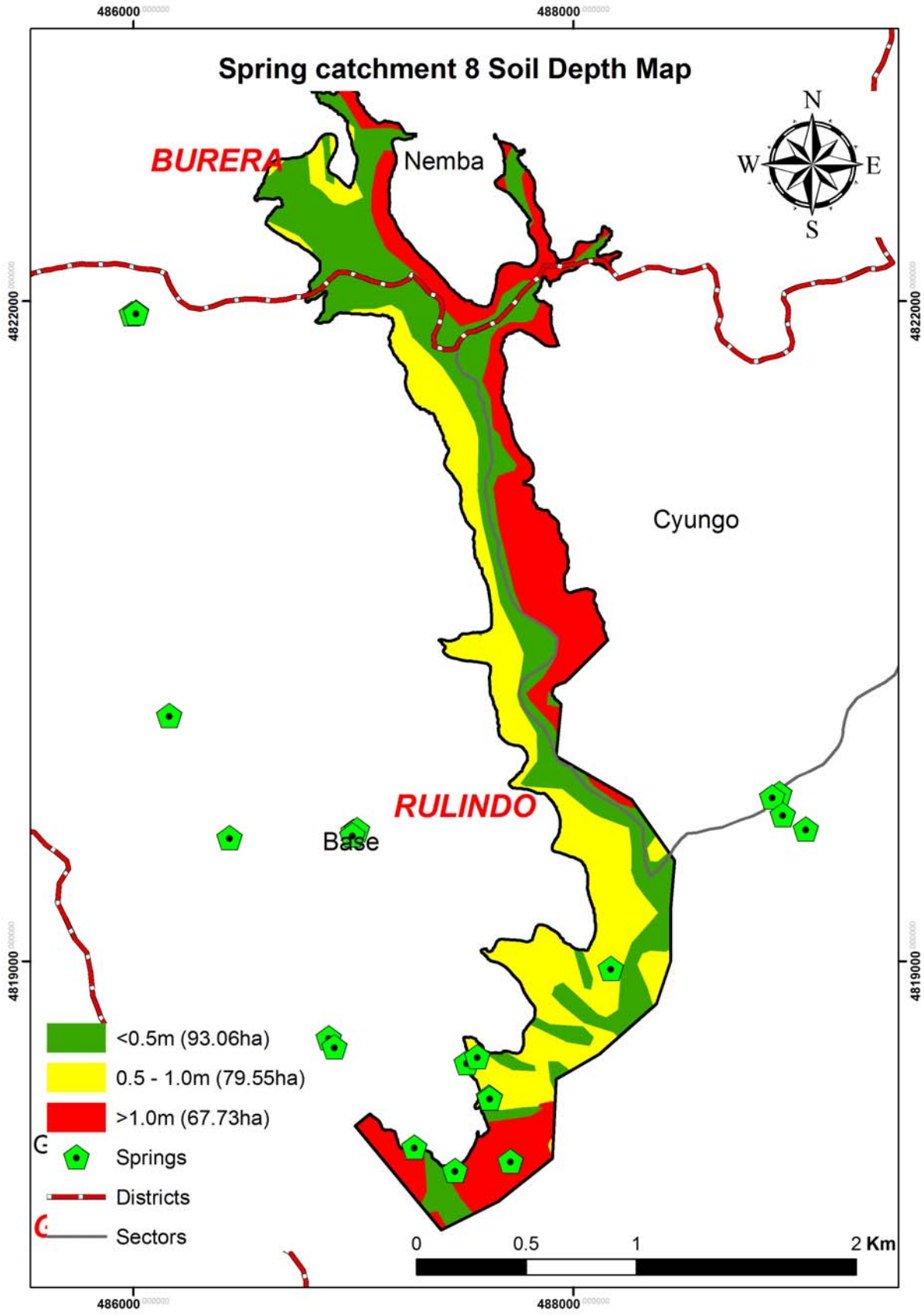

Spring catchment 8 Soil Depth Map
BURERA
Nemba
Cyungo
RULINDO
Base
N
W
E
S
486000
488000
4822000
4819000
<0.5m (93.06ha)
0.5 - 1.0m (79.55ha)
>1.0m (67.73ha)
Springs
Districts
Sectors
0
0.5
1
2 Km

Figure 59: Spring recharge catchment 8 soil depth map

Table 42: Spring recharge catchment 8 resilience unit coverage

Spring recharge catchment 8		
resilience	**Area Ha**	**% of Area Covered**
cropland	89.40	37.20
forest plantation	36.93	15.37
natural forest	25.23	10.50
rangeland	88.78	36.94

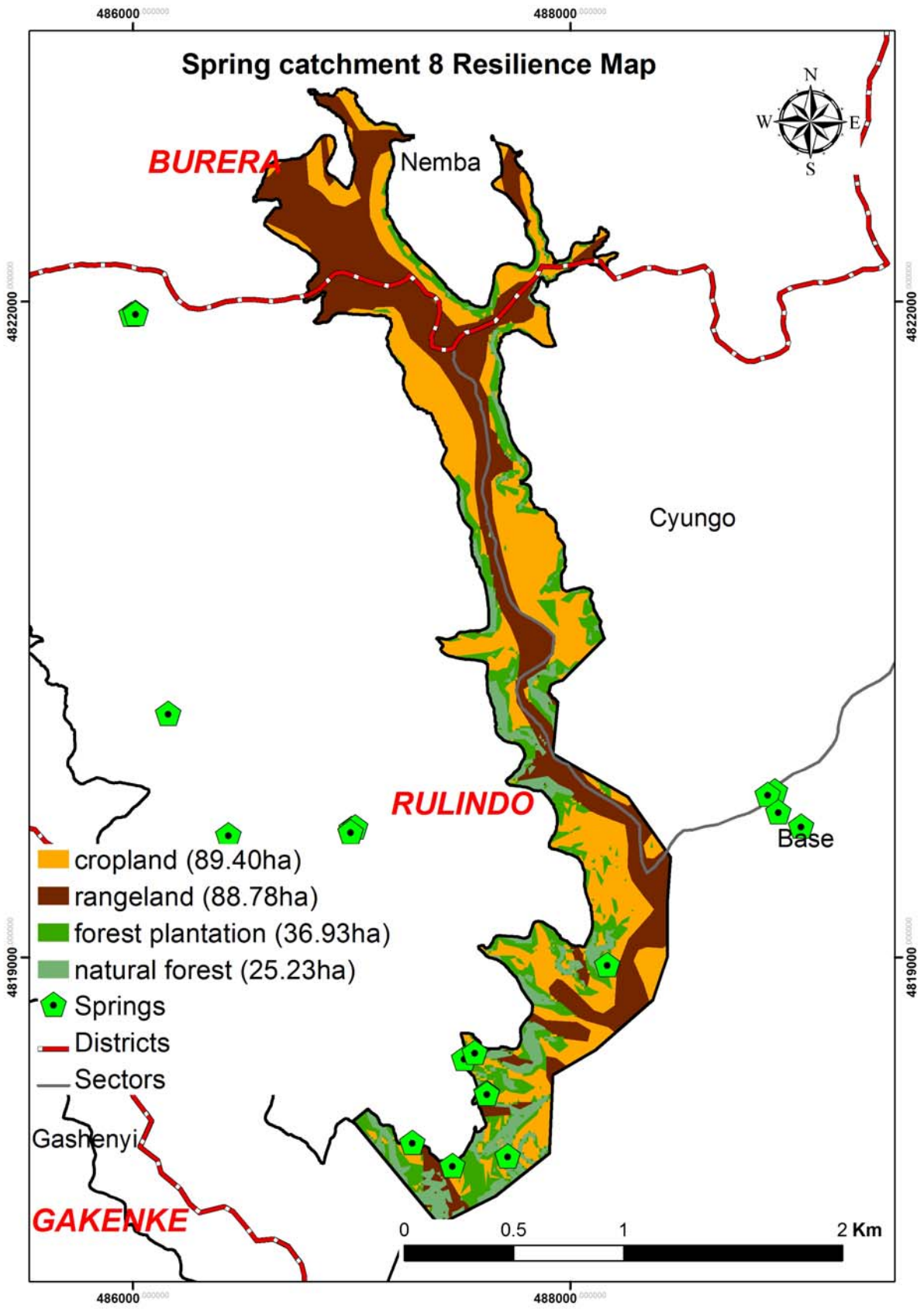

Spring catchment 8 Resilience Map
N
W
E
S
BURERA
Nemba
Cyungo
RULINDO
Base
Gashenyi
GAKENKE
cropland (89.40ha)
rangeland (88.78ha)
forest plantation (36.93ha)
natural forest (25.23ha)
Springs
Districts
Sectors
0
0.5
1
2 Km
486000
488000
4822000
4819000

Figure 60: Spring recharge catchment 8 soil resilience map

Table 43: Spring recharge catchment 8 management measures coverage

Spring recharge catchment 8		
Measures	**Area Ha**	**% Area Covered**
Agroforestry+progressive terraces/cuttoff drains	82.36	46.27
Agroforestry+cuttoff drains/horizontal trenches	89.06	50.04
Agroforestry+radical terraces/gully treatment	6.56	3.69
Forest Plantation	36.92	20.75
Natural Forest	25.42	14.28

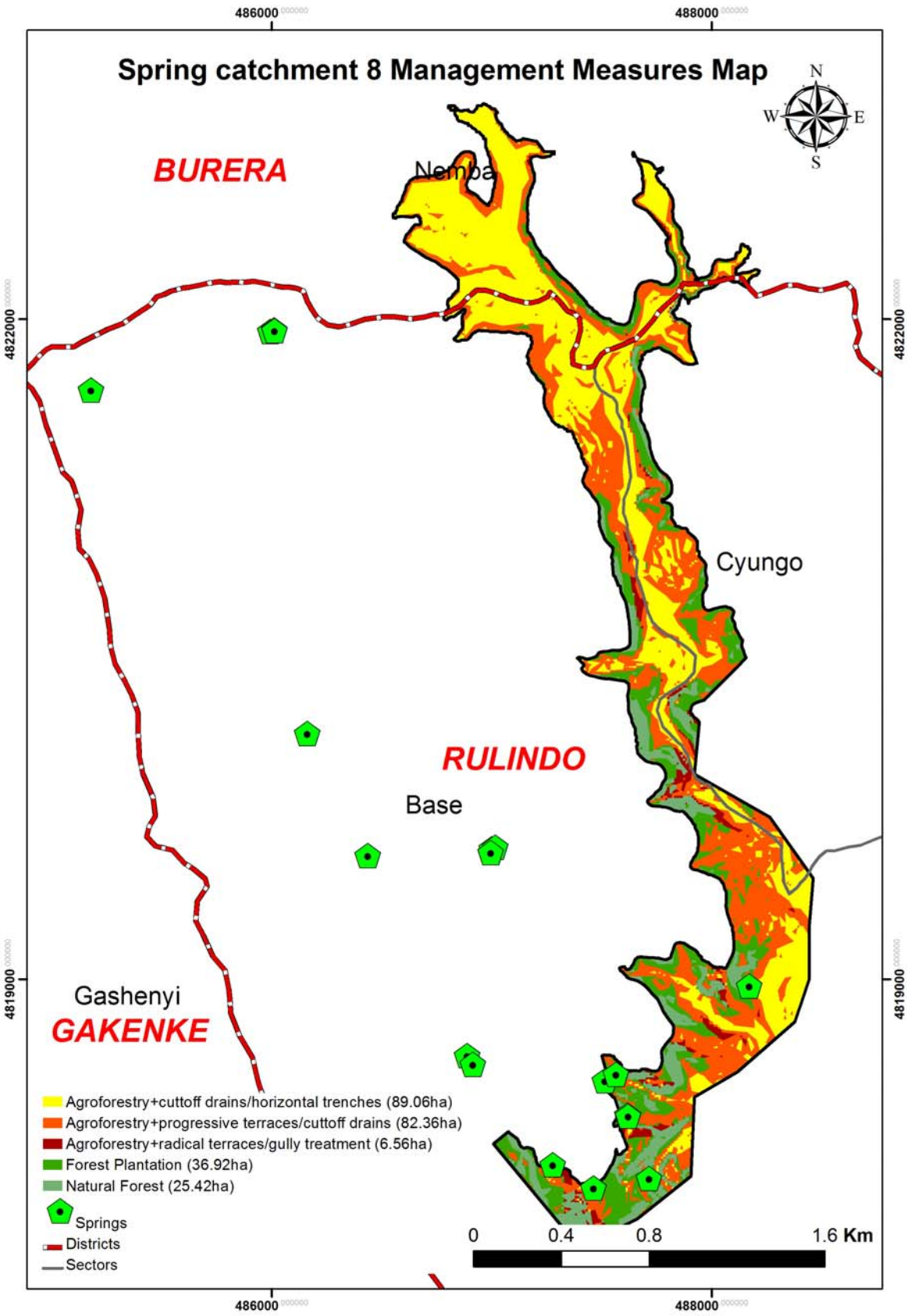

Spring catchment 8 Management Measures Map
N
W
E
S
BURERA
Nemba
Cyungo
RULINDO
Base
Gashenyi
GAKENKE
486000
488000
4822000
4819000
Agroforestry+cuttoff drains/horizontal trenches (89.06ha)
Agroforestry+progressive terraces/cuttoff drains (82.36ha)
Agroforestry+radical terraces/gully treatment (6.56ha)
Forest Plantation (36.92ha)
Natural Forest (25.42ha)
Springs
Districts
Sectors
0
0.4
0.8
1.6 Km

Figure 61: Spring recharge catchment 8 management measures map

RUTEMBE 1 AND RUTEMBE 2

The Rutembe 1 is a spring serving an old distribution system located in Base centre downhill at 1776 m asl. At Rutembe 1, there are no fences that delineate the direct spring catchment and the spring is located next to a small channel where people are passing. The pipelines are exposed with a lot of leakages and consequently this spring need a complete rehabilitation. The threat to this spring is very real as it is located next to human settlement with potential contaminants such as pit latrines and wastewater upslope from the spring outlet. Therefore, settlements may introduce a whole series of contaminants that are not present in natural systems.

Besides, the Rutembe 2 spring is located at the middle hill at 1753 m asl in the eucalyptus plantation. The spring will also serve the Base centre water supply system and was still under rehabilitation during the February 2016 field trip. The spring catchment is well protected with Imihate fences but also need to be planted with passparum.

Required activities:

- Establishment of a water diversion ditch around the immediate spring catchment for Rutembe 1 and Rutembe 2 springs
- Total rehabilitation of Rutembe 1 and a regular monitoring of this spring

- Introduce passparum plantations for the two springs

RUGARAGARA

The Rugaragara spring is uncaptured and located next to Base River and surrounded by eucalyptus forest. Upstream of the spring there is a recharge forest and there are no settlements at least in 200 m. Given its location, far from the human activities and the livestock, it could be hypothesised that there are no potential contaminant source at the direct spring catchment and discharge area. It is however necessary to provide fences in order to ensure the protection of the spring.

KIDOGO

This area called Kidogo contains three springs that can be combined in one water supply system. Two of them originate downstream of the forest and the third one is surrounded by the agricultural activities dominated by seasonal crops.

As shown by the photos above, these springs were captured by the local population and their surroundings are not maintained.

Required activities:

- Rehabilitation of trenches in the forested areas
- Establishment of a spring immediate catchment
- Establishment of water diversion way around the spring immediate catchment
- Establishment of terraces in cultivated areas next to the spring

KABINGO 1

The Kabingo 1 spring is located at 1795 m asl in eucalyptus forest plantation. The spring was still under rehabilitation during the field trip of February 2016. The spring catchment is well protected with Imihate but there is a need to clean the neighbouring forest for a distance of at least 10 m. In addition, to protect the direct catchment area, passparum should be planted in the area.

The Kabingo 2 source is located at 1804 m asl and is surrounded by agriculture activities and there is no clear spring catchment area. This source is neighbouring settlements that may introduce contaminants mainly from pit latrines. Upslope of Kabingo 2 source they are Eucalyptus plantations and human settlements.

Required activities:

- Clean the neighbouring forest of Kabingo 1 source at 10 m of distance from the direct catchment area to avoid the spring disruption by the root systems
- Delineate the spring catchment area for Kabingo 2
- Establishment a water diversion ditch around the immediate spring catchment for the two springs

RUJENERI

The Rujeneri water source is a small spring located downslope of the Eucalyptus forest. This spring was not captured and was not on the list of the inventoried water sources by WFP. The water from Rujeneri spring is currently being used by the nearby population. To be used as a water fountain, this spring will need a total rehabilitation and proper water capturing in remediation of the current leakages at the source.

A.1.7 Spring recharge catchment 9

The spring recharge catchment 9 has an area of 282.15 ha. It is fully located in the District of Rulindo. It lies in 4 Sectors known as Mbogo, Ngoma,Rusiga and Shyorongi. The recharge catchment has 1 spring source which is not captured. The resulting maps based on the above classification are presented below.

Table 44: Spring recharge catchment 9 slope coverage

Spring recharge catchment 9		
slope class	**Area Ha**	**% of Area Covered**
0-6%	42.37	15.02
6-16%	73.65	26.10
16-40%	124.65	44.18
40-60%	34.69	12.29
>60%	6.79	2.41

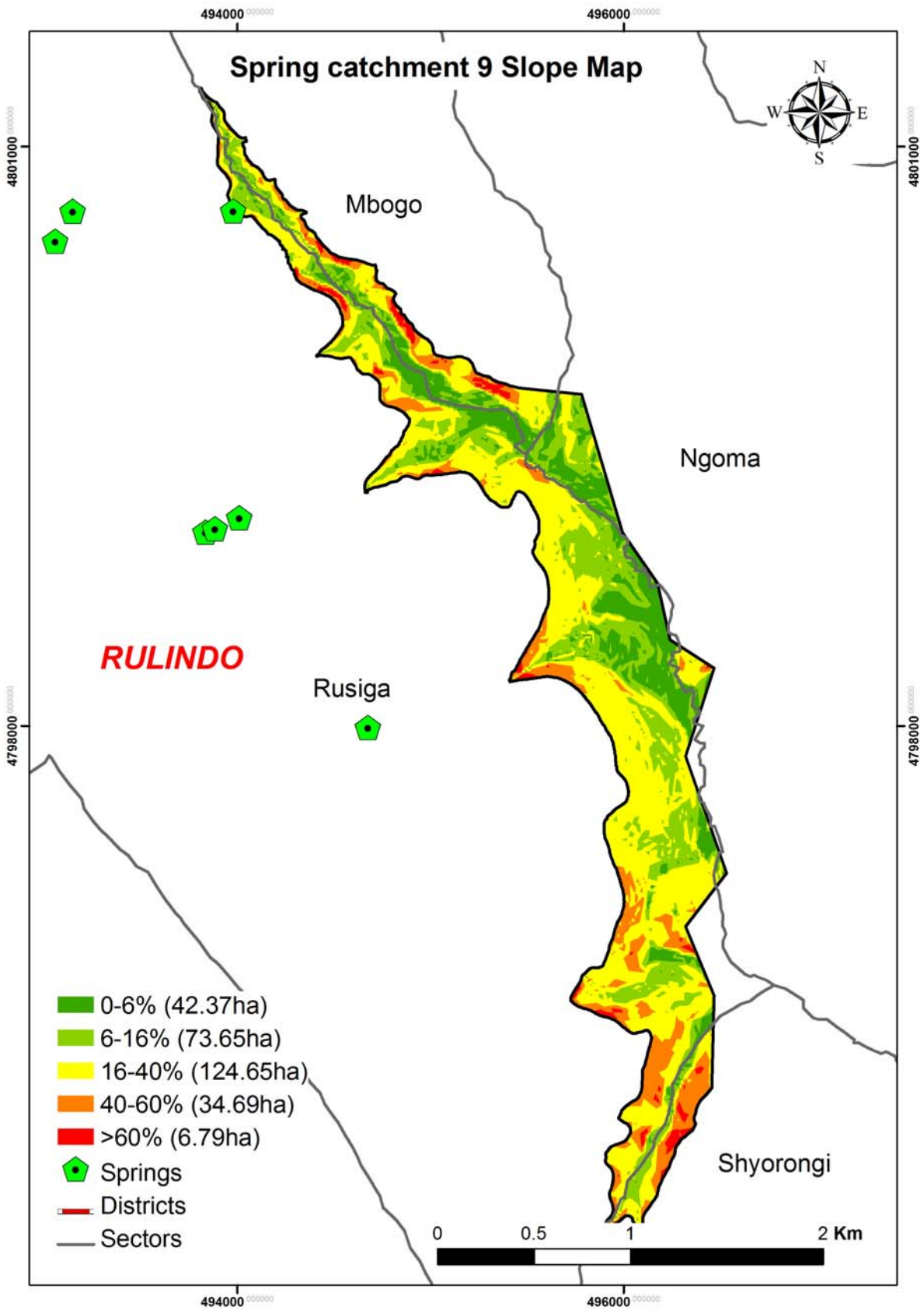

Spring catchment 9 Slope Map
N
W
E
S
494000
496000
4801000
4798000
Mbogo
Ngoma
RULINDO
Rusiga
Shyorongi
0-6% (42.37ha)
6-16% (73.65ha)
16-40% (124.65ha)
40-60% (34.69ha)
>60% (6.79ha)
Springs
Districts
Sectors
0
0.5
1
2 Km

Figure 62: Spring recharge catchment 9 slope map

Table 45: Spring recharge catchment 9 soil depth coverage

Spring recharge catchment 9		
soil depth	**Area Ha**	**% of Area covered**
<0.5m	87.91	31.16
0.5 - 1.0m	132.51	46.96
>1.0m	61.73	21.88

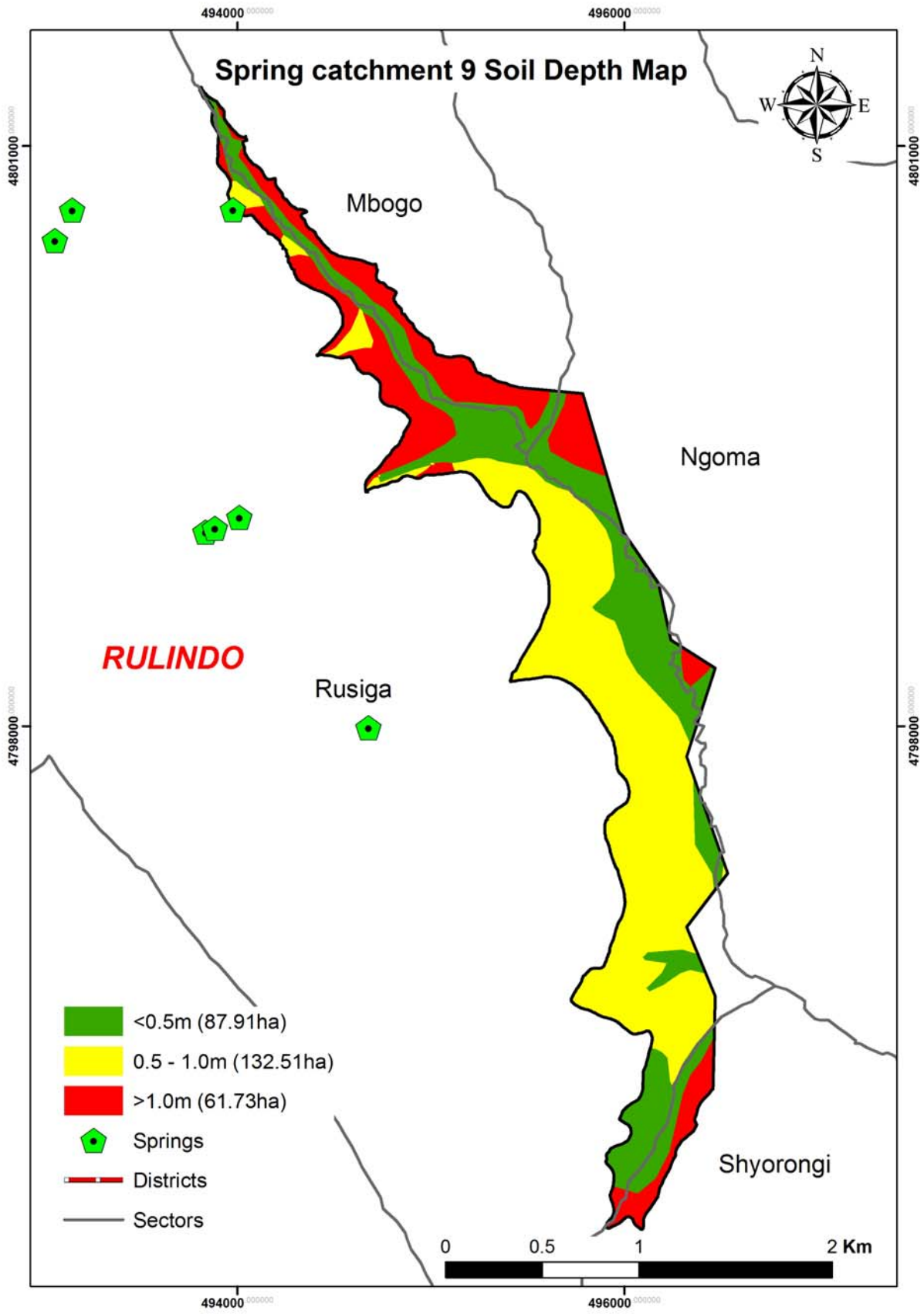

Spring catchment 9 Soil Depth Map
N
W
E
S
494000
496000
4801000
4798000
Mbogo
Ngoma
RULINDO
Rusiga
Shyorongi
<0.5m (87.91ha)
0.5 - 1.0m (132.51ha)
>1.0m (61.73ha)
Springs
Districts
Sectors
0
0.5
1
2 Km

Figure 63: Spring recharge catchment 9 soil depth map

Table 46: Spring recharge catchment 9 resilience unit coverage

Spring recharge catchment 9		
resilience	**Area Ha**	**% of Area Covered**
cropland	159.98	56.70
forest plantation	28.10	9.96
natural forest	6.77	2.40
rangeland	87.29	30.94

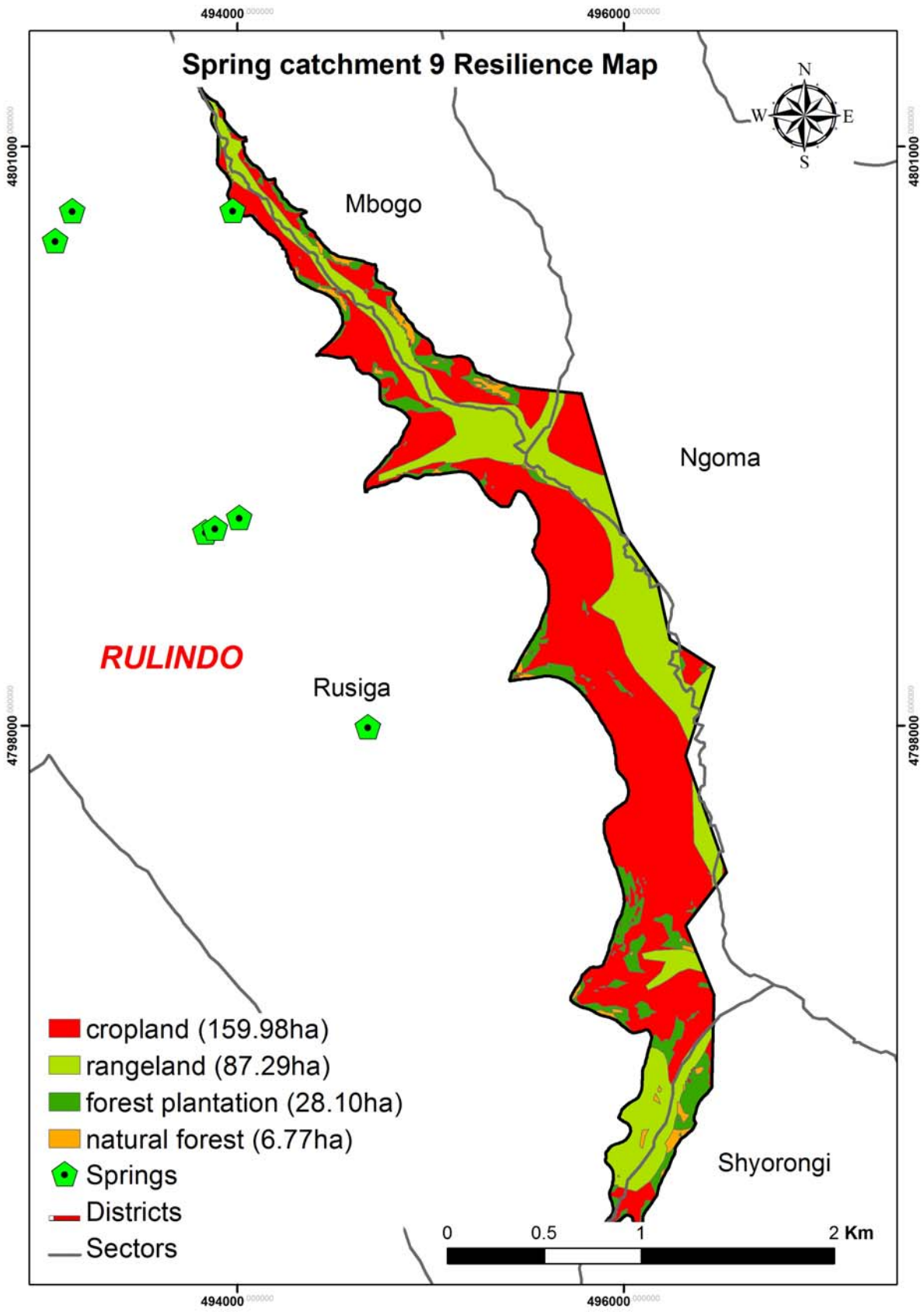

Spring catchment 9 Resilience Map
494000
496000
4801000
4798000
N
W
E
S
Mbogo
Ngoma
RULINDO
Rusiga
Shyorongi
cropland (159.98ha)
rangeland (87.29ha)
forest plantation (28.10ha)
natural forest (6.77ha)
Springs
Districts
Sectors
0
0.5
1
2 Km

Figure 64: Spring recharge catchment 9 soil resilience map

Table 47: Spring recharge catchment 9 management measures coverage

Spring recharge catchment 9		
Measures	**Area Ha**	**% Area Covered**
Agroforestry+progressive terraces/cuttoff drains	124.37	50.33
Agroforestry+cuttoff drains/horizontal trenches	116.36	47.09
Agroforestry+radical terraces/gully treatment	6.37	2.58
Forest Plantation	28.20	11.41
Natural Forest	6.84	2.77

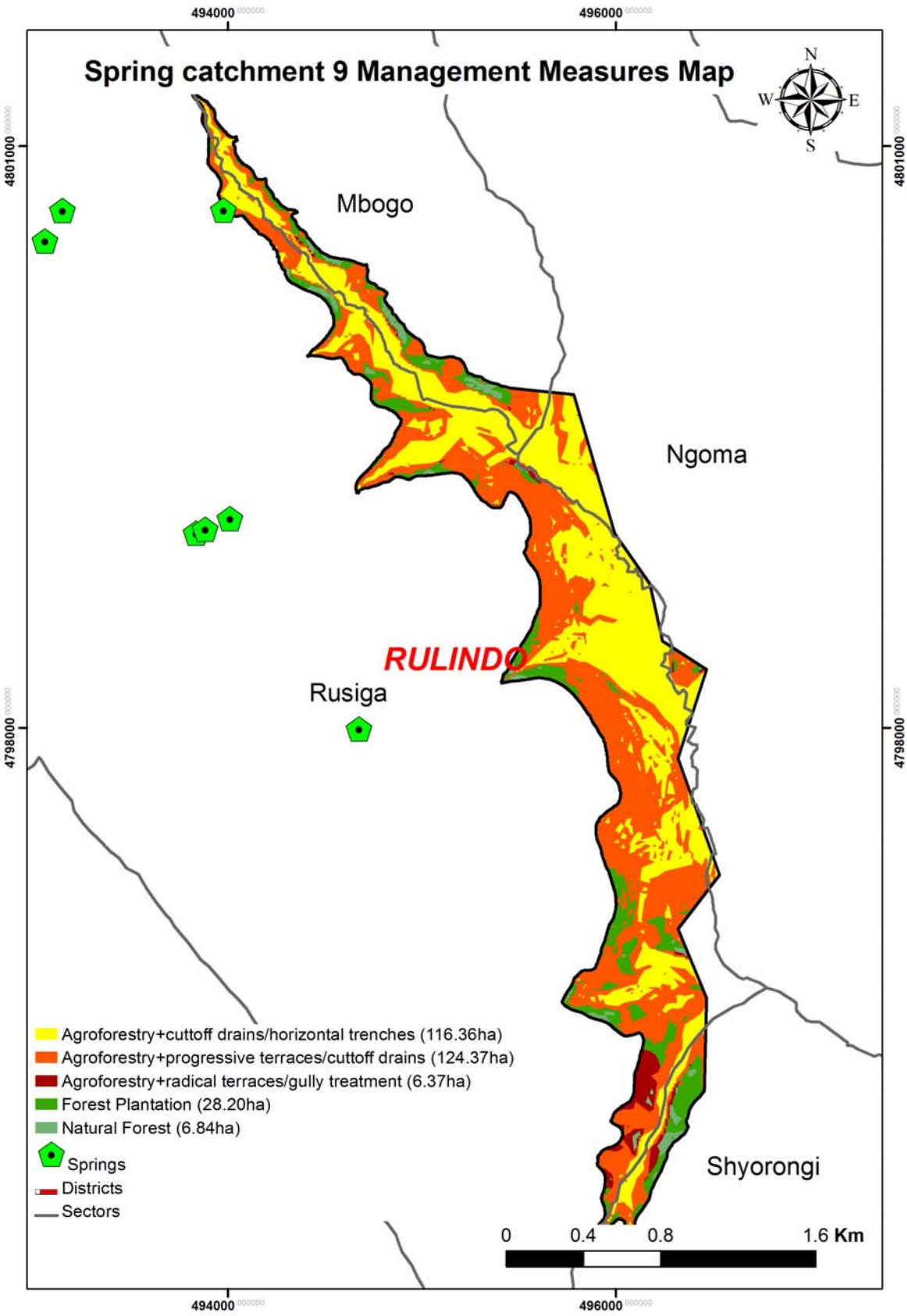

Spring catchment 9 Management Measures Map
N
W
E
S
494000
496000
4801000
4798000
Mbogo
Ngoma
RULINDO
Rusiga
Shyorongi
Agroforestry+cuttoff drains/horizontal trenches (116.36ha)
Agroforestry+progressive terraces/cuttoff drains (124.37ha)
Agroforestry+radical terraces/gully treatment (6.37ha)
Forest Plantation (28.20ha)
Natural Forest (6.84ha)
Springs
Districts
Sectors
0
0.4
0.8
1.6 Km

Figure 65: Spring recharge catchment 9 management measures map

A.1.8 Spring recharge catchment 10

The spring recharge catchment 10 is the smallest recharge catchment delineated in this study. It has an area of 84.88 ha. The recharge catchment is fully located in the Rulindo District and lies within two sectors known as Base and Cyungo. It has four spring sources of which two are not captured, one is captured and one is newly identified. The resulting maps based on the above classification are presented below.

Table 48: Spring recharge catchment 10 slope coverage

Spring recharge catchment 10		
slope class	**Area Ha**	**% of Area Covered**
0-6%	14.06	16.56
6-16%	21.99	25.91
16-40%	31.39	36.99
40-60%	12.87	15.16
>60%	4.56	5.37

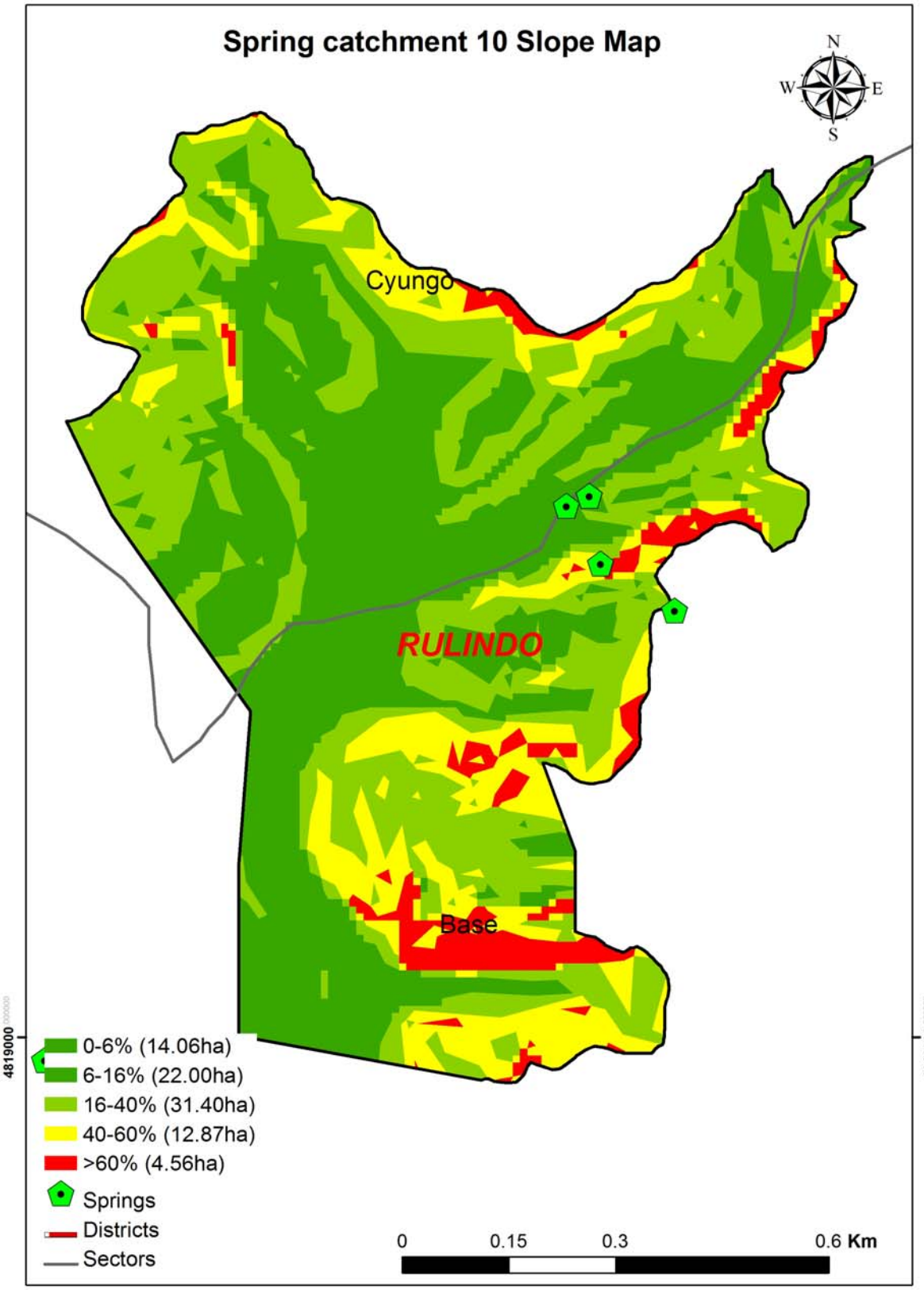

Spring catchment 10 Slope Map
N
W
E
S
Cyungo
RULINDO
Base
4819000
4819000
0-6% (14.06ha)
6-16% (22.00ha)
16-40% (31.40ha)
40-60% (12.87ha)
>60% (4.56ha)
Springs
Districts
Sectors
0
0.15
0.3
0.6 Km

Figure 66: Spring recharge catchment 10 slope map

Table 49: Spring recharge catchment 10 soil depth coverage

Spring recharge catchment 10		
soil depth	**Area Ha**	**% of Area covered**
<0.5m	39.62	46.67
0.5 - 1.0m	21.65	25.50
>1.0m	23.61	27.82

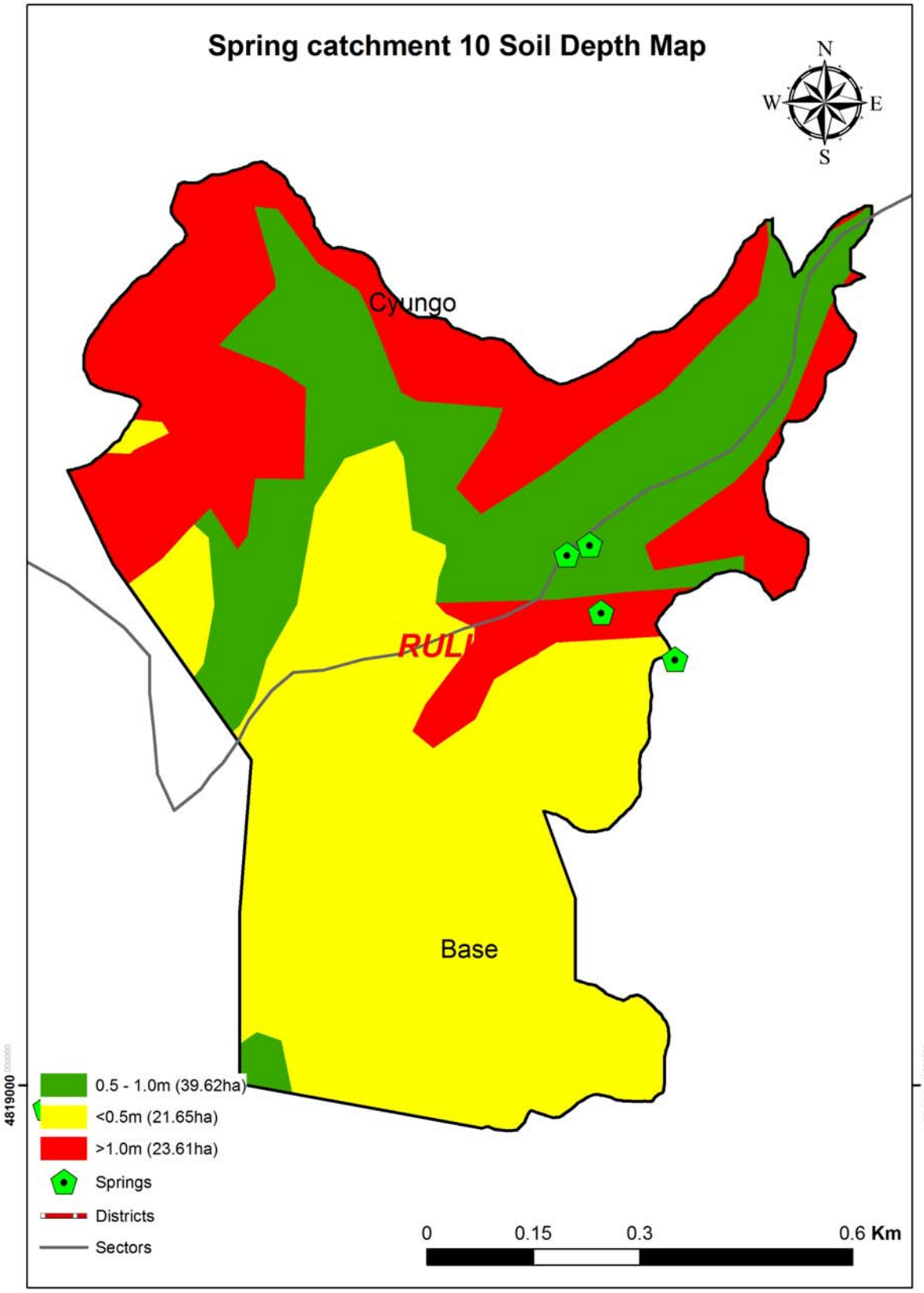

Spring catchment 10 Soil Depth Map
N
W
E
S
Cyungo
RULI
Base
4819000
4819000
0.5 - 1.0m (39.62ha)
<0.5m (21.65ha)
>1.0m (23.61ha)
Springs
Districts
Sectors
0
0.15
0.3
0.6 Km

Figure 67: Spring recharge catchment 10 soil depth map

Table 50: Spring recharge catchment 10 resilience unit coverage

Spring recharge catchment 10		
resilience	**Area Ha**	**% of Area Covered**
cropland	38.22	45.03
forest plantation	5.33	6.28
natural forest	4.53	5.33
rangeland	36.80	43.36

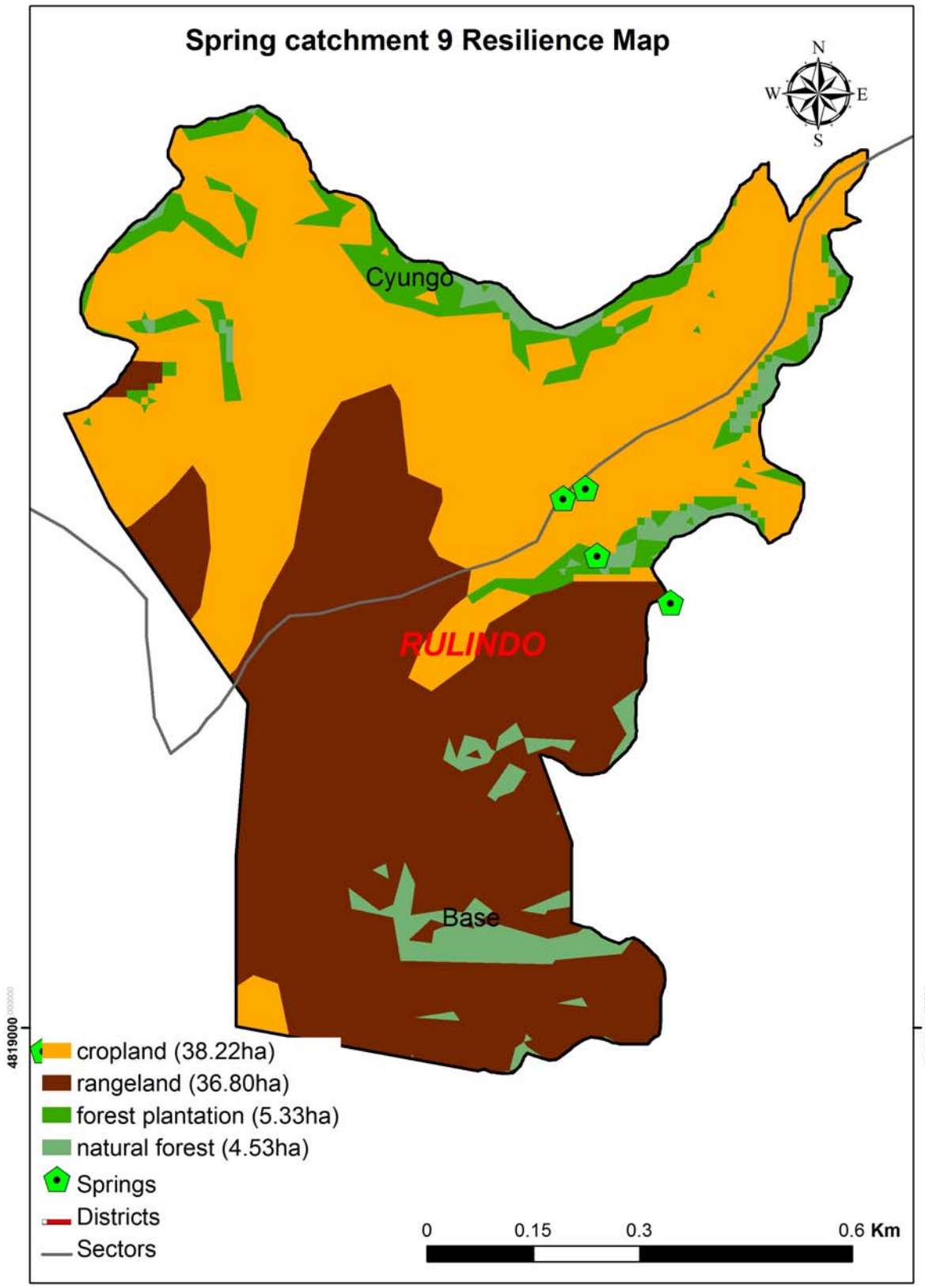

Spring catchment 9 Resilience Map
N
W
E
S
Cyungo
RULINDO
Base
4819000
4819000
cropland (38.22ha)
rangeland (36.80ha)
forest plantation (5.33ha)
natural forest (4.53ha)
Springs
Districts
Sectors
0
0.15
0.3
0.6 Km

Figure 68: Spring recharge catchment 10 soil resilience map

Table 51: Spring recharge catchment 10 management measures coverage

Spring recharge catchment 10		
Measures	**Area Ha**	**% Area Covered**
Agroforestry+progressive terraces/cuttoff drains	31.09	41.39
Agroforestry+cuttoff drains/horizontal trenches	36.37	48.42
Agroforestry+radical terraces/gully treatment	7.66	10.20
Forest Plantation	5.21	6.93
Natural Forest	4.56	6.07

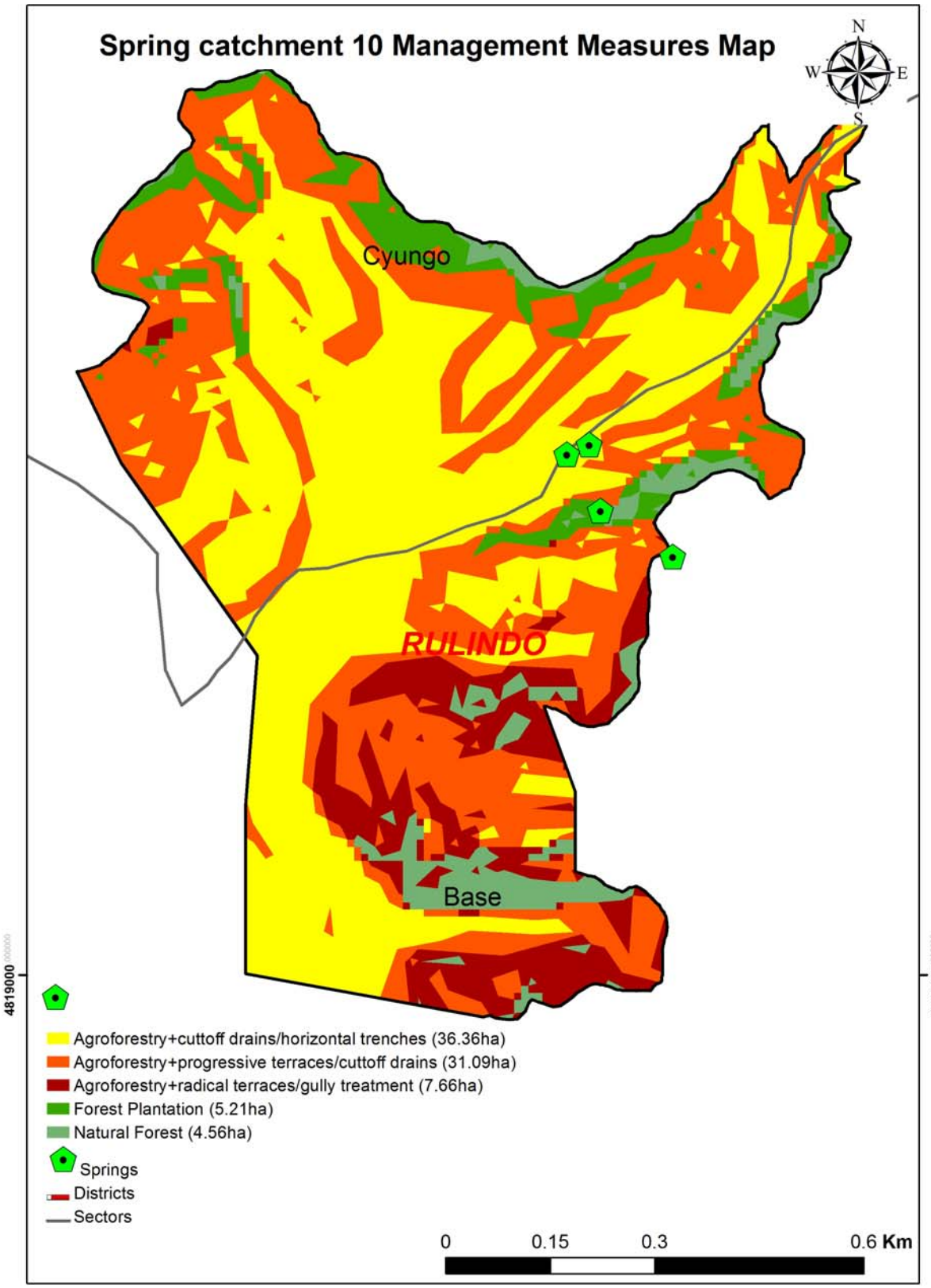

Spring catchment 10 Management Measures Map
N
W
E
S
Cyungo
RULINDO
Base
4819000
4819000
Agroforestry+cuttoff drains/horizontal trenches (36.36ha)
Agroforestry+progressive terraces/cuttoff drains (31.09ha)
Agroforestry+radical terraces/gully treatment (7.66ha)
Forest Plantation (5.21ha)
Natural Forest (4.56ha)
Springs
Districts
Sectors
0
0.15
0.3
0.6 Km

Figure 69: Spring recharge catchment 10 management measures map

MIGOGO

The four neighbouring springs called Migogo were identified in Base sector. The water of the first spring called Migogo 1 has been captured by a private operator and is located downhill in Banana plantations that cross the water capturing zone. There are no fences that delineate the water catchment zone for the four springs of Migogo and this should results in the direct spring contamination by the agriculture activities. In particular for Migogo 1, there is potential of diffuse pollution (for example, fertilisers leaching from land) which requires restricting land uses given the intense agriculture activities in the immediate catchment area.

The two springs of Migogo 2 and Migogo 3 are not captured and are located uphill in the Eucalyptus plantation and with grassland above the head of the springs. The inspection of the two springs upstream (catchment) has shown that there is no danger of pollution, however it is essential to insure that catchment fences are introduced. In addition, the area needs to have a cut-off drain to divert surface water. Another spring in the area is Migogo 4 which is located downhill west of the other Migogo springs. The Migogo 4 spring discharges from a rock and has been captured by the local population in a small tank of about 1.5 m^3. The water has been captured directly from the rock to the tank; however the tank is completely closed and can't be cleaned. To protect the Migogo 4 spring there is need to provide fences, especially due to the fact that people are collecting building stones next to the spring.

Required activivties :

- Provide fences that delineate the spring catchment zone for the four springs of Migogo
- Remove the banana plantation in the catchment zone of the Migogo 1 spring
- Introduce the runoff water diversion ditch for Migogo 1, 2 and 3.

A.1.9 Spring recharge catchment 11

The spring recharge catchment 11 has an area of 1,630.95 ha. It is located in the Districts of Rulindo and Burera. It lies within four sectors known as Cyungo, Nemba, Ruhande and Rwerere. The recharge catchment has three spring sources which are not captured. The resulting maps based on the above classification are presented below.

Table 52: Spring recharge catchment 11 slope coverage

Spring recharge catchment 11		
slope class	**Area Ha**	**% of Area Covered**
0-6%	12.83	0.79
6-16%	82.97	5.09
16-40%	605.03	37.10

40-60%	587.97	36.05
>60%	342.06	20.97

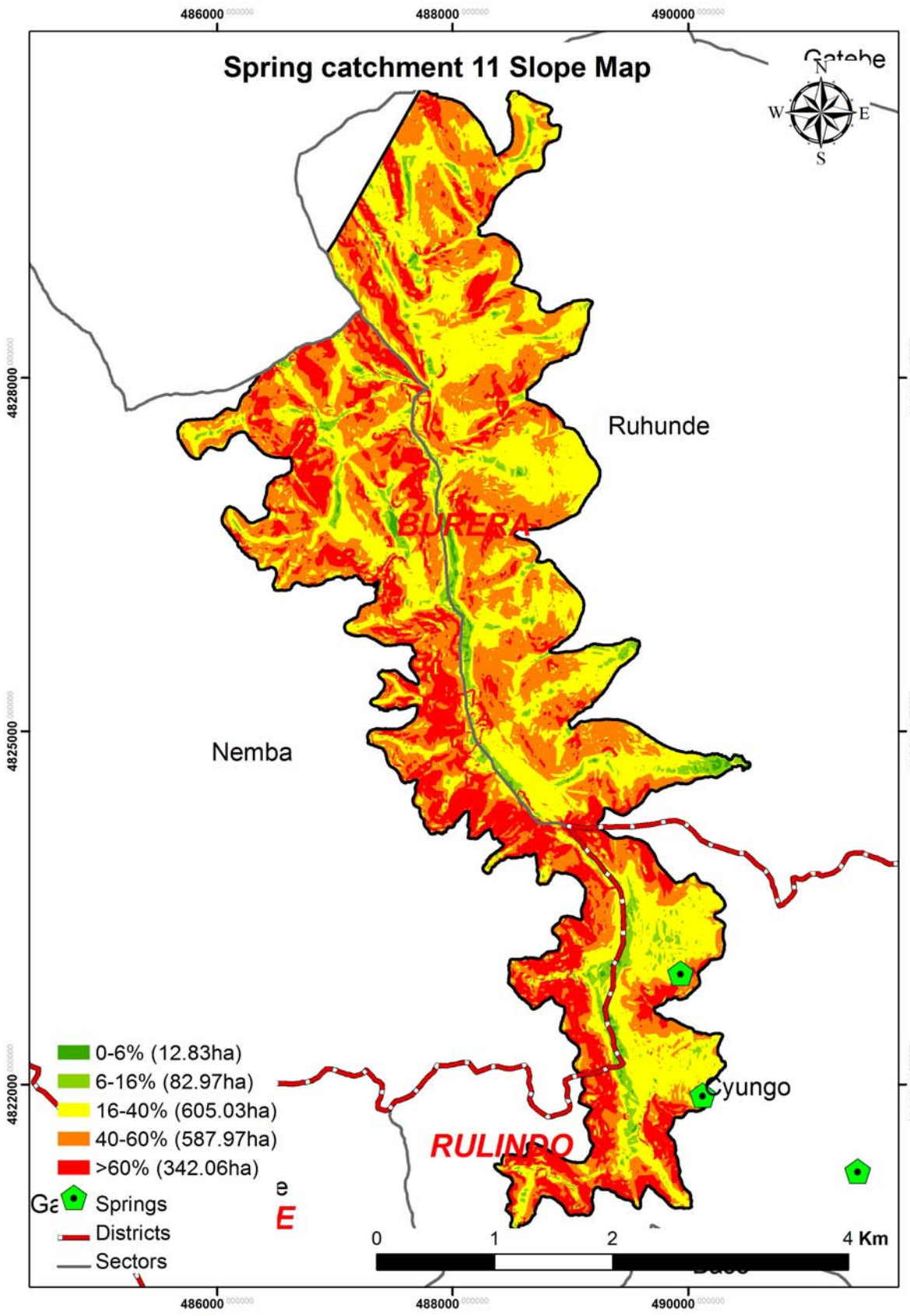

Spring catchment 11 Slope Map
N
W
E
S
486000
488000
490000
4828000
4825000
4822000
Ruhunde
BURERA
Nemba
Cyungo
RULINDO
0-6% (12.83ha)
6-16% (82.97ha)
16-40% (605.03ha)
40-60% (587.97ha)
>60% (342.06ha)
Springs
Districts
Sectors
0
1
2
4 Km

Figure 70: Spring recharge catchment 11 slope map

Table 53: Spring recharge catchment 11 soil depth coverage

Spring recharge catchment 11		
Soil depth	**Area Ha**	**% of Area covered**
<0.5m	453.18	27.79
0.5 - 1.0m	445.25	27.30
>1.0m	732.53	44.91

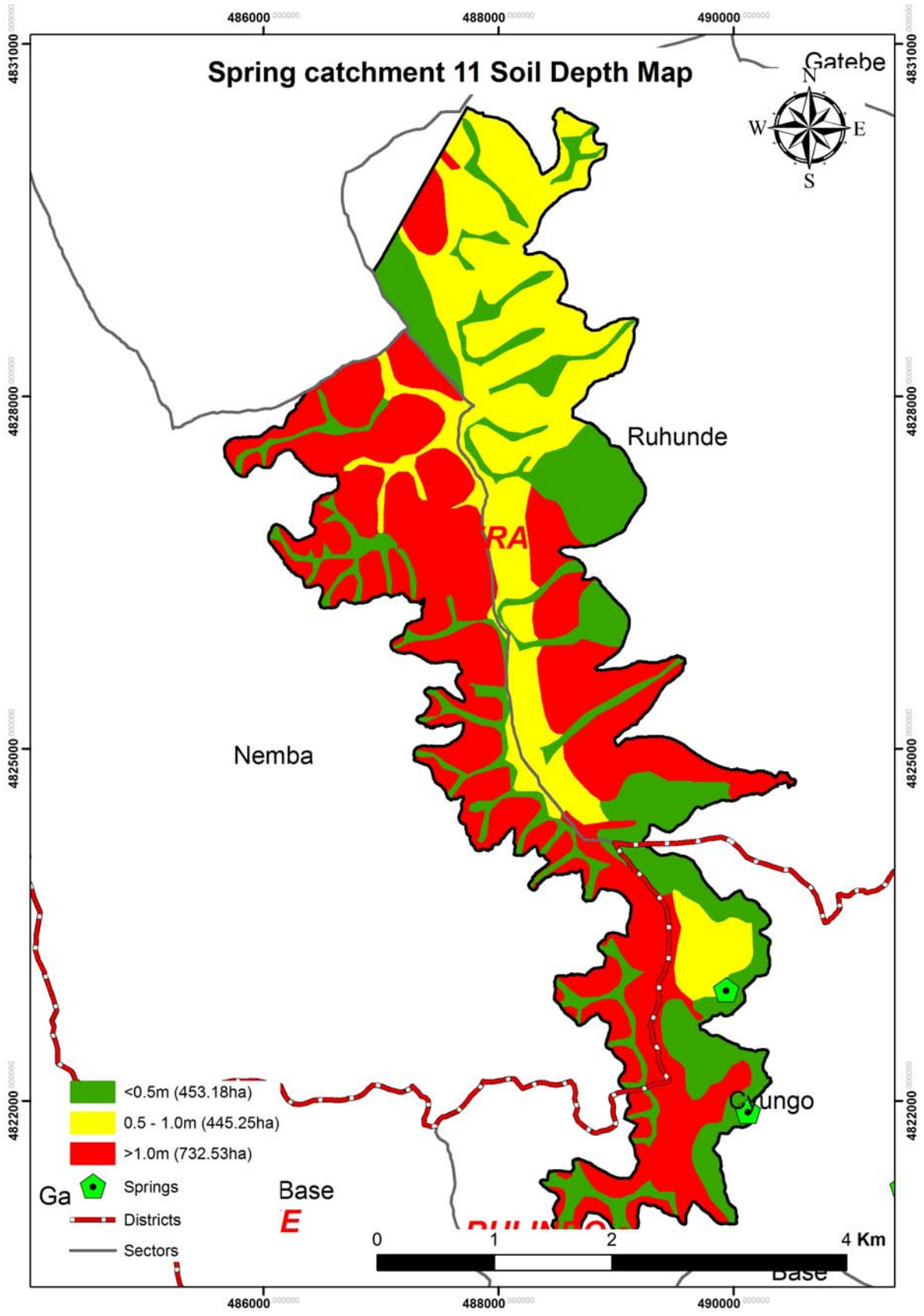

Spring catchment 11 Soil Depth Map
Gatebe
N
W
E
S
Ruhunde
Nemba
Cyungo
Base
<0.5m (453.18ha)
0.5 - 1.0m (445.25ha)
>1.0m (732.53ha)
Springs
Districts
Sectors
0
1
2
4 Km
486000
488000
490000
4831000
4828000
4825000
4822000

Figure 71: Spring recharge catchment 11 soil depth map

Table 54: Spring recharge catchment 11 resilience unit coverage

Spring recharge catchment 11		
resilience	**Area Ha**	**% of Area Covered**
cropland	473.85	29.06
forest plantation	449.44	27.56
natural forest	340.99	20.91
rangeland	366.36	22.47

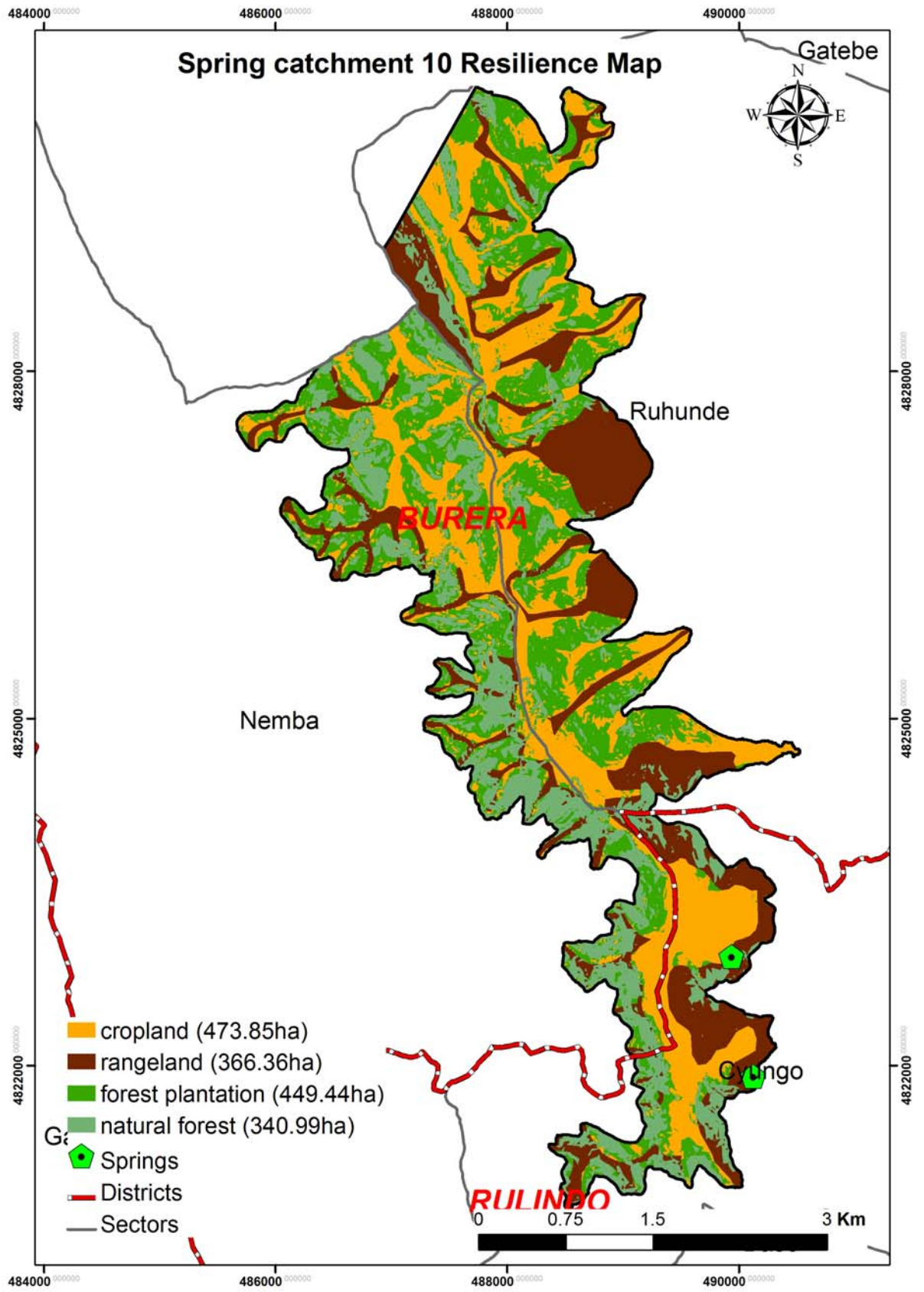

Spring catchment 10 Resilience Map
Gatebe
Ruhunde
BURERA
Nemba
Cyungo
RULINDO
N
S
W
E
484000
486000
488000
490000
4828000
4825000
4822000
cropland (473.85ha)
rangeland (366.36ha)
forest plantation (449.44ha)
natural forest (340.99ha)
Springs
Districts
Sectors
0
0.75
1.5
3 Km

Figure 72: Spring recharge catchment 11 soil resilience map

Table 55: Spring recharge catchment 11 management measures coverage

Spring recharge catchment 11		
Measures	**Area Ha**	**% Area Covered**
Agroforestry+progressive terraces/cuttoff drains	605.10	72.17
Agroforestry+cuttoff drains/horizontal trenches	96.28	11.48
Agroforestry+radical terraces/gully treatment	137.09	16.35
Forest Plantation	449.75	53.64
Natural Forest	342.58	40.86

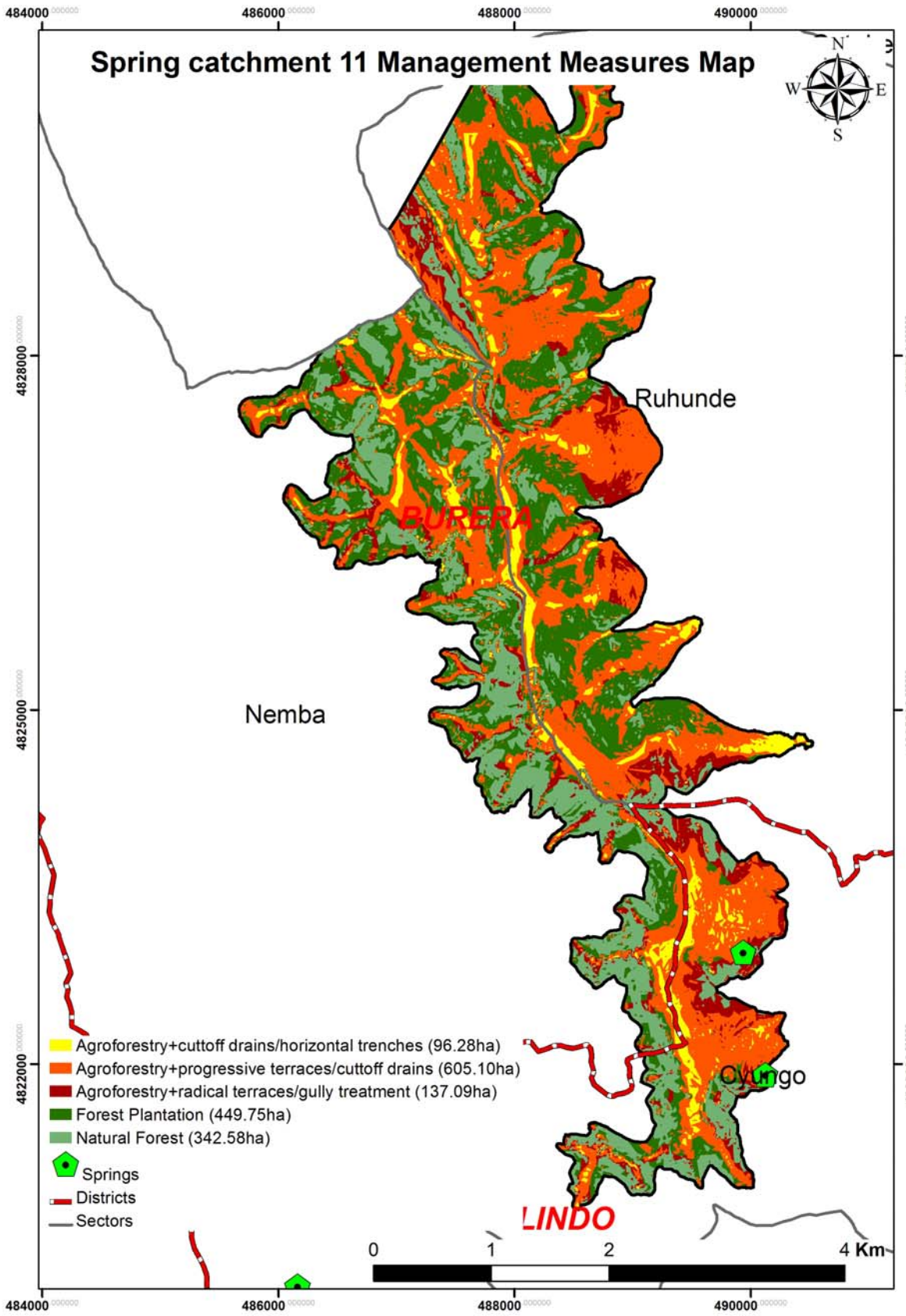

Spring catchment 11 Management Measures Map
N
W
E
S
484000
486000
488000
490000
4828000
4825000
4822000
Ruhunde
BURERA
Nemba
Cyungo
LINDO
Agroforestry+cuttoff drains/horizontal trenches (96.28ha)
Agroforestry+progressive terraces/cuttoff drains (605.10ha)
Agroforestry+radical terraces/gully treatment (137.09ha)
Forest Plantation (449.75ha)
Natural Forest (342.58ha)
Springs
Districts
Sectors
0
1
2
4 Km

Figure 73: Spring recharge catchment 11 management measures map

A.1.10 Spring recharge catchment 12

The spring recharge catchment 12 has an area of 466.48 ha. It is fully located in the Rulindo District. It lies within three sectors known as Base, Cyungo and Rukozo. The recharge catchment has five spring sources of which three are not captured, one is captured and another one is newly identified. The resulting maps based on the above classification are presented below.

Table 56: Spring recharge catchment 12 slope coverage

Spring recharge catchment 12		
slope class	**Area Ha**	**% of Area Covered**
0-6%	6.34	1.36
6-16%	29.68	6.36
16-40%	150.63	32.29
40-60%	164.46	35.26
>60%	115.38	24.73

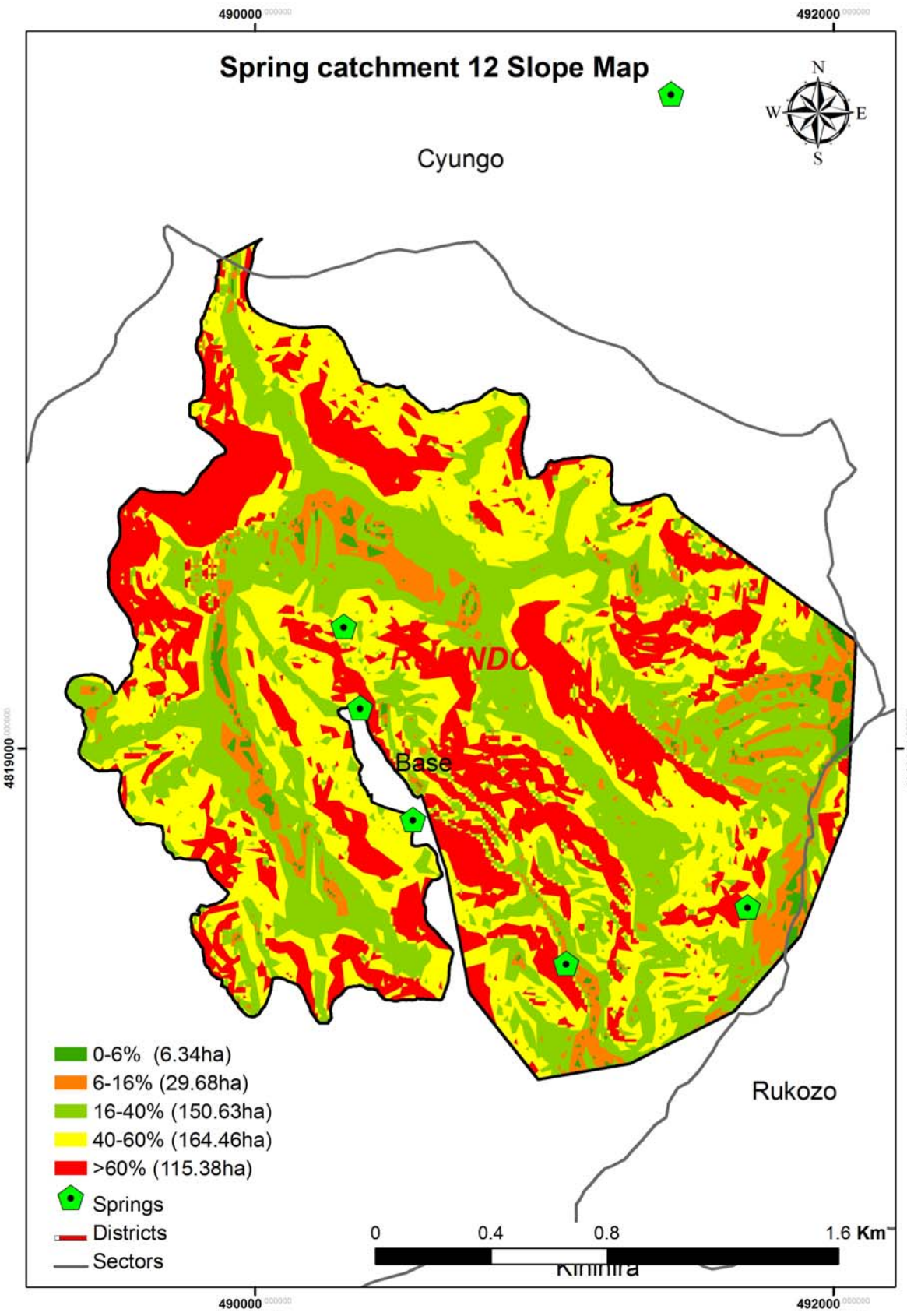

Spring catchment 12 Slope Map
N
W
E
S
Cyungo
Base
Rukozo
Kinihira
490000
492000
4819000
0-6% (6.34ha)
6-16% (29.68ha)
16-40% (150.63ha)
40-60% (164.46ha)
>60% (115.38ha)
Springs
Districts
Sectors
0
0.4
0.8
1.6 Km

Figure 74: Spring recharge catchment 12 slope map

Table 57: Spring recharge catchment 12 soil depth coverage

Spring recharge catchment 12		
soil depth	**Area Ha**	**% of Area covered**
<0.5m	250.29	53.65
0.5 - 1.0m	111.70	23.95
>1.0m	104.49	22.40

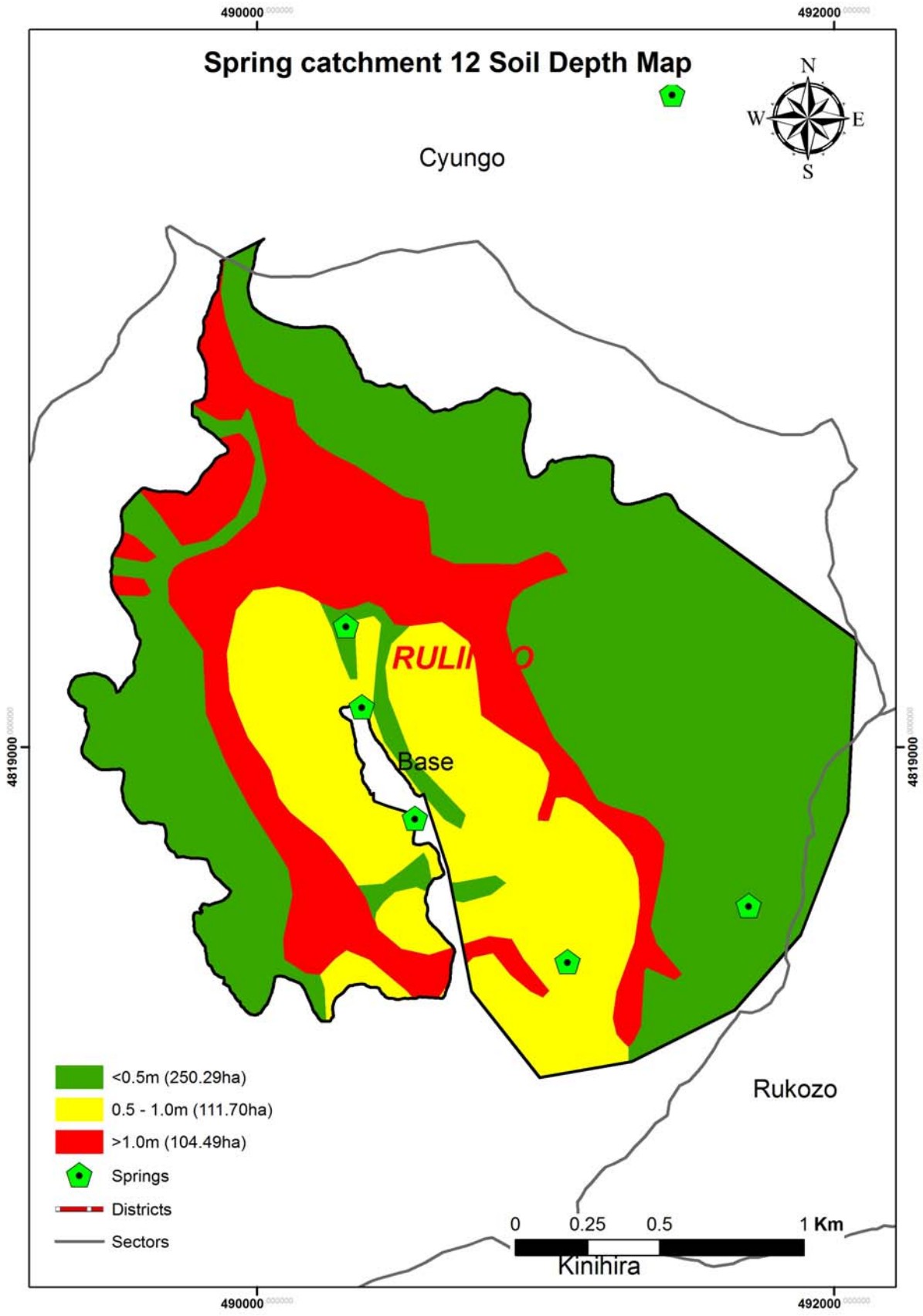

Spring catchment 12 Soil Depth Map
N
W
E
S
Cyungo
Base
Rukozo
Kinihira
490000
492000
4819000
<0.5m (250.29ha)
0.5 - 1.0m (111.70ha)
>1.0m (104.49ha)
Springs
Districts
Sectors
0
0.25
0.5
1 Km

Figure 75: Spring recharge catchment 12 soil depth map

Table 58: Spring recharge catchment 12 resilience unit coverage

Spring recharge catchment 12		
resilience	**Area Ha**	**% of Area Covered**
cropland	98.22	21.05
forest plantation	62.11	13.32
natural forest	114.93	24.64
rangeland	191.22	40.99

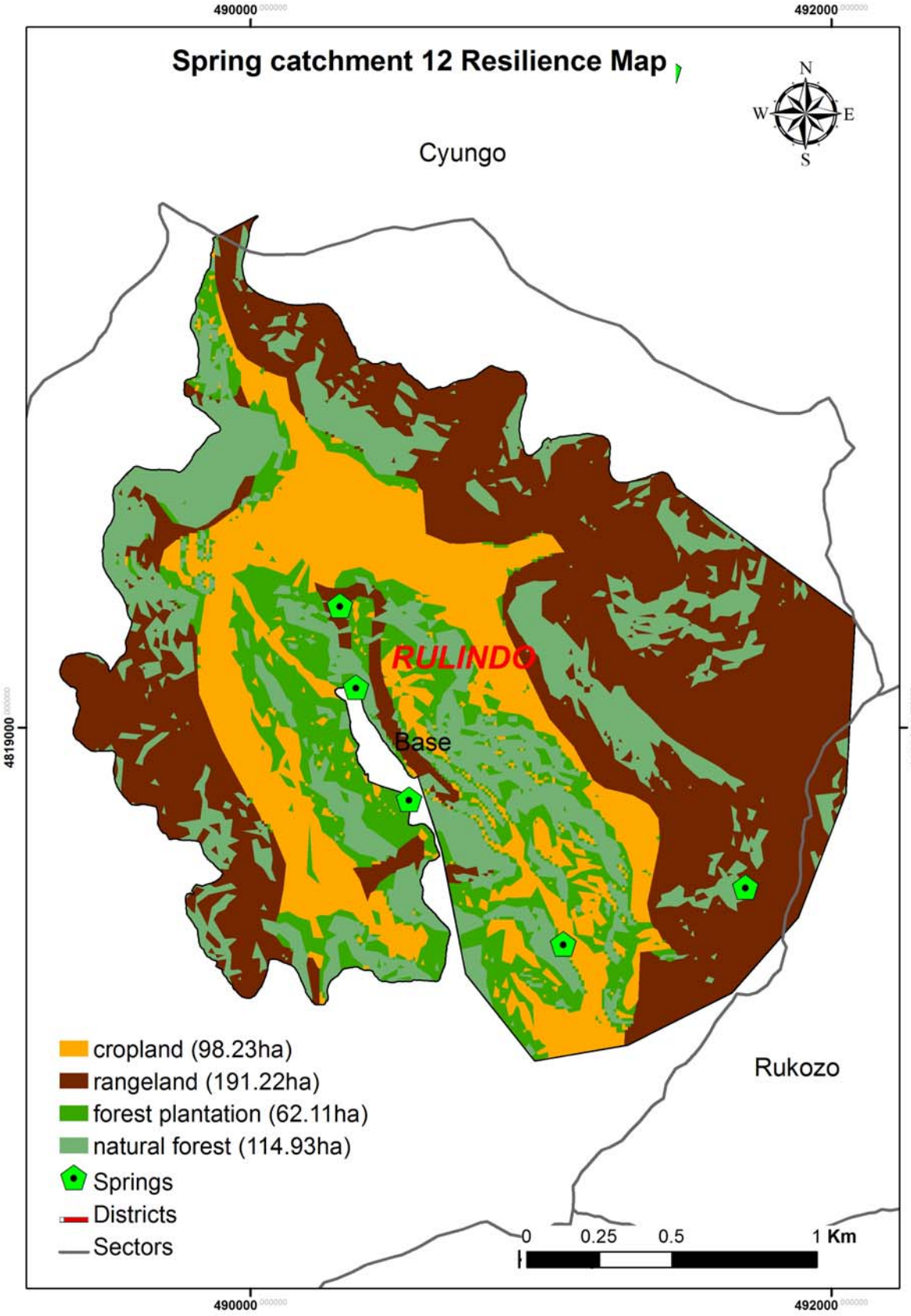

Spring catchment 12 Resilience Map
N
W
E
S
Cyungo
RULINDO
Base
Rukozo
490000
492000
4819000
cropland (98.23ha)
rangeland (191.22ha)
forest plantation (62.11ha)
natural forest (114.93ha)
Springs
Districts
Sectors
0
0.25
0.5
1 Km

Figure 76: Spring recharge catchment 12 soil resilience map

Table 59: Spring recharge catchment 12 management measures coverage

Spring recharge catchment 12		
Measures	**Area Ha**	**% Area Covered**
Agroforestry+progressive terraces/cuttoff drains	150.53	52.13
Agroforestry+cuttoff drains/horizontal trenches	36.22	12.54
Agroforestry+radical terraces/gully treatment	102.01	35.33
Forest Plantation	62.26	21.56
Natural Forest	115.47	39.99

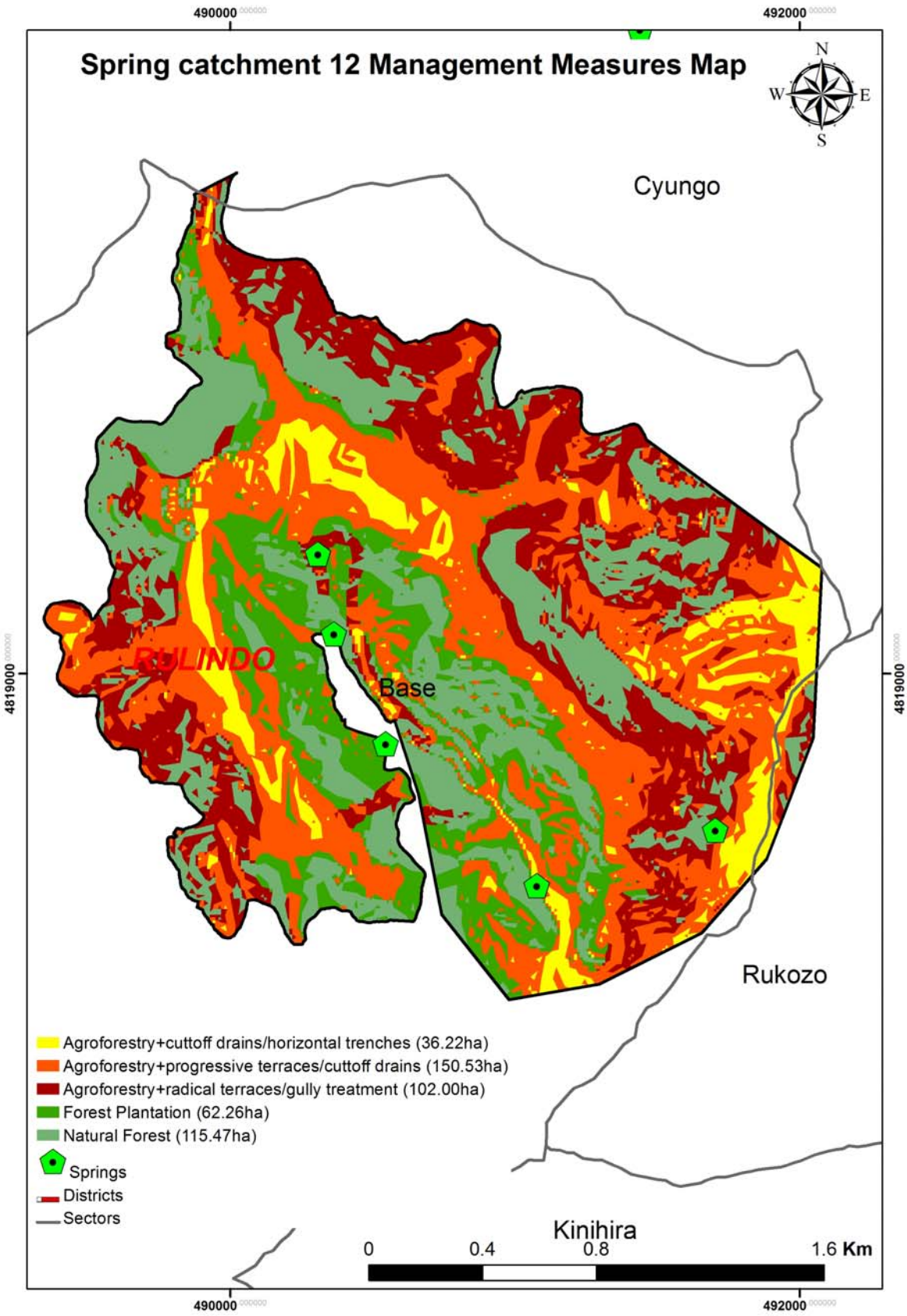

Spring catchment 12 Management Measures Map
N
W
E
S
490000
492000
4819000
Cyungo
RULINDO
Base
Rukozo
Kinihira
Agroforestry+cuttoff drains/horizontal trenches (36.22ha)
Agroforestry+progressive terraces/cuttoff drains (150.53ha)
Agroforestry+radical terraces/gully treatment (102.00ha)
Forest Plantation (62.26ha)
Natural Forest (115.47ha)
Springs
Districts
Sectors
0
0.4
0.8
1.6 Km

Figure 77: Spring recharge catchment 12 management measures map

GIHANGA 1 AND 2

The Gihanga 1 spring is located at the foot of the hill that is used only for seasonal agricultural activities. The immediate spring catchment is protected by the fence of imiyenzi and a water diversion ditch that needs the extension. In addition, there is a need to plant passparum in the immediate spring catchment area. Upstream of the spring intake, there is a need to establish bench terraces that could reduce surface water runoff and increase the water seepage downwards. Also, there is an active gully which needs to be strengthened next to the pipelines from the water collection chamber. The Gihanga 1 spring was under completion of construction activities during the field visit of February 2016 and is serving many villages that include Bukangano, Musenyi, Gihanga, Buramba, Gitwa, Mushongi and Gihemba. Nevertheless, one tap of water was left to these many villages and the local population are claiming about the insufficiency of tap at the source and often the evening queue goes up to 11h00 pm.

The Gihanga 2 spring is a new spring that was inventoried during the field visit. The spring originates from a forest plantation of eucalyptus. This spring has an old open water fountain that was erected to serve the nearby population. The Gihanga 2 source requires however a total rehabilitation, the spring catchment localisation and protection, and also a water diversion ditch that deviate the runoff from passing in the spring immediate catchment.

Required activities for Gihanga 1:

- Grow passparum in the immediate spring catchment area
- There is a need of at least other 2 water tap stand along the distribution line Gihanga-Ruhozo. This should be done to protect the distribution pipes which in some cases should be destroyed by the population claiming that their water was taken away.
- To protect the pipeline, signals should be added to mark the location of the pipelines as they get ahead of different fields with intense agriculture activities.
- Establish terraces and water percolation pit that could reduce surface water runoff and increase the aquifer recharge.

Required activities for Gihanga 2:

- Establishment of immediate spring catchment with a fence
- Establishment of a water diversion ditch around the immediate spring catchment
- Clearance of eucalyptus next to the spring discharge area

NYIRAKAGOROGORO

Nyirakagorogoro spring is an uncaptured spring located downhill and is entirely covered by shrubs plantation which also protects its immediate spring catchment area. The spring immediate catchment is not fenced and downstream of the catchment there are agricultural activities. Upslope from the spring outlet of Nyirakagorogoro, they are eucalyptus plantation and a livestock (sheep) gathering point. If well rehabilitated this source could connect to Gihanga sources to increase the volume of the water supplied by gravity.

Required activities:

- Total rehabilitation

The Kabingo 2 source is located at 1804 m asl and is surrounded by agriculture activities and there is no clear spring catchment area. This source is neighbouring settlements that may introduce contaminants mainly from pit latrines. Upslope of Kabingo 2 source they are Eucalyptus plantations and human settlements.

Required activities:

- Clean the neighbouring forest of Kabingo 1 source at 10 m of distance from the direct catchment area to avoid the spring disruption by the root systems
- Delineate the spring catchment area for Kabingo 2
- Establishment of a water diversion ditch around the immediate spring catchment for the two springs

A.1.11 Spring recharge catchment 13

The spring recharge catchment 13 has an area of 3,611.36 ha. It is located in the Districts of Rulindo, Burera and Gicumbi. It lies within six sectors known as Cyungo, Kisaro, Ruhunde, Miyove and Nyankenke. The recharge catchment has twelve spring sources of which eleven are not captured and one is newly identified. The resulting maps based on the above classification are presented below.

Table 60: Spring recharge catchment 13 slope coverage

Spring recharge catchment 13		
slope class	**Area Ha**	**% of Area Covered**
0-6%	50.21	1.39
6-16%	349.24	9.67
16-40%	1516.88	42.00
40-60%	1318.18	36.50
>60%	376.85	10.44

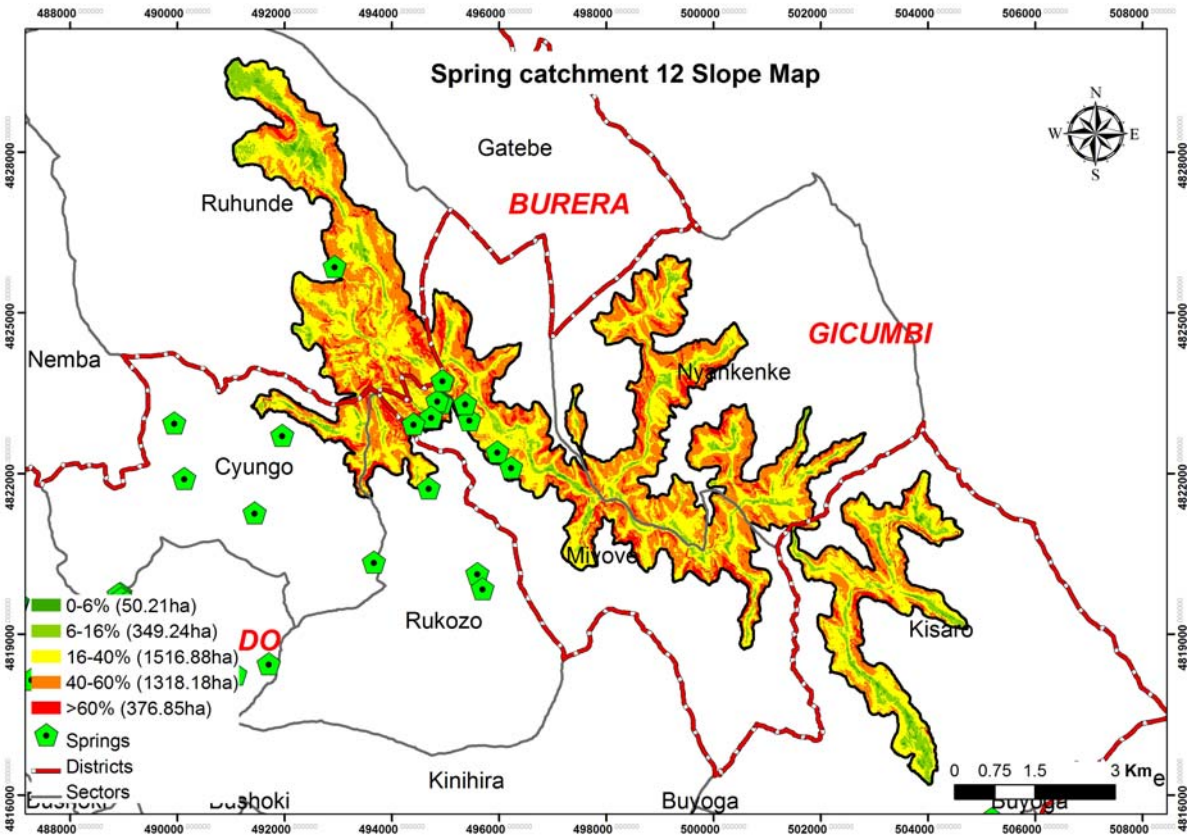


Figure 78: Spring recharge catchment 13 slope map

Table 61: Spring recharge catchment 13 soil depth coverage

Spring recharge catchment 13		
soil depth	**Area Ha**	**% of Area covered**
<0.5m	712.34	19.73
0.5 - 1.0m	1253.31	34.70
>1.0m	1645.70	45.57

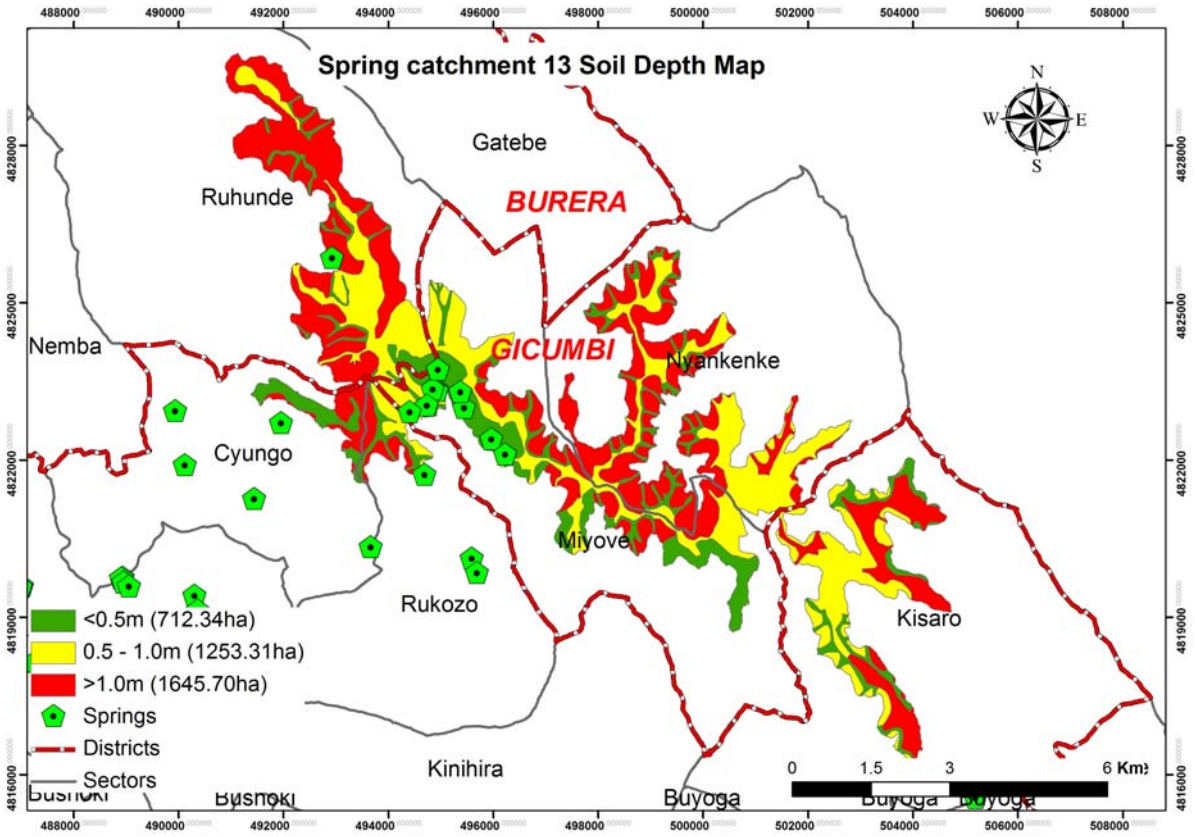


Figure 79: Spring recharge catchment 13 soil depth map

Table 62: Spring recharge catchment 13 resilience unit coverage

Spring recharge catchment 13		
resilience	**Area Ha**	**% of Area Covered**
cropland	1489.34	41.24
forest plantation	1103.69	30.56
natural forest	375.18	10.39
rangeland	643.14	17.81

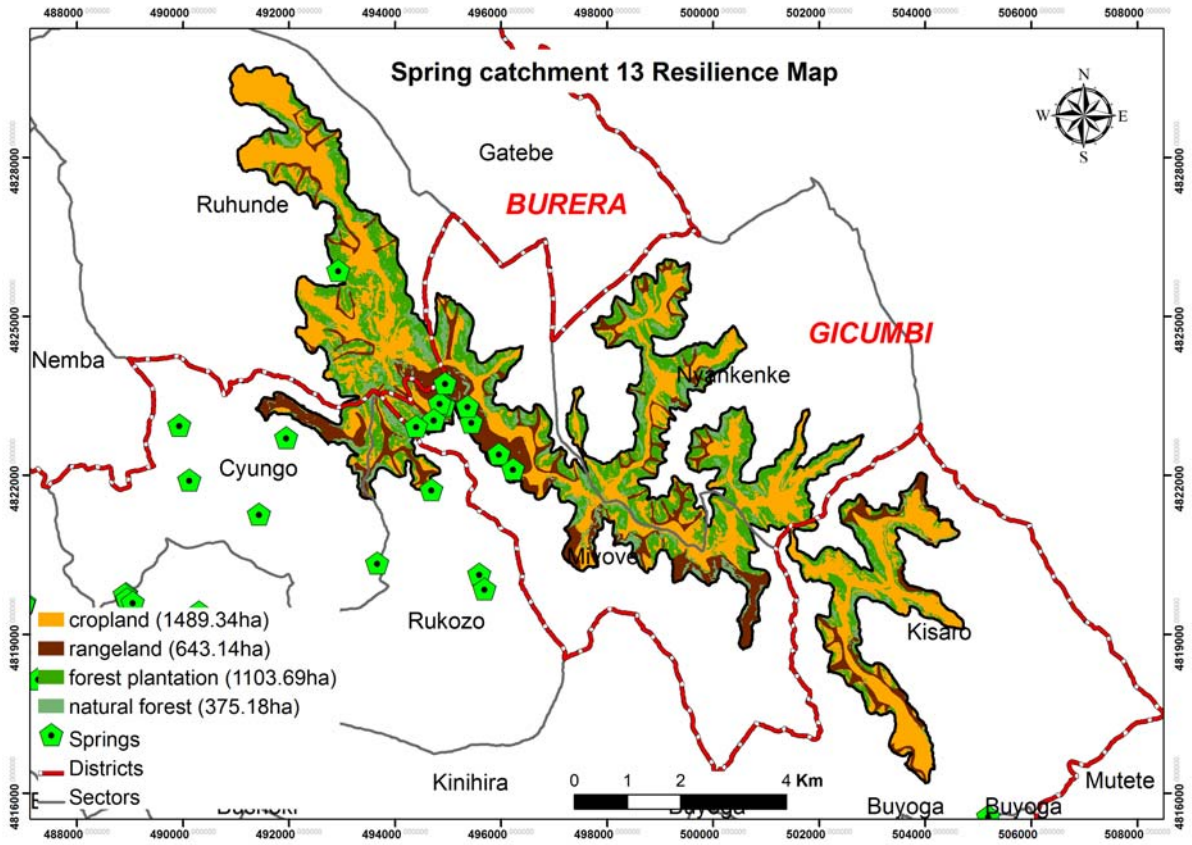


Figure 80: Spring recharge catchment 13 soil resilience map.

Table 63: Spring recharge catchment 13 management measures coverage

Spring recharge catchment 13		
Measures	**Area Ha**	**% Area Covered**
Agroforestry+progressive terraces/cuttoff drains	1516.29	71.16
Agroforestry+cuttoff drains/horizontal trenches	401.72	18.85
Agroforestry+radical terraces/gully treatment	212.94	9.99
Forest Plantation	1103.22	51.77
Natural Forest	377.18	17.70

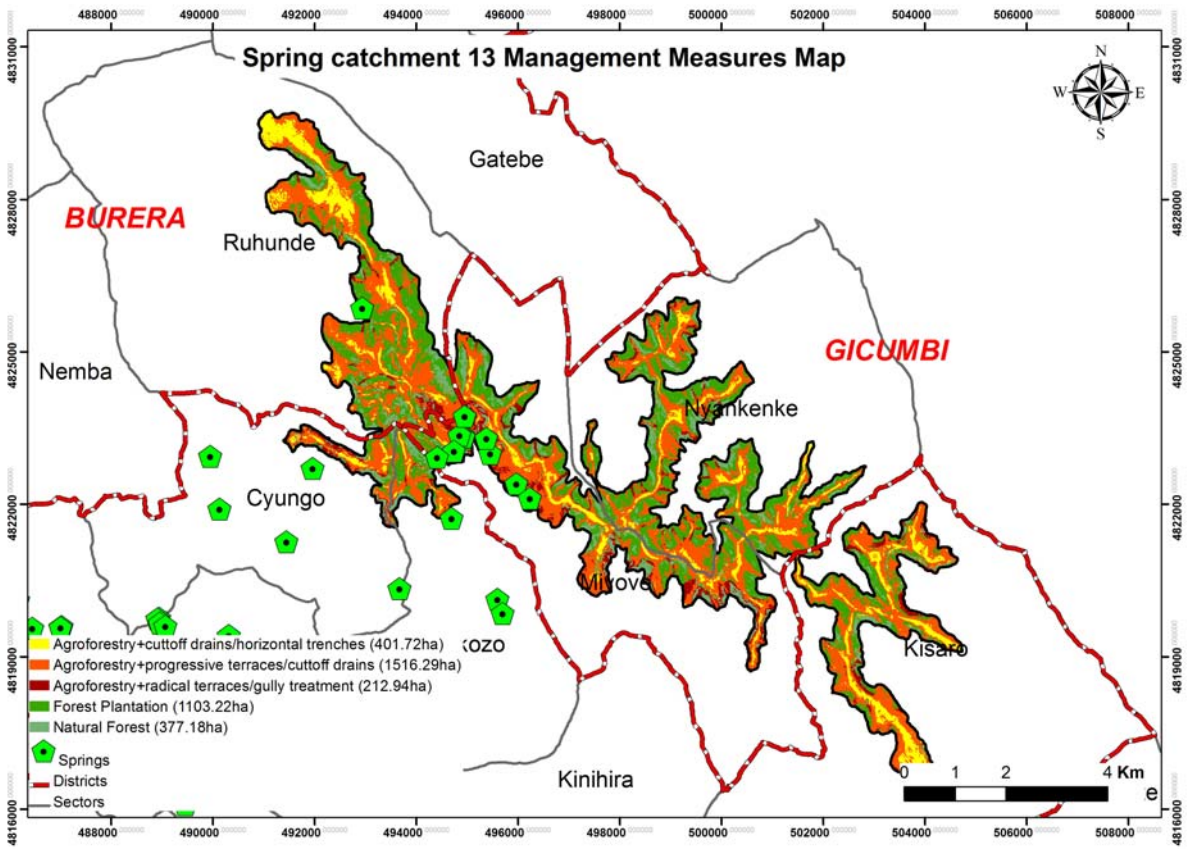


Figure 81: Spring recharge catchment 13 management measures map.

NYARUBUYE 2

This spring is surrounded by the area stabilized by benches terraces with embankment protect by elephant grasses. However some of them are experiencing the landslides. Upper stream parts of those terraces are occupied by a forest with trenches that are not maintained.

As illustrated by the figure above the immediate spring catchment area is fenced by imihati while the immediate spring is planted with passpalum which is still developing. Unlike other spring this spring lacks the water diversion ditch.

Required activity

- Stabilization of bench terraces embankments
- Establishment of a water diversion ditch around the immediate spring catchment

NYARUBUYE 1

Required actvities

- Water diversion ditch is required particulary in these earlier stage of the spring where the vegetation in the immediate spring catchment are still stabilizing
- Estabilshment of benche terraces in the field that are upstream of the immediate

NYARUGANZU

Nyaruganzu spring is located in the forest of eucalyptus, upstream of the road coming from Nyaruganzu center. This forest has trenches that were established many years ago. The eucalyptus are planted up to the edge of the spring immediate catchment as illustrated on the figure below. This is a concern as the roots of these eucalyptuses may clog even the intake pipes without ignoring the reduction of the spring discharge as they may uptake a considerable volume once their roots are in the intake. Furthermore there is a gully that passes next to the spring immediate catchment that is probably affecting the quality of water of this spring.

The immediate spring catchment is fenced by Imiyenzi and its vegetation is still young as this spring was captured recently. According to the local community, this spring experiences a higher turbidity during the rainy season. This turbidity is a sign of the interaction between the spring water and the runoff.

Required activities

- Rehabilitation of forest trenches
- Clearance of eucalyptus up to 10 m from the spring catchment
- Establishment of water percolation pit along the gully that passes next to the spring

KIBARE 1 &2

These springs have recently rehabilitated immediate spring catchment fenced by imiyenzi. The enrecharged catchment that surrounds their intakes are occupied by the forest plantation of eucalyptus with trenches that are not maintained.

The presence of these eucalyptus is a threat to the water quantities of these two sources as they will orient their roots in the intakes in order to uptake water for their growth which will led to the water quantity depletion. In addition to that, roots may clog even pipes in intake and causes the water to deviate and leak.

Required measures

- Maintenance of trenches in the forest; this will reduce the runoff and increases the ground water recharge
- Clearance of eucalyptus at around 50m from the immediate spring catchment

Table 64: Spring recharge catchment 14 slope coverage

Spring recharge catchment 14		
slope class	**Area Ha**	**% of Area Covered**
0-6%	6.36	0.58
6-16%	50.02	4.53
16-40%	296.35	26.82
40-60%	408.89	37.00
>60%	343.41	31.08

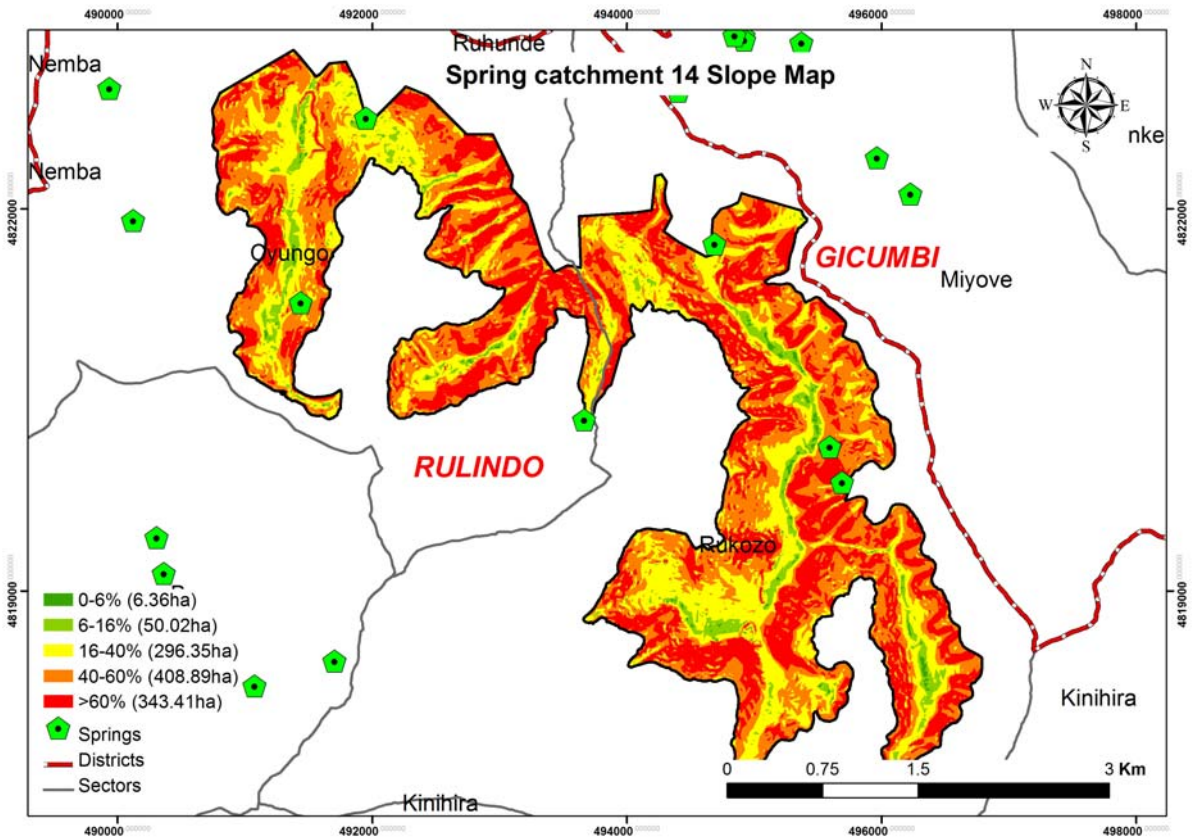


Figure 82: Spring recharge catchment 14 slope map

A.1.12 Spring recharge catchment 14

The spring recharge catchment 14 has an area of 1,105.03 ha. It is fully located in the District of Rulindo. It lies in two sectors known as Cyungo and Rukozo. The recharge catchment has five spring sources of which three are not captured, one is captured and another one is newly identified. The resulting maps based on the above classification are presented below.

Table 65: Spring recharge catchment 14 soil depth coverage

Spring recharge catchment 14		
soil depth	**Area Ha**	**% of Area covered**
<0.5m	389.75	35.27
0.5 - 1.0m	85.50	7.74
>1.0m	629.78	56.99

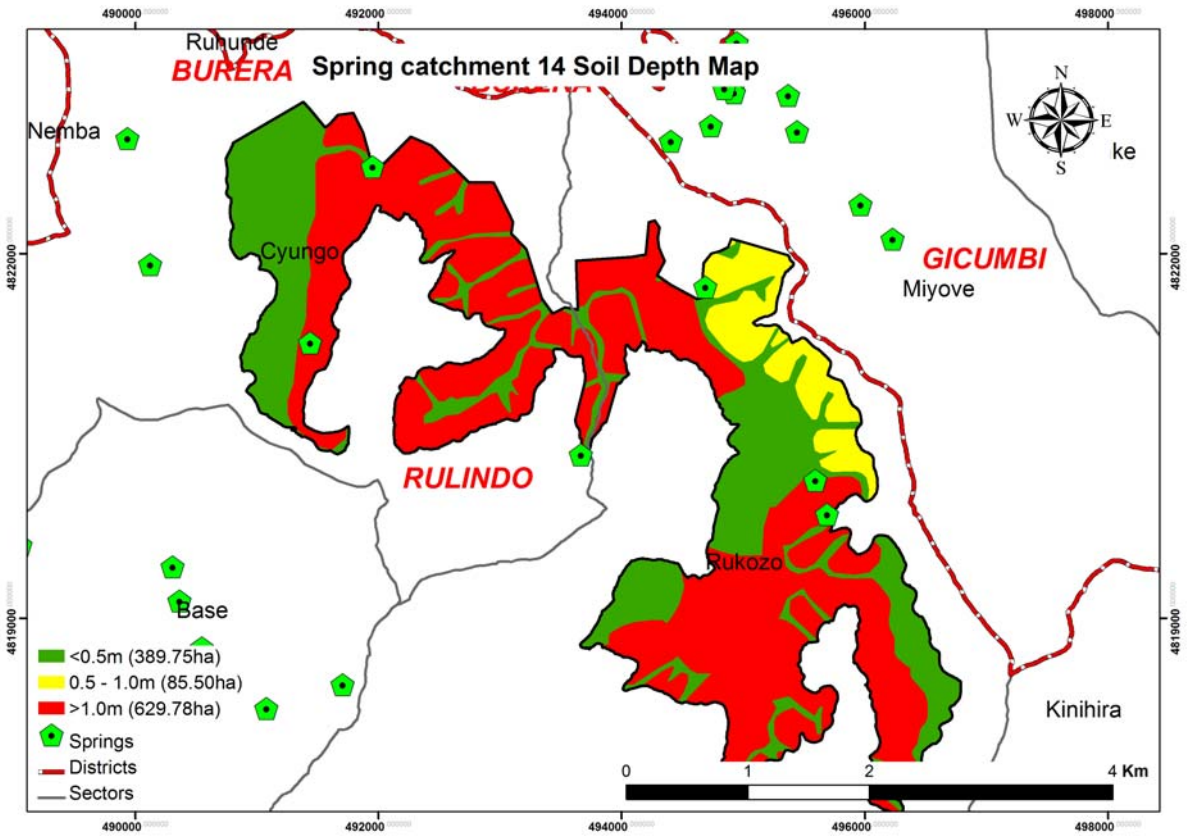


Figure 83: Spring recharge catchment 14 soil depth map.

Table 66: Spring recharge catchment 14 resilience unit coverage

Spring recharge catchment 14		
resilience	**Area Ha**	**% of Area Covered**
cropland	213.93	19.36
forest plantation	262.98	23.80
natural forest	342.62	31.01
rangeland	285.50	25.84

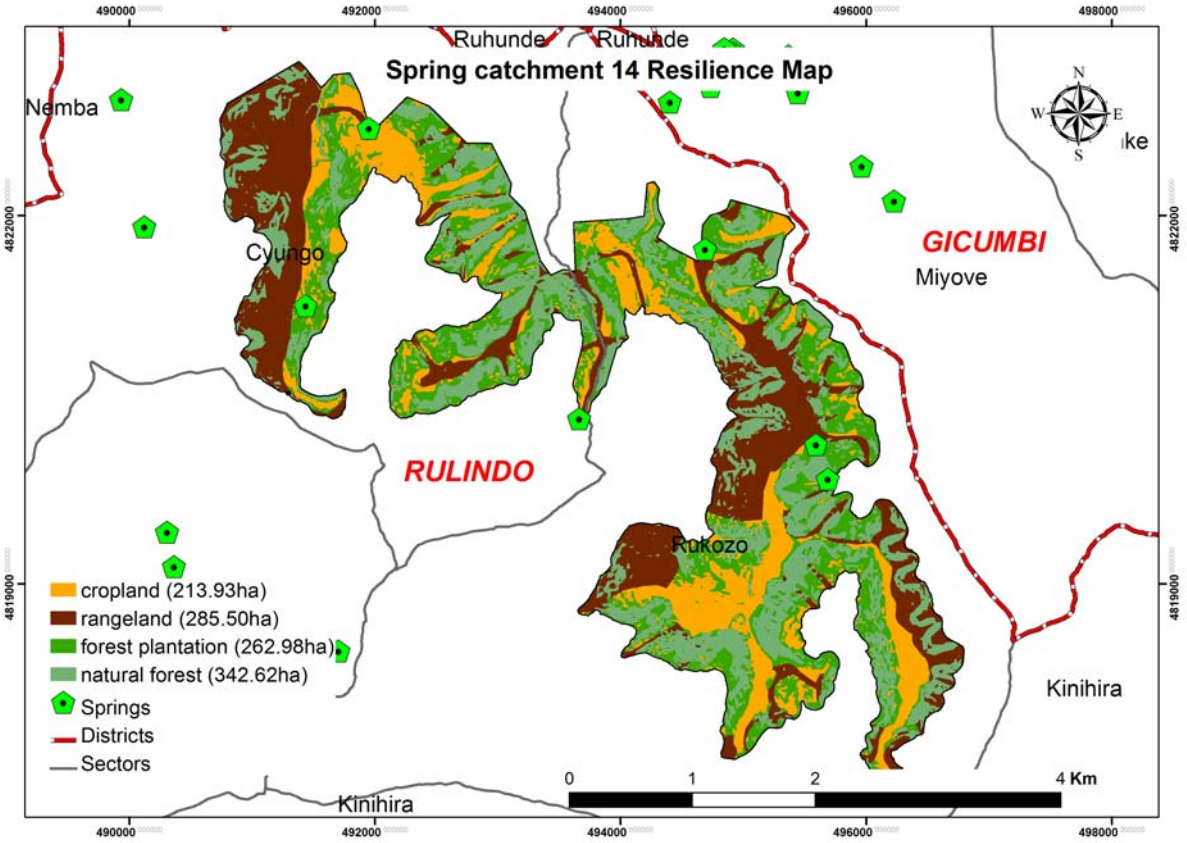


Figure 84: Spring recharge catchment 14 soil resilience map.

Table 67: Spring recharge catchment 14 management measures coverage

Spring recharge catchment 14		
Measures	**Area Ha**	**% Area Covered**
Agroforestry+progressive terraces/cuttoff drains	296.24	59.47
Agroforestry+cuttoff drains/horizontal trenches	56.88	11.42
Agroforestry+radical terraces/gully treatment	145.04	29.11
Forest Plantation	263.13	52.82
Natural Forest	343.75	69.00

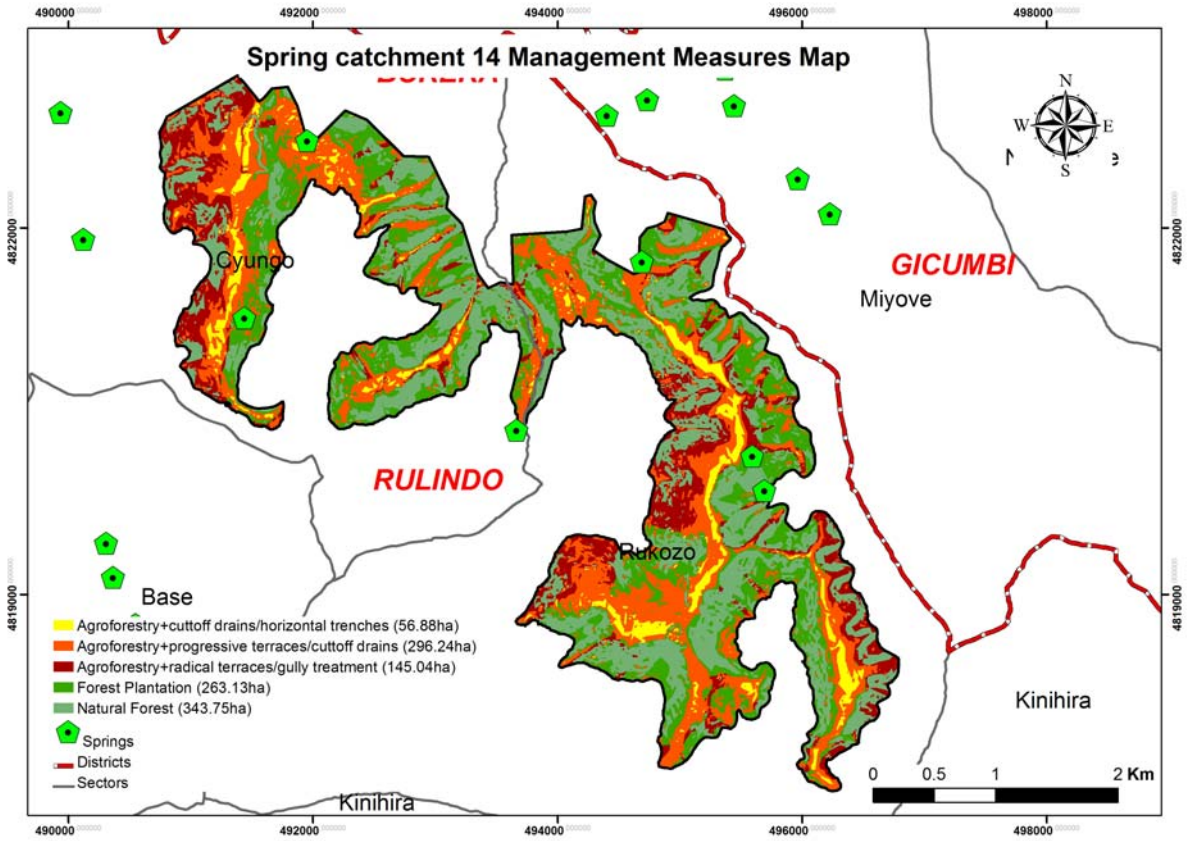


Figure 85: Spring recharge catchment 14 management measures map.

Appendix 2: Water demand analysis and findings per sector

Type of consumption	Number 2020	Water demand(l/day/ unit)	Number 2025	Water demand(l/day/ unit)	Number 2030	Water demand (l/day/unit)	Number 2035	Water demand(l/day/u nit)	Number 2040	Water demand (l/day/unit)	Specific water demand per category
Human consumption	19,886.91	795,476.60	21,635.76	865,430.45	23,538.40	1,412,304.02	25,608.36	1,536,501.40	27,860.34	2,786,034.40	40, 60, 80,100
Livestock											
Cow	2,244.00	112,200.00	2,244.00	112,200.00	2,244.00	112,200.00	2,244.00	112,200.00	2,244.00	112,200.00	50.00
Goat	2,240.00	17,920.00	2,240.00	17,920.00	2,240.00	17,920.00	2,240.00	17,920.00	2,240.00	17,920.00	8.00
sheep	2,748.00	21,984.00	2,748.00	21,984.00	2,748.00	21,984.00	2,748.00	21,984.00	2,748.00	21,984.00	8.00
swime	396.00	1,980.00	396.00	1,980.00	396.00	1,980.00	396.00	1,980.00	396.00	1,980.00	5.00
Chicken / Rabbit	5,274.00	2,637.00	5,274.00	2,637.00	5,274.00	2,637.00	5,274.00	2,637.00	5,274.00	2,637.00	0.50
Schools											
E.Primaire Cyondo	765.00	38,250.00	765.00	38,250.00	765.00	38,250.00	765.00	38,250.00	765.00	38,250.00	50.00
ES Nyamugari	497.00	24,850.00	497.00	24,850.00	497.00	24,850.00	497.00	24,850.00	497.00	24,850.00	50.00
GS Mushongi	1,409.00	70,450.00	1,409.00	70,450.00	1,409.00	70,450.00	1,409.00	70,450.00	1,409.00	70,450.00	50.00
Institut IBB	1,200.00	60,000.00	1,200.00	60,000.00	1,200.00	60,000.00	1,200.00	60,000.00	1,200.00	60,000.00	50.00
GS Kiruri	1,704.00	85,200.00	1,704.00	85,200.00	1,704.00	85,200.00	1,704.00	85,200.00	1,704.00	85,200.00	50.00
EP Rwiri	351.00	17,550.00	351.00	17,550.00	351.00	17,550.00	351.00	17,550.00	351.00	17,550.00	50.00
Health facilities											
Health Post	3.00	300.00	3.00	300.00	3.00	300.00	3.00	300.00	3.00	300.00	100.00
Health centers	100.00	10,000.00	100.00	10,000.00	100.00	10,000.00	100.00	10,000.00	100.00	10,000.00	100.00
Industries											
Market (malls)	1.00	60.00	2.00	120.00	2.00	120.00	2.00	120.00	2.00	120.00	60.00
Quarries	2.00	80.00	2.00	80.00	2.00	80.00	2.00	80.00	2.00	80.00	40.00
Total water Demand		**1,258,937.60**		**1,328,951.45**		**1,875,825.02**		**2,000,022.40**		**3,249,555.40**	
Available		**920,160.00**		**920,160.00**		**920,160.00**		**920,160.00**		**920,160.00**	
Deficit or surpuls		**-338777.60**		**-408791.45**		**-955665.02**		**-1079862.40**		**-2329395.40**	

Table 68: Base Sector water demand/analysis findings.

Type of consumption	Number 2020	Water demand(l/day/ unit)	Number 2025	Water demand(l/day/ unit)	Number 2030	Water demand (l/day/unit)	Number 2035	Water demand(l/day/ unit)	Number 2040	Water demand (l/day/unit)	Specific water demand per category
Human consumption	14119.0504	564,762.02	15026.3028	601,052.11	15991.8528	959,511.17	17019.4464	1,021,166.79	18113.0705	1,811,307.05	40, 60, 80,100
Livestock											
Cow	2240	112,000.00	2240	112,000.00	2240	112,000.00	2240	112,000.00	2240	112,000.00	50.00
Goat	2748	21,984.00	2748	21,984.00	2748	21,984.00	2748	21,984.00	2748	21,984.00	8.00
sheep	2240	17,920.00	2240	17,920.00	2240	17,920.00	2240	17,920.00	2240	17,920.00	8.00
swime	396	1,980.00	396	1,980.00	396	1,980.00	396	1,980.00	396	1,980.00	5.00
Chicken / Rabbit	5474	2,737.00	5474	2,737.00	5474	2,737.00	5474	2,737.00	5474	2,737.00	0.50
Schools											
GS BUTANGAMPUNDU	928	46,400.00	928	46,400.00	928	46,400.00	928	46,400.00	928	46,400.00	50.00
GS Burega	1222	61,100.00	1222	61,100.00	1222	61,100.00	1222	61,100.00	1222	61,100.00	50.00
Health facilities											
Health Post	3.00	300.00	3.00	300.00	3.00	300.00	3.00	300.00	3.00	300.00	100.00
Health centers	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	100.00
Total water Demand		**831,183.02**		**867,473.11**		**1,225,932.17**		**1,287,587.79**		**2,077,728.05**	
Available		**793,152.00**		**793,152.00**		**793,152.00**		**793,152.00**		**793,152.00**	
Deficit or surpuls		**-38031.02**		**-74321.11**		**-432780.17**		**-494435.79**		**-1284576.05**	

Table 69: Burega Sector water demand/analysis findings.

Type of consumption	Number 2020	Water demand(l/day/unit)	Number 2025	Water demand(l/day/unit)	Number 2030	Water demand (l/day/unit)	Number 2035	Water demand(l/day/unit)	Number 2040	Water demand (l/day/unit)	Specific water demand per category
Human consumption	21534.52965	861,381.19	22521.18415	900,847.37	23553.04451	1,413,182.67	24632.18196	1,477,930.92	25760.76259	2,576,076.26	40, 60, 80,100
Livestock											
Cow	3187	159,350.00	3187	159,350.00	3187	159,350.00	3187	159,350.00	3187	159,350.00	50.00
Goat	2085	16,680.00	2085	16,680.00	2085	16,680.00	2085	16,680.00	2085	16,680.00	8.00
sheep	2209	17,672.00	2209	17,672.00	2209	17,672.00	2209	17,672.00	2209	17,672.00	8.00
swime	380	1,900.00	380	1,900.00	380	1,900.00	380	1,900.00	380	1,900.00	5.00
Chicken / Rabbit	7359	3,679.50	7359	3,679.50	7359	3,679.50	7359	3,679.50	7359	3,679.50	0.50
Schools											
GS RULINDO	421	21,050.00	421	21,050.00	421	21,050.00	421	21,050.00	421	21,050.00	50.00
COLLEGE F.SINA GERARD	685	34,250.00	685	34,250.00	685	34,250.00	685	34,250.00	685	34,250.00	50.00
GS MUGENDA	166	8,300.00	166	8,300.00	166	8,300.00	166	8,300.00	166	8,300.00	50.00
EP BUHANDE	982	49,100.00	982	49,100.00	982	49,100.00	982	49,100.00	982	49,100.00	50.00
EP GASIZA	665	33,250.00	665	33,250.00	665	33,250.00	665	33,250.00	665	33,250.00	50.00
EP BUSHOKI 1	461	23,050.00	461	23,050.00	461	23,050.00	461	23,050.00	461	23,050.00	50.00
EP BUSHOKI 2	370	18,500.00	370	18,500.00	370	18,500.00	370	18,500.00	370	18,500.00	50.00
EP BURAMIRA	1159	57,950.00	1159	57,950.00	1159	57,950.00	1159	57,950.00	1159	57,950.00	50.00
Health facilities											
Health Post	5.00	500.00	5.00	500.00	5.00	500.00	5.00	500.00	5.00	500.00	100.00
Health centers	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	100.00
Industries											
Market (malls)	1.00	60.00	1.00	60.00	1.00	60.00	1.00	60.00	1.00	60.00	60.00
Food processing industry	1.00	20,000.00	1.00	20,000.00	1.00	20,000.00	1.00	20,000.00	1.00	20,000.00	20,000.00
Coffee washing stations	2.00	200.00	2.00	200.00	2.00	200.00	2.00	200.00	2.00	200.00	100.00
Milk collection	1.00	100.00	1.00	100.00	1.00	100.00	1.00	100.00	1.00	100.00	100.00
Total water Demand		**1,328,972.69**		**1,368,438.87**		**1,880,774.17**		**1,945,522.42**		**3,043,667.76**	
Available		**1,658,880.00**		**1,658,880.00**		**1,658,880.00**		**1,658,880.00**		**1,658,880.00**	
Deficit or surpuls		**329907.31**		**290441.13**		**-221894.17**		**-286642.42**		**-1384787.76**	

Table 70: Bushoki Sector water demand/analysis findings.

Type of consumption	Number 2020	Water demand(l/day/ unit)	Number 2025	Water demand(l/day/ unit)	Number 2030	Water demand (l/day/unit)	Number 2035	Water demand(l/day/ unit)	Number 2040	Water demand (l/day/unit)	Specific water demand per category
Human consumption	24108.72169	964,348.87	25338.5088	1,013,540.35	26631.0274	1,597,861.64	27989.47744	1,679,368.65	29417.22209	2,941,722.21	40, 60, 80,100
Livestock											
Cow	4640	232,000.00	4640	232,000.00	4640	232,000.00	4640	232,000.00	4640	232,000.00	50.00
Goat	4676	37,408.00	4676	37,408.00	4676	37,408.00	4676	37,408.00	4676	37,408.00	8.00
sheep	2258	18,064.00	2258	18,064.00	2258	18,064.00	2258	18,064.00	2258	18,064.00	8.00
swime	262	1,310.00	262	1,310.00	262	1,310.00	262	1,310.00	262	1,310.00	5.00
Chicken / Rabbit	7345	3,672.50	7345	3,672.50	7345	3,672.50	7345	3,672.50	7345	3,672.50	0.50
Schools											
E.Primaire busoro	680	34,000.00	680	34,000.00	680	34,000.00	680	34,000.00	680	34,000.00	50.00
ES BUYOGA	597	29,850.00	597	29,850.00	597	29,850.00	597	29,850.00	597	29,850.00	50.00
GS BUYOGA	1543	77,150.00	1543	77,150.00	1543	77,150.00	1543	77,150.00	1543	77,150.00	50.00
GS GITUMBA	1410	70,500.00	1410	70,500.00	1410	70,500.00	1410	70,500.00	1410	70,500.00	50.00
EP SHAGASHA	855	42,750.00	855	42,750.00	855	42,750.00	855	42,750.00	855	42,750.00	50.00
GS MUYANZA	1060	53,000.00	1060	53,000.00	1060	53,000.00	1060	53,000.00	1060	53,000.00	50.00
EP NYABISIGA	855	42,750.00	855	42,750.00	855	42,750.00	855	42,750.00	855	42,750.00	50.00
EP KADENDEGERI	849	42,450.00	849	42,450.00	849	42,450.00	849	42,450.00	849	42,450.00	50.00
EP RUNOGA	690	34,500.00	690	34,500.00	690	34,500.00	690	34,500.00	690	34,500.00	50.00
EP KADENDEGERI	849	42,450.00	849	42,450.00	849	42,450.00	849	42,450.00	849	42,450.00	50.00
Health facilities											
Health Post	7.00	700.00	7.00	700.00	7.00	700.00	7.00	700.00	7.00	700.00	100.00
Health centers	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	100.00
Industries											
Market (malls)	1.00	60.00	1.00	60.00	1.00	60.00	1.00	60.00	1.00	60.00	60.00
Food processing industry	1.00	20,000.00	1.00	20,000.00	1.00	20,000.00	1.00	20,000.00	1.00	20,000.00	20,000.00
Coffee washing stations	2.00	200.00	2.00	200.00	2.00	200.00	2.00	200.00	2.00	200.00	100.00
Milk collection	1.00	100.00	1.00	100.00	1.00	100.00	1.00	100.00	1.00	100.00	100.00
Total water Demand		**1,749,263.37**		**1,798,454.85**		**2,382,776.14**		**2,464,283.15**		**3,726,636.71**	
Available		**1,006,560.00**		**1,006,560.00**		**1,006,560.00**		**1,006,560.00**		**1,006,560.00**	
Deficit or surpuls		**-742703.37**		**-791894.85**		**-1376216.14**		**-1457723.15**		**-2720076.71**	

Table 71: Buyoga Sector water demand/analysis findings.

Type of consumption	Number 2020	Water demand(l/day/ unit)	Number 2025	Water demand(l/day/ unit)	Number 2030	Water demand (l/day/unit)	Number 2035	Water demand(l/day/ unit)	Number 2040	Water demand (l/day/unit)	Specific water demand per category
Human consumption	14901.75212	596,070.08	15739.57904	629,583.16	16624.51143	997,470.69	17559.19771	1,053,551.86	18546.43521	1,854,643.52	40, 60, 80,100
Livestock											
Cow	2098	104,900.00	2098	104,900.00	2098	104,900.00	2098	104,900.00	2098	104,900.00	50.00
Goat	1122	8,976.00	1122	8,976.00	1122	8,976.00	1122	8,976.00	1122	8,976.00	8.00
sheep	2052	16,416.00	2052	16,416.00	2052	16,416.00	2052	16,416.00	2052	16,416.00	8.00
swime	245	1,225.00	245	1,225.00	245	1,225.00	245	1,225.00	245	1,225.00	5.00
Chicken / Rabbit	3919	1,959.50	3919	1,959.50	3919	1,959.50	3919	1,959.50	3919	1,959.50	0.50
Schools											
E.Primaire KIGALI	717	35,850.00	717	35,850.00	717	35,850.00	717	35,850.00	717	35,850.00	50.00
ES CYINZUZI	600	30,000.00	600	30,000.00	600	30,000.00	600	30,000.00	600	30,000.00	50.00
EPrimaire CYINZUZI	1200	60,000.00	1200	60,000.00	1200	60,000.00	1200	60,000.00	1200	60,000.00	50.00
EPrimaire KIMIRYI	1761	88,050.00	1761	88,050.00	1761	88,050.00	1761	88,050.00	1761	88,050.00	50.00
Health facilities											
Health Post	5.00	500.00	5.00	500.00	5.00	500.00	5.00	500.00	5.00	500.00	100.00
Health centers	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	100.00
Hospital	100.00	10,000.00	100.00	10,000.00	100.00	10,000.00	100.00	10,000.00	100.00	10,000.00	100.00
Industries											
Market (malls)	1.00	60.00	1.00	60.00	1.00	60.00	1.00	60.00	1.00	60.00	60.00
Mining sites	3.00	240.00	3.00	240.00	3.00	240.00	3.00	240.00	3.00	240.00	80.00
Milk collection	1.00	100.00	1.00	100.00	1.00	100.00	1.00	100.00	1.00	100.00	100.00
Total water Demand		**956,346.58**		**989,859.66**		**1,357,747.19**		**1,413,828.36**		**2,214,920.02**	
Available		**393,984.00**		**393,984.00**		**393,984.00**		**393,984.00**		**393,984.00**	
Deficit or surpuls		**-562362.58**		**-595875.66**		**-963763.19**		**-1019844.36**		**-1820936.02**	

Table 72: Cyinzuzi Sector water demand/analysis findings.

Type of consumption	Number 2020	Water demand(l/day/unit)	Number 2025	Water demand(l/day/unit)	Number 2030	Water demand (l/day/unit)	Number 2035	Water demand(l/day/unit)	Number 2040	Water demand (l/day/unit)	Specific water demand per category
Human consumption	14086.24	563,449.72	14513.93	580,557.28	14954.61	897,276.38	15408.66	924,519.64	15876.50	1,587,650.09	40, 60, 80,100
Livestock											
Cow	2098	104,900.00	2098	104,900.00	2098	104,900.00	2098	104,900.00	2098	104,900.00	50.00
Goat	1122	8,976.00	1122	8,976.00	1122	8,976.00	1122	8,976.00	1122	8,976.00	8.00
sheep	2052	16,416.00	2052	16,416.00	2052	16,416.00	2052	16,416.00	2052	16,416.00	8.00
swime	245	1,225.00	245	1,225.00	245	1,225.00	245	1,225.00	245	1,225.00	5.00
Chicken / Rabbit	3919	1,959.50	3919	1,959.50	3919	1,959.50	3919	1,959.50	3919	1,959.50	0.50
Schools											
E.Primaire KIGALI	717	35,850.00	717	35,850.00	717	35,850.00	717	35,850.00	717	35,850.00	50.00
ES CYINZUZI	600	30,000.00	600	30,000.00	600	30,000.00	600	30,000.00	600	30,000.00	50.00
EPrimaire CYINZUZI	1200	60,000.00	1200	60,000.00	1200	60,000.00	1200	60,000.00	1200	60,000.00	50.00
EPrimaire KIMIRYI	1761	88,050.00	1761	88,050.00	1761	88,050.00	1761	88,050.00	1761	88,050.00	50.00
Health facilities											
Health Post	5.00	500.00	5.00	500.00	5.00	500.00	5.00	500.00	5.00	500.00	100.00
Health centers	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	100.00
Hospital	100.00	10,000.00	100.00	10,000.00	100.00	10,000.00	100.00	10,000.00	100.00	10,000.00	100.00
Industries											
Market (malls)	1.00	60.00	1.00	60.00	1.00	60.00	1.00	60.00	1.00	60.00	60.00
Touristic sites	3.00	300.00	3.00	300.00	3.00	300.00	3.00	300.00	3.00	300.00	100.00
Total water Demand		**923,686.22**		**940,793.78**		**1,257,512.88**		**1,284,756.14**		**1,947,886.59**	
Available		**1,017,792.00**		**1,017,792.00**		**1,017,792.00**		**1,017,792.00**		**1,017,792.00**	
Deficit or surpuls		**94105.78**		**76998.22**		**-239720.88**		**-266964.14**		**-930094.59**	

Table 73: Cyungo Sector water demand/analysis findings.

Type of consumption	Number 2020	Water demand(l/day/ unit)	Number 2025	Water demand(l/day/ unit)	Number 2030	Water demand (l/day/unit)	Number 2035	Water demand(l/day/ unit)	Number 2040	Water demand (l/day/unit)	Specific water demand per category
Human consumption	16284.8846	651,395.38	16862.8912	674,515.65	17461.41326	1,047,684.80	18081.17892	1,084,870.73	18722.94219	1,872,294.22	40, 60, 80,100
Livestock											
Cow	2098	104,900.00	2098	104,900.00	2098	104,900.00	2098	104,900.00	2098	104,900.00	50.00
Goat	1122	8,976.00	1122	8,976.00	1122	8,976.00	1122	8,976.00	1122	8,976.00	8.00
sheep	2052	16,416.00	2052	16,416.00	2052	16,416.00	2052	16,416.00	2052	16,416.00	8.00
swime	245	1,225.00	245	1,225.00	245	1,225.00	245	1,225.00	245	1,225.00	5.00
Chicken / Rabbit	3919	1,959.50	3919	1,959.50	3919	1,959.50	3919	1,959.50	3919	1,959.50	0.50
Schools											
E.Primaire KIGALI	717	35,850.00	717	35,850.00	717	35,850.00	717	35,850.00	717	35,850.00	50.00
ES Kinihira	600	30,000.00	600	30,000.00	600	30,000.00	600	30,000.00	600	30,000.00	50.00
EPrimaire Kinihira	1200	60,000.00	1200	60,000.00	1200	60,000.00	1200	60,000.00	1200	60,000.00	50.00
EPrimaire KIMIRYI	1761	88,050.00	1761	88,050.00	1761	88,050.00	1761	88,050.00	1761	88,050.00	50.00
Health facilities											
Health Post	5.00	500.00	5.00	500.00	5.00	500.00	5.00	500.00	5.00	500.00	100.00
Health centers	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	100.00
Hospital	100.00	10,000.00	100.00	10,000.00	100.00	10,000.00	100.00	10,000.00	100.00	10,000.00	100.00
Industries											
Market (malls)	1.00	60.00	1.00	60.00	1.00	60.00	1.00	60.00	1.00	60.00	60.00
Touristic sites	1.00	100.00	1.00	100.00	1.00	100.00	1.00	100.00	1.00	100.00	100.00
Tea factory	1.00	100.00	3.00	300.00	3.00	300.00	3.00	300.00	3.00	300.00	100.00
Total water Demand		**1,011,531.88**		**1,034,852.15**		**1,408,021.30**		**1,445,207.23**		**2,232,630.72**	
Available		**1,584,576.00**		**1,584,576.00**		**1,584,576.00**		**1,584,576.00**		**1,584,576.00**	
Deficit or surpuls		**573044.12**		**549723.85**		**176554.70**		**139368.77**		**-648054.72**	

Table 74: Kinihira Sector water demand/analysis findings.

Type of consumption	Number 2020	Water demand(l/day/ unit)	Number 2025	Water demand(l/day/ unit)	Number 2030	Water demand (l/day/unit)	Number 2035	Water demand(l/day/ unit)	Number 2040	Water demand (l/day/unit)	Specific water demand per category
Human consumption	21439.99	857,599.62	22422.31	896,892.54	23449.64	1,406,978.63	24524.04	1,471,442.62	25647.67	2,564,766.97	40, 60, 80,100
Livestock											
Cow	2701	135,050.00	2701	135,050.00	2701	135,050.00	2701	135,050.00	2701	135,050.00	50.00
Goat	2140	17,120.00	2140	17,120.00	2140	17,120.00	2140	17,120.00	2140	17,120.00	8.00
sheep	2108	16,864.00	2108	16,864.00	2108	16,864.00	2108	16,864.00	2108	16,864.00	8.00
swime	661	3,305.00	661	3,305.00	661	3,305.00	661	3,305.00	661	3,305.00	5.00
Chicken / Rabbit	5646	2,823.00	5646	2,823.00	5646	2,823.00	5646	2,823.00	5646	2,823.00	0.50
Schools											
E. Batista P ST Jean	280	14,000.00	280	14,000.00	280	14,000.00	280	14,000.00	280	14,000.00	50.00
EP SAYO	631	31,550.00	631	31,550.00	631	31,550.00	631	31,550.00	631	31,550.00	50.00
GS Murama	1871		1871		1871		1871		1871		
GS RUBONA	1400		1400		1400		1400		1400		
EP Mutandi	800	40,000.00	800	40,000.00	800	40,000.00	800	40,000.00	800	40,000.00	50.00
EP RUTABO	725	36,250.00	725	36,250.00	725	36,250.00	725	36,250.00	725	36,250.00	50.00
Health facilities											
Health Post	6.00	600.00	6.00	600.00	6.00	600.00	6.00	600.00	6.00	600.00	100.00
Health centers	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	100.00
Industries											
Market (malls)	1.00	60.00	1.00	60.00	1.00	60.00	1.00	60.00	1.00	60.00	60.00
Total water Demand		**1,157,221.62**		**1,196,514.54**		**1,706,600.63**		**1,771,064.62**		**2,864,388.97**	
Available		**1,118,016.00**		**1,118,016.00**		**1,118,016.00**		**1,118,016.00**		**1,118,016.00**	
Deficit or surpuls		**-39205.62**		**-78498.54**		**-588584.63**		**-653048.62**		**-1746372.97**	

Table 75: Kisaro Sector water demand/analysis findings.

Type of consumption	Number 2020	Water demand(l/day/ unit)	Number 2025	Water demand(l/day/ unit)	Number 2030	Water demand (l/day/unit)	Number 2035	Water demand(l/day/ unit)	Number 2040	Water demand (l/day/unit)	Specific water demand per category
Human consumption	24981.1	999,242.56	27989.1	1,119,564.43	31359.4	1,881,561.95	35135.4	2,108,126.61	39366.2	3,936,621.03	40, 60, 80,100
Livestock											
Cow	2375	118,750.00	2375	118,750.00	2375	118,750.00	2375	118,750.00	2375	118,750.00	50.00
Goat	3561	28,488.00	3561	28,488.00	3561	28,488.00	3561	28,488.00	3561	28,488.00	8.00
sheep	728	5,824.00	728	5,824.00	728	5,824.00	728	5,824.00	728	5,824.00	8.00
swime	546	2,730.00	546	2,730.00	546	2,730.00	546	2,730.00	546	2,730.00	5.00
Chicken / Rabbit	4217	2,108.50	4217	2,108.50	4217	2,108.50	4217	2,108.50	4217	2,108.50	0.50
Schools											
Grand Seminaire de Rutungo	90	4,500.00	90	4,500.00	90	4,500.00	90	4,500.00	90	4,500.00	50.00
ES RUTONGO	271	13,550.00	271	13,550.00	271	13,550.00	271	13,550.00	271	13,550.00	50.00
GS MASORO	2419	120,950.00	2419	120,950.00	2419	120,950.00	2419	120,950.00	2419	120,950.00	50.00
GS KIRWA	720	36,000.00	720	36,000.00	720	36,000.00	720	36,000.00	720	36,000.00	50.00
EP BUREHE	779	38,950.00	779	38,950.00	779	38,950.00	779	38,950.00	779	38,950.00	50.00
EP SHENGAMPULI	607	30,350.00	607	30,350.00	607	30,350.00	607	30,350.00	607	30,350.00	50.00
Health facilities											
Health Post	5.00	500.00	5.00	500.00	5.00	500.00	5.00	500.00	5.00	500.00	100.00
Health centers	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	100.00
Hospital	100.00	10,000.00	100.00	10,000.00	100.00	10,000.00	100.00	10,000.00	100.00	10,000.00	100.00
Industries											
Mixed Industry	1.00	100.00	1.00	100.00	1.00	100.00	1.00	100.00	1.00	100.00	100.00
Market (malls)	1.00	60.00	1.00	60.00	1.00	60.00	1.00	60.00	1.00	60.00	60.00
Total water Demand		**1,414,103.06**		**1,534,424.93**		**2,296,422.45**		**2,522,987.11**		**4,351,481.53**	
Available		**689,472.00**		**689,472.00**		**689,472.00**		**689,472.00**		**689,472.00**	
Deficit or surpuls		**-724631.06**		**-844952.93**		**-1606950.45**		**-1833515.11**		**-3662009.53**	

Table 76: Masoro Sector water demand/analysis findings.

Type of consumption	Number 2020	Water demand(l/day/ unit)	Number 2025	Water demand(l/day/ unit)	Number 2030	Water demand (l/day/unit)	Number 2035	Water demand(l/day/ unit)	Number 2040	Water demand (l/day/unit)	Specific water demand per category
Human consumption	18274	730,960.04	19111.3	764,450.67	19986.9	1,199,213.63	20902.6	1,254,158.39	21860.3	2,186,034.28	40, 60, 80,100
Livestock											
Cow	3187	159,350.00	3187	159,350.00	3187	159,350.00	3187	159,350.00	3187	159,350.00	50.00
Goat	2085	16,680.00	2085	16,680.00	2085	16,680.00	2085	16,680.00	2085	16,680.00	8.00
sheep	2209	17,672.00	2209	17,672.00	2209	17,672.00	2209	17,672.00	2209	17,672.00	8.00
swime	380	1,900.00	380	1,900.00	380	1,900.00	380	1,900.00	380	1,900.00	5.00
Chicken / Rabbit	7359	3,679.50	7359	3,679.50	7359	3,679.50	7359	3,679.50	7359	3,679.50	0.50
Health facilities											
Health Post	5.00	500.00	5.00	500.00	5.00	500.00	5.00	500.00	5.00	500.00	100.00
Health centers	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	100.00
Industries											
Mining	1.00	80.00	1.00	80.00	1.00	80.00	1.00	80.00	1.00	80.00	80.00
Market (malls)	1.00	60.00	1.00	60.00	1.00	60.00	1.00	60.00	1.00	60.00	60.00
Total water Demand		**932,881.54**		**966,372.17**		**1,401,135.13**		**1,456,079.89**		**2,387,955.78**	
Available		**1,763,424.00**		**1,763,424.00**		**1,763,424.00**		**1,763,424.00**		**1,763,424.00**	
Deficit or surpuls		**830542.46**		**797051.83**		**362288.87**		**307344.11**		**-624531.78**	

Table 77: Mbogo Sector water demand/analysis findings.

Type of consumption	Number 2020	Water demand(l/day/unit)	Number 2025	Water demand(l/day/unit)	Number 2030	Water demand (l/day/unit)	Number 2035	Water demand(l/day/unit)	Number 2040	Water demand (l/day/unit)	Specific water demand per category
Human consumption	21492.8794	859,715.18	24080.90312	963,236.12	26980.55873	1,618,833.52	30229.37079	1,813,762.25	33869.3823	3,386,938.23	40, 60, 80,100
Livestock											
Cow	2098	104,900.00	2098	104,900.00	2098	104,900.00	2098	104,900.00	2098	104,900.00	50.00
Goat	1122	8,976.00	1122	8,976.00	1122	8,976.00	1122	8,976.00	1122	8,976.00	8.00
sheep	2052	16,416.00	2052	16,416.00	2052	16,416.00	2052	16,416.00	2052	16,416.00	8.00
swime	245	1,225.00	245	1,225.00	245	1,225.00	245	1,225.00	245	1,225.00	5.00
Chicken / Rabbit	3919	1,959.50	3919	1,959.50	3919	1,959.50	3919	1,959.50	3919	1,959.50	0.50
Schools											
GS APAPEC	442	22,100.00	442	22,100.00	442	22,100.00	442	22,100.00	442	22,100.00	50.00
GS Murambi L S1	600	30,000.00	600	30,000.00	600	30,000.00	600	30,000.00	600	30,000.00	50.00
GS MURAMBI L S2	600	30,000.00	600	30,000.00	600	30,000.00	600	30,000.00	600	30,000.00	50.00
GS MUGAMBAZI	1171	58,550.00	1171	58,550.00	1171	58,550.00	1171	58,550.00	1171	58,550.00	50.00
GS MUHORORO	1914	95,700.00	1914	95,700.00	1914	95,700.00	1914	95,700.00	1914	95,700.00	50.00
EP NTYABA	549	27,450.00	549	27,450.00	549	27,450.00	549	27,450.00	549	27,450.00	50.00
Health facilities											
Health Post	4.00	400.00	4.00	400.00	4.00	400.00	4.00	400.00	4.00	400.00	100.00
Health centers	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	100.00
Industries											
Market (malls)	3.00	180.00	3.00	180.00	3.00	180.00	3.00	180.00	3.00	180.00	60.00
Total water Demand		**1,259,571.68**		**1,363,092.62**		**2,018,690.02**		**2,213,618.75**		**3,786,794.73**	
Available		**819,072.00**		**819,072.00**		**819,072.00**		**819,072.00**		**819,072.00**	
Deficit or surpuls		**-440499.68**		**-544020.62**		**-1199618.02**		**-1394546.75**		**-2967722.73**	

Table 78: Murambi Sector water demand/analysis findings.

Type of consumption	Number 2020	Water demand(l/day/ unit)	Number 2025	Water demand(l/day/ unit)	Number 2030	Water demand (l/day/unit)	Number 2035	Water demand(l/day/ unit)	Number 2040	Water demand (l/day/unit)	Specific water demand per category
Human consumption	12148.73817	485,949.53	12895.36783	515,814.71	13687.88341	821,273.00	14529.10491	871,746.29	15422.0257	1,542,202.57	40, 60, 80,100
Livestock											
Cow	2098	104,900.00	2098	104,900.00	2098	104,900.00	2098	104,900.00	2098	104,900.00	50.00
Goat	1122	8,976.00	1122	8,976.00	1122	8,976.00	1122	8,976.00	1122	8,976.00	8.00
sheep	2052	16,416.00	2052	16,416.00	2052	16,416.00	2052	16,416.00	2052	16,416.00	8.00
swime	245	1,225.00	245	1,225.00	245	1,225.00	245	1,225.00	245	1,225.00	5.00
Chicken / Rabbit	3919	1,959.50	3919	1,959.50	3919	1,959.50	3919	1,959.50	3919	1,959.50	0.50
Schools											
GS Gaseke	825	41,250.00	825	41,250.00	825	41,250.00	825	41,250.00	825	41,250.00	50.00
EP GITETE	473	23,650.00	473	23,650.00	473	23,650.00	473	23,650.00	473	23,650.00	50.00
EP YANZE	644	32,200.00	644	32,200.00	644	32,200.00	644	32,200.00	644	32,200.00	50.00
EP NYABUKO	486	24,300.00	486	24,300.00	486	24,300.00	486	24,300.00	486	24,300.00	50.00
Health facilities											
Health Post	4.00	400.00	4.00	400.00	4.00	400.00	4.00	400.00	4.00	400.00	100.00
Health centers	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	100.00
Hospital	100.00	10,000.00	100.00	10,000.00	100.00	10,000.00	100.00	10,000.00	100.00	10,000.00	100.00
Industries											
Milk Collection	1.00	80.00	1.00	80.00	1.00	80.00	1.00	80.00	1.00	80.00	80.00
Total water Demand		**753,306.03**		**783,171.21**		**1,088,629.50**		**1,139,102.79**		**1,809,559.07**	
Available		**311,904.00**		**311,904.00**		**311,904.00**		**311,904.00**		**311,904.00**	
Deficit or surpuls		**-441402.03**		**-471267.21**		**-776725.50**		**-827198.79**		**-1497655.07**	

Table 79: Ngoma Sector water demand/analysis findings.

Type of consumption	Number 2020	Water demand(l/day/unit)	Number 2025	Water demand(l/day/unit)	Number 2030	Water demand (l/day/unit)	Number 2035	Water demand(l/day/unit)	Number 2040	Water demand (l/day/unit)	Specific water demand per category
Human consumption	24658.87715	986,355.09	30001.29445	1,200,051.78	36501.16197	2,190,069.72	44409.24466	2,664,554.68	54030.63641	5,403,063.64	40, 60, 80,100
Livestock											
Cow	2513	125,650.00	2513	125,650.00	2513	125,650.00	2513	125,650.00	2513	125,650.00	50.00
Goat	3418	27,344.00	3418	27,344.00	3418	27,344.00	3418	27,344.00	3418	27,344.00	8.00
sheep	1111	8,888.00	1111	8,888.00	1111	8,888.00	1111	8,888.00	1111	8,888.00	8.00
swime	456	2,280.00	456	2,280.00	456	2,280.00	456	2,280.00	456	2,280.00	5.00
Chicken / Rabbit	11483	5,741.50	11483	5,741.50	11483	5,741.50	11483	5,741.50	11483	5,741.50	0.50
Schools											
GS Ntarabana	1166	58,300.00	1166	58,300.00	1166	58,300.00	1166	58,300.00	1166	58,300.00	50.00
ES RUSASA	1146	57,300.00	1146	57,300.00	1146	57,300.00	1146	57,300.00	1146	57,300.00	50.00
EP KAYENZI	562	28,100.00	562	28,100.00	562	28,100.00	562	28,100.00	562	28,100.00	50.00
EP NYABUKO	442	22,100.00	442	22,100.00	442	22,100.00	442	22,100.00	442	22,100.00	50.00
EP KIYANZA	227	11,350.00	227	11,350.00	227	11,350.00	227	11,350.00	227	11,350.00	50.00
Health facilities											
Health Post	3.00	300.00	3.00	300.00	3.00	300.00	3.00	300.00	3.00	300.00	100.00
Health centers	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	100.00
Industries											
Markets (Malls)	2.00	120.00	2.00	120.00	2.00	120.00	2.00	120.00	2.00	120.00	60.00
Mining sites	2.00	160.00	2.00	160.00	2.00	160.00	2.00	160.00	2.00	160.00	80.00
Milk Collection	1.00	80.00	1.00	80.00	1.00	80.00	1.00	80.00	1.00	80.00	80.00
Total water Demand		**1,336,068.59**		**1,549,765.28**		**2,539,783.22**		**3,014,268.18**		**5,752,777.14**	
Available		**660,096.00**		**660,096.00**		**660,096.00**		**660,096.00**		**660,096.00**	
Deficit or surpuls		**-675972.59**		**-889669.28**		**-1879687.22**		**-2354172.18**		**-5092681.14**	

Table 80: Ntarabana Sector water demand/analysis findings.

Type of consumption	Number 2020	Water demand(l/day/ unit)	Number 2025	Water demand(l/day/ unit)	Number 2030	Water demand (l/day/unit)	Number 2035	Water demand(l/day/ unit)	Number 2040	Water demand (l/day/unit)	Specific water demand per category
Human consumption	15856.64109	634,265.64	16419.44786	656,777.91	17002.23058	1,020,133.83	17605.69827	1,056,341.90	18230.5851	1,823,058.51	40, 60, 80,100
Livestock											
Cow	2098	104,900.00	2098	104,900.00	2098	104,900.00	2098	104,900.00	2098	104,900.00	50.00
Goat	1122	8,976.00	1122	8,976.00	1122	8,976.00	1122	8,976.00	1122	8,976.00	8.00
sheep	2052	16,416.00	2052	16,416.00	2052	16,416.00	2052	16,416.00	2052	16,416.00	8.00
swime	245	1,225.00	245	1,225.00	245	1,225.00	245	1,225.00	245	1,225.00	5.00
Chicken / Rabbit	3919	1,959.50	3919	1,959.50	3919	1,959.50	3919	1,959.50	3919	1,959.50	0.50
Schools											
Health facilities											
Health Post	4.00	400.00	4.00	400.00	4.00	400.00	4.00	400.00	4.00	400.00	100.00
Health centers	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	100.00
Industries											
Markets (Malls)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Milk Collection	1.00	80.00	1.00	80.00	1.00	80.00	1.00	80.00	1.00	80.00	80.00
Total water Demand		**770,223.14**		**792,735.41**		**1,156,091.33**		**1,192,299.40**		**1,959,016.01**	
Available		**636,768.00**		**636,768.00**		**636,768.00**		**636,768.00**		**636,768.00**	
Deficit or surpuls		**-133455.14**		**-155967.41**		**-519323.33**		**-555531.40**		**-1322248.01**	

Table 81: Rukozo Sector water demand/analysis findings.

Type of consumption	Number 2020	Water demand(l/day/ unit)	Number 2025	Water demand(l/day/ unit)	Number 2030	Water demand (l/day/unit)	Number 2035	Water demand(l/day/ unit)	Number 2040	Water demand (l/day/unit)	Specific water demand per category
Human consumption	11995.82007	479,832.80	12733.05179	509,322.07	13515.59184	810,935.51	14346.22475	860,773.49	15227.9062	1,522,790.62	40, 60, 80,100
Livestock											
Cow	2098	104,900.00	2098	104,900.00	2098	104,900.00	2098	104,900.00	2098	104,900.00	50.00
Goat	1122	8,976.00	1122	8,976.00	1122	8,976.00	1122	8,976.00	1122	8,976.00	8.00
sheep	2052	16,416.00	2052	16,416.00	2052	16,416.00	2052	16,416.00	2052	16,416.00	8.00
swime	245	1,225.00	245	1,225.00	245	1,225.00	245	1,225.00	245	1,225.00	5.00
Chicken / Rabbit	3919	1,959.50	3919	1,959.50	3919	1,959.50	3919	1,959.50	3919	1,959.50	0.50
Schools											
EP NKANGA	876	43,800.00	876	43,800.00	876	43,800.00	876	43,800.00	876	43,800.00	50.00
GS RUSIGA	985	49,250.00	985	49,250.00	985	49,250.00	985	49,250.00	985	49,250.00	50.00
GS GITANDA	1200	60,000.00	1200	60,000.00	1200	60,000.00	1200	60,000.00	1200	60,000.00	50.00
E .P RUKINGU	761	38,050.00	761	38,050.00	761	38,050.00	761	38,050.00	761	38,050.00	50.00
Health facilities											
Health Post	4.00	400.00	4.00	400.00	4.00	400.00	4.00	400.00	4.00	400.00	100.00
Health centers	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	100.00
Industries											
Markets (Malls)	1.00	60.00	1.00	60.00	1.00	60.00	1.00	60.00	1.00	60.00	60.00
Mining sites	2.00	160.00	2.00	160.00	2.00	160.00	2.00	160.00	2.00	160.00	80.00
Milk Collection	1.00	80.00	1.00	80.00	1.00	80.00	1.00	80.00	1.00	80.00	80.00
Total water Demand		**807,109.30**		**836,598.57**		**1,138,212.01**		**1,188,049.99**		**1,850,067.12**	
Available		**1,878,336.00**		**1,878,336.00**		**1,878,336.00**		**1,878,336.00**		**1,878,336.00**	
Deficit or surpuls		**1071226.70**		**1041737.43**		**740123.99**		**690286.01**		**28268.88**	

Table 82: Rusiga Sector water demand/analysis findings.

Type of consumption	Number 2020	Water demand(l/day/ unit)	Number 2025	Water demand(l/day/ unit)	Number 2030	Water demand (l/day/unit)	Number 2035	Water demand(l/day/ unit)	Number 2040	Water demand (l/day/unit)	Specific water demand per category
Human consumption	29020.02226	1,160,800.89	32993.96771	1,319,758.71	37512.09753	2,250,725.85	42648.93128	2,558,935.88	48489.193	4,848,919.30	40, 60, 80,100
Livestock											
Cow	5660	283,000.00	5660	283,000.00	5660	283,000.00	5660	283,000.00	5660	283,000.00	50.00
Goat	4542	36,336.00	4542	36,336.00	4542	36,336.00	4542	36,336.00	4542	36,336.00	8.00
sheep	739	5,912.00	739	5,912.00	739	5,912.00	739	5,912.00	739	5,912.00	8.00
swime	516	2,580.00	516	2,580.00	516	2,580.00	516	2,580.00	516	2,580.00	5.00
Chicken / Rabbit	14360	7,180.00	14360	7,180.00	14360	7,180.00	14360	7,180.00	14360	7,180.00	0.50
Schools											
E.Primaire Rutonde	876	43,800.00	876	43,800.00	876	43,800.00	876	43,800.00	876	43,800.00	50.00
ES SHYORONGI	985	49,250.00	985	49,250.00	985	49,250.00	985	49,250.00	985	49,250.00	50.00
GS SHYORONGI	1200	60,000.00	1200	60,000.00	1200	60,000.00	1200	60,000.00	1200	60,000.00	50.00
GS RWAHI	761	38,050.00	761	38,050.00	761	38,050.00	761	38,050.00	761	38,050.00	50.00
GS KIJABAGWE	1220	61,000.00	1220	61,000.00	1220	61,000.00	1220	61,000.00	1220	61,000.00	50.00
ES RWAHI	105	5,250.00	105	5,250.00	105	5,250.00	105	5,250.00	105	5,250.00	50.00
Health facilities											
Health Post	4.00	400.00	4.00	400.00	4.00	400.00	4.00	400.00	4.00	400.00	100.00
Health centers	40.00	4,000.00	40.00	4,000.00	40.00	4,000.00	40.00	4,000.00	40.00	4,000.00	100.00
Industries											
Markets (Malls)	1.00	60.00	1.00	60.00	1.00	60.00	1.00	60.00	1.00	60.00	60.00
Mining sites	2.00	160.00	2.00	160.00	2.00	160.00	2.00	160.00	2.00	160.00	80.00
Mix industry	1.00	100.00	1.00	100.00	1.00	100.00	1.00	100.00	1.00	100.00	100.00
Total water Demand		**1,757,878.89**		**1,916,836.71**		**2,847,803.85**		**3,156,013.88**		**5,445,997.30**	
Available		**721,440.00**		**721,440.00**		**721,440.00**		**721,440.00**		**721,440.00**	
Deficit or surpuls		**-1036438.89**		**-1195396.71**		**-2126363.85**		**-2434573.88**		**-4724557.30**	

Table 83: Shyorongi Sector water demand/analysis findings.

Type of consumption	Number 2020	Water demand(l/day/ unit)	Number 2025	Water demand(l/day/ unit)	Number 2030	Water demand (l/day/unit)	Number 2035	Water demand(l/day/ unit)	Number 2040	Water demand (l/day/unit)	Specific water demand per category
Human consumption	20299.79966	811,991.99	21020.30942	840,812.38	21766.39255	1,305,983.55	22538.95674	1,352,337.40	23338.9419	2,333,894.19	40, 60, 80,100
Livestock											
Cow	3458	172,900.00	3458	172,900.00	3458	172,900.00	3458	172,900.00	3458	172,900.00	50.00
Goat	3067	24,536.00	3067	24,536.00	3067	24,536.00	3067	24,536.00	3067	24,536.00	8.00
sheep	4244	33,952.00	4244	33,952.00	4244	33,952.00	4244	33,952.00	4244	33,952.00	8.00
swime	357	1,785.00	357	1,785.00	357	1,785.00	357	1,785.00	357	1,785.00	5.00
Chicken / Rabbit	9753	4,876.50	9753	4,876.50	9753	4,876.50	9753	4,876.50	9753	4,876.50	0.50
Schools											
E .P RUKORE	698	34,900.00	698	34,900.00	698	34,900.00	698	34,900.00	698	34,900.00	50.00
EP TUMBA LS	769	38,450.00	769	38,450.00	769	38,450.00	769	38,450.00	769	38,450.00	50.00
GS NYIRABIRORI	900	45,000.00	900	45,000.00	900	45,000.00	900	45,000.00	900	45,000.00	50.00
EP RUVUMBA	652	32,600.00	652	32,600.00	652	32,600.00	652	32,600.00	652	32,600.00	50.00
ES APAKI-TUMBA	654	32,700.00	654	32,700.00	654	32,700.00	654	32,700.00	654	32,700.00	50.00
Health facilities											
Health Post	6.00	600.00	6.00	600.00	6.00	600.00	6.00	600.00	6.00	600.00	100.00
Health centers	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	20.00	2,000.00	100.00
Industries											
Markets (Malls)	1.00	60.00	1.00	60.00	1.00	60.00	1.00	60.00	1.00	60.00	60.00
Coffee washing station	2.00	200.00	2.00	200.00	2.00	200.00	2.00	200.00	2.00	200.00	100.00
Total water Demand		**1,236,551.49**		**1,265,371.88**		**1,730,543.05**		**1,776,896.90**		**2,758,453.69**	
Available		**1,251,936.00**		**1,251,936.00**		**1,251,936.00**		**1,251,936.00**		**1,251,936.00**	
Deficit or surpuls		**15384.51**		**-13435.88**		**-478607.05**		**-524960.90**		**-1506517.69**	

Table 84: Tumba Sector water demand/analysis findings.

Appendix 3: Costing of long term intervention measures for the spring catchment protection

Spring recharge catchment 1				
Measures	**Area Ha**	**% Area Covered**	**unit cost rwf**	**budget rwf**
Agroforestry+progressive terraces/cuttoff drains	1,355.36	47.43	1,500,000	2,033,040,000
Agroforestry+cuttoff drains/horizontal trenches	616.98	21.59	250,000	154,245,000
Agroforestry+radical terraces/gully treatment	469.21	16.42	2,000,000	938,420,000
Forest Plantation	206.91	7.24	500,000	103,455,000
Natural Forest	209.43	7.33	1,200,000	251,316,000
Total				3,480,476,000
Spring recharge catchment 2				
Measures	**Area Ha**	**% Area Covered**	**unit cost rwf**	**budget rwf**
Agroforestry+progressive terraces/cuttoff drains	2,628.72	61.21	1,500,000	3,943,080,000
Agroforestry+cuttoff drains/horizontal trenches	1,200.12	27.95	250,000	300,030,000
Agroforestry+radical terraces/gully treatment	465.53	10.84	2,000,000	931,060,000
Forest Plantation	1,087.11	25.31	500,000	543,555,000
Natural Forest	756.48	17.62	1,200,000	907,776,000
Total				6,625,501,000
Spring recharge catchment 3				
Measures	**Area Ha**	**% Area Covered**	**unit cost rwf**	**budget rwf**
Agroforestry+progressive terraces/cuttoff drains	120.97	72.75	1,500,000	181,455,000
Agroforestry+cuttoff drains/horizontal trenches	20.33	12.23	250,000	5,082,500
Agroforestry+radical terraces/gully treatment	24.98	15.02	2,000,000	49,960,000
Forest Plantation	138.04	83.01	500,000	69,020,000
Natural Forest	105.60	63.5	1,200,000	126,720,000
Total				432,237,500
Spring recharge catchment 4				
Measures	**Area Ha**	**% Area Covered**	**unit cost rwf**	**budget rwf**
Agroforestry+progressive terraces/cuttoff drains	992.66	70.43	1,500,000	1,488,990,000
Agroforestry+cuttoff drains/horizontal trenches		13.9		48,970,000

	195.88		250,000	
Agroforestry+radical terraces/gully treatment	220.89	15.67	2,000,000	441,780,000
Forest Plantation	1,174.34	83.32	500,000	587,170,000
Natural Forest	1,272.68	90.3	1,200,000	1,527,216,000
Total				4,094,126,000
Spring recharge catchment 5				
Measures	**Area Ha**	**% Area Covered**	**unit cost rwf**	**budget rwf**
Agroforestry+progressive terraces/cuttoff drains	938.51	62.76	1,500,000	1,407,765,000
Agroforestry+cuttoff drains/horizontal trenches	309.74	20.71	250,000	77,435,000
Agroforestry+radical terraces/gully treatment	247.22	16.53	2,000,000	494,440,000
Forest Plantation	477.29	31.92	500,000	238,645,000
Natural Forest	497.00	33.23	1,200,000	596,400,000
Total				2,814,685,000
Spring recharge catchment 6				
Measures	**Area Ha**	**% Area Covered**	**unit cost rwf**	**budget rwf**
Agroforestry+progressive terraces/cuttoff drains	251.81	64.81	1,500,000	377,715,000
Agroforestry+cuttoff drains/horizontal trenches	62.45	16.07	250,000	15,612,500
Agroforestry+radical terraces/gully treatment	74.29	19.12	2,000,000	148,580,000
Forest Plantation	238.66	61.42	500,000	119,330,000
Natural Forest	274.59	70.67	1,200,000	329,508,000
Total				990,745,500
Spring recharge catchment 7				
Measures	**Area Ha**	**% Area Covered**	**unit cost rwf**	**budget rwf**
Agroforestry+progressive terraces/cuttoff drains	129.74	66.76	1,500,000	194,610,000
Agroforestry+cuttoff drains/horizontal trenches	52.20	26.86	250,000	13,050,000
Agroforestry+radical terraces/gully treatment	12.41	6.39	2,000,000	24,820,000
Forest Plantation	102.54	52.76	500,000	51,270,000
Natural Forest	64.96	33.43	1,200,000	77,952,000
Total				361,702,000
Spring recharge catchment 8				

Measures	Area Ha	% Area Covered	unit cost rwf	budget rwf
Agroforestry+progressive terraces/cuttoff drains	82.36	46.27	1,500,000	123,540,000
Agroforestry+cuttoff drains/horizontal trenches	89.06	50.04	250,000	22,265,000
Agroforestry+radical terraces/gully treatment	6.56	3.69	2,000,000	13,120,000
Forest Plantation	36.92	20.75	500,000	18,460,000
Natural Forest	25.42	14.28	1,200,000	30,504,000
Total				207,889,000
Spring recharge catchment 9				
Measures	**Area Ha**	**% Area Covered**	**unit cost rwf**	**budget rwf**
Agroforestry+progressive terraces/cuttoff drains	124.37	50.33	1,500,000	186,555,000
Agroforestry+cuttoff drains/horizontal trenches	116.36	47.09	250,000	29,090,000
Agroforestry+radical terraces/gully treatment	6.37	2.58	2,000,000	12,740,000
Forest Plantation	28.20	11.41	500,000	14,100,000
Natural Forest	6.84	2.77	1,200,000	8,208,000
Total				250,693,000
Spring recharge catchment 10				
Measures	**Area Ha**	**% Area Covered**	**unit cost rwf**	**budget rwf**
Agroforestry+progressive terraces/cuttoff drains	31.09	41.39	1,500,000	46,635,000
Agroforestry+cuttoff drains/horizontal trenches	36.37	48.42	250,000	9,092,500
Agroforestry+radical terraces/gully treatment	7.66	10.2	2,000,000	15,320,000
Forest Plantation	5.21	6.93	500,000	2,605,000
Natural Forest	4.56	6.07	1,200,000	5,472,000
Total				79,124,500
Spring recharge catchment 11				
Measures	**Area Ha**	**% Area Covered**	**unit cost rwf**	**budget rwf**
Agroforestry+progressive terraces/cuttoff drains	605.10	72.17	1,500,000	907,650,000
Agroforestry+cuttoff drains/horizontal trenches	96.28	11.48	250,000	24,070,000
Agroforestry+radical terraces/gully treatment	137.09	16.35	2,000,000	274,180,000
Forest Plantation	449.75	53.64	500,000	224,875,000
Natural Forest		40.86	1,200,000	411,096,000

	342.58			
Total				1,841,871,000
Spring recharge catchment 12				
Measures	**Area Ha**	**% Area Covered**	**unit cost rwf**	**budget rwf**
Agroforestry+progressive terraces/cuttoff drains	150.53	52.13	1,500,000	225,795,000
Agroforestry+cuttoff drains/horizontal trenches	36.22	12.54	250,000	9,055,000
Agroforestry+radical terraces/gully treatment	102.01	35.33	2,000,000	204,020,000
Forest Plantation	62.26	21.56	500,000	31,130,000
Natural Forest	115.47	39.99	1,200,000	138,564,000
Total				608,564,000
Spring recharge catchment 13				
Measures	**Area Ha**	**% Area Covered**	**unit cost rwf**	**budget rwf**
Agroforestry+progressive terraces/cuttoff drains	1,516.29	71.16	1,500,000	2,274,435,000
Agroforestry+cuttoff drains/horizontal trenches	401.72	18.85	250,000	100,430,000
Agroforestry+radical terraces/gully treatment	212.94	9.99	2,000,000	425,880,000
Forest Plantation	1,103.22	51.77	500,000	551,610,000
Natural Forest	377.18	17.7	1,200,000	452,616,000
Total				3,804,971,000
Spring recharge catchment 14				
Measures	**Area Ha**	**% Area Covered**	**unit cost rwf**	**budget rwf**
Agroforestry+progressive terraces/cuttoff drains	296.24	59.47	1,500,000	444,360,000
Agroforestry+cuttoff drains/horizontal trenches	56.88	11.42	250,000	14,220,000
Agroforestry+radical terraces/gully treatment	145.04	29.11	2,000,000	290,080,000
Forest Plantation	263.13	52.82	500,000	131,565,000
Natural Forest	343.75	69	1,200,000	412,500,000
Total				**1,292,725,000**
Total for 14 catchments				**26,885,310,500**