REPUBLIC OF RWANDA

RWANDA WATER RESOURCES BOARD

Water Users and Uses Assessment in Rwanda

Report

Kigali, October 2020

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Acronyms

CART	Classification and Regression Trees
CKIV	Kivu Level 1 Catchment
CRUS	Rusuzi Level 1 Catchment
CSV	Comma Separated Value
EFR	Environmental Flow Requirements
EFR	Environmental flow requirements
ERWR	External Renewable Water Resources
FAO	Food and Agricultural Organization of the United Nations
GIS	Geo-information Science
GLM	Generalized Linear Regression
GoR	Government of Rwanda
IMP	Irrigation Master Plan
IRWR	Internal Renewable Water Resources
ISIC	International Standard Industrial Classification
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
KNN	k-Nearest Neighbors
KnoWat	Know Water
LR	Linear Regression
LWIR	Short Wavelength Infrared
MINICOM	Ministry of Information and Communication
MINIFRA	Ministry of Infrastructure
MINIRENA	Ministry of Natural Resources
MOE	Ministry of Environment
MS	Microsoft Access
MySQL	My Structured Query Language

NAEB	National Agricultural Export Development Board
NAKL	Akagera Lower
NAKN	Akanyaro
NAKU	Akagera Upper
NAKU	Akagera upper catchment
NISR	National Institute of Statistics of Rwanda
NMUK	Mukungwa
NMUV	Muvumba catchment
NMUV	Muvumva
NNYL	Nyabarongo Lower
NNYU	Nyabarongo Upper
NNYU	Nyabarongo Upper catchment
NWRMP	National Water Resources Master Plan
PHP	Hypertext Preprocessor
RAB	Rwanda Agricultural Board
RBM&E	Natural Resources Results-Based Monitoring and Evaluation
RDBMS	Relational Database Management System
REG	Rwanda Energy Group
RMB	Rwanda Mining Board
RNRA	Rwanda Natural Resources Authority
RTDA	Rwanda Transport Development Authority
RWB	Rwanda Water Resources Board
SDG	Sustainable Development Goals
SVR	Support Vector Regression
TFWW	Total fresh water withdrawn
TFWW	Total freshwater withdrawal
TRWR	Total renewable freshwater resources
UN	United Nations

UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations International Children's Emergency Fund
USGS	United States Geological Survey
WASAC	Water and Sanitation Cooperation
WMO	World Meteorological Organisation
WS	Water Stress

Executive Summary

About 2 billion people live in countries experiencing high water stress globally and it is estimated that by 2040, one in four of the world's children under 18 – some 600 million in all, will be living in areas of extremely high-water stress. It was also projected intense water scarcity may cause the displacement of about 700 million people globally, by 2030. Currently about 4 billion people, representing nearly two-thirds of the world population, experience severe water scarcity during at least one month of the year and with the existing climate change scenario, by 2030, water scarcity in some arid and semi-arid places will displace between 24 million and 700 million people. Nearly half the global population is already living in potential water scarce areas at least one month per year and this could increase to some 4.8–5.7 billion in 2050. About 73% of the affected people live in Asia (69% by 2050). These and many others are some of the water related challenges that faced the global community and Rwanda is not an exception (UN, 2020).

The Rwanda Water Resources Board (RWB) maintains an annual inventory for registered water users through its Water Use permit system. However, information on water use by major user categories is not reported on a regular basis to the RWB and many of the users are neither registered nor entitled to use water resources. The Environmental and Natural Resources Results-Based Monitoring and Evaluation (RBM&E) system report published in August in 2013 highlighted that the ability to monitor water use and actual or potential conflicts over water use by different users in catchments is a priority for Integrated Water Resources Management (IWRM). The Government of Rwanda (GoR) considers this as an important issue for sustainable development of the country.

The project "Knowing water better: Towards fairer and more sustainable access to natural resources for greater food security" (KnoWat) of the Food and Agriculture Organization of the United Nations (FAO) has been developed to address water scarcity issues in Rwanda and around the world. The project recognizes this challenge and thus aims to strengthen water governance processes in Rwanda for better preparedness and to ensure food security and adaptation to climate change, water scarcity and increased competition for water resources in an equitable and sustainable manner. The water users are categorized into Big and small water users as follows:

Big water users: (1) Hydropower plants, (2) Large Irrigation schemes, (3) Domestic Water Supply, (4) Coffee washing stations, (5) Mining companies, (6) Industries/Manufacturing, (7) Fish ponds, (8) Fish farming in the Lake, (9) Gas extraction, and (10) Boat ports.

Small water users' category: (1) Small-scale irrigation, (2) Public Boreholes, and (3) Public Springs.

Based on the obtained results the highest abstractions were observed in hydropower, irrigation, and domestic water supply with 3,381.9 (84.76%), 363.4 (9.11%) and 234.8 (5.88%) million m^3/year, respectively. The hydropower water use was considered to be non-consumptive as there are only two hydropower (Nyabarongo I and Rukarara) where dams were constructed before power generation. For hydropower on Lakes there was no increase in surface area due to dam construction, therefore no

additional evaporation as the result of hydropower construction. However, when considering consumptive water use irrigation is leading with 59.75%, followed by domestic water use is second with 38.61% of the water use, then followed by mining, industries, fish ponds and coffee washing stations with 0.79%, 0.53%, 0.17% and 0.4% respectively. The results also show that except for Muvumba catchment with low water stress level, all other catchments have no water stress (Table 7). This is different from the methodology used in the National Water Resource Master Plan of 2015, classified Rwanda as a water stress with annual per capita renewable water availability of less than 700 m^3.

1. Introduction

According to World Water Development Report 2020 there was an increase in the global water use by a factor of six for the last 100 years and this continues to grow steadily at a rate of about 1% per year. The growth in water use is as the results of increasing population, economic development and shifting consumption patterns. The situation is expected to worsen in the regions that are currently water-stressed and generate water stress in regions where water resources are still abundant today, because of more erratic and uncertain supply and climate change (UNESCO, UN Water, 2020). The case is identical in Rwanda where the statistical year book, 2019 shows increase in population, economic development and rise in standard of leaving living leading to both shifting and increase in consumption patterns (NISR, 2020). According to several reports (RNRA, 2014, NIRAS, 2017, and IMP, 2020) Rwanda is considered to be water stress. There is also trend in increased use of water for irrigation, domestic water supply, hydropower generation, industries, and many other aspects of water use. All these necessitated the need for assessing water use and users in the country to ensure sustainable water resources management.

Rwanda is the head water of two major African basins i.e. the Congo Basin from the West and Nile Basin from the East. The Congo basin covers 33% of the total territory of Rwanda and drains 10% of the water resources, while the Nile basin covers 67% of the territory and drains 90% of the water. Being at the upstream of each of the two basins, the demand for the water resources generated in Rwanda could be high downstream especially at the side of the Nile Basin. In order to ensure sound and sustainable management of water resources in the country it is critically important to assess resources in terms of its quantity, quality, spatial distribution and demand. This is especially important because of the rapid population growths, increase in human activities generating various impacts on the natural resources, natural disasters resulting from unsustainable human activities and climate change with its related uncertainties. Clear understanding of availability, spatial and temporal distribution, quality and trends is crucial for sound-decision making that will lead to effective water resources management (WMO, 2008). This study intends to update water users and use in Rwanda based on 20 level two catchments. It is therefore important to review the existing information to ensure clarity and be able to make relevant comparisons.

Worldwide over 2 billion people live in countries experiencing high water stress, (UN, 2018) and it is estimated that by 2040, one in four of the world's children under 18 – some 600 million in all, will be living in areas of extremely high-water stress. UNICEF, 2017. Projected intense water scarcity may cause the displaced of about 700 million people globally, by 2030. Currently about 4 billion people, representing nearly two-thirds of the world population, experience severe water scarcity during at least one month of the year and with the existing climate change scenario, by 2030. Nearly half the global population is already living in potential water scarce areas at least one month per year and this could increase to some 4.8–5.7 billion in 2050. About 73% of the affected people live in Asia (69% by 2050). These and many others are some of the water related challenges that face the global community and Rwanda is not an exception (UN, 2020). Rwanda is categorized as a moderately water scarce country with an estimated annual water availability level of approximately 670 Cubic meters of water per capita (RNRA, 2015). Based on current trends, the level of scarcity is expected to increase in the future as the country continues to develop economically, and as its population continues to increase. Hence, the level of competition for water to satisfy the needs of communities, farms, and industry is expected to grow significantly.

The above statistics show that having accurate information on the amount of water used and the purposes of its use is important for effective water resources management. Therefore, consistent, comprehensive, and reliable water use data is crucial in order to take appropriate decisions on water use management. Well-structured water use data must be a part of the national water spatial data infrastructure to make sound future decisions regarding water allocation both at catchment and national levels (USGS, 2002). Also, creating and maintaining an inventory of water withdrawals and water uses is important for national policy and planning as well as for complying with regulations, agreements and water resources management systems. Article 21 of the Law No 49/2018 of 13/08/2018 that determine the use and management of water resources in Rwanda stated that "*the use of water resources in different activities and installations susceptible to modify the flow or the level of water or to degrade their quality, or to threaten water related ecosystems, wetlands and the environment are subjected to water use permit"* (Government of Rwanda, 2018).

The Rwanda Water Resources Board (RWB) maintains an annual inventory for registered water users through its Water Use permit system. However, information on water use by major user categories is not reported on a regular basis to the RWB and many of the users are neither registered nor entitled to use water resources.

This report is based on the existing water users and uses assessment conducted in 2017, data collected from relevant organizations, review of updated literature and existing data and field data collection conducted for some identified users.

1.1 Background

The Environmental and Natural Resources Results-Based Monitoring and Evaluation (RBM&E) system report published in August in 2013 highlighted that the ability to monitor water use and actual or potential conflicts over water use by different users in catchments is a priority for Integrated Water Resources Management (IWRM). The Government of Rwanda (GoR) considers this as an important issue for sustainable development of the country. It is for this reason that the baseline study on water users and uses in 20 level 2 catchments across the country showed that water withdrawn in 2016 at national level was 499,468,512 m^3 and the highest water withdraw-availability ratio was observed in Akagera upper catchment (NAKU), Nyabarongo Upper catchment (NNYU) and Muvumba catchment (NMUV), which demonstrated an annual withdrawal ratio of 11.62%, 10.78 and 10.48%, respectively (MINIRENA, 2017).This year, findings of this study have been updated by Best Associated Consultants who was contracted by FAO Rwanda in partnership with RWB under the KnoWat Project.

FAO's project "Knowing water better: Towards fairer and more sustainable access to natural resources for greater food security" (KnoWat) has been developed to address water scarcity issues in Rwanda and around the world. The KnoWat project aims to strengthen water governance processes in Rwanda for better preparedness and to ensure food security and adaptation to climate change, water scarcity and increased competition for water resources in an equitable and sustainable manner.

1.2 Objectives of the water users and uses assessment

The main objective of the Water Users and Uses Assessment was to assess and update the existing approach of water users and uses data collection and apply it to all 20 Level 2 catchments in Rwanda, and update existing water users & uses database.

Specifically, the assessment reviewed/updated the approach for collecting data on the following indicators of the IWRM sub-sector:

1. Water Withdrawal-Availability ratio;
2. Proportion of total water use by each major user category (national and disaggregated by level 2 catchment);
3. Number of water use conflicts/issues (by type of conflict/issue) – overall and disaggregated by level 2 catchment;
4. Proportion (%) of water users with water permits.

1.3 Scope of the study

On request from the Rwanda Water Resources Board, the KnoWat project would build on the results of previous assessment of water users and water uses in 20 level 2 catchments of Rwanda in order to update and monitor water users & uses and actual or potential conflicts over water use by different users in catchments. The scope of the study involved the identification and mapping of all 'users of water' as defined by the law (extracting water from either surface water sources or groundwater). Concerned water users include significant individual users such as mines, urban and rural water supply agencies, industrial plants, hydropower plants, commercial farms, large irrigation schemes, aquaculture cooperatives/companies, government facilities and public institutions not supplied by water service providers, etc., as well as collectives of small users such as water users' associations.

1.4 Level 2 Catchments

Figure 1: Level 2 Catchments and Districts

Table 1: Level 2 catchment of Rwanda

Level 2 code	Catchment names
NAKL_1	Akagera Lower
NAKU_1	Akagera-Mugesera
NAKU_2	Akagera-Rweru
NAKN_1	Akanyaru Upper
NAKN_2	Akanyaru Lower
NAKN_3	Cyohoha South
CKIV_1	Sebeya
CKIV_2	Kivu Upper
CKIV_3	Kivu Lower
NMUK_1	Burera-Ruhondo
NMUK_2	Mukungwa-Giciye
NMUV_1	Murindi
NMUV_2	Muvumba-Warufu
NNYU_1	Mbirurume
NNYU_2	Mwogo
NNYU_3	Nyabarongo1 Dam-Satinsyi
NNYL_1	Nyabugogo
NNYL_2	Nyabarongo Valley-Base
CRUS_1	Rusizi-Rubyiro
CRUS_2	Ruhwa

2. A review of the national, regional and international water use information

2.1 Definition and concepts of water use

The term "*water use*" is defined by The United States Geological Survey (USGS) as all in-stream and off-stream uses of water for human purposes from any water source (USGS, 2002). Off-stream use refers to water that is abstracted from surface water sources or withdrawn from groundwater sources (i.e., a "*withdrawal*") and is conveyed to the place of use. ***In-stream use*** refers to water use that takes place without water being withdrawn from surface water or groundwater, such as by hydropower stations (Wayne B. Solley & Perlman, 1998).

Research shows that water use data come mainly from different user categories. In Rwanda, water use estimates come from domestic water supply, irrigation, aquaculture, Industries: coffee washing station, tea, bottled water, soft drinks and beer processing, mining and hydropower plants (RNRA, 2015).

Water that is diverted or withdrawn from surface or groundwater sources (off-stream use) either is lost to the system (consumed) or returned to surface or groundwater bodies. Detailed definitions and glossary can be found in AQUASTAT Glossary, FAO, (2019) on the following terms:

- **Consumptive use** refers to the withdrawn water that is evaporated, transpired or incorporated into products, animals or crops. It is generally evaluated based on the amount of water delivered and the amount returned to the water source.
- **Conveyance loss** is the amount of water lost in the transit, either between the source and the point of use or from the point of use to the point of return. Most of the conveyance loss is due to evaporation along with seepage and leaks.
- **Return flow** is the quantity of water that is returned to surface or groundwater sources. However, the quality of this water may be different from the initial water quality at the point of withdrawal.

2.2 Registration and permits for water users

Registration and issuing permits to water users play an important role in the data collection process for the water use. In the Rwandan context, registration and permits are governed by water law N°49/2018 of 13/08/2018 determining the use and management of water resources in Rwanda, in its Article 21. The use of water resources in different activities and installations susceptible to modify the flow or the level of water or to degrade their quality, or to threaten water related ecosystems, wetlands and the environment are subject to water use permit (Government of Rwanda, 2018). Referring to the ministerial order nº 002/16.01 of 24/05/2013; the water use permit is classified into three types namely; authorization, concession and declaration which are valid for the period agreed upon by contracting parties. The period cannot exceed fifteen (15) years, but the beneficiary of the authorisation or concession may apply for the extension of its validity (Government of Rwanda, 2013).

Water users subject to water use permit are categorized as follows: irrigation schemes of above 1 ha; owners of water treatment plants for domestic water supply; owners of hydropower plants; owners of industries/coffee washing stations/mining companies getting water from surface water or groundwater ; fish farmers in lakes or ponds; construction of dams; any deviation of a water body (lake, river or stream); groundwater abstraction; physical or juridical persons wishing to carry out research in water bodies or exploration of water resources.

2.3 The need for water use data

In parts of a country or region where precipitation is greater than evapotranspiration, most water is used in the basin from which it is withdrawn. On the contrary, in areas where precipitation is less than evapotranspiration, groundwater and surface water are often limited (USGS, 2002). In Rwanda, about half of precipitation occurs in one quarter of the year. The western half of Rwanda receives an average of 1400 mm, while the eastern half receives less than 1000 mm. In addition, critical wetlands and catchments have been converted into agricultural lands, leading to drying up of some wetlands. This constrains water use, affects people and ecosystems, and challenges resource managers to adopt innovative approaches to manage the water resources equitably and sustainably (MINIRENA, 2015).

Much as debits, credits, and savings in a financial budget need to be quantified to maintain financial accountability. Therefore, the nation's water use needs to be comprehensively quantified within the water budget to ensure adequate availability of water to meet future water demands, taking into account regional fluctuations due to changes in climate, urban growth patterns, agricultural practices, and energy needs (USGS, 2002).

2.4 Sources of secondary data by categories of water use and withdrawal

The categorization of water users varies from one country to another but the literature shows that there are great similarities of water user categories across the globe. For example, the AQUASTAT's main user categories are (agriculture, industry and domestic). The Government of Rwanda, in its water resources management sub-sector strategic plan, has categorized water uses into domestic, agricultural (Irrigation), industrial use, as well into water use for fisheries (Aquaculture), energy (Hydropower), infrastructure, recreation and ecosystem maintenance (MINIRENA, 2015).

BIG WATER USERS' CATEGORY:

Coffee washing stations: The very recently updated database (March 2020) of coffee washing stations containing all needed information were collected from NAEB and were analyzed and compared with the existing information stored in RWB database and water permit system. In this category, the assessment was only based on the secondary data.

Domestic Water Supply: The recently updated database of rural water supply networks containing all needed information was collected from WASAC Ltd. These data were analyzed and compared with the existing information stored in the RWB database and water permit system. The assessment focused on the rural water supply networks, as all urban water supply sources of WASAC Ltd have been collected from the RWB water permit system with full information needed.

Hydropower plants: The records of all hydropower plants based on information from REG were collected from the RWB water permit system. This information contained all needed information. In this category, the assessment was only based on secondary data.

Mining companies: The recently updated database of mining companies with most of the needed information was collected from RMB. These data were analyzed and compared with the existing information stored in the RWB's database and water permit system. The field survey was done at all the mining sites, which were not visited during the last survey of 2017, and do not have water permits, to complete/confirm the collected information.

Large Irrigation schemes: The very recently updated database and shapefiles (December 2019) of large irrigation schemes containing all useful information were collected from RAB. SSIT database and the existing information from RWB database and water permit system were also obtained. The information was put together and analyzed. Duplications and overlapping were removed to double counting of the irrigation sites. Though SSIT does not require permits, they were added in the calculation of water use as the aim of the study was to find out the amount of water use in the country.

Industries/Factories: The list of tea factories with some useful information have been collected from NAEB. There was also a list of industries from the existing RWB database that needed to be analyzed for separating factories/industries and coffee washing stations observed in the list. All the factories/industries which were not surveyed or don't have water permits, were fully surveyed.

Fish farming: An interesting information is that all fish farmers in lakes are owned water permits, meaning that all useful information are available in the water permit system of RWB, however, this category of water users were not included in the previous water users survey. This time this category was considered and categorized in big water users. But water use is not calculated as this category is considered not to consume water, though it has a negative impact on water quality.

Fish ponds: The list of all fish ponds with all useful information updated recently has been collected from MINAGRI/RAB. These secondary data were analyzed and included in the water users' database in the category of small water users. This category of water users was not included in the previous water users' survey, but this time it was considered as suggested by RWB.

Gas extraction: In this category, there are three companies in Lake Kivu; some information was collected from RWB, and RMB was consulted for validating the obtained information. This category of water users was not included in the previous water users' survey, but this time it was considered and categorized in big water waters as suggested by RWB. However, water use by this category is classified in terms of area necessary for the operation not volume of water.

Boat ports: This is also a new water user category, but very important to be considered. It was included based on the full information collected from the RWB and consulting RTDA to confirm the available information. This category is also considered as big water users.

SMALL WATER USERS' CATEGORY:

Small-scale irrigation: The recent updated database (December 2019) of small-scale irrigation containing some useful information were collected from RAB. All those with area equal and above 10 ha were visited to confirm their status and all those appears to have the indicated area of 10 ha or greater were moved to the large irrigation.

Public Boreholes: In this category of water use, the existing database was analyzed and updated with the secondary data from RWB without field survey as this assessment focuses on big water users' categories. The water use was estimated on the assumption that the borehole is in continuous use for a period of 4 hours daily. The annual water use was calculated as follows:

$$V = \frac{Q}{1000} \times T$$

Where V- Volume of water withdrawn m^3/year, Q-discharge of the borehole in L/s, T- total time in seconds the borehole is in operation per year.

Public Springs: The recent update database of rural water supply networks containing all needed information were collected from WASAC Ltd. These data were analyzed and compared with the existing springs database and water permit system of RWB. The volume of water withdrawn from springs that were not captured by water service providers were calculated as for the public borehole above.

3. Methodology

3.1 General set up for data collection

Most of the useful secondary data was collected from different institutions related to water use, and we gathered any useful information from different stakeholders in the water sector. The secondary data was complemented by the primary data collected using a field survey. To conduct the field survey, the training of field staff (enumerators) was organized and conducted for two days from July 13 to July 14, 2020, for better understanding and to increase the quality of data collection assignment.

The field data collection was done in 20 working days from 3rd to 26th September 2020 with 10 well-trained enumerators to cover 373 water users (approximately two water users per enumerator and per day) among mining, large-scheme irrigation, and industry/factory water users, based on the discussions conducted with RWB, and following their suggestions and existing gaps of information. Data collected from different stakeholders also involved vulnerable users (small irrigation, public boreholes and public springs), this is necessary in order to understand the level of vulnerability and how to mitigate it. In addition, secondary data of vulnerable users were analyzed where possible. The collected data were processed and analyzed as detailed in the following sections. The summary of data collection and analysis is provided in Figure 2.

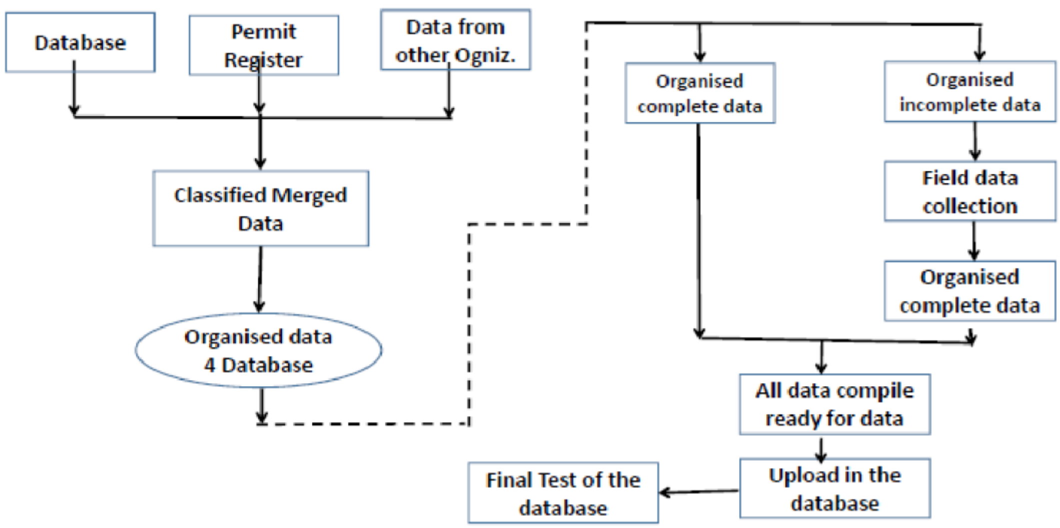


Figure 2: Schematic summarized of the methodology

3.2 Method and classification of water stress

Water stress is under the SDG goal 6.4 related to water use and scarcity in its indicator 6.4.2 related to the level of water stress: freshwater withdrawal in percentage of available freshwater resources.

An indicator on water stress existed already in the MDG monitoring framework, denominated "proportion of total water resources used". Although the definition of that indicator was quite near to the definition proposed for SDG indicator 6.4.2, it did not take into consideration the environmental flow requirements (EFR), being limited to considering the water needed for human activities in front of the overall water availability.

This point has been addressed in the identification of the present water stress indicator 6.4.2, leading to the following definition: the ratio between total freshwater withdrawal by all major sectors and total renewable freshwater resources, after having taken into account environmental water requirements.

Main sectors, as defined by ISIC standards, can include for example agriculture; forestry and fishing; manufacturing; electricity industry; and services. The data on freshwater withdrawal are also used for the calculation of indicator 6.4.1 on water use efficiency, and the data on environmental water requirements feeds into indicator 6.6.1 on water-related ecosystems.

The indicator is computed based on three components, as described below (FAO, 2017):

i. **Total renewable freshwater resources (TRWR)** are expressed as the sum of (a) internal renewable water resources (IRWR) and (b) external renewable water resources (ERWR). The term "water resources" is understood here as freshwater resources.
   a. **Internal renewable water resources (IRWR)** are defined as the long-term average annual flow of rivers and recharge of groundwater for a given country generated from endogenous precipitation.
   b. **External renewable water resources (ERWR)** refer to the flows of water entering the country, taking into consideration the quantity of flows reserved to upstream and downstream countries through agreements or treaties (and, where available, the reduction of flow due to upstream withdrawal).

ii. **Total freshwater withdrawal (TFWW)** is the volume of freshwater extracted from its source (rivers, lakes, aquifers) for agriculture, industries and services. It is estimated at the country level for the following three main sectors: agriculture, services (including domestic water withdrawal) and industries (including cooling of thermoelectric plants). Freshwater withdrawal includes fossil groundwater. It does not include direct use of non-conventional water, i.e. direct use of treated wastewater, direct use of agricultural drainage water and desalinated water.

iii. **Environmental flow requirements (EFR)** are the quantities of water required to sustain freshwater and estuarine ecosystems. Water quality and the resulting ecosystem services are excluded from this formulation, which is confined to water volumes. This does not imply that quality and the support to societies, which are dependent on environmental flows are not important and should not be taken care of. They are indeed taken into account by other targets and indicators, such as 6.3.2, 6.5.1 and 6.6.1. Methods of computation of EFR are extremely variable and range from global estimates to comprehensive assessments for river reaches. For the purpose of the SDG indicator, water volumes can be expressed in the same units as the TFWW, and then as percentages of the available water resources. EFR in river basins ranges from 20 to 50% of the total renewable water resources (TRWR) (IWMI, 2017). On average, at least 30 % of the world's water resources have to be allocated for the environment to maintain a fair condition of freshwater ecosystems worldwide. But for the case of Rwanda, we will use 22% as found by IWMI in 2017.

The indicator is computed using the following formula (FAO, 2017):

$$WaterStress\ (\%) = \frac{TFWW}{TRWR - EFR} * 100$$

Where:

- TFWW Total freshwater withdrawn,
- TRWR Total renewable freshwater resources
- EFR Environmental flow requirements (this is taken to be 22% of the total renewable water resource) then the above formula can be transformed as follows:

$$WaterStress\ (\%) = \frac{TFWW}{TRWR - 0.22TRWR} * 100, = \frac{TFWW}{7.8\,TRWR}$$

Table 2: Level of water stress according to SDGs

S/N	Ratio of withdrawal to availability after EFR (%)	Stress Level
1	0-25	no water stress
2	25-50	low water stress
3	50-75	medium water stress
4	75-100	high water stress
5	>100	critical stress

This indicator neglects temporal and spatial variations as well as water quality data.

In Rwanda like in other development countries, water stress (WS) will continue to increase due to population growth and economic development. The World Economic Forum has listed WS as one of the global systemic risks of high concern. Water use efficiency improvements may slow down the growth in water demand, but, particularly in irrigated agriculture, such improvements will most likely be offset by increased production (Hoekstra, 2014). Similarly, water storage and transfer infrastructure improve water availability but allow further growth in demand as well. The expected increase in climate variability will exacerbate the WS problem in dry seasons through reduced water availability and increased demand (Haddeland et al., 2014).

3.3 Data processing and analysis

3.3.1 Data entry

We computerized water users and used survey questionaries so that the enumerators could use emerging devices or wireless-enabled computing devices such as smartphones and tablets in data collection. The supporting tool is designed to run on PC, smartphones, tablet computers, and other mobile devices with Internet connection.

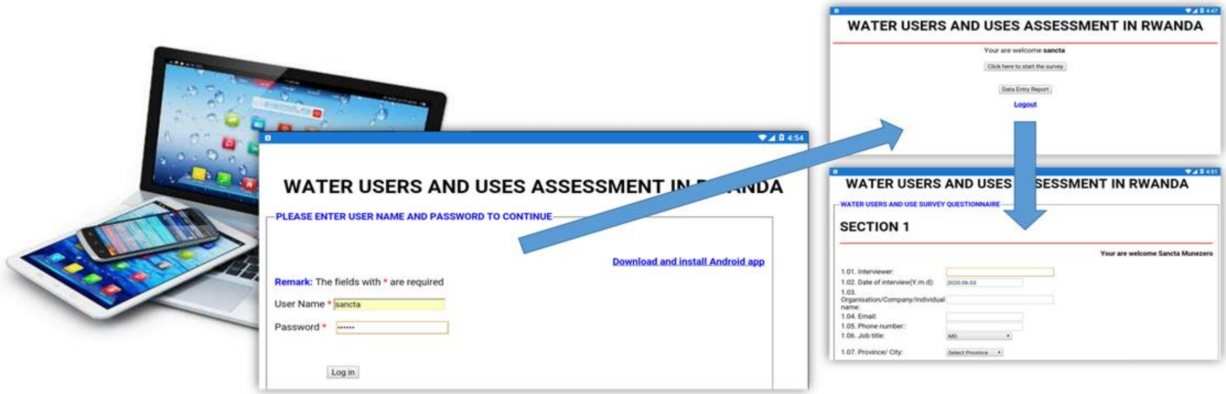


Figure 3: Online data collection tool

To support offline data collection in environments with slow or no Internet access, we integrated data collection tool with kobotoolbox (an open-source offline data collection tool).

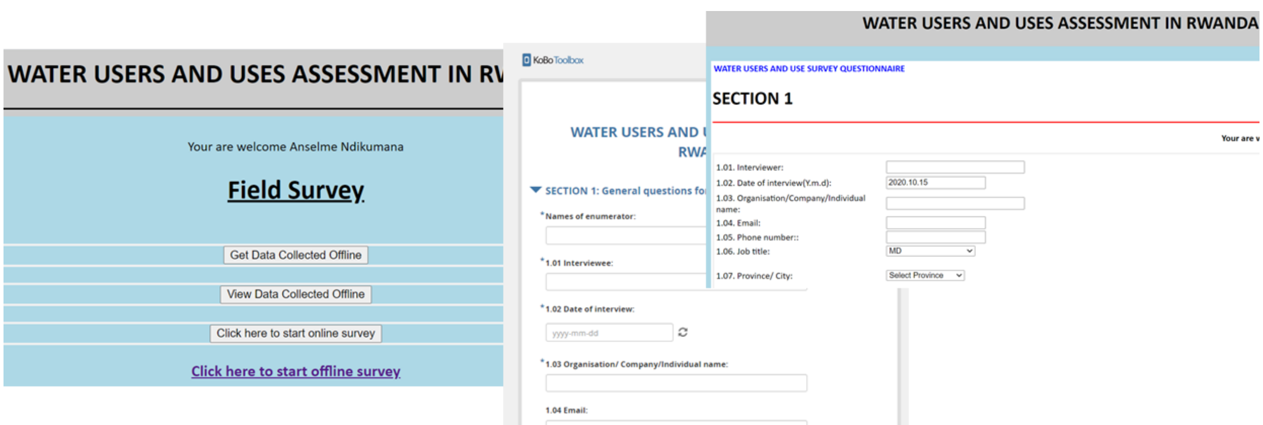


Figure 4: Integration of kobotoolbox to data collection tool for offline data collection

In computerizing the questionnaire, we used kobotoolbox as an offline data collection tool and Hypertext Preprocessor (PHP) as script writing language for designing online data collection tool. The PHP will be connected to My Structured Query Language (MySQL) as Relational Database Management System (RDBMS) so that the data collected by enumerators/ field staff will be directly entered into kobotoolbox and computerized database, i.e., MySQL. We chose MySQL over other RDBMSs because MySQL is compatible with many relational database management systems such as Microsoft Access (MS Access), PostgreSQL, and Microsoft SQL Server. The data collection tool is now available for online use by the client. New water user or use can be added directly from the field to kobotoolbox as a temporary database to ensure control by the person in charge at Rwanda Water Board, and then allow the data to the MySQL database. In addition, after data cleaning, preprocessing, and analysis, we used Microsoft Access (MS Access) as a database management system. Data from MySQL and other stakeholder' databases were exported to Microsoft Access as a final updated database containing all final water users and use data that was submitted to the client at the final stage. We chose Microsoft Access over other database management systems because Microsoft Access is widely available in many computers within the Microsoft Office software package. In addition, Microsoft Access is quick, easy to use for data exploration, and sharing.

After data collection, we put data in two databases, MySQL database as temporally database and MS Access as final database.

Figure 5: Database and data collection tool

For GIS data, we identified and mapped all users of water by respecting the area of interest. To achieve this, all users of water were mapped into the district and level two catchment maps using shapefiles in ArcGIS software. Furthermore, in GIS data processing and analysis procedures, we used ArcGIS software and database.

3.3.2 Data cleaning

Daily, all entered data was checked for detecting and correcting corrupt or inaccurate records from the database. During the field survey, field supervisors were able to check the data entered by enumerators if there are no omissions in the responses given by respondents before validating the data. This helped in identifying incomplete, incorrect, inaccurate or irrelevant parts of the data and then replace, modify, or delete the dirty or coarse data. Once data collected was validated by the supervisor , the database editor had to check consistency of data and send observations to the field supervisor by reporting the case to be rechecked, giving more precisely the codes of the enumerators, of the villages (clusters) and of the households in question. After cleaning the data sent daily by the supervisors, the dataset thus constituted was transmitted to the study leader for analyzing data and writing the report.

3.3.3 Data processing

After data preprocessing, we started the data processing, where the database was exported as a comma separated value (CSV) file. The CSV option is an easy way to load data from many different sources into statistical and data analytics software. CSV is a standard file format mostly used for exchanging data between applications. Then, the CSV file was loaded into statistical and data analytics software as inputs. Here, we will use R studio as a statistical software with R language and Pandas as data analysis software with Python language. We performed data processing using well-known algorithms in statistical analysis. Those algorithms are described below in the data analysis subsection.

We computerized water users and used survey questionnaires so that the enumerators could use emerging devices or wireless-enabled computing devices such as smartphones and tablets in data collection. In computerizing the questionnaire, we used kobotoolbox as offline data collection and Hypertext Preprocessor (PHP) as scriptwriting language for web-based application development. The PHP is connected to My Structured Query Language (MySQL) as Relational Database Management System (RDBMS) so that the data collected by enumerators/ field staff will be directly entered into kobotoolbox and computerized database, i.e., MySQL. We chose MySQL over other RDBMSs because MySQL is compatible with many relational database management systems such as Microsoft Access (MS Access), PostgreSQL, and Microsoft SQL Server. The data collection tool is now available for online use by the client. New water user or use can be added directly from the field to kobotoolbox as a temporary database to ensure control by the person in-charge at Rwanda Water Board, and then allow the data to the MySQL database. In addition, after data cleaning, preprocessing, and analysis, we used Microsoft Access (MS Access) as a database management system. Data from MySQL and other stakeholder' databases were exported to Microsoft Access as a final updated database containing all final water users and use data that was submitted to the client at the final stage. We chose Microsoft Access over other database management systems because Microsoft Access is widely available in many computers within the

Microsoft Office software package. In addition, Microsoft Access is quick, easy to use for data exploration, and sharing.

For GIS data, we identified and mapped all users of water by respecting the area of interest. To achieve this, all users of water were mapped into the district and level two catchment maps using shapefiles in ArcGIS software. Furthermore, in GIS data processing and analysis procedures, we used ArcGIS software and database.

4. Water availability and demand

4.1 Review of water availability by level 2 catchments

According to World Water Development Report 2020 there was an increase in the global water use by a factor of six for the last 100 years and this continues to grow steadily at a rate of about 1% per year. It is therefore important to periodically review the water resources availability and demand of the country to ensure sustainable management and equitable allocation. A review of water resources based on the National Water Resources Master Plan 2015 was conducted and summarized in Table 3.

Table 3: Available renewable resource of Rwanda based on level 1 catchments

Item	Unit	CKIV	CRUS	NNYU	NMUK	NNYL	NAKN	NAKU	NAKL	NMUV
		transboundary	transbou	closed	transbou	closed	transbou	transbou	transbou	transbou
Base Flow	m^3/s	19.22	11.15	31.00	19.90	17.27	24.43	11.13	17.00	3.50
MQ	m^3/s	28.5	13.7	40.9	28.7	28.5	25.4	16.0	28.7	6.1
Recharge	mm/y	250	350	292	322	164.8	226.5	115	125	70.5
Area	km^2	2425	1005	3348	1949	3304	3402	3053	4288	1565
Yield	hm^3/y	6,100,000	3,500,000	9,800,000	6,300,000	5,400,000	7,700,000	3,500,000	5,400,000	1,100,000
Rainfall	mm/y	1240	1295	1365	1315	1191	1225	925	835	995
Flow	mm/y	370	430	385	464	272	235	165	211	123
Water balance	mm/y	870	865	980	851	919	990	760	624	872
Base flow	mm/y	250	350	292	322	164.8	226.5	115	125	70.5
Base flow index		0.68	0.81	0.76	0.69	0.61	0.96	0.70	0.59	0.57
Rainfall	hm^3	30,000,000	13,000,000	46,000,000	26,000,000	54,000,000	42,000,000	28,000,000	36,000,000	16,000,000
Base flow	hm^3	6,100,000	3,500,000	9,800,000	6,300,000	5,400,000	7,700,000	3,500,000	5,400,000	1,100,000
Water availability per Ha	$m^3/ha/y$	3700	4300	3850	4640	2720	2350	1650	2110	1230
Average Renewable Resource	Mm^3	898	432	1290	905	899	798	504	907	193

Source: Adopted from Rwanda National Water Resources Master Plan, 2015.

4.2 Assessment of water withdrawal by major users' category at level 2 catchments

The importance of freshwater to our life and existence cannot be over emphasized. Water is crucial to sustain life and has no replacement. However, fresh water is scarce in some regions and countries including Rwanda. Assessment of water uses and users is essential to ensure sustainable and effective management of our vital water resources. Rwanda's water uses and users were compiled on catchment basis based on major water users. Record available at RWB and other institution (such as MOE, MINAGRI, RAB, NAEB, MINIFRA, WASAC, REG, MINICOM, WARwanda, LWIR, etc.), Literature review and field survey of identified users.

The Highest abstractions were observed in hydropower, irrigation, and domestic water supply with 3,381.9 (84.76%), 363.4 (9.11%) and 234.8 (5.88%) million m3/year, respectively (see Table 4 and 5). In this study, the hydropower water use was considered to be non-consumptive as there are only two hydropower (Nyabarongo I and Rukarara) where dams were constructed before power generation. For hydropower on Lakes there was no increase in surface area of the dam, therefore no additional evaporation as the result of hydropower construction. But when considering consumptive water use irrigation is leading with 59.75%, followed by domestic water use is second with 38.61% of the water use, then followed by mining, industries, fish ponds and coffee washing stations with 0.79%, 0.53%, 0.17% and 0.4% respectively (see Table 4 and 5 and Figure 6 and 7).

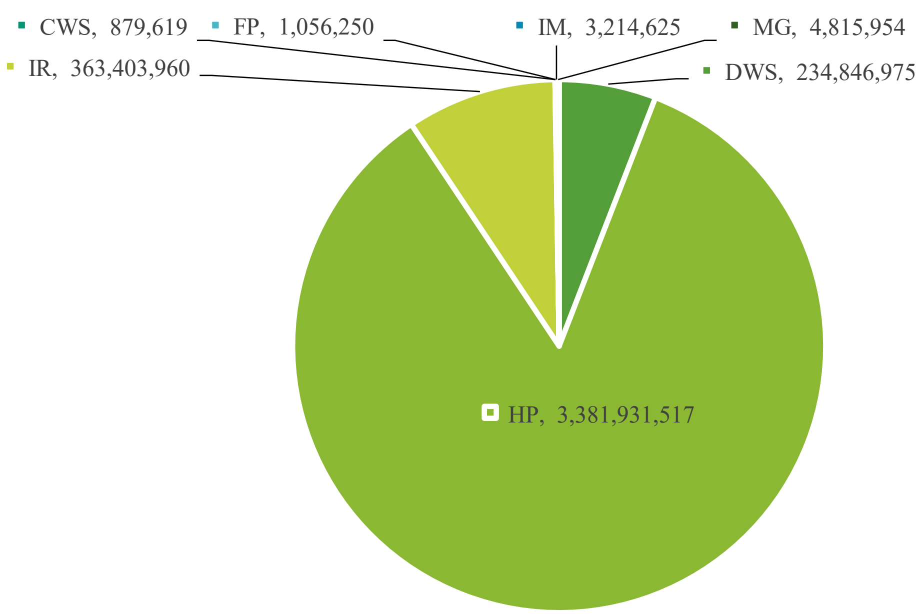


Figure 6: Distribution of water use amongst major water users including hydropower in m3/year

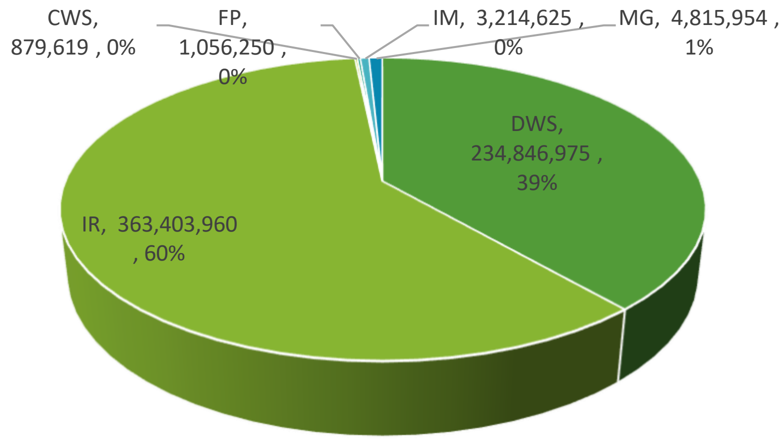


Figure 7: Distribution of water use amongst major water users without hydropower in m3/year

The total water use per level 2 catchments is shown in Figure 8 with Nyabarongo Lower 1 having the highest water withdrawal, Akagera Lower and Akanyaru2 catchments.

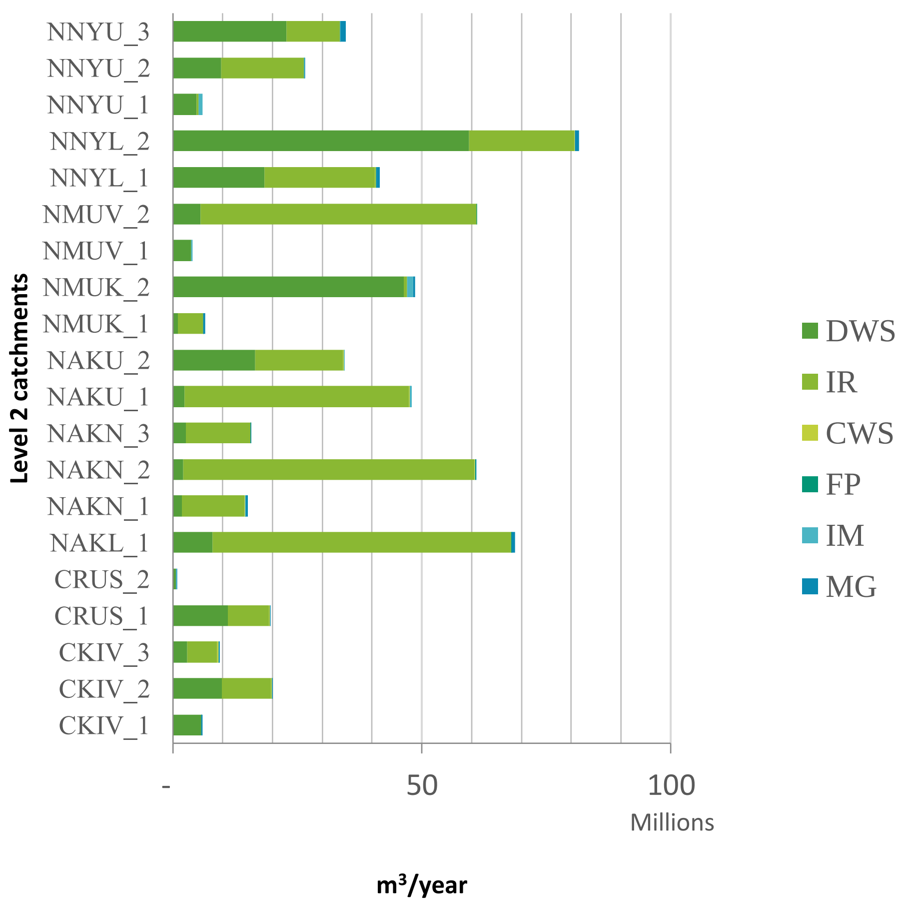


Figure 8: Total water use (m3/year) by each major user category per catchment excluding hydropower plants

The proportions of water use per level 2 catchments and accordance category of users is shown in Figure 9 and Figure 10.

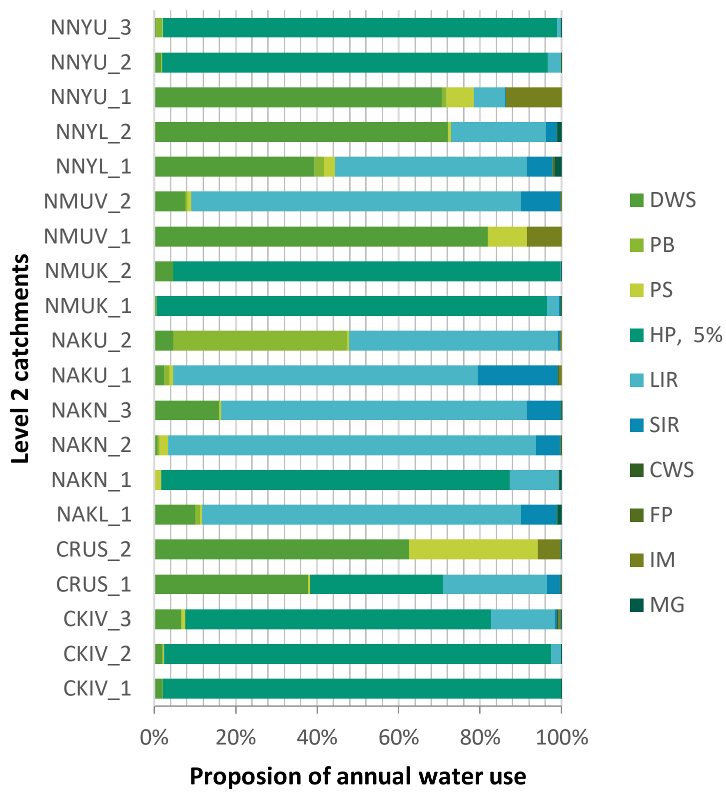


Figure 9: Proportion of water use (%) by each major water user category per catchment

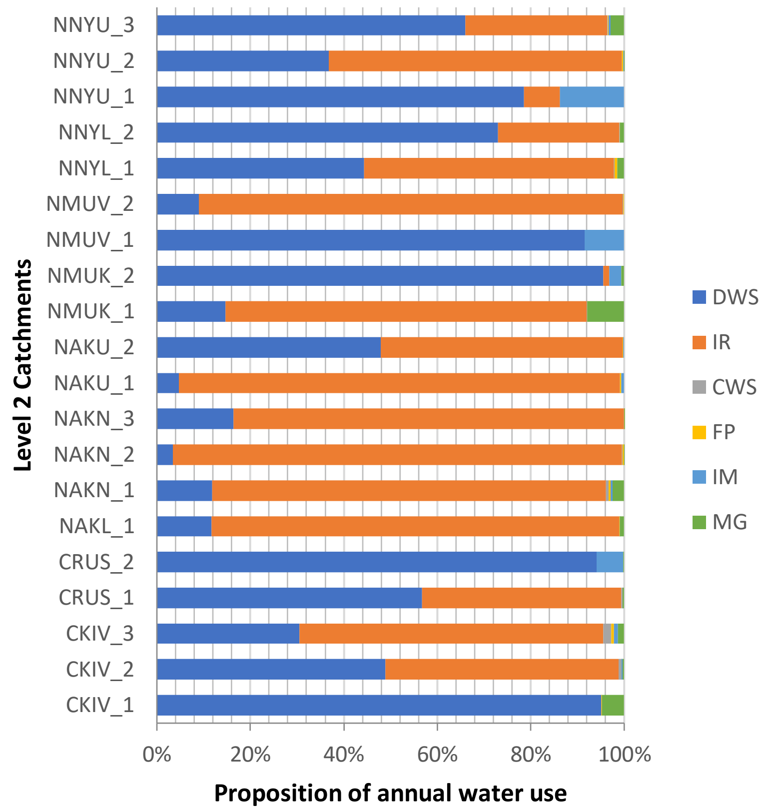


Figure 10: Proportion of water use (%) by each major water user category per catchment excluding hydropower plants

Table 4: Water use (m3/year) per category of use according to catchment

S/N	Catchment	DWS	PB	PS	HP	LIR	SIR	CWS	FP	IM	MG	Total
1	CKIV_1	5475000	7674	125050	268056000	0	0	4510	5829	0	283482	273,957,545
2	CKIV_2	8607146	834272	320842	387262080	9770750	197385	107897	24360	43186	68700	407,236,618
3	CKIV_3	2533261	0	327564	28382400	5880218	205525	164237	51983	81120	120669	37,746,977
4	CRUS_1	10911902	0	159099	9460800	7406640	892846	76180	0	634	56421	28,964,523
5	CRUS_2	417750	0	211028	0		0	0	0	38040	1299	668,118
6	NAKL_1	6921270	836679	248104	0	53904335	6019845	52105	25980	13631	662683	68,684,632
7	NAKN_1	39373	10249	1724739	88931520	12390955	228316	93168	69201	48420	380907	103,916,847
8	NAKN_2	485635	251981	1320418	0	54975693.5	3527567	97794	182978	0	8686	60,850,752
9	NAKN_3	2482000	11846	56607	0	11670577.5	1321600	2860	3446	0	319	15,549,255
10	NAKU_1	1171416	609824	495147	0	35785533	9429930	33492	101736	318676.8	0	47,945,755
11	NAKU_2	1623720	14676076	163267	0	17564364	191281	35496	45600	57060	0	34,356,863
12	NMUK_1	876291	1235	79286	154526400	4678439	369674	7967	8161	0	511989	161,059,442
13	NMUK_2	45566398	0	867776	929208240	0	601652	0	0	1264992	306353	977,815,412
14	NMUV_1	3245239	0	377433	0	0	0	0	0	336428.64	0	3,959,101
15	NMUV_2	4627555	298492	598816	0	49444543	6015097	14613	156517	0	0	61,155,633
16	NNYL_1	16362944	977299	1109791	0	19552067	2647134	73640	185200	0	646733	41,554,807
17	NNYL_2	58767301	17277	748575	0	18821871	2314394	84320	55952	0	748831	81,558,520
18	NNYU_1	4234818	65700	404308	0	444000	20349	2716	0	819470.36	0	5,991,361
19	NNYU_2	8678294	107631	903460	475152912	16011851.78	542097	17284	60270	66178	1332	501,541,311
20	NNYU_3	5254723	14975788	2641603	1040951165	9926943	650490	11341	79037	126788	1017549	1,075,635,427
	Total	188,282,037	33,682,023	12,882,915	3,381,931,517	328,228,781	35,175,179	879,619	1,056,250	3,214,625	4,815,954	3,990,148,899
		4.72%	0.84%	0.32%	84.76%	8.23%	0.88%	0.02%	0.03%	0.08%	0.12%	100.00%

DWS- Domestic Water Supply, HP- Hydropower, PB- Public Boreholes, PS- Public Springs, LIR-Large Irrigation, SIR – Small Irrigation, CWS- Coffee Washing Stations, FP – Fish Ponds, IM- Industries/ Manufacturing, MG- Mining.

Table 5: Water use (m3/year) per category of use according to catchment without hydropower

S/N	Catchment	DWS	IR	CWS	FP	IM	MG	Total
1	CKIV_1	5607724	0	4510	5829	0	283482	5,901,545
2	CKIV_2	9762260	9968135.3	107897	24360	43186	68700	19,974,538
3	CKIV_3	2860826	6085742.9	164237	51983	81120	120669	9,364,577
4	CRUS_1	11071002	8299486.29	76180	0	634	56421	19,503,723
5	CRUS_2	628779	0	0	0	38040	1299	668,118
6	NAKL_1	8006053	59924179.67	52105	25980	13631	662683	68,684,632
7	NAKN_1	1774361	12619270.78	93168	69201	48420	380907	14,985,327
8	NAKN_2	2058034	58503260	97794	182978	0	8686	60,850,752
9	NAKN_3	2550453	12992177.22	2860	3446	0	319	15,549,255
10	NAKU_1	2276387	45215463.09	33492	101736	318676.8	0	47,945,755
11	NAKU_2	16463063	17755644.6	35496	45600	57060	0	34,356,863
12	NMUK_1	956812	5048112.5	7967	8161	0	511989	6,533,042
13	NMUK_2	46434174	601652.1	0	0	1264992	306353	48,607,172
14	NMUV_1	3622673	0	0	0	336428.64	0	3,959,101
15	NMUV_2	5524863	55459639.57	14613	156517	0	0	61,155,633
16	NNYL_1	18450034	22199200.58	73640	185200	0	646733	41,554,807
17	NNYL_2	59533153	21136264.52	84320	55952	0	748831	81,558,520
18	NNYU_1	4704825	464349	2716	0	819470.36	0	5,991,361
19	NNYU_2	9689386	16553949.14	17284	60270	66178	1332	26,388,399
20	NNYU_3	22872115	10577432.7	11341	79037	126788	1017549	34,684,262
	Total	234,846,975	363,403,960	879,619	1,056,250	3,214,625	4,815,954	608,217,382
		38.61%	59.75%	0.14%	0.17%	0.53%	0.79%	100.00%

DWS- Domestic Water Supply, IR- Irrigation, CWS- Coffee Washing Stations, FP – Fish Ponds, IM- Industries/ Manufacturing, MG- Mining.

4.2.1 Hydropower water use

Electricity is a critical ingredient in all sectors of national socio-economic development, and its supply is directly correlated with the economic performance of the countries, NBI (2012). The current access to electricity in Rwanda is 40.7% (226.7 MW generation) and the government is aiming to attain 100% (556 MW generation) for household and productive use by 2024. Hydropower plays an important role in electricity generation in Rwanda. It contributes about 55% of the total electricity generation capacity in

Rwanda. There are a total 39 hydropower plants in Rwanda including 33 that are grid connected. Rwanda's major Rivers have proven 333 potential sites for Micro-hydropower countrywide. Some upcoming medium hydropower plants include: Nyabarongo II (43.5MW), Rusizi III (145MW), Rusumo Falls HydroElectric Power (80MW). In Rwanda currently most of the hydropower plants are located western part of the country Figure 10. This is mostly because of the mountainous nature of the topography of the area.

The current study revealed that hydropower has the highest water need in Rwanda with a total 3,381.9 MCM/year. Hydropower water use are in Nyabarongo Upper, Mukungwa, Kivu, Akanyaru, and Rusizi catchment with the water use of 1,516.1 MCM, 1,083.7 MCM, 683.7 MCM, 88.9 MCM and 9.5 MCM respectively (see Table 4 and Figure 10). This represents 84.97% of all water use of the country. Hydropower water use is 5.56 times of all other water use. Fortunately, the water used by this sector is available for use by other sectors downstream. It is essential to ensure that hydropower plants are sited strategically to avoid conflict with upstream water uses and also ensure the use of water downstream.

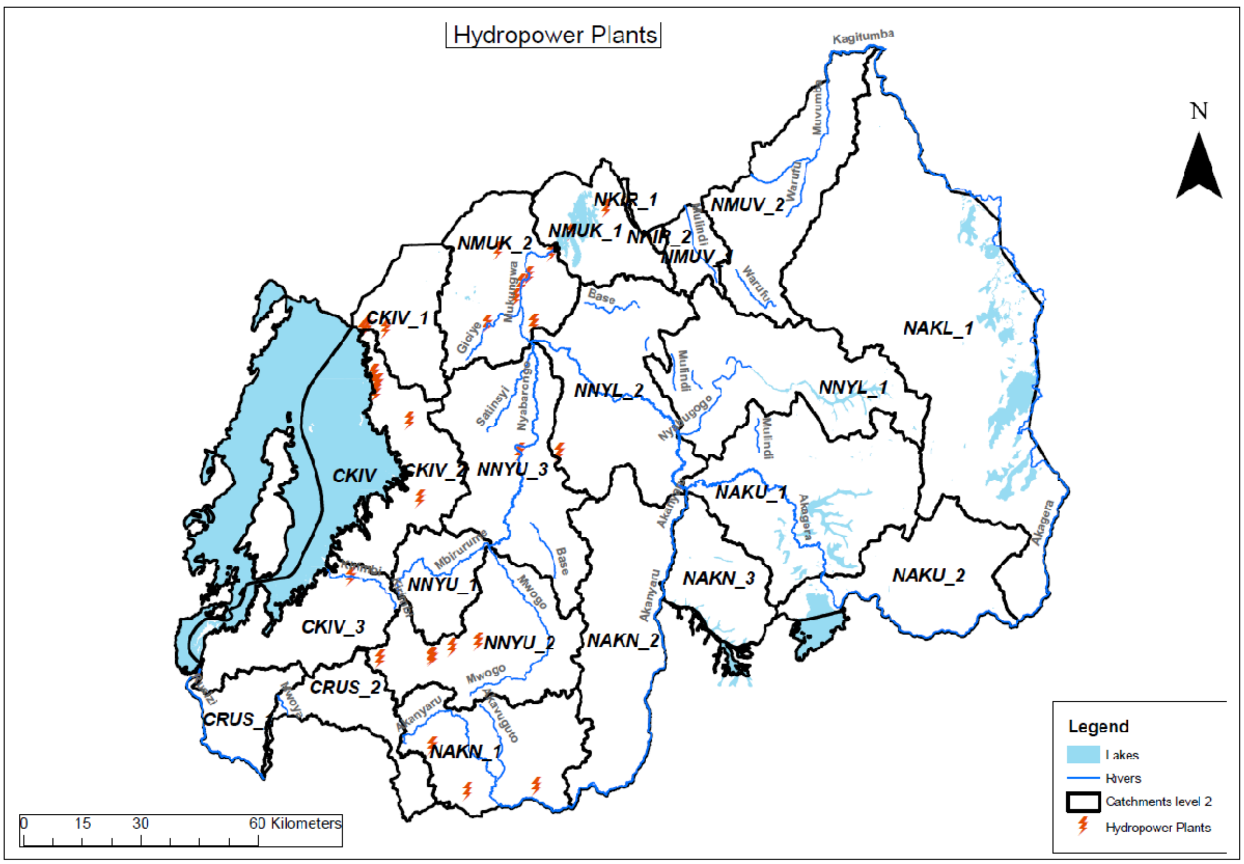


Figure 11: Location of hydropower plants in level 2 catchments

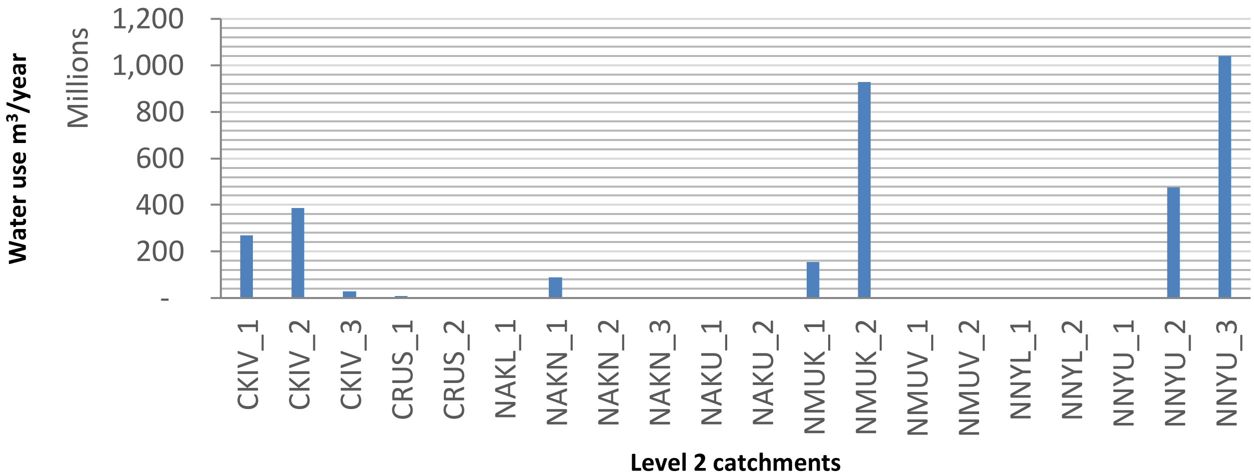


Figure 12: Annual water use by hydropower in Rwanda

4.2.2 Irrigation water use

Agricultural sector contributes over 30% of the GDP of Rwanda. Irrigation is one of the most efficient ways of improving agricultural production with up to about 15%. About 48,500ha are currently irrigated and the government is targeting to expand this to 102,281 ha by 2025 (RAB, 2020). Irrigation is the highest water consuming sector in Rwanda with about 363,403,960 m3/year. The highest irrigation water consumption is found in Akagera Lower, Akanyaru -2, Muvumba -2 and Akagera Upper -1 catchment with 59,924,180, 58503260, 55,459,640, and 45,215 m3/year respectively. The location of a large irrigation scheme in the country is shown in Figure 13. While the distribution of irrigation water use per level 2 catchment is shown in Figure 14.

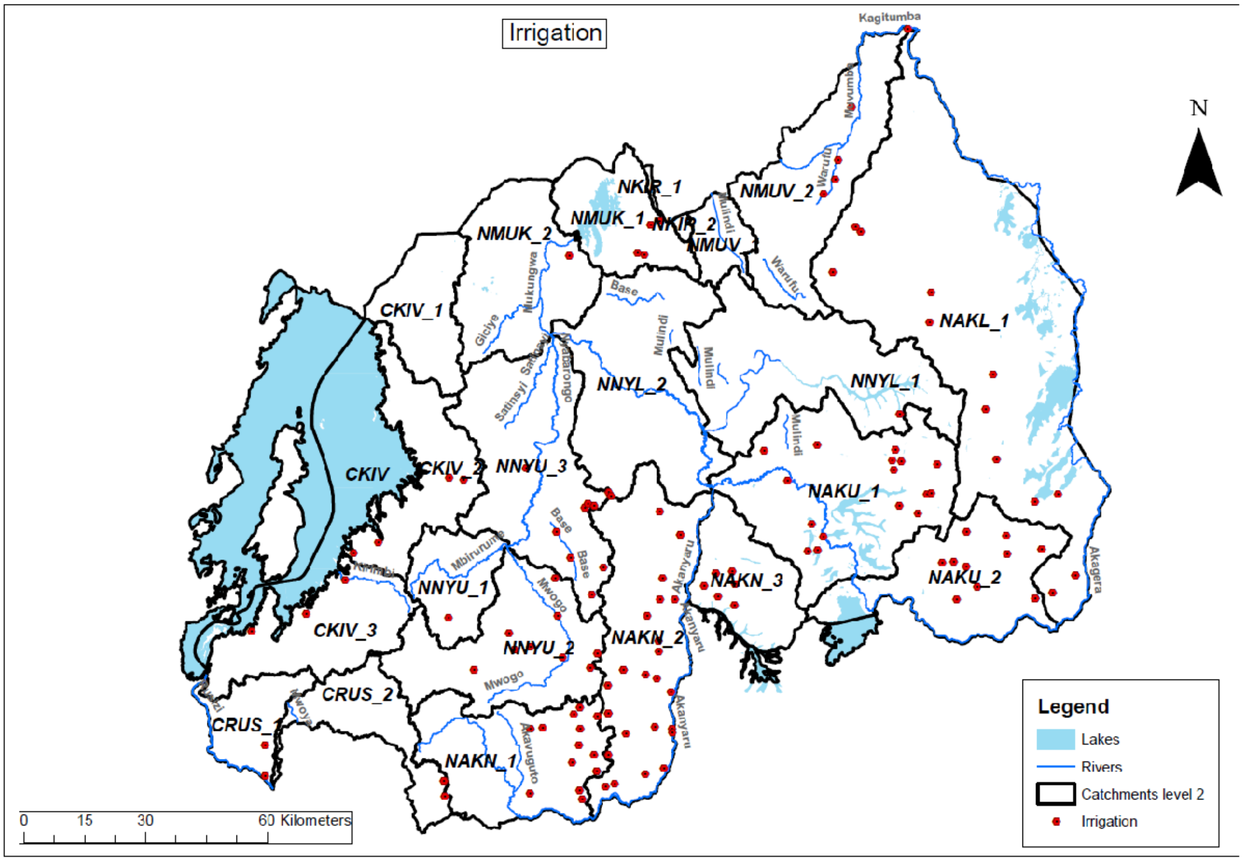


Figure 13: Location of Large Irrigation Schemes in Rwanda

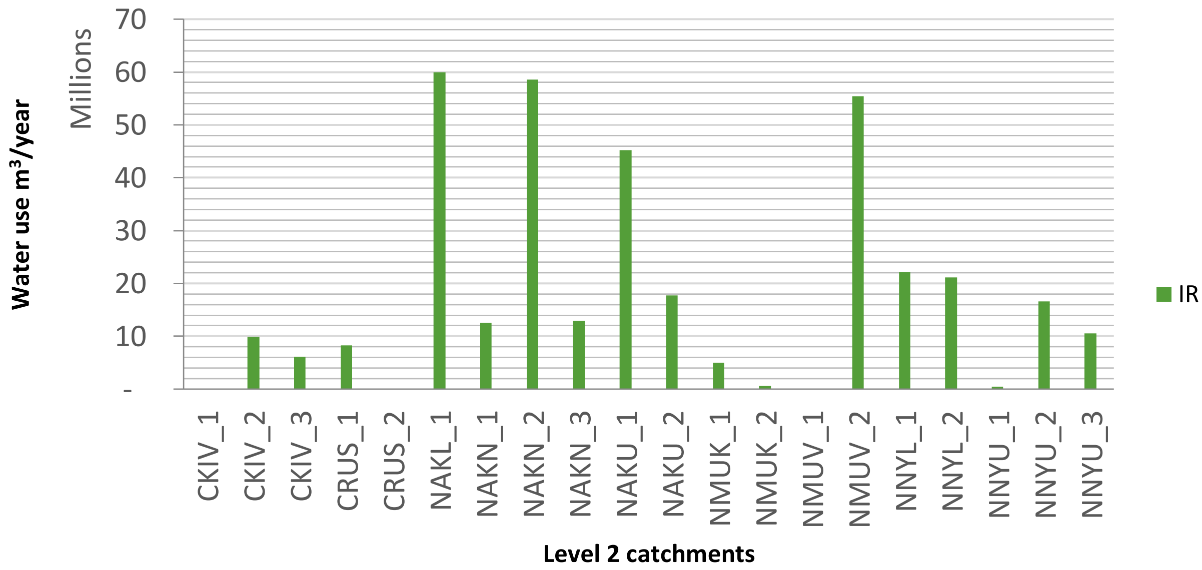


Figure 14: Distribution of irrigation water use per level 2 catchment

4.2.3 Domestic water use

Rwanda is currently implementing its water and sanitation strategic plan for 2018-2024. According to this strategy the Water and Sanitation sector in Rwanda is being guided by the Vision 2050 which is about ensuring high standards of living for all Rwandans; improve quality of life, modern infrastructure, and transformation for prosperity. That said, the water and sanitation sector plays a critical role in ensuring targets of the Vision 2050, National Strategy for Transformation and Prosperity (NST 2018/19-2023/24) as well as SDGs (2030) are attained. In order for this to happen, adequate investment in water and sanitation infrastructure, providing sanitation facilities and promoting hygiene at every level is a prerequisite. The implementation of the water and sanitation strategy is expected to bring about achieving broad water supply and sanitation targets of at least basic water supply services for100% of people by fast-tracking implementation of strategic investment programs as well as achieving at least basic household sanitation coverage for100%of households (ROR, 2017). The water and sanitation sector in Rwanda aims to increase the proportion of the population/households accessing improved source of water from 87% (EICV 5) to 100% and the proportion with improved sanitation services/ facilities from 86% (EICV 5) to 100% all by 2024. It is also envisioned to increase the proportion of the rural population living within 500m of an improved water source from 47% (EICV4) to 100%, and to raise the proportion of the urban population residing within 200m (0-4 minutes) of an improved water source from 61% (EICV5) to 100%. It is then clear that, more water is needed to ensure the implementation of the strategy. This study considers the following type of sources as domestic water use viz: water treatment plants, public boreholes and hand pumps, and capture/capped springs. Industries and other kinds of users that are connected to these systems of water supply were not counted separately but considered as part and parcel of domestic water supply.

EICV5 shows the progress observed in the use of improved drinking water source (87% compared to 85% in EICV4) over the period of three years at national level. Usage rates are higher in urban areas (96%) compared to rural areas (85%). At national level, 27% of households are within 0–4 minutes walking distance of an improved drinking water source while 61% of households are within 0–14 minutes walking distance one-way). The percentage of households having access to improved sanitation increased from 83% in 2013-14 to 86% in 2016-17. Considerable improvement is notable across quintiles as well.

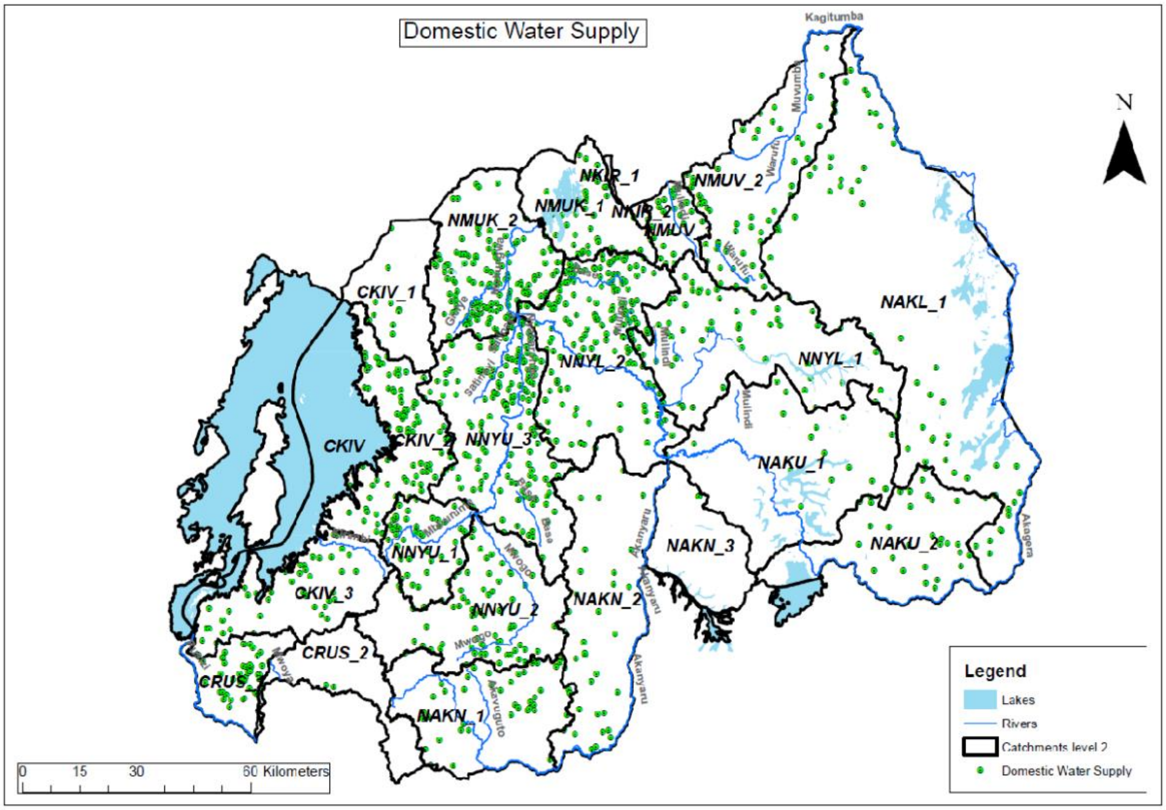


Figure 15: Locations of domestic water use (WTP, boreholes, and springs)

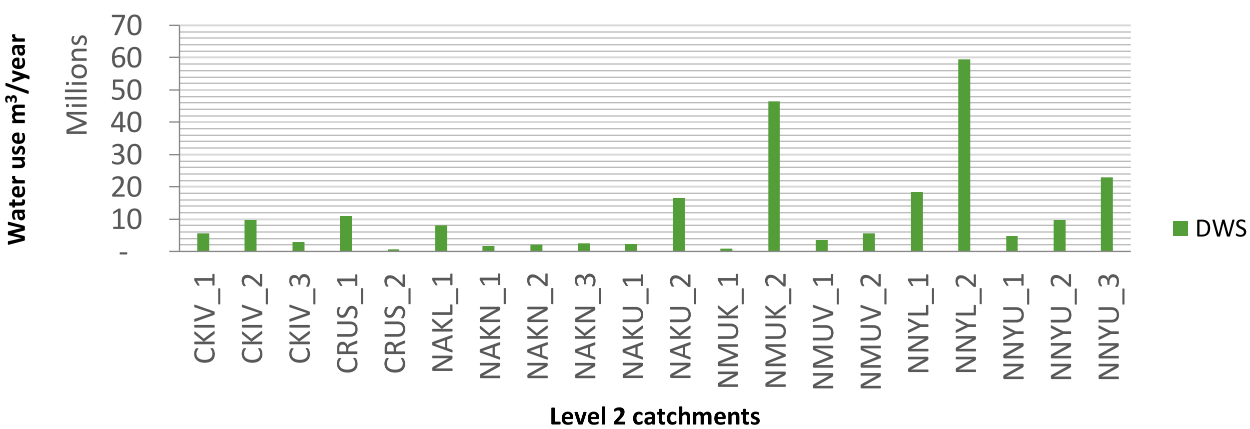


Figure 16: Distribution of domestic water use per level 2 catchment

4.2.4 Coffee washing station water use

Coffee was first introduced to Rwanda in 1893 by German missionaries. At this time, Adolf von Gotzen who represented the Catholic Church in Rusizi District, Western Province introduced the crop theoretically until 1904 when the first tree was planted in the Mibirizi sector of Rusizi District. In 1935 coffee production greatly increased, becoming the main cash crop for many farmers, but it was mostly low-grade coffee, and the export market was limited, because there was low coffee consumption internationally. Now Rwanda is the world's 22nd exporter of coffee and ranked 9th among Africa's growers. More than 400,000 people and their families in the country defend on coffee for their livelihood. Coffee production ranges from 20,000 to about 22,000 metric tons per year. It is an important product that contributes substantially to the GDP of the country. In Rwanda coffee is wet process with 311 coffee washing stations the country can process up to 62% of the production. Water use by the coffee washing is consider among the major water users in this study however, the total water use for coffee washing which is about 879,619 m3 is insignificant in comparison with water uses for irrigation and domestic water uses.

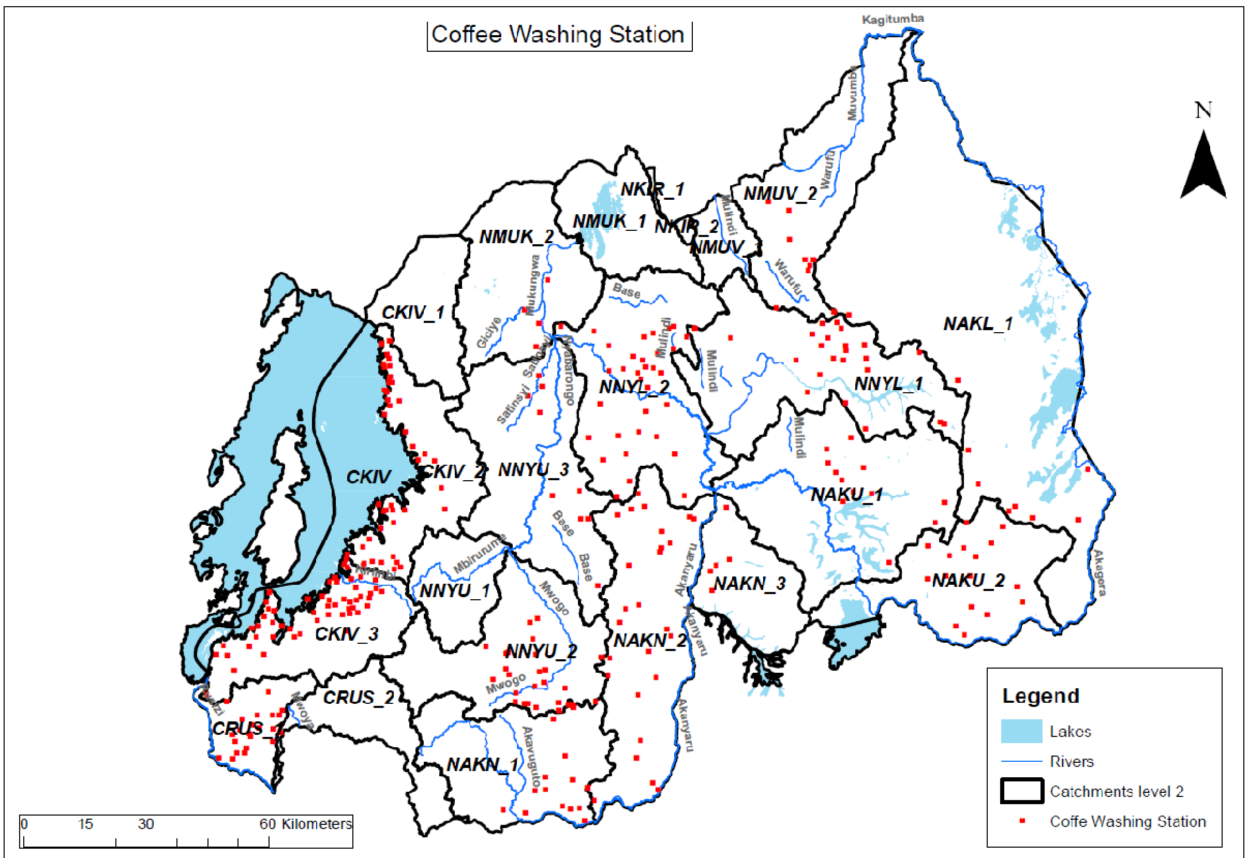


Figure 17: Location of Coffee Washing Stations in Rwanda

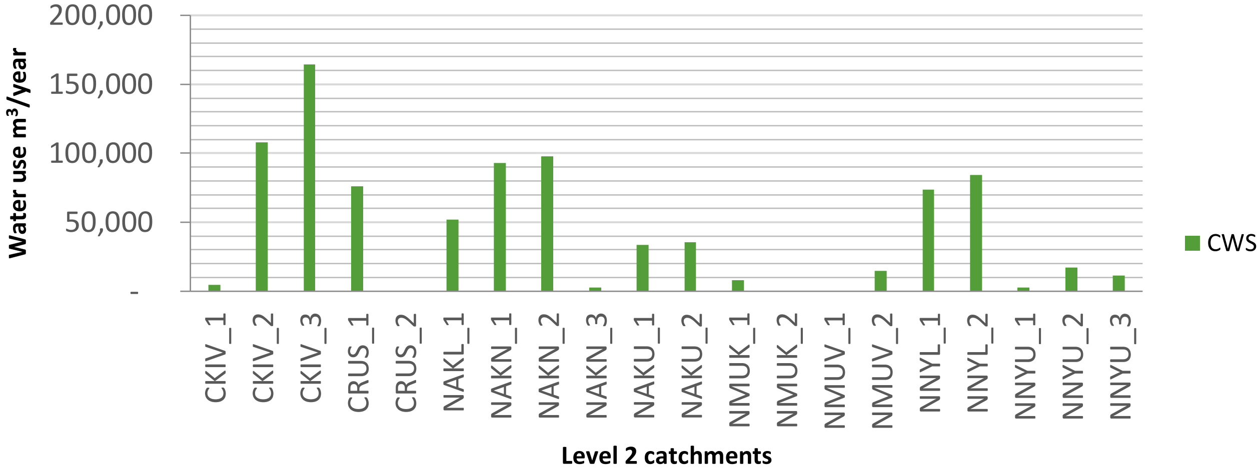


Figure 18: Distribution of coffee washing stations per level 2 catchment in Rwanda

4.2.5 Fish ponds water use

In Rwanda Fish Farming Pond was introduced during the Belgium colonial period at around 1925 and currently there are 79 pounds from 10 sites and produces over 17,000 metric tons from ponds. The types of fish reared in the ponds in Rwanda include the following: Tilapia and Catfish. Water use of fish ponds was estimated based on open water evaporation in the catchment.

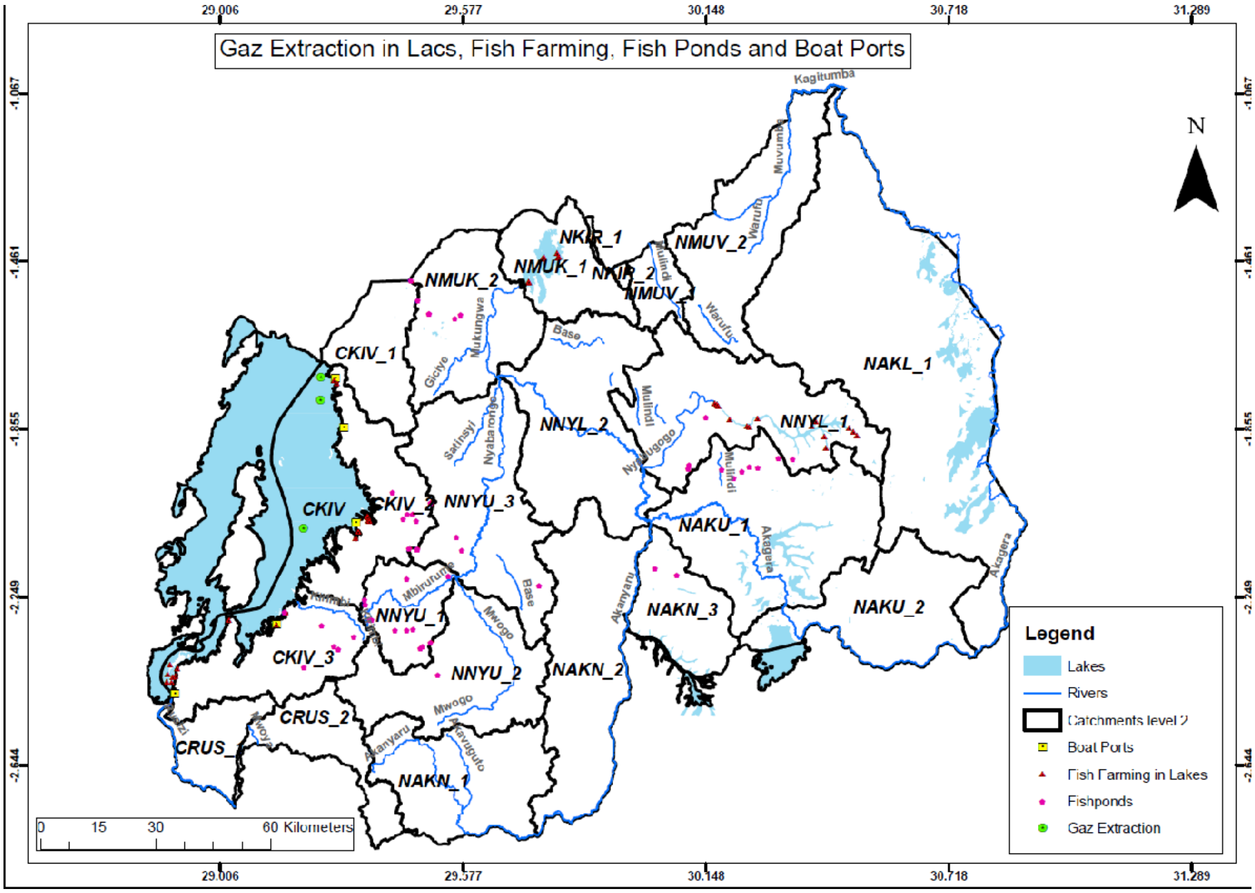


Figure 19: Locations of water use related to industries, mining, gas extraction, WTP and fish farming

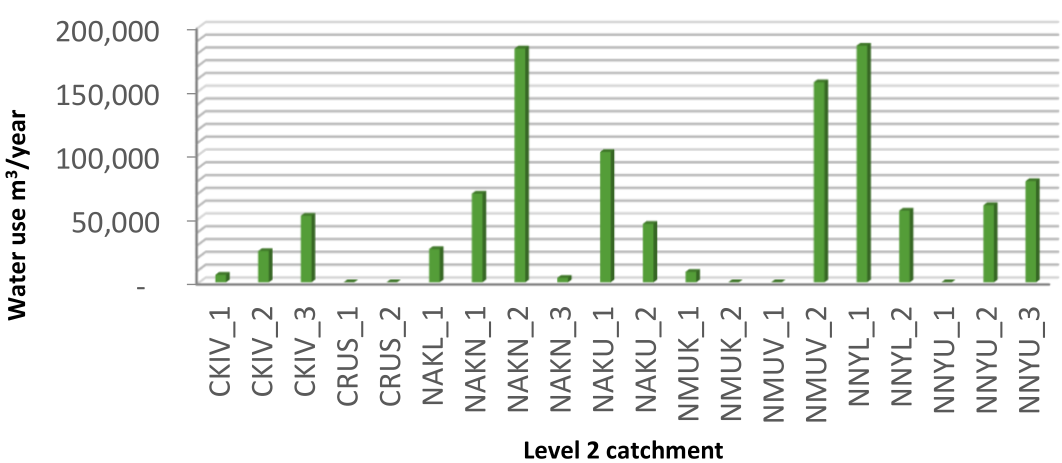
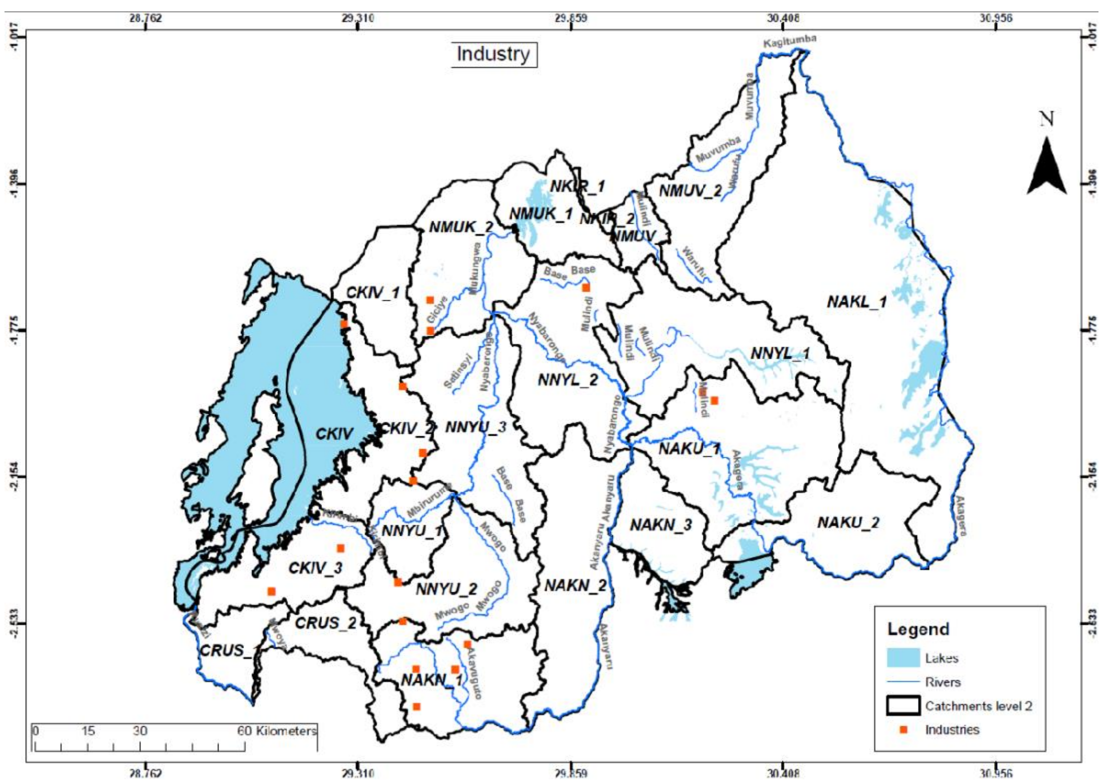


Figure 20: Distribution of fish ponds water use per level 2 catchment in Rwanda

4.2.6 Industries and manufacturing water use

Rwandan industrial policy in line with National Strategy for Transformation (NST1) 2017-2024, prioritizes inclusive economic growth, job creation, and private sector-led development with a focus on high-value intensive agriculture and agro-processing, manufacturing, tourism, and knowledge-based services and ICT (NISR, 2019). To increase the local domestic and foreign supply of manufactured goods, the Government has put in place the Special Economic Zone and 9 Industrial parks in Bugesera, Rwamagana, Muhanga, Nyagatare, Musanze, Huye, Nyabihu, Rusizi (RDB). The manufacturing industry in Rwanda is still small but growing. In 2019 its contribute about 17 % of the GDP of the country’s. Water withdrawal by industries and manufacturing was considered in two forms direct and indirect withdrawal. The indirect withdrawal is related to those industries that drive the water supply from WASAC or other water suppliers, this category was counted under domestic water supply. While those that get the water supply from Lakes, Rivers, Groundwater etc. are counted under industries and manufacturing. The annual withdrawal for this sub-category was estimated to be 3,214,625 m3 and constitute 0.53% of the total water withdrawal of the country.



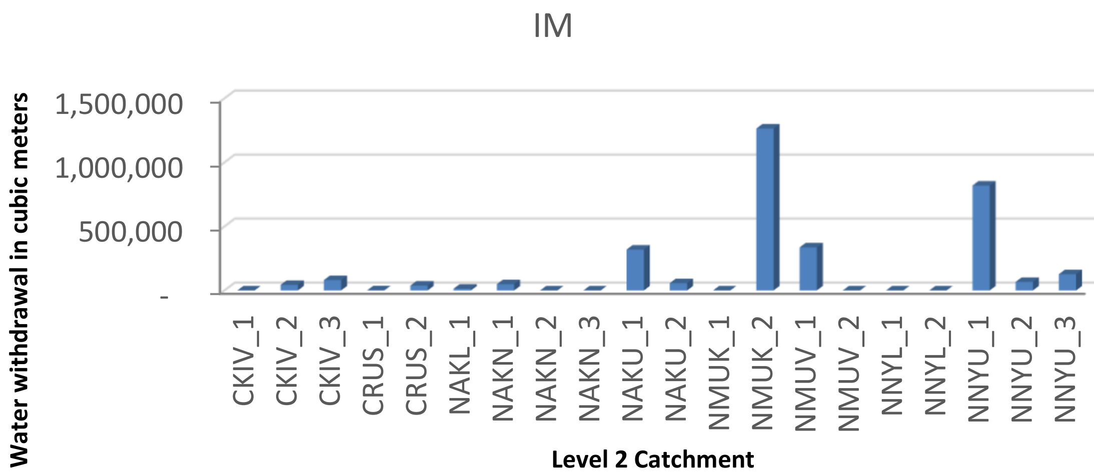
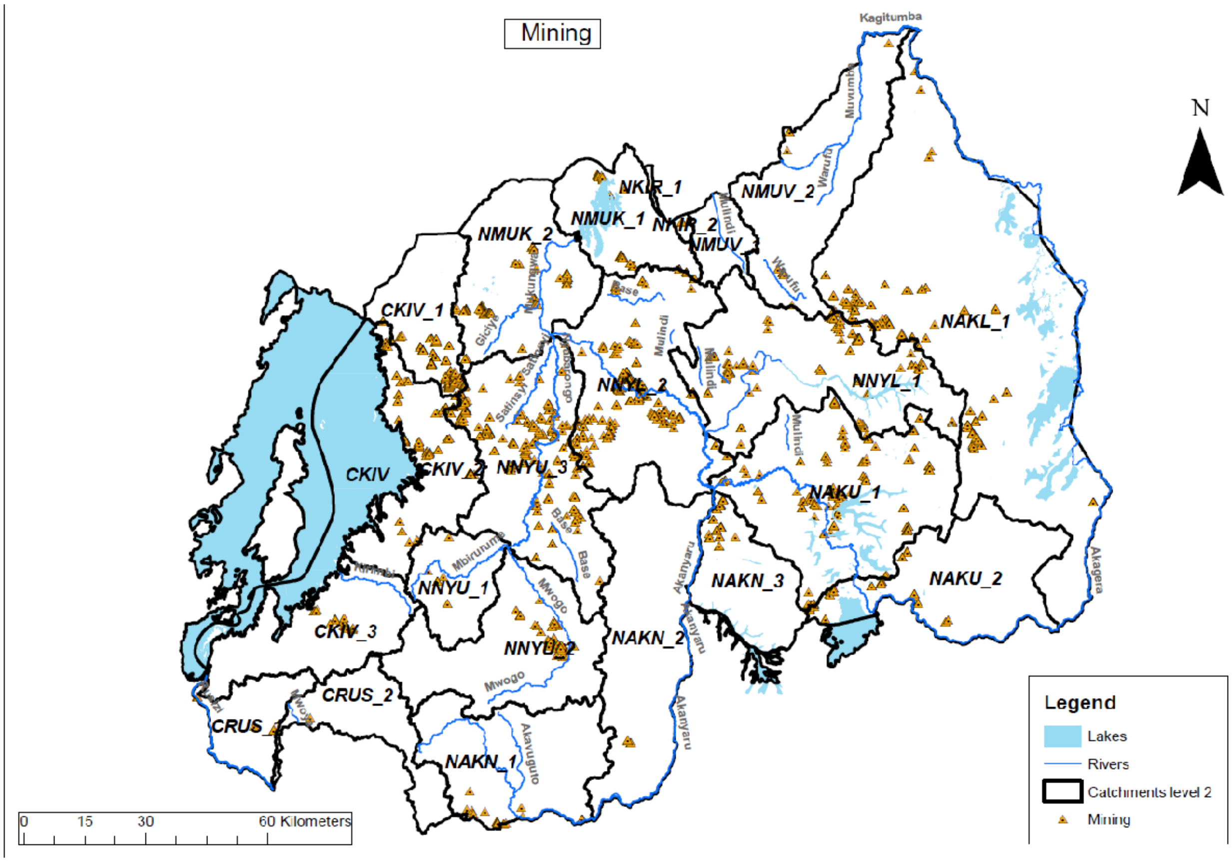


Figure 21: Distribution of industries and manufacturing water use per level 2 catchment

4.2.7 Mining water use

In Rwanda mining commenced in the early 1930s and since then the sector has undergone a wide range of reforms. The mining sector is now the second-largest export revenue earner for the country. Some of the mineral resources of Rwanda include Cassiterite, Coltan, wolfram, gold, Nickel and peat (used for electricity generation or processed as an alternative for firewood). In addition to these, Rwanda has other precious stones such as amphibolite, granites, quartzite, volcanic rocks, clay, sand and gravel. Annually Rwanda produces between 8,000 and 9,000 tons of mineral compounds (RDB, 2020). Rwanda is among the top global producers of Tantalum, producing about 9% of the world's Tantalum used in electronics manufacturing. Rwanda also has two refineries of gold and tin, both of which have the capacity to process large amounts of minerals from within the country and the region (RDB, 2020).



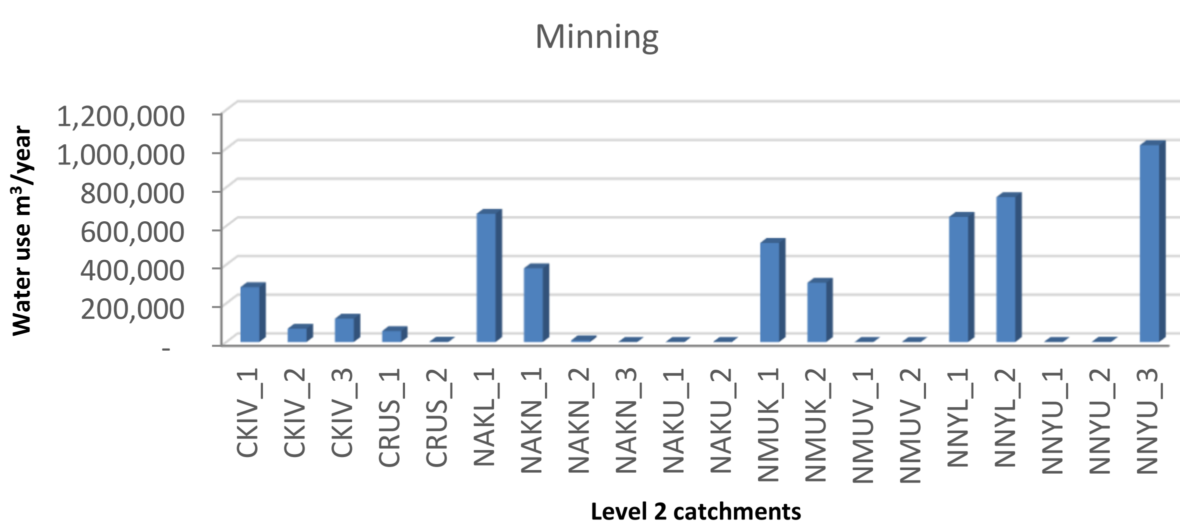


Figure 22: Distribution of mining site water use per level 2 catchment in Rwanda

4.2.8 Water use and availability ratio

The estimate of the water withdrawal and availability ratio across the country was conducted according to level 1 catchment. This was done by summing up the total water withdrawn at level 2 catchment to get the total water use by level 1 catchment, this then was divided by the volume of water available at level 1 catchments (Table 3). This approach was used because data on water availability as contained in the National Water Resources Master Plan, are only available at level of catchment level 1. Water use and availability ratio was estimated and the country was found to have a ratio of 8.9% while the Muvumba catchment was found to have a ratio of 33.7% followed by Akagera Upper catchment with a ratio of 16.3 %. This estimation did not take into consideration the hydropower water use as this was considered non-consumptive. The ratio at Muvumba and Akagera Upper catchment is attributed to the presence of large-scale irrigation in those catchments.

Table 6: Water stress level according to SDG indicator 6.4.2

Catchment Level 1	Catchment name Level 1	Catchment Level 2	Proposed catchment name Level 2	Total water use (m^3/year)	Total withdrawal (m^3)	Total Available Renewable Water Resources (m^3)	Withdraw-Available Ratio
CKIV	Kivu	CKIV_1	Sebeya	5,901,545	35,240,660	898,000,000	3.9
		CKIV_2	Kivu Upper	19,974,538			
		CKIV_3	Kivu Lower	9,364,577			
CRUS	Rusizi	CRUS_1	Rusizi-Rubyiro	19,503,723	20,171,841	432,000,000	4.7
		CRUS_2	Ruhwa	668,118			
NAKL	Akagera Lower	NAKL_1	Akagera Lower	68,684,632	68,684,632	904,000,000	7.6
NAKN	Akanyaru	NAKN_1	Akanyaru Upper	14,985,327	91,385,334	798,000,000	11.5
		NAKN_2	Akanyaru Lower	60,850,752			
		NAKN_3	Cyohoha South	15,549,255			
NAKU	Akagera Upper	NAKU_1	Akagera-Mugesera	47,945,755	82,302,618	504,000,000	16.3
		NAKU_2	Akagera-Rweru	34,356,863			
NMUK	Mukungwa	NMUK_1	Burera-Ruhondo	6,533,042	55140214	904,000,000	6.1
		NMUK_2	Mukungwa-Giciye	48,607,172			
NMUV	Muvumva	NMUV_1	Murindi	3,959,101	65114734	193,000,000	33.7
		NMUV_2	Muvumba-Warufu	61,155,633			
NNYL	Nyabarango Lower	NNYL_1	Nyabugogo	41,554,807	123113328	899,000,000	13.7
		NNYL_2	Nyabarongo Valley-Base	81,558,520			
NNYU	Nyabarango Upper	NNYU_1	Mbirurume	6,062,038	191,372,170	1,289,000,000	13.7
		NNYU_2	Mwogo	142,352,015			
		NNYU_3	Nyabarongo 1 Dam-Satinsyi	42,958,170			

608,217,382	6,821,000,000	8.9%

Though the information in Table 6 can give an indication of stress, it could not be used to explain water stress at the level of the catchment according to SDG indicator 6.4.2. The information on water stress is provided in Table 7. This was computed as the total freshwater withdrawn (TFWW) divided by the difference between the total renewable freshwater resources (TRWR) and the environmental flow requirements (EFR), multiplied by 100. The results show that except for Muvumba catchment with low water stress level, all other catchments have no water stress (Table 7). This is different from the methodology used in the National Water Resource Master Plan classified Rwanda as a water stress with annual per capita renewable water availability of less than 700 m3.

Table 7: Water stress level

S/N	Level 1 catchment	Total withdrawal (m^3)	Total Available Renewable Water Resources(m^3)	Level of stress (%) (SDG 6.4.2)	
1	CKIV	35,240,660	898,000,000	5	no water stress
2	CRUS	20,171,841	432,000,000	6	no water stress
3	NAKL	68,684,632	904,000,000	10	no water stress
4	NAKN	91,385,334	798,000,000	15	no water stress
5	NAKU	82,302,618	504,000,000	21	no water stress
6	NMUK	55,140,214	904,000,000	8	no water stress
7	NMUV	65,114,734	193,000,000	43	low water stress
8	NNYL	123,113,328	899,000,000	18	no water stress
9	NNYU	191,372,170	1,289,000,000	19	no water stress

4.3 Key issues on water availability and demand

i. Rwanda is currently implementing its ambitious National Strategy for transformation achieving and sustaining associated targets will require more water withdrawal from various catchments. This is affected to result in significant increase in water use.
ii. There is limited infrastructure for management of urban wastewater (sewage and storm). Providing these kinds of infrastructures will improve the water availability by enabling treatment and recycling of treated wastewater.
iii. About 13% and 14% of the population of the country have no access to improve water supply and sanitation respectively and the government is targeting to achieve 100% access for both by 2024.
iv. About 48,500 ha are currently irrigated in the country and the government is targeting to expand this to about 102,281 ha by 2025.

5. Database and data category

In this assessment, we combined the secondary data collected from different institutions and the data from field survey into one database. In database, we grouped the data into 13 categories: Coffee washing stations, Domestic Water Supply, Hydropower plants, Mining companies, Large Irrigation schemes, Industries/Factories, Fish farming in lake, Fishponds, Gas extraction, Boat ports, Small-scale irrigation, Public Boreholes, and Public Springs.

6. Analysis of water use issues/Conflicts

During field visit data were collected on the issues that use to arise among the water users. A total of 197 were interviewed and a total of 15 issues were reported. The issues are mainly caused by shortage of water, flooding and others.

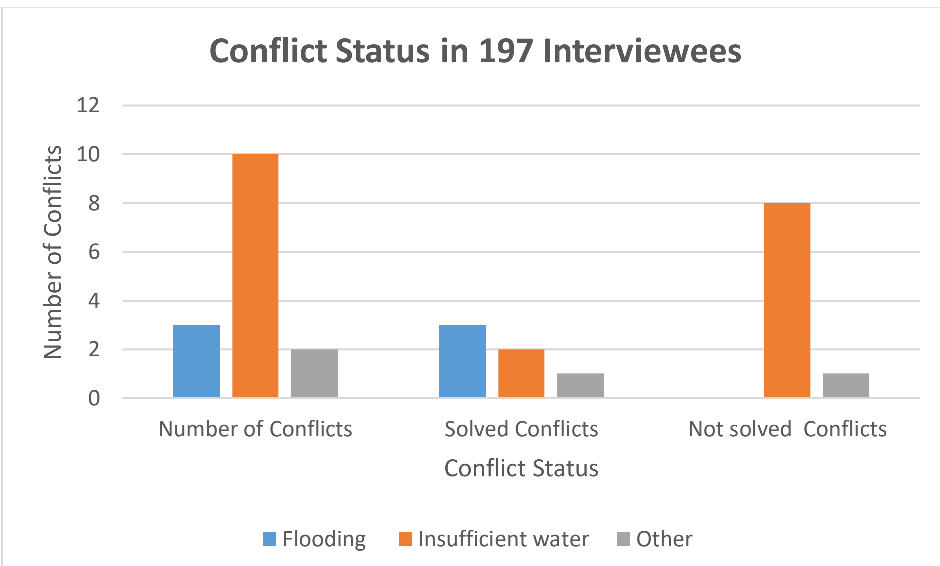


Figure 23: Status of conflict

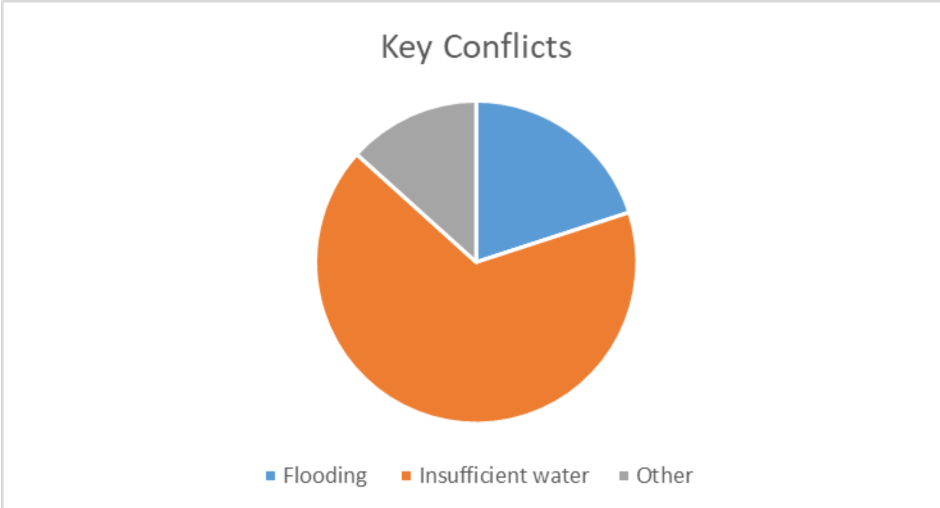


Figure 24: Key conflicts

Table 8: Issues Reported by level 2 catchment visited

Catchment	Type of event or conflict			Total
	Flooding	Insufficient water	Other	
CKIV_2	1			1
NNYL_2	1			1
NAKN_2	1	4		5
NAKL_1	1			1
NMUV_2		2		2
NAKU_1		2		2
NNYU_3		1		1
NNYL_1			1	1
NMUK_1			1	1
Total	4	9	2	15

7. Conclusion and recommendations

7.1 Conclusions

Rwanda's rapid population growth and industrial development as well as implementation of the National Strategy for Transformation (NST) have opened does for more water use there by increasing the water use of the country. This study recorded an average water use of 608,217,382m3.

Some of the findings of this study are:

i. Ten (10) main categories of water users and uses were agreed on based on consultation with Rwanda Water Resources Board (RWB), they are hydropower plants, large irrigation, domestic water supply, mining, industries/manufacturing, coffee washing stations, fish ponds, fish farming on the lake, ports and gas extraction in lake kivu.
ii. Data on water users and uses were collected from RWB and other public and private organizations and 2,139 major water users were identified and mapped according to level 2 catchments.
iii. In consultation with RWB a self-supporting tool for field data collection was developed together with an application that enables data to be directly entered into a database through the use of telephone or tablets. This application was used for data collection from a total of 377 water users that were visited.
iv. Data analysis revealed the followings:
v. The total water use was estimated to be 608,217,382 m3/year. There is a need to ensure holistic acceptance of integrated water resources management (IWRM) to ensure sustainable water resources management.
vi. On-job training of RWB staff in data collection, processing, and analysis procedures for hydrological data, establishing water resources information and integration of data sources was conducted to ensure future updating of the database. This includes training key personnel in the use and maintenance of relevant software and tools for data collection and communication.
vii. The existing water users and use database of RWB was updated with the new findings including the GPS coordinates.

7.2 Recommendations

i. Rwanda Water Resources Board (RWB) should use the developed apps for future monitoring and updating the water users and use database;
ii. RWB share the format of the water users and use database with other organization to ensure consistency in acquiring and storing water use and users data;
iii. RWB should compile the collected data on annual basis and published an updated water use and users at the end of every year.
iv. A clear framework should be established between Government institutions on water related data sharing.

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Annexes

Annex 1. Terms of References (ToRs)

Annex 2. Water users and use survey questionnaire

Annex 3. List of visited water users

Annex 4. Rwanda water user's database

Annex 5. Shape files

Annex 6. Processed data.