This project is co-funded by the European Union

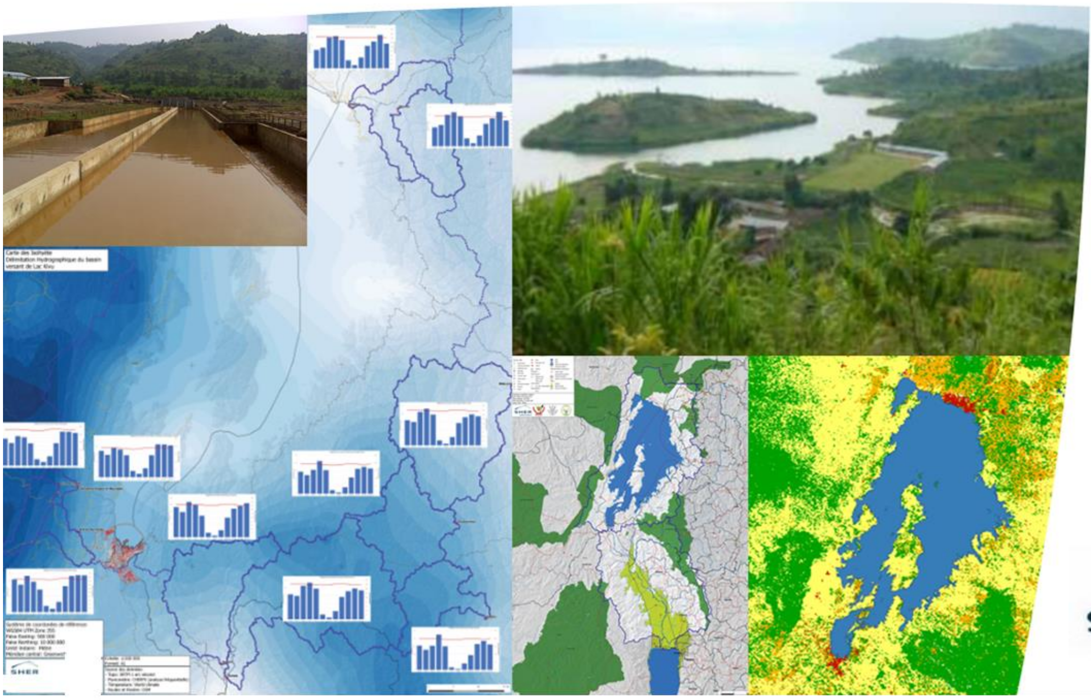
LAKE KIVU AND RUZIZI RIVER BASIN AUTORITHY (ABAKIR)

REFERENCE: 20.214.5-022.00

BASELINE STUDY FOR THE BASIN OF LAKE KIVU AND THE RUZIZI RIVER

REPORT

DECEMBER 2020



Identification sheet

Countries	Rwanda, Burundi, DRC
Funder	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)
Project	Baseline study of the Lake Kivu and Ruzizi River basin
Study	Baseline study
Document	Baseline study report on the Basin
Date	December 2020
Consultant	SHER Consult Ltd

SHER Consult Ltd

Rue de l'Akagera - KN 16 Ave #65
Nyarugenge - Kigali / B.P. 1526, Kigali

Rwanda

Tel. : +250 788 304 364

www.sherconsult.com

Coordination *M. Goffin*

Reference : *SCR16*

Phone : *+250 782 521 410*

E-mail : *goffin@sher.be*

Rev. n°	Date	Content	Prepared by:	Verified by:
0	11/2020	Work package 1 and Work package 2	J. Derouane, Q. Goor, A. Linel, F. Kayigamba	M. Goffin
1	12/2020	Work package 1 and Work package 2	J. Derouane, Q. Goor, A. Linel, F. Kayigamba	M. Goffin
2	12/2020	Work package 1 and Work package 2	J. Derouane, Q. Goor, A. Linel, F. Kayigamba	M. Goffin

Table of Contents

List of tables

List of figures

List of maps

A USB key is also provided as a supplement to this report. This USB key contains the shapefiles (GIS format), the KMZs (Google Earth format) and the maps (pdf format).

Nom

- Cartes
- KMZ
- Shapefiles_Rasters

The plans, numbered in the order in which they appear in the report, are listed as follows:

#	Name/Nom
001	Administrative map/ Carte administrative
002	Map of projected population density in 2020/ Carte de densité de population projetée pour 2020
003	Map of projected population density in 2050/ Carte de densité de population projetée pour 2050
004	Elevation map/ Carte d'élévation
005	Slope map/ Carte des pentes
006	Soil map/ Carte des sols
007	Geological map/ Carte géologique
008	Aquifers potentiality map/ Carte des potentialités des aquifères
009	Aquifers potentiality map in the Ruzizi plain/ Carte des potentialités des aquifères dans la plaine de la Ruzizi
010	Annual average temperature map (Worldclim, 1970-2000)/ Carte de température annuelle moyenne (Worldclim, 1970-2000)
011	Annual average evapotranspiration map (FEWS NET, 2002-2018) / Carte de l'evapotranspiration annuelle moyenne (FEWS NET, 2002-2018)
012	Map of isohyet and temperature and precipitation graphs/ Carte des isohyètes et diagrammes ombrothermiques
013	Map of the sub-catchments of Lake Kivu and the Ruzizi River/ Carte des sous-bassins versant du lac Kivu et de la rivière Ruzizi
014	Hydrological map (Surface water)/ Carte hydrologique (Eaux de surface)
015	Map of Rivers/ Carte des rivières

#	Name/Nom
016	Map of the land cover (Satellite image landsat 5, 1989)/ Carte d'occupation du sol (Image satellite landsat 5, 1989)
017	Map of the land use (Satellite image landsat 7, 2011)/ Carte d'occupation du sol (Image satellite landsat 7, 2011)
018	Map of the land use (ESA-CCI) (2016)/ Carte d'occupation du sol de la zone (ESA-CCI) (2016)
019	Map of Forests and parks/ Carte des forêts et parcs
020	Water uses map of the study area/ Carte des usages de l'eau de la zone d'étude
021	Map of water demand in 2020 and projected water demand in 2050/ Carte de la demande en eau en 2020 et de la demande en eau projetée pour 2050
022	Map of Industries and Mines/ Carte des Industries et des Mines
023	Transportation map/ Carte des transports
024	Map of potential for soil erosion by water/ Carte de potentiel d'érosion de sols par l'eau
025	Catchment restoration opportunities mapping/ Cartographie des opportunités de restauration des bassins versants
026	Natural hazards map/ Carte de risques naturels

For the KMZ files, they are grouped into 11 distinct categories as shown in the nomenclature below.

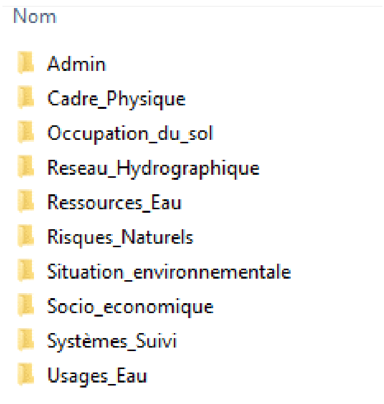
- Admin
- AEP_RWANDA
- Cadre physique
- Logo
- Occupation du sol
- Ressources en EAU
- Risques Naturels
- Situations environnementale
- Socio-éco
- Système de suivi
- Usage de l'eau

The table below describes the KMZ files :

File name/ Nom Dossier	Description
Admin	Administrative boundaries from level 1 to 5/ Limites administratives de niveau 1 à 5
AEP_RWANDA	Potable water supply infrastructures/ Infrastructures d'adduction en eau potable
Cadre physique	Digital Elevation Model/ Modèle Numérique de Terrain
Logo	Logos of the organizations/ Logos des organisations
Occupation du sol	Urban areas in 2011 and 2020/ Zones urbaines en 2011 et 2020
	National parks/ Parcs nationaux
	Mining and industries/ Mines et industries
	Main cities/ Principales villes
	Land use in 2016/ Occupation du sol en 2016

File name/ Nom Dossier	Description
Ressources en EAU	Limits of catchments, sub-catchments, compartiments, sub-compartiments, rivers, lakes, groundwater, swamps and location of drills and springs/ Limites de bassins versants, sous-bassins versants, compartiments, rivières, lacs, eaux souterraines, marais et localisation des forages et sources.
Risques Naturels	Volcanic eruptions : Lava flow for 1977 and 2002/ Eruptions volcaniques : Coulées de lave de 1977 et 2002
Situation environnementale	Deforested areas/ zones déforestées
	Polluted rivers/ Cours d'eau pollués
Socio-éco	Projected population for 2022/ Population projetée pour 2022
Système de suivi	Location of hydrometric and piezometric stations/ Localisation des stations hydrométriques et piezométrique
Usages de l'eau	Location of the gaz extraction plateforms, hydropower plants, irrigation areas, waterways, tourism spots/ Localisation des plateformes d'extraction de gaz, hydrocentrales, périmètres irrigués, lieux touristiques.

Finally, for shapefiles, the same nomenclature is used.



Folder/ Dossier	Sub-folder/ Sous-dossier	File/ Fichier	Description	Type of file/fichier
Admin		Admin0, Admin1, Admin2, Admin3_RWA_BU, Admin4_RWA_BU	Administratives boundaries from level 1 to 5/ Limites administratives de niveau 1 à 5.	Shapefile
Cadre physique	Evapotranspiration	Raster_annuel	Evapotranspiration P20, P50, P80	Raster
		Evapotranspiration	Evapotranspiration class limits/ Limites des classes d'évapotranspiration	Raster
	Géologie	Geologie_hydrogeologie	Geological class and aquifers/ Catégories géologiques et des aquifères	Shapefile
	Précipitation	Précipitation_BV	Limites des classes de précipitations dans le bassin versant	Raster
		Raster_Annuel	Rainfall P20, P50, P80/ Précipitations P20, P50, P80	Raster
	Routes	Route_BV_KIVU_RUZIZI_Proj	Roads/ Routes	Shapefile
	Température	Temperature_BV	Limites des classes des températures dans le bassin versant	Raster
		HBV_Pente	Slopes/ Pentes	Image

Folder/ Dossier	Sub-folder/ Sous-dossier	File/ Fichier	Description	Type of file/fichier
	Topographie et pente	HBV_SRTM	Digital Elevation Model/ Modèle numérique de terrain	Image
Occupation du sol	Centre urbains	Villes_principales_Ruzizi_Kivu	Location of main towns/ Localisation des villes principales	Shapefile
	Extractions de gaz plateformes	Platformes_BV	Location of gaz extraction platforms/ Localisation des plateformes d'extraction de gaz	Shapefile
	Forêts et parcs_zones naturelles	HBV_Parc_national	Boundaries of national parks, natural reserves, forest/ Limites des parcs nationaux, réserves naturelles, forets	Shapefile
		Parc national	National park boundaries/ Limites des parcs nationaux	Shapefile
		RMSA_Zone protegée	Naturel reserves boundaries/ Limites des réserves naturelles	Shapefile
	Industrie_Mine	Gisement d'or	Location of gold deposits /Localisation des gisements d'or/	Shapefile
		Station_Epuration	Location of treatment plant/ Localisation des stations d'épuration	Shapefile
		Usines_Industries	Location of factories and industries/ Localisation des usines et industriels	Shapefile
	Occupation du Sol 2016	Landcover 2016	Land cover in 2016/ Couverture du sol en 2016	Shapefile
Reseau_Hydrograhiques		Rivière	Main rivers/ Principales rivières	Shapefile
Ressources en_EAU	Bassin_versant		Catchment limits/ Limites du bassin versant	Shapefile
	Forage	AEP_forages_Burundi	Location of drillings/ Localisation des forages au Burundi	Shapefile
	Hydrologie	Lake_Kivu_Tanganyika	Kivu and Tanganyika lakes limits/ Limites des lacs Kivu et Tanganyika	Shapefile
	Marais_Plaine_Ruzizi	HBV_KIVU_RUZIZI_Marais	Marshlands limits/ Limites des marais	Shapefile
		Plaine Ruzizi	Ruzizi plain limits/ Limites de la plaine de la Ruzizi	Shapefile
	Source_Thermale	Source thermale	Location of thermal springs/ Localisation des sources thermales	Shapefile
	Sous_Bassins_Versant	BV_KI_RU_Name_zone_compartiments	Compartiment limits/ Limites des compartiments	Shapefile
		BV_KI_RU_Name-V2	Sub-catchments limits/ Limites des sous-bassins versants	Shapefile
Risques_Naturels	Eruptions_Volcaniques	Basaltes	Volcanic spreading limits/ Limites de l'épandage volcanique	Shapefile
		Lava_Flow_1977	1977 Lava flow limit/ Limite de l'écoulement de lave de 1977	Shapefile
		Lava_Flow_2002	2002 Lava flow limit/ Limite de l'écoulement de lave de 2002	Shapefile
		Volcan	Location of volcanoes/ Localisation des volcans	Shapefile
	Tremblements de terre	Tremblements_de_terre	Location and magnitude of earthquakes/ Localisation et magnitude des tremblements de terre	Shapefile
	Déforestation	deforestation	Deforested area limits/ Limites de zone déforestée	Shapefile

Folder/ Dossier	Sub-folder/ Sous-dossier	File/ Fichier	Description	Type of file/fichier
Situation environnementale	Erosion	CROM_BV	CROM model results/ Résultat du modèle CROM	Raster
		RUSLE_BV	Parameters and RUSLe Model results/ Paramètres et résultat du modèle RUSLE	Raster
	Qualité des eaux de surface	Cours d'eau pollués	Polluted rivers/ Cours d'eau pollués	Shapefile
Socio-économique	Population_Densité	Population_Densité	Population and population density in 2020 and projections/ Population et densité de population en 2020 et projections pour 2050	Shapefile
Système de suivi	Réseau de suivi des eaux souterraines	Stations_GW	Location of piezometric stations/ Localisation des stations de suivi piezométriques	Shapefile
	Stations hydrométriques	Proposed_stations	Location of proposed limnimetric stations/ Localisation des stations limnimétriques proposées	Shapefile
	Stations hydrométriques	Stations_Hydrom_Site	Location of existing limnimetric stations/ Localisation des stations limnimétriques existantes	Shapefile
	Stations_pluviométrique_harmonise	Station_pluviométrique_harmonise	Location of precipitation stations/ Localisation des stations pluviométriques	Shapefile
Usages de l'eau	AEP	AEP_Rwanda	Location of PWS infrastructures/ Localisation des infrastructures d'AEP	Shapefile
	Demande_Eau	Demande	Water demand in 2020 and projections/ Consommation en eau en 2020 et projections	Shapefile
	Hydro_élecricité_Centrales	Hydro_centrale_existant_HBV	Location of existing hydro stations/ Localisation des hydrocentrales existantes	Shapefile
		Hydro_centrale_potentiel_HBV	Location of potential hydro stations/ Localisation des hydrocentrales potentielles	Shapefile
		Hydro_centrale_underconstruction	Location of stations underconstruction/ Localisation des hydrocentrales en construction	Shapefile
	Périmètre_Irrigué_BV	Périmètres irrigués	Location of irrigated perimeters/ Localisation des périmètres irrigués	Shapefile
	Pisciculture	Pisciculture_RWA	Location of fish farms/ Localisation des fermes piscicoles	Shapefile
	Ports_routes navigables	HBV_Transport_Lacustre	Waterways/ Voies navigables	Shapefile
		Ports	Location of ports/ Localisation des ports	Shapefile
	Sources	SNA_NonAmenage	Locations of unprotected springs/ Localisation des sources non aménagées	Shapefile
		Sources_BV_Amenagé	Locations of protected springs/ Localisation des sources aménagées	Shapefile
		Sources_BV_Captée	Location of WSS springs/ Localisation des sources d'eau pour AEP	Shapefile

List of acronymns

Acronymn	Meaning
ABAKIR	Lake Kivu and Ruzizi River Basin Authority (Autorité du Bassin du Lac Kivu et de la Rivière Ruzizi)
ADB	African Development Bank
AEM	Anti-Erosive Mission
AHAMR	Rural Water and Sanitation Agency (Agence pour Hydraulique et l'Assainissement en Milieu Rural)
AIP	Annual Investment Plan
ASM	Artisinal and Small-Scale Mining
BMZ	Federal Ministry for Economic Cooperation and Development
BOD	Biological Oxygen Demand
CEPGL	Economic Community of the Great Lakes Countries (Communauté Economique des Pays des Grands Lacs)
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
CICOS	International Commission of the Congo-Oubangui-Sangha Basin (Commission Internationale du bassin Congo-Oubangui-Sangha)
CROM	Catchment Restoration Opportunities Mapping
DEM	Digital Elevation Model
DRC	Democratic Republic of Congo
EMAPE	Artisanal and Small-scale Mining Extraction
ESA-CCI	European Space Agency - Climate Change Initiative
ESIA	Environmental and Social Impact Assessement
ETP	Evapotranspiration
EU	European Union
FDLR	Rwandan Liberation Democratic Forces (Forces Démocratiques de Libération du Rwanda)
GCF	Green Climate Fund
GCM	General Circulation Model
GEF	Global Environment Facility
GIS	Geographical Information System
GIZ	German Agency for International Cooperation GmbH
IA	Irrigation area
IGEBU	Burundi Geographical Institute (Institut Géographique du Burundi)
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
IUSS	The International Union of Soil Sciences
IWRM	Integrated Water Resource Management
KFW	German Credit Institute for Reconstruction (Kreditanstalt für Wiederaufbau)
LKMP	Lake Kivu Monitoring Programme
NGO	Non-Governmental Organisation
NP	National Park
PES	Payment for ecosystemic systems
PPP	Public-Private Partnership
PWS	Potable Water Supply
RBMP	River Basin Management Plan

Acronymn	Meaning
RDB	Rwanda Development Board
REG	Rwanda Energy Group Limited
RUSLE	Revised Universal Soil Loss Equation
RWB	Rwanda Water Resources Board
SINELAC	International Society for Electricity in the Great Lakes Region (Société Internationale d’Électricité des Pays des Grands Lacs)
SNEL	National Electricity Company (DRC) (Société Nationale d’Électricité)
SNV	Netherland Development Organisation
SOTERCAF	Soil and Terrain Database for Central Africa
SWOT	Strengths, Weaknesses, Opportunities and Threats
TOR	Terms Of Reference
WASAC	Water and Sanitation Corporation (Rwanda)
WEAP	Water Evaluation And Planning
WEF	Water-Energy-Food
WP	Work Package
WRB	World Reference Base

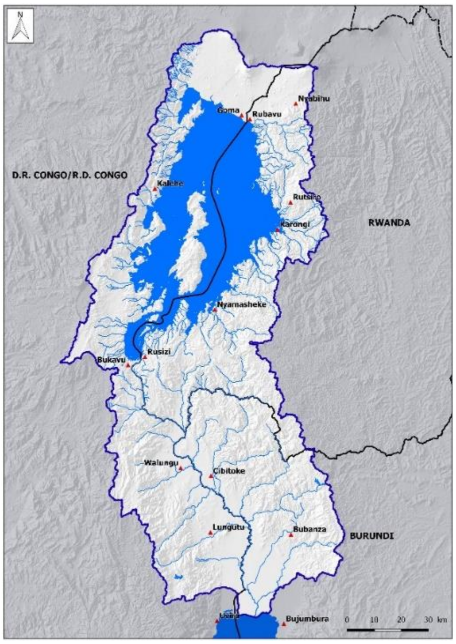
Executive Summary

General context and methodology

The implementation of an extended baseline study of the transboundary basin of Lake Kivu and the Ruzizi River is part of the project "Support to the integrated management of water resources of Lake Kivu and Ruzizi River", initiated in the framework of the support provided by the European Union (EU Delegation to Rwanda) and the German Federal Ministry for Economic Cooperation and Development (BMZ).

The study aims to support making operational the Lake Kivu and Ruzizi River Basin Authority (ABAKIR) created on 04 November 2014, following the signature of the International Convention on the Integrated management of Water Resources of the Lake Kivu and Ruzizi River Basin by Burundi, DRC and Rwanda. It is also intended to be cross-sectoral, through the NEXUS Water Energy Food approach.

This study is divided into two parts. The first part consists of the elaboration of the baseline study of the Lake Kivu and Ruzizi River basin, while the second part focuses on defining management options, and an evaluation framework, aimed at contributing to ABAKIR's strategic plan for an integrated and long-term management of the basin.



The study area corresponds to the cross-border catchment area of Lake Kivu and the Ruzizi River up to its outflow at Lake Tanganyika. It corresponds to the zone of intervention of the Lake Kivu and Ruzizi River Basin Authority (ABAKIR), and concerns 3 countries: Burundi, DRC and Rwanda. The total area of the study zone is 13,385 km², with 2,706 km² (20.2%) in Burundi, 6,227 km² (46.5%) in DRC and 4,452 km² (33.3%) in Rwanda.

In terms of the methodology employed, the priority objective is to undertake a baseline study that is harmonized and homogeneous on the scale of the whole basin. The strategy developed for its implementation consists in combining the data available and accessible at the level of the three member states, with global data produced on a larger scale and available in a homogeneous way over the whole basin.

First part: Baseline study of the Lake Kivu and Ruzizi River basin

Administrative and socio-economic context

The population of the basin is estimated at 11 million inhabitants for the year 2020, distributed as 6.8 million inhabitants in DRC (62%), 2.5 million inhabitants in Rwanda (23%) and 1.7 million inhabitants in Burundi (15%).

The rural population of the basin is estimated at 8.5 million (77%), while the urban population is estimated at 2.5 million (23%). The cities of Goma and Bukavu, which dominate the urban population of the basin, each have more than one million inhabitants in 2020, with a population density of around 13,500 inhabitants/km².

Based on a hypothesis of maintaining the current annual population growth rates for the three countries, the population of the basin should reach 27.5 million inhabitants by 2050, an increase of almost 150% over 30 years.

Throughout the basin, the population is characterised by a high level of poverty, especially in areas where insecurity and the presence of armed groups are still prevalent, as well as in rural areas affected by political disturbances.

Although the situation varies from country to country, food security for a large part of the population in the basin remains relatively volatile. Indeed, food security in the region is linked to many structural factors such as land pressure linked to rapid population growth, soil depletion or advanced degradation, limited agricultural production factors, economic vulnerability as well as cyclical factors such as climatic hazards, socio-political insecurity and health crises.

Physical setting

The altitude of the Lake Kivu basin is between 1,462 and 4,507 m, while that of the Ruzizi River basin is between 770 and 3,400 m. The Ruzizi plain, located within the eponymous basin, extends over approximately 1,345 km² at an altitude of between 770 and 950 m.

The generally very rugged relief in the north of the basin is reflected in the often steep slopes, frequently exceeding 60%.

The geological configuration of the basin of Lake Kivu and the Ruzizi River is essentially made up of Precambrian age lithostratigraphic units. The main metamorphic rocks are gneiss, gneissic and micaschist complexes, as well as quartzites, quartzite, granitoid and schist metasediments, and numerous granitic intrusions. In addition to these Precambrian rocks, the study area also includes fluvio-lacustrine sedimentary deposits of Cenozoic age (mainly in the plain of the Middle and Lower Ruzizi), as well as volcanic rocks (mainly basaltic) that have been formed from the Tertiary period to the present day through successive volcanic eruptions.

Climate context

The study area is characterised by a tropical climate, marked by a seasonal regime with a long and a short dry season, as well as a long and a short rainy season.

Temperatures and evapotranspiration are closely correlated with the topography, which is very rugged on the basin. The average annual temperatures in the nine main urban centres of the basin range from 14.7°C (Bigogwe) to 23°C (Bubanza and Bugurama), while the average annual rainfall ranges from 1,020 mm (Cibitoke and Rubavu) to 1,830 mm (Kalonge).

Water resources

The watersheds of Lake Kivu and the Ruzizi River have respective surface areas of 7,392 km² and 6,057 km², for a total surface area of 13,449 km² representing the entire study area. The division into sub-basins carried out within the study area includes a total of 128 sub-basins, of which 97 are rivers flowing into Lake Kivu, and 31 are tributaries of the Ruzizi River.

With a surface area of 2,412 km², Lake Kivu is situated at an altitude of 1,462 m above sea level and its surrounding catchment areas - very steep - can reach a maximum altitude of 4,507 m. Its average and maximum depths are 240 m and 485 m respectively. It is divided by the large island Idjwi (279 km²) and contains more than 560 billion m³ of water. The hydrology of Lake Kivu directly determines the supply of the Ruzizi River at its outflow. The Ruzizi River, 168 km long, has an average annual flow of around

80 m³/s. It drains water from Lake Kivu to Lake Tanganyika and forms a natural border between Rwanda, DRC and Burundi. On the first 50 km long section from Lake Kivu to the locality of Kamanyola (upper river), the river is embedded between the steep, heavily deforested and bare watersheds of South Kivu in DRC and the District of Rusizi in Rwanda. The river crosses an escarpment and the altitude decreases from 1,450 m to 962 m with numerous waterfalls (gorges), giving it significant potential for hydroelectric power generation. After the escarpment zone, the Ruzizi river extends over a length of 118 km in the plain, gradually falling from an altitude of 962 m to 770 m with a low average slope, before flowing into Lake Tanganyika.

From a hydrogeological point of view, four main types of aquifers can be defined in the basin, based on their hydrodynamic properties and aquifer potential: i) Quaternary sedimentary aquifers corresponding to alluvial (fluvio-lacustrine) deposits, mainly found in the alluvial plain of the Middle and Lower Ruzizi, ii) superficial aquifers located in the alteration zones of metamorphic and crystalline Precambrian bedrock, (iii) deeper discontinuous aquifers located in the fissured zones of Precambrian metamorphic and crystalline bedrock, and finally (iv) complex aquifers located in volcanic terrains (basalt, pyroclastic deposits) of the Cenozoic.

The aquifers with one of the highest groundwater capacities are found in the alluvial aquifer of the Ruzizi plain. Groundwater in the basin is mainly exploited from natural springs, primarily for drinking water supply in rural areas.

Land use

The catchment area is covered by 45% agricultural area, 30% forest area, 20% grassland, 3% shrub area and 1% urban area.

Agricultural areas thus occupy almost half of the study area. They are located on steep slopes, with the exception of those located in the Ruzizi plain.

Forest areas with a particularly interesting biodiversity are also present in the basin. They have a major impact on soil conservation, water resources and biodiversity. They account for 30% of the catchment area's land cover.

Land use in the basin has changed significantly in recent decades. In a quarter of a century, the area devoted to agriculture has increased by 29%, to the detriment of forests and meadows. The urban area of the basin has increased by 43% in the last ten years, due to the rapid development of the main cities of the basin.

Main uses of the basin water resources

In the basin, drinking water is mainly supplied from spring catchments, with the exception of the large urban centres, which use water intake structures from rivers or Lake Kivu. The basin's drinking water needs are estimated at 111 million m³/year for the year 2020, while projections for the year 2050 amount to 277 million m³/year given the estimated population growth for the basin.

Agricultural development in the Lake Kivu basin is based almost entirely on rain-fed and subsistence agriculture; it is practised on sometimes steep slopes, highly exposed to erosion and is associated with husbandry in stalls, particularly in Burundi and Rwanda. Irrigated agriculture is mainly found in the Ruzizi plain. There are a large number of irrigated areas with a total surface area of 59,287 ha, mostly split between Burundi and DRC, of which the part corresponding to functional agricultural areas is only 12,500 ha. However, the agricultural potential of the entire plain is estimated at 125,713 ha.

A monthly and annual water demand was determined for each of the irrigated areas. In total, the estimated annual water needs for all the areas (functional, planned and projected) amount to 486 million m³. The annual water needs corresponding to the functional areas amount to 102 million m³, while the annual water needs corresponding to the irrigable potential of the whole plain are estimated at 1 billion m³.

As far as hydroelectricity is concerned, the three countries bordering the Ruzizi River decided several years ago to work together on the construction of run-of-river dams along the river's steep zone. The Ruzizi I power plant, operational since 1959, is located 3 km downstream from the outflow of Lake Kivu and has an installed capacity of 29.8 MW. The Ruzizi II power plant came into service in 1989, with an installed capacity of 43.8 MW. The Ruzizi III hydropower plant, with a planned installed capacity of 147 MW, will be the third hydropower development on the same Ruzizi River for which an agreement was signed between the three countries in July 2019 in Kinshasa. Finally, the African Development Bank approved in January 2020 a project to prepare the construction of a fourth power station, Ruzizi IV, which should be located between the Ruzizi II and Ruzizi III waterfalls, with an installed capacity of 287 MW.

Although the hydroelectric potential on the first 50 kilometres of the Ruzizi River is considerable as mentioned above, there are other sites with potential in the basin. Thus, in total, whilst the current installed capacity of the basin is 82 MW, the potential capacity is estimated at 681 MW.

Rwanda has embarked on the exploitation of methane gas for power generation and distribution in the national grid. Two investments are already operational since 2015, namely the KivuWatt project with a gross nominal capacity of 26 MW and the Symbion Power Lake Kivu Ltd project with a net capacity of 50 MW.

Fishing on Lake Kivu is still an artisanal activity today. Before the introduction of Limnothrissa miodon (Isambaza) into Lake Kivu in the 1960s, fishing was a marginal activity for the riverside populations, with an estimated annual production of around 1,500 T/year. Fish production gradually increased to reach an average annual production estimated at 6,000 T/year. Currently, the total number of people working in this sector can be estimated at between 6,500 and 7,000 in Rwanda and a similar population in DRC. Aquaculture, which is an alternative to overfishing, is developing in the basin with an annual production capacity of 5,000 tonnes on Lake Kivu, and numerous fish ponds in the Imbo plain.

Water balance of the basin

A hydrological balance sheet was developed at the basin scale as part of the study. It enables the monthly water flows (inflows and outflows) to be determined for each of the 128 sub-basins in the study area, in a dry year, an average year and a wet year situation. The hydrological balance carried out thus allows the evaluation of the monthly volumes flowing at the level of each sub-basin, the total inflows into Lake Kivu, the outflows (such as direct evaporation from the lake and withdrawals for irrigation in the Ruzizi plain), as well as the flow of the Ruzizi river at three key points defined in the basin.

The results obtained indicate an average outflow from Lake Kivu to Ruzizi of around 71 m³/s in an average year. At the Kamanyola level, the average flow of the Ruzizi is estimated at 89 m³/s in an average year. Downstream at its entry into Lake Tanganyika, the Ruzizi has a mean flow estimated at 206 m³/s in an average year.

Water inflows by runoff to Lake Kivu, from the rivers of the Lake Kivu basin, are estimated at about 3.2 billion m³ for an average year. This is in addition to the 3 billion m³ of direct rainfall at the lake level, while direct evaporation from the lake's open surface is estimated at 3.45 billion m³. Runoff water inflow into the Ruzizi River basin is estimated at about 4.1 billion m³, of which just under 500 million m³ is consumed for irrigation in the Ruzizi plain. The total water input by runoff over the whole basin is thus estimated at 7.3 billion m³ in an average year.

Soil degradation

In order to quantify the annual soil loss within the study area and at the scale of each catchment, the Revised Universal Soil Loss Equation (RUSLE) model was used. The results obtained give an average soil loss of 102 t/ha/year over the whole catchment area. For the Lake Kivu basin only, the model gives an average value of 116 t/ha/year and for the Ruzizi River basin an average of 91 t/ha/year. For the whole area, the figures are very high and expose the major problem of erosion faced by the populations. These figures are consistent with the filling rates of reservoirs observed in these areas. The Chabiringa catchment area in DRC has the highest average erosion rate with a maximum value of 170 t/ha/year. Conversely, the rate of erosion on undisturbed forest land is generally very low, as in the Nyungwe-Kibira forest. However, other forests, reserves and national parks such as Gishwati, Virunga, South Masisi and Itombwe have severe erosion rates that reflect ecosystem disturbance. Canopy reduction, removal or alteration of understorey vegetation, mining, forest destruction, human-induced fires and soil compaction through grazing by domestic animals greatly increase the risk of soil erosion.

Another model was used as part of the study to determine the appropriate anti-erosion measures within the catchment area. This model, Catchment Restoration Opportunity Mapping (CROM), is based on 3 criteria: soil depth, soil cover and slope. The four types of anti-erosion measures considered are radical terracing, progressive terracing, agroforestry and afforestation. A mapping of the proposed restoration measures was thus carried out as part of the study, on the scale of the basin.

Potential sources of pollution

The potential sources of pollution are diverse and can present a real danger for Lake Kivu and the Ruzizi River. Throughout the study area, there is little collective sanitation infrastructure and little solid waste collection.

Bacteriological and chemical contamination due to inadequately treated, poorly treated or untreated domestic and industrial wastewater from the rapidly growing urban agglomerations on the shores of Lake Kivu constitutes a significant risk of degradation of the quality of the lake water near these areas.

As far as solid waste is concerned, large urban agglomerations, in particular, lead to an accumulation of waste, including non-degradable plastic packaging that ends up in lake and river waters.

In addition to the lack of sanitation and solid waste collection infrastructure, there is also pollution from industrial and mining sources. Mining activities in the region are dominated by artisanal mining, with very little investment to improve working conditions and environmental protection. The legislation in place is not really binding for these small-scale mines, which are a source of deterioration in the quality of surface water. Artisanal gold mining has developed significantly in the region, particularly in South Kivu province and in the rivers of Burundi.

From an agricultural point of view, the Imbo plain is an area of intensive agriculture and it can be estimated that the surface and ground waters of the plain receive locally significant amounts of pesticides and fertilisers. However, there is no regular and detailed monitoring of the quality of the water resources of the plain to quantify this potential impact at present.

Physico-chemical quality of water

The major problem encountered in relation to surface water quality is the massive erosion observed in the basin, with an average soil loss value of around 100 t/ha/year in the basin. This erosion generates extremely high and widespread turbidity in most of the basin's watercourses. The phenomena of sediment transport in the rivers and sediment accumulation, with the extreme turbidity observed, is one of the main environmental challenges facing the basin.

Very little data on the physicochemical quality of the water of Lake Kivu is available, and the same is true for the rivers that form part of its catchment area: regular monitoring of the water quality (physicochemical, bacteriological, biological) of the lake and its tributaries is so far limited, with the exception of the data from Rwanda, which are included in the Rwanda Water Portal. The situation is similar for the Ruzizi River and its tributaries, with a rather limited availability of data on the physicochemical quality of the rivers.

The waters of Lake Kivu are influenced by the salt content of the volcanic lava in the region and show consistent concentrations of soluble cations and anions that increase with depth. Electrical conductivity and concentrations of major elements are relatively high at the surface of the lake, with electrical conductivity values of the order of 1,000 to 1,500 µS/cm and a salinity of the order of 1 g/l. A basic pH level of between 8 and 9 is generally observed in the lake.

In its upper course, in addition to the waters of the lake, the Ruzizi River collects the high salinity waters from the volcanic regions of South Kivu and the waters of the thermal springs. The Ruzizi River retains in its upper course many of the physicochemical characteristics of the water of Lake Kivu: pH close to 9, electrical conductivity of around 1000 µS/cm, and high ionic concentrations (above 1 g/l). After crossing the volcanic zones and entering the plain, the salinity decreases from upstream to downstream, under the effect of dilution by the tributaries of the low salinity Moyenne Ruzizi. In fact, the tributaries of the Ruzizi show, overall, pH values close to neutrality, and very low electrical conductivity (rarely exceeding 200 µS/cm). The major ions are also present in low concentrations compared to the Ruzizi.

Although the mining, industrial and agricultural activities encountered in the basin generate discharges likely to significantly degrade the quality of water resources, the data available to date does not allow a complete and detailed diagnosis to be made. An improvement of the network for monitoring the quality of water resources is therefore particularly recommended.

Natural hazards

The most likely natural hazards in the basin are landslides, floods, volcanic eruptions and earthquakes.

Landslides are directly related to steep slopes, geology and heavy rainfall. Most of them occur along new roads as a result of a decrease in soil resistance, as well as a decrease in vegetation cover.

Floods are directly linked to a rainy event but also depend on the size and shape of the catchment area, its land use and topography. These floods, known as "flash floods", will potentially be more numerous in the future due to climate change, increasing urbanisation and the context of soil degradation linked in particular to land pressure.

The study area is located in the Albertine Rift, the western branch of the East African Rift composed of divergent tectonic plates moving apart at a rate of 6 to 7 mm per year. Numerous earthquakes occur every year. In the last 15 years, more than 28 earthquakes of magnitude greater than 4 on the Richter scale have occurred in the study area. The most powerful of these was recorded in August 2015 with a magnitude of 5.8 in the locality of Kabare in DRC.

In the north of the study area, there are several volcanoes including Nyamulagira and Nyiragongo. The latter is an active volcano located at an altitude of 3,470 m, north of the city of Goma and is particularly well known for containing the largest lava lake in the world. It poses a real danger to the cities of Goma and Gisenyi, which during the eruptions of 1976 and 2002 saw tens of people perish and thousands of others displaced.

Overview of the basin's ecosystem services

The study distinguishes and describes aquatic, forest, agro-sylvo-pastoral and urban ecosystems.

The aquatic ecosystem is characterised by the basin's potential for food supply, through fishing activities (mainly on Lake Kivu) and aquaculture, by energy production linked to the exploitation of methane gas on Lake Kivu and the production of hydroelectric power on the Ruzizi River and various secondary rivers in the basin, and finally by the supply of drinking water for the basin's populations. The level of potential conflicts between drinking water and other uses remains limited to date; nevertheless, quality aspects are crucial and constitute the main problem encountered in the basin.

As far as forest ecosystems are concerned, a large part of the basin is delimited by high mountains resulting from tectonic crests covered with dense primary forests at high altitude. The forests represent an area equivalent to 30% of the basin. Many of these forests constitute the main source of wood supply for domestic energy (biomass) but also for other uses. The forest ecosystems also provide climate regulation services, making it possible to maintain a temperate climate and limit violent winds in the basin. The forests also store large quantities of carbon dioxide ($CO2$), both in the above-ground vegetation and in the underground biomass. Finally, the forests play an essential role in preventing erosion on the slopes and sedimentation of Lake Kivu and the tributaries of the Ruzizi River. In terms of culture and tourism, three forests have the status of UNESCO World Natural Heritage Sites, namely the Virunga National Park and the Kahuzi-Biega National Park in DRC and the Gishwati-Mukura National Park in Rwanda.

With regards to agro-sylvo-pastoral and urban ecosystems, these cover the entire area between the forests, which are mostly protected areas, and the aquatic ecosystem. It is in this area that a large part of human activities are carried out and where the majority of the basin's population lives. Increasing urbanisation and land use planning confront the basin with many challenges, hampered by the lack of urban development and structured land use plans. In terms of agriculture, two types of production can be identified in the catchment area, namely irrigated agriculture in the Ruzizi plain and rain-fed agriculture on the slopes. The maintenance - and development - of intensive irrigated agriculture in the Ruzizi plain implies the simultaneous implementation of monitoring measures and preventive and restorative actions, while agricultural practices on the slopes are a source of soil degradation that can favour erosion. Soil conservation and erosion control are essential not only to enable farmers on sensitive lands to maintain their productive capacity, but also to ensure the ecosystem services encountered downstream.

Synthesis of challenges and opportunities in the basin and for ecosystem systems

A SWOT analysis was carried out for the Lake Kivu and Ruzizi River basin as part of the study, highlighting not only the threats and challenges facing the basin, but above all the real development opportunities available to the people of the basin.

Part 2: Management options and evaluation framework

Hydrometeorological and environmental monitoring networks

Within the study area and in the close vicinity, a total of thirteen functional weather stations with time series data are available. This figure does not include the few stations located in the DRC for which data are not available or are too fragmented.

In view of the disparity in meteorological data coverage and the availability of global data sets, it is recommended to maintain the existing meteorological stations, with no specific need for network densification, and to use the global data sets (CHIRPS and GLOBAL-PET of the CGIAR-CSI) possibly corrected based on the few ground stations in relation to regional specificities not taken into account in the global data sets.

In terms of surface water monitoring, an overview of the current situation was established during the field visits organised as part of the study. In the study area on the Burundian side, eight existing stations were visited. On the Congolese part of the catchment area, no limnimetric stations were reported. In Rwanda, in the study area concerned, seven stations were identified, as well as a non-functional station for measuring the water level of Lake Kivu. Five additional stations are listed in the Sebeya basin on the Rwanda water portal site, some functional, others old and disused. New hydrological stations have been installed on the Rwandan side and may not yet be fully functional.

The hydrometric monitoring network deserves to be densified. Unlike climate data, it is not possible to use global data sets. It is therefore imperative to plan a series of new stations and to maintain the quality of the data currently produced on the rivers being monitored. With this in mind, 24 potential sites for the installation of new hydrological stations were identified in the course of the study.

Monitoring of surface water quality is relatively limited in the basin and varies greatly from one country to another. In Rwanda 15 quality monitoring stations are listed in the study area on the Water Portal website, but few of them are operational. No surface water quality monitoring stations are listed in Burundi and DRC.

In terms of watercourse quality, it is proposed as a matter of priority to periodically monitor turbidity, initially in the three key basins identified in the framework of the study. A periodic monitoring of the water quality of the Ruzizi River is also proposed, from the plain to the mouth with Lake Tanganyika. This monitoring aims to characterise the potential impact of hydro-agricultural activities in the plain on the water quality of the Ruzizi River, with regards to the risks of contamination of the latter that may result from the drainage of irrigation water loaded with residues of agricultural inputs (nitrogen compounds, phosphates, pesticides).

With regards to Lake Kivu, regular monitoring of the physicochemical quality of the lake water is recommended, on a quarterly basis, on the lake's shore waters in the towns of Bukavu / Rusizi, Kalehe, Goma / Rubavu, and Karongi.

Regular groundwater monitoring is very limited in the basin. There are only four groundwater monitoring stations in the entire basin, all located in Rwanda. There are no groundwater monitoring points in Burundi or DRC. Concerning the monitoring of groundwater quality, no point has yet been identified in the basin. It is recommended that the current network be completed by setting up a network to monitor the levels of the alluvial water table in the Ruzizi plain, and to monitor the quality of this water table. This network would essentially aim at better understanding and monitoring the spatiotemporal evolution of the dynamics of the accumulation of agricultural inputs (fertilizers and pesticides) in the alluvial water table at the level of the plain.

Institutional and legal framework

Burundi, DRC and Rwanda have basic legislative frameworks for environmental management. These are set out in various laws and decrees relating to environmental protection and natural resource management, as well as environmental impact assessment. Water resource management is regulated by the water code in Burundi (2012), the water law in the DRC (2015) and the law determining the use and management of water resources in Rwanda (2018).

However, these legal and institutional frameworks are not fully operational, let alone harmonised. Despite the dynamic of regulatory and institutional reform, land management in Burundi and the DRC remains hampered by several constraints, including the lack of clarity of customary law, the absence or inadequacy of land tenure security, severances of land and women's precarious access to land.

The three countries have ratified international environmental protection initiatives such as the Convention on Biological Diversity, the United Nations Framework Convention on Climate Change and the Convention to Combat Desertification.

The study identifies the government institutions in the three countries that are responsible for natural resource management, at the level of the respective ministries responsible for these matters in the three countries. The role of territorial organisations, at provincial level (Burundi and DRC) and at district level (Rwanda), is also defined in relation to natural resource management.

Finally, the main stakeholders in IWRM and the WEF NEXUS approach, operating at basin level, are also identified in the study.

Cross-border and international legal framework

The main regional organisations operating at the basin level are the Economic Community of the Great Lakes Countries (CEPGL), the Economic Community of Central African States (ECCAS), and the International Conference of the Great Lakes Region (ICGLR).

The basin management organisations intervening at the level of the Lake Kivu and Ruzizi River basin are the Lake Tanganyika Authority (LTA), the International Commission of the Congo-Oubangui-Sangha Basin (CICOS), the Nile Basin Initiative (NBI), and finally the Lake Kivu and Ruzizi River Basin Authority (ABAKIR).

Basin management options: structural strengthening of ABAKIR

The Lake Kivu and Ruzizi River Basin Authority (ABAKIR) was created on 04 November 2014, following the signing of the International Convention on the Integrated management of Water Resources of the Lake Kivu and Ruzizi River Basin by Burundi, DRC and Rwanda. The Convention aims to promote the economic, industrial and social development of the use of the basin's water resources for energy production or any other beneficial use while preserving the environment. ABAKIR is headquartered in Rubavu, Rwanda.

A strengthening of ABAKIR's capacity to implement its mandate, and the missions associated with it, could materialise through:

- The creation within ABAKIR of (i) a Planning and Studies Unit, to ensure the implementation and monitoring of studies and projects within the framework of a planned process, (ii) an "Observatory of water resources and associated environments of the basin" to ensure the management, exploitation, capitalisation and sharing of data for monitoring water resources and associated environments of the basin and (iii) Technical Committees composed of representatives of member states and aimed at dealing with specific matters (erosion, water quality, natural risks, etc.) ;
- The establishment of data exchanges between the three member states and ABAKIR, based in particular on the definition of standardised exchange processes and the designation of national focal points ;
- The use of external technical expertise, in support of the development of data management and exploitation tools, the carrying out of specific studies on the basin, the implementation of projects, and the strengthening of ABAKIR's capacities (training modules).

An organisational chart is proposed in Figure 44, based on these elements. Particular mention should be made of the major interest in setting up an Observatory of the water resources of the basin and associated environments, which will be made operational based on the development and implementation of basin management tools.

Development of basin management tools

A series of information, data management, communication and decision support tools have been identified to be implemented within ABAKIR and in particular the Observatory. These tools include the implementation of a GIS application and an adjoining database, the development of a "Water Geoportal" type solution, the development and management of hydrological and water resource planning models, the use of an IWRM toolbox, and the implementation of an observation and early warning system.

Among the tools proposed above for making ABAKIR's missions operational, those aimed at the sustainable management and planning of the basin's water resources occupy a predominant place. It is based on this observation that such a tool has been developed, through the use of the *Water Evaluation and Planning* (WEAP) software, within the framework of the present study. The model produced could be consolidated and used in a sustainable way within the framework of the activities of the basin managers (including ABAKIR and particularly its Observatory).

Adoption of indicators

The International Network of Basin Organizations (INBO) and its regional network in Africa (the African Network of Basin Organizations - ANBO) have developed performance indicators relating to the implementation of IWRM principles in African transboundary basins. These indicators could usefully be used within the framework of the activities of the ABAKIR Observatory, especially for periodically establishing the environmental status of the basin. Among these indicators, a selection has been made on the basis of the parameters deemed most relevant for the Lake Kivu and Ruzizi River basin and best suited to the current context of cross-border management of this basin.

Integrating Payments for Ecosystem Services (PES) into basin management

The first phase of setting up a PES system could focus on reducing water turbidity by mobilising funding to limit soil erosion, which is the main problem encountered in the basin.

The PES would be aimed at very specific actions such as strengthening the management and conservation of the protected areas present in the Basin, and supporting soil restoration projects based on anti-erosion practices.

A later phase of PES could be to encourage local communities to limit certain environmentally degrading actions, even though they may be important sources of income. This is the case for artisanal mineral exploitation, sand quarrying or brick making. This phase would require significant advocacy by stakeholders and local authorities, but also propose substantial economic alternatives that ensure compliance with best environmental practices.

Synthesis of the options proposed for the development of the legal and technical bases in the basin

The development of legal framework is based on the harmonisation of policies and regulations related to environmental protection and water resource management. This harmonisation must be achieved by strengthening the capacities and responsibilities of decentralised entities, but also of organisations in charge of watershed management and institutions for the management of protected areas.

The development of the technical framework is based on the strengthening and optimisation of the existing hydro-meteorological monitoring networks in the three countries, on the establishment within ABAKIR of operational technical structures, on the definition of a protocol for the exchange of information and data between the member states and ABAKIR, on the development of management, information and extension tools, and on the adoption of indicators.

Recommendations for the elaboration and prioritisation of an action programme

Measures aimed at the sustainable management, preservation and restoration of water resources and associated environments of the basin are necessary, through enhanced cooperation between Member States. Under the coordination and with the support of ABAKIR, an action programme is thus proposed to achieve these objectives. A prioritisation of actions is then proposed, taking into account the main risks and issues identified in the basin.

It is proposed to implement an action programme consisting of the following six types of measures:

1. Measures to improve knowledge (hydrology, hydrogeology, withdrawals and discharges, potential sources of pollution, quality of water resources, degradation of the basin, natural risks, etc.);
2. Resource monitoring measures and data transmission;
3. Measures to reduce pressure on the environment;
4. Natural risk management measures;
5. Institutional support measures for ABAKIR;
6. Measures to develop the legal bases in the basin.

Among the options for the development of the legal and technical framework presented in the study, and particularly among the measures included in the proposed action programme, the following actions are recommended to be implemented as a matter of priority:

- Setting up of ABAKIR's internal technical units: Studies and Planning Unit, and Observatory of Water Resources and Associated Environments.
- Establishment of data exchange protocols between ABAKIR and the member states, notably through the designation of national focal points for data transfer.
- Making ABAKIR's technical units operational by setting up and operating the proposed management tools: computer infrastructure, database, geographic information system, water resources planning model (WEAP), erosion assessment model (CROM and RUSLE).
- Implementation of communication tools, to improve the visibility of ABAKIR within the member states and to share information on the basin with the general public. In particular, establishment of a Water Geoportal, and publication of a popularised version of the inventory of water resources and the environment of the Lake Kivu and Ruzizi River basin.
- Setting up pilot projects to combat soil degradation and erosion in sensitive sub-basins in the intervention zone.
- Improvement of the network for monitoring surface and groundwater resources.
- Implementation of measures to improve knowledge on (i) the hydrogeology of the basin (characterisation of aquifers, exploitation potential, vulnerability), (ii) water abstraction and discharges, (iii) the quality of surface and groundwater resources.

General conclusions

The main issues related to the management and preservation of the basin's water resources are globally linked to the quality of the water resources, rather than to the quantity. The control of environmental degradation, in particular with regards to soil erosion and the resulting significant turbidity of the watercourses, is one of the major issues encountered in the basin.

The threats to the quality of Lake Kivu's water, in relation to the uncontrolled development of the urban areas bordering the lake, as well as the industrial development - especially mining - which poses environmental threats to the surface waters of the basin, are all factors that require coordinated action at the scale of the basin and the most vulnerable sub-basins.

Finally, there is a need to control natural risks in the basin, which is particularly exposed to extreme events such as floods, landslides, volcanic eruptions and seismic phenomena.

Faced with these threats, the challenges of sustainable management and preservation of water resources and the associated environments in the basin can be overcome in a coordinated manner between the three countries, through making ABAKIR operational. The priority in this respect should be to give this structure the visibility and legitimacy that will enable it to strengthen the support of the authorities, the populations and the users of the basin's resources, prior to the implementation of measures that could be considered binding.

Introduction and general framework

1. Context of the study

The three Member States of the Lake Kivu and Ruzizi River Basin, the Republic of Burundi, the Democratic Republic of Congo and the Republic of Rwanda, have established the Lake Kivu and Ruzizi River Basin Authority, known by the French acronym "ABAKIR", as the authority responsible for the integrated management of water resources in the Lake Kivu and Ruzizi River Basin. In support of making this structure operational, the present study follows a request from the GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH) for an extended baseline study of the cross-border basin of Lake Kivu and the Ruzizi River. The GIZ is currently conducting a project to provide "Support for the integrated management of the water resources of Lake Kivu and the Ruzizi River", initiated in the framework of support from the European Union (EU Delegation to Rwanda) and the German Federal Ministry for Economic Cooperation and Development (BMZ). The baseline study that is the subject of this mission will contribute to the implementation of this project.

The study aims to be integrated: Integrated Water Resources Management (**IWRM**) involves the coordination, development and management of water, land and related resources to produce economic and social well-being, taking into account sustainability and environmental and ecosystem aspects. It is also intended to be cross-sectoral: the **NEXUS** approach for water, energy and food security focuses on the interdependencies between these three sectors and the need to create synergies and regulate equitable trade-offs between competing uses of resources. By supporting the cross-border basin organisation ABAKIR, the study also provides an opportunity to foster regional cooperation.

2. Objectives of the study and expected results

Two main areas can be identified to achieve the mission's objectives:

- The reinforcement and capitalisation of knowledge, through the realisation of an extensive baseline study covering the whole basin of Lake Kivu and the Ruzizi River;
- The strengthening of managerial and evaluation capacities for the benefit of ABAKIR's strategic plan, through the development of key policy options and tools for evaluating these options.

The two main expected results of the study, based on these two areas, correspond to the two parts of this report:

- Part 1: Baseline study of the Lake Kivu basin and the Ruzizi River. In this first part, a description of the basin presents the administrative and socio-economic context encountered, the physical context, water resources, land use and its evolution, water uses, the environmental situation of the basin, natural risks, ecosystem services and biodiversity as well as water resource monitoring systems.
- Part 2: Management options and evaluation framework. Under this part, management options and an evaluation framework, contributing to ABAKIR's strategic plan for integrated and long-term management of the basin, are developed. The objective of these options is to assess the main development trajectories in key areas of the basin, taking into account the main drivers of change.

3. Definition of the study area

The study area corresponds to the cross-border catchment area of Lake Kivu and the Ruzizi River up to its mouth at Lake Tanganyika. It corresponds to the zone of intervention of the Lake Kivu and Ruzizi River Basin Authority (ABAKIR), and concerns 3 countries: Burundi, DRC and Rwanda.

The total surface area of the study area is 13,385 km², with 2,706 km² (20.2%) in Burundi, 6,227 km² (46.5%) in DRC and 4,452 km² (33.3%) in Rwanda. Taking into account the surface area of Lake Kivu (2,412 km²), the land area of the study area is 10,973 km². It should be noted that the Lake Kivu basin is shared between DRC and Rwanda only. Figure 1 below illustrates the extent of the study area.

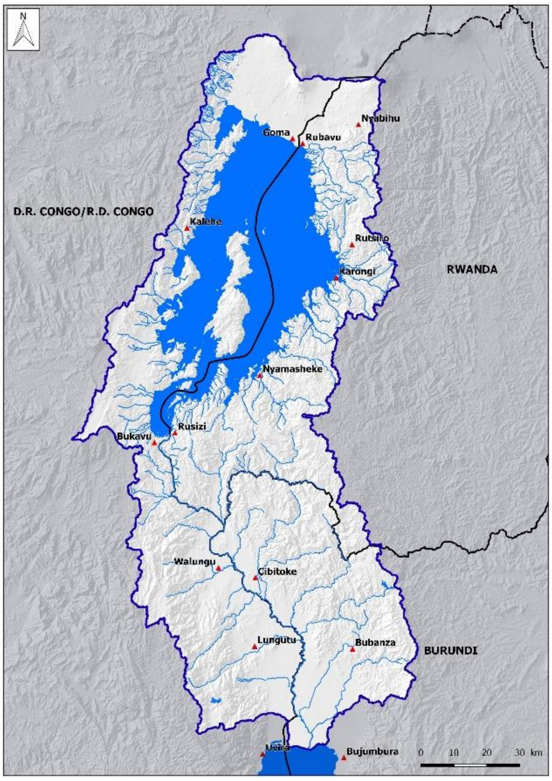


Figure 1: General map of the study area.

The river is spelled Rusizi in Burundi and Rwanda and Ruzizi in DRC. In this report, the choice has been made to refer to this river as Ruzizi for all countries.

4. Methodology

The priority objective pursued by the methodology developed is to undertake a baseline study which is intended - above all - to be harmonious and homogeneous on the scale of the entire basin.

The study area covers three countries (Burundi, DRC, Rwanda), where the availability of certain thematic data and the level of precision of these data are not always equivalent. In order to overcome these differences and to achieve a harmonised level of information throughout the basin, the strategy developed for the implementation of the study consists of combining the data available and accessible at the level of the three member states, which have been collected, with global data produced on a larger scale and available in a homogeneous manner throughout the basin. The latter data are processed as part of the study, with the aim of calibrating them, if necessary, to the available field data and validating them on all the sub-basins in the study area.

The thematic information combined according to this approach is organised - and presented in the first part of this report at basin and sub-basin scales - into socio-economic and administrative data, physical data, climatic context, water resources, land use, water uses, water balance, environmental situation, natural hazards, ecosystem services and biodiversity.

Thematic data were collected from stakeholders. In addition, high-quality *open-source* data were used in the study. Information on the socio-economic context was taken from reference publications by national institutions or their partners (demographic and health survey, household living conditions survey, poverty profile, etc.).

The physical data are taken from *open-source* databases (SRTM for topography) and SHER cartographic database (for pedology).

The climatic context was drawn up using hydrological data from the basin's hydrometric monitoring networks and meteorological data from the basin's climate stations, combined with the use of global rainfall (CHIRPS) and potential evapotranspiration (GLOBAL-PET CGIAR-CSI) data calibrated over the basin, to establish, with the same level of representation, hydrological balances on the scale of the basin and of each sub-basin in the study area.

The study of water resources was based on geomorphological data and supplemented with information from scientific literature and geophysical studies of the basin (Tassi *et al.*; Muvundja FA *et al.*).

The land cover data come from the ESA-CCI database. Soil degradation mapping and watershed restoration options (RUSLE and CROM models) are based on the use of physical data specific to each sub-basin.

Concerning water uses, information on irrigation, water supply and hydropower is derived from various studies/projects (master plan of the Ruzizi plain, ProSecEau database, water supply project for the city of Uvira, SHER feasibility studies and hydropower atlases) and field visits. Other information comes from a literature review.

A model was developed for the water balance based on an analysis of land use change, including the extension of urban areas and changes in wooded areas, using land use and land cover data (ESA-CCI) and satellite image classification. This analysis was based on statistical data on population growth provided by the relevant ministries of the three countries.

Environmental degradation and disaster risks have been covered by different tools: (i) changes in land use and land cover (ESA-CCI), (ii) simple flood forecasting based on gauging data, producing intensity-duration-frequency curves, (iii) use of the RUSLE models produced by GIZ in 2014, and (iv) a literature review. Water quality data, which is very limited, comes from 9 stations in Rwanda for Lake Kivu and its tributaries and from an environmental study (SMEC 2018) for the Ruzizi River. Information on natural hazards comes from studies (Artelia, Dewitte *et al.*, Ross *et al.*) and institutional publications (MIDIMAR).

The analysis of ecosystem services was based on a literature review and the collection of information from relevant institutions.

The second part of the study, relating to the managerial options and the evaluation framework, presents the institutional and legal framework in relation to the environmental management of the basin, the regional and basin management organisations concerned, the ongoing projects and the state of the IWRM policy in the basin. This second part also presents a characterisation of the hydro-meteorological monitoring networks, a diagnosis of them, and recommendations for their optimisation at basin level. Based on these recommendations, basin management options are defined for the benefit of ABAKIR, aiming in particular at proposing mechanisms for sharing and developing data with the member states.

Part 1: Baseline study of the Lake Kivu and Ruzizi River basin

5. Administrative and socio-economic context

5.1. Administrative framework

Three countries cover the study area: Burundi, DRC and Rwanda. From an administrative point of view, the three countries have a first-level administrative division corresponding to the provinces. The study area is crossed by the following eight provinces: Cibitoke, Bubanza, Kayanza and rural Bujumbura in Burundi, North Kivu and South Kivu in DRC and West and South in Rwanda. Figure 2 below illustrates the administrative division into provinces in the study area.

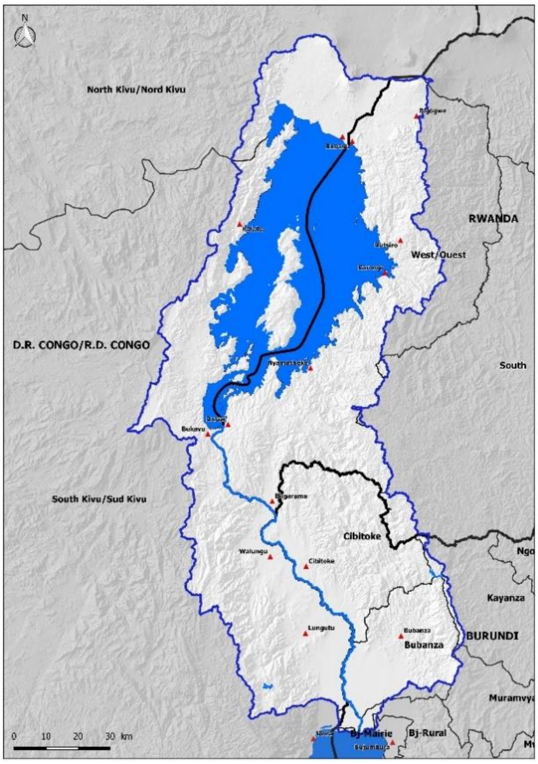


Figure 2: Administrative boundaries of the Study Area (provincial boundaries)

The second-level administrative division corresponds to communes for Burundi (18 communes in the basin), territories for the DRC (9 territories in the basin) and districts for Rwanda (10 districts in the basin).

The main urban centres in the study area are Cibitoke and Bubanza in Burundi, Goma, Bukavu, Kalehe, Walungu and Lungutu in the DRC and Rubavu, Nyabihu, Rutsiro, Karongi, Nyamasheke and Ruzizi in Rwanda.

The cities of Uvira (DRC) and Bujumbura (Burundi) are not located within the catchment area. However, these two cities are located a few kilometres away and also play a role in the southern part of the Ruzizi catchment area.

Map No. 001 in the appendix illustrates the administrative division of the study area.

5.2. Demography

5.2.1. Current population of the basin (2020)

Based on the population censuses conducted in Rwanda in 2012 and Burundi in 2008, and the statistical yearbook produced in 2014 by the DRC's National Institute of Statistics, and taking into account the expected annual population growth rates for the three countries (3.1% in Burundi, 3.3% in the DRC and 2.4% in Rwanda respectively), the population of the basin is estimated at 11 million inhabitants for the year 2020. The population of the basin is distributed as follows: 1.7 million inhabitants in Burundi (15%), 6.8 million inhabitants in DRC (62%) and 2.5 million inhabitants in Rwanda (23%).

This population corresponds to an average density of 1,000 inhabitants/km² in the basin. However, this density is not very representative of the configuration encountered, given the high concentration of population observed in the main cities of the basin. The rural population of the basin is estimated at 8.5 million inhabitants (or 77%), while the urban population is estimated at 2.5 million inhabitants (or 23%). The main cities are Goma and Bukavu, which dominate the basin and each have more than one million inhabitants in 2020, with a population density of around 13,500 inhabitants/km². Taking into account the population concentrated in the different cities of the basin, the rural environment is characterised by population densities generally between 150 and 400 inhabitants/km².

The population under 15 in the catchment area represents more than 45% in Burundi, 50% in South and North Kivu and 40% in Rwanda. The average age of the basin's population is 17.1 years in Burundi, 18.8 years in DRC and 19.2 years in Rwanda. As a result, the youth dependency ratio, which represents the proportion of young people not yet in the labour force, remains very high in the basin, varying between 70 and 90 per 100 persons in the labour force (15-64 years).

Maps No. 002 in the appendix illustrates the estimated population distribution in 2020 in the basin, and the distribution of population density.

5.2.2. Projections of population growth up to 2050

Based on a hypothesis of maintaining the current accepted annual population growth rates for the three countries, the population of the basin should reach 27.5 million inhabitants in 2050, an increase of almost 150% over 30 years. It would thus reach 4 million inhabitants in Burundi (15%), 18 million in the DRC (67%) and 5 million in Rwanda (18%). The projected rural population of the basin in 2050 is estimated at 21 million (76%), while the projected urban population in 2050 is estimated at 6.4 million (24%). These figures are presented in Table 1.

Table 1: Current and future distribution of the urban and rural population in the catchment area.

		Population (millions of inhabitants)			
Year	**Environment**	**Burundi**	**DRC**	**Rwanda**	**Total pool**
2020	Rural	1.5	4.7	2.2	8.4
	Urban	0.1	2.1	0.3	2.5
	Total	**1.6**	**6.8**	**2.5**	**10.9**
2050	Rural	3.8	12.6	4.5	20.9
	Urban	0.3	5.5	0.6	6.4
	Total	**4.1**	**18.1**	**5.1**	**27.3**

Map No. 003 in the appendix illustrates the estimated population distribution in 2050 in the basin, and the distribution of population density at this horizon.

5.3. Level of socio-economic development of the basin

Throughout the basin, the population is mainly rural except in DRC. It is characterised by a high level of poverty, especially in areas where insecurity and the presence of armed groups still prevail and in rural areas affected by political disturbances.

5.3.1. Situation in Burundi

Burundi is experiencing significant population growth at over 3% per year linked to a high fertility rate (5.5 children/woman). Households are made up of an average of 6.4 people and the demographic dependency ratio is 53% on average. The literacy rate among 15-24 year olds is 88%.

Burundi's poverty rate was 72.9% in 2016[1], with large disparities between rural and urban areas. Nearly 95% of the poor live in rural areas, where the poverty rate is estimated at 68.9%. In urban areas, the average poverty rate is 40.9%, with the exception of the capital, Bujumbura, where the rate falls to 20.8%[2]. The provinces of Cibitoke, Bubanza and Bujumbura-Rural included in the basin nevertheless present a less critical situation of poverty estimated at 45.5% due to better access to basic services and infrastructure and ownership of assets, including access to irrigation areas in the Imbo plain and to various sources of income.

In 2014, more than 85% of working-age adults had their main job in agriculture. Informal employment dominates in all sectors, accounting for more than 95% of total employment.

The rate of access to drinking water is estimated at 60% in rural areas and 83% for the city of Bujumbura in 2013. Access to domestic electricity in urban areas is 39.6%[3]. A third of the population has access to improved sanitation[4].

[1] Using a poverty line of $1.9 per capita per day according to the World Bank 2016 study (reference below).

[2] World Bank - 2016. "Doing Business 2016: Measuring Regulatory Quality and Efficiency. Economic Profile 2016, Burundi." The International Bank for Reconstruction and Development / The World Bank.

[3] Ministry of Water, Environment, Spatial Planning and Urbanism/UNDP - 2015. National Habitat Report III.

[4] National Water and Sanitation Inventory 2007 and INEA urban 2009.

5.3.2. Situation in the DRC

In the provinces of South and North Kivu, more than 40% of the population lives in urban areas. The average household size is 6 people and more than 50% of the population is under 15 years old[5].

The literacy rate is 56% for women aged 15-49 and 75% for men, with a higher proportion in urban areas (71% for women and 81% for men). The net school attendance rate in 2018 is 62%.

With poverty rates of 84.7% and 72.9%, South and North Kivu are among the provinces in DRC with a higher incidence of poverty than the national average (71.3%). The unemployment rate is among the highest in the country (22%). The informal sector employs nearly 90% of the working population and generates nearly 95% of household income. The informal agricultural sector provides nearly seven out of ten jobs. Child labour is a sad reality, with an activity rate for the 10-14 age group of 19.2% in North Kivu (compared with 9.1% in the DRC)[6].

The general insecurity linked to the presence of armed groups and the difficulties in the movement of goods and people lead to a reduction in agricultural and livestock production, increased unemployment and reduced access to essential goods and basic services (food, transport, health, education, etc.).

In addition, 38% of the population has access to electricity (52% in urban areas and 23% in rural areas) but only 0.1% use clean fuels and technologies for cooking, heating and lighting. 82% of the population use an improved source of drinking water (94% in urban areas and 69% in rural areas)[7]. As for sanitation, 16% have access to improved sanitation facilities (29% in urban areas and only 2% in rural areas) and 99.5% of households do not have access to road services for rubbish disposal.

The limited access of the population to safe drinking water reinforces water-borne diseases, which are among the major causes of mortality and morbidity. The infant mortality rate is 57 ‰ compared to 92 ‰ for the DRC, while the infant and child mortality rate is estimated at 102 ‰ compared to 148 ‰ for the country. Similarly, the inadequacy of toilets for the evacuation of excreta also accentuates the spread of infectious diseases and especially diarrhoeal diseases, which are also one of the causes of malnutrition.

5.3.3. Situation in Rwanda

Over the last two decades, Rwanda has managed to gradually reduce its population growth to 2.2% with a fertility rate of 4.6 children/woman. The overall improvement of health care and the establishment of a community-based health insurance scheme run by the government has made it possible to reduce child mortality from 107 ‰ to 32 ‰ and maternal mortality from 1071 ‰ to 210 ‰ between 2000 and 2015[8].

Between 2000 and 2017, Rwanda's economy grew by an average of 6% per year[9], placing it on the list of the ten fastest growing countries in the world. This strong growth has led to a rapid reduction in poverty, with the share of the population living below the national poverty line falling from 59% in 2000 to 38% in 2017, of which 16% are in extreme poverty. However, the Western province of the country

---

[5] UNICEF. MICS-Malaria 2017-2018. Report on the results of the survey. South Kivu Province and North Kivu Province. February 2020.

[6] UNDP DRC: Profile Summary Poverty and household living conditions North Kivu Province and South Kivu Province, 2009.

[7] MICS-Malaria 2017-2018. Report on the results of the survey. South Kivu Province. February 2020.

[8] Rwanda Demography and Health Survey, 2015

[9] National Institute of Statistics of Rwanda, National Accounts, 2017.

has the greatest economic poverty. The Nyamasheke district has a poverty rate of 69% (of which 45% is extreme poverty) and the districts of Karongi, Rutsiro and Ngororero have a rate of over 45%. The districts of Ruzizi and Rubavu are below the national average with 33% and 35% of the population being poor[10].

More than half of the population (16 years and over) is active. 75% of the population works in the informal sector, and the unemployment rate is 15.2%[11]. Agriculture is the main occupation and the main source of income for the majority of the population except for the richest 20% of households.

By 2017, 34% of the population had access to electricity, 87.1% to an improved water source and 87.3% to improved sanitation[12].

5.4. Food security situation

Although the situation varies from country to country, food security for a large part of the population in the basin remains relatively volatile. Indeed, food security[13] in the region is linked to many structural factors such as land pressure linked to rapid population growth, soil depletion or advanced degradation, limited agricultural production, economic vulnerability as well as cyclical factors such as climatic hazards, socio-political insecurity and health crises. These factors have an impact on agricultural production, access to food and food consumption, which define the food security of the population.

5.4.1. Situation in Burundi

Burundi has one of the highest levels of chronic food insecurity in the world. In 2014, the country ranked last in the global hunger index with a score of 35.6[14]. In 2019[15], 44% of Burundian households were food secure, 9.5% of which were severely food insecure, and more than half of the households were economically vulnerable. More than three-quarters of households spend more than 65% of their income on food. Moreover, food consumption is very poorly diversified, leading to numerous dietary deficiencies and stunted growth among children. According to the preliminary results of the SMART 2020 survey[16], one in two Burundian children under the age of five is affected by chronic malnutrition[17]. Global acute malnutrition (GAM) affects 6.1% of children, 1.2% of whom are severely malnourished.

The Ruzizi plain, the provinces of Cibitoke, Bubanza and Bujumbura Rural have a food insecurity rate of almost 40% (Figure 3). The rates of chronic malnutrition and global acute malnutrition (GAM) among children under 5 years of age reached 51.7% and 5.6% respectively in Cibitoke and 50.3% and 5.4% in Bubanza in November 2020.

---

[10] National Institute of Statistics of Rwanda (2018). Fifth Integrated Household Living Conditions Survey (EICVM) 2016/2017, December 2018

[11] National Institute of Statistics of Rwanda (2020). Labour Force Survey. Annual Report 2019.

[12] *Idem*

[13] Food security is defined by a population's capacity to cover its food and non-food needs without engaging in survival strategies, to have a balanced diet (food consumption) using a small share of its income (economic vulnerability).

[14] K. von Grebmer, A. Saltzman, E. Birol, D. Wiesmann, N. Prasai, S. Yin, Y. Yohannes, P. Menon, J. Thompson, A. Sonntage. 2014. 2014 Global Hunger Index: The challenge of hidden hunger. Bonn, Washington D.C, and Dublin: Welthungerhilfe, International Food Policy Research Institute, and Concern Worldwide.

[15] ISTEEBU, 2019, Rapport principal de l'enquête nationale sur la situation nutritionnelle et la sécurité alimentaire au Burundi January 2019

[16] ISTEEBU, 2020. National survey on the nutritional situation and mortality in Burundi. Presentation of preliminary results. November 2020.

[17] In terms of public health, a prevalence of chronic malnutrition in children under 5 years of age of more than 30% is considered a critical situation.

These provinces, located along the Ruzizi River, have indeed been strongly affected by heavy rains and floods during the last cropping season (March-May 2020) resulting in the destruction of several thousand hectares of crops and population displacements. In addition, the COVID-19 pandemic disrupted cross-border movements and trade, especially informal, leading to a loss of the usual economic opportunities and a limitation of food supplies.

5.4.2. Situation in the DRC

According to the latest food security surveys in July 2020[18], two-thirds of the population of North and South Kivu were food insecure. More specifically in the basin area, food insecurity affects more than 70% of the population in the territories, 52% in the city of Goma and 38.5% in the city of Bukavu (Figure 3). Nearly 48% of children under the age of five are stunted due to chronic malnutrition and 2.6% suffer from acute malnutrition[19].

More than half of households have inadequate food consumption. The economic vulnerability of households is high. More than 90% of households in the province spend more than half of their income on food and almost one in two households spend 75% of their income on food.

The activism of armed groups and growing insecurity continue to have a strong impact on household livelihoods by limiting people's access to their fields, and therefore the productive capacity of households. In addition, the COVID-19 pandemic that followed the Ebola crisis, as well as national and international restrictive measures, have slowed down economic activity and created job losses for a large part of the population. Household purchasing power has also been disrupted by fluctuations in the exchange rate, due to the depreciation of the Congolese franc against the US dollar. Several sources also indicate that the informal sector has been strongly impacted by the effects of the COVID-19 pandemic. It should be emphasised that the price volatility induced by the COVID-19 crisis has led to an increase in the generic cost of the food basket of around 15% (March-April), particularly in the eastern and south-eastern regions of Congo. Finally, South Kivu province was particularly hard hit by the torrential rains and floods in April 2020, which destroyed much infrastructure, crops and household livelihoods that were already severely reduced. According to a report by some partners in the area, nearly 77,000 people are homeless.

5.4.3. Situation in Rwanda

According to the latest CFSVA data from 2018[20], 18% of the Rwandan population was food insecure during the hunger gap and 1.7% is severely food insecure. The Western Province is the most affected with an average of 30% food insecurity. Food insecurity mainly affects households living from daily agricultural work and/or having little access to land (<0.1 ha) and who do not own livestock. It should be noted that in Rwanda, the majority (65%) of food is bought on the market and households spend on average less than 50% of their income on food, which is an indicator of lower economic vulnerability compared to neighbouring countries (Burundi, DRC).

Despite an improvement in the situation, the western zone of the Congo Nile ridge (located in the Ruzizi basin) is particularly affected by food insecurity, driven by a large proportion of households with

[18] Analyse de la Sécurité Alimentaire en Situation d'Urgence au Sud Kivu, September 2020 (WFP) and Analyse de la Sécurité Alimentaire en Situation d'Urgence au Nord Kivu, July 2020 (WFP).

[19] MICS-Malaria 2017-2018. Report on the results of the survey. South Kivu Province. February 2020.

[20] The 2020 Food Safety Assessment (FSNMS) could not be finalised in view of the health crisis. The data for the CFSVA 2018 was collected during the lean season (March-April).

inadequate food consumption (in terms of frequency and diversity of food groups) and difficult access to markets, especially in the rainy season. Indeed, in the districts of Rutsiro and Ngororero 49% and 41% of households, respectively, were food insecure in April 2018. The situation is less critical in Nyabihu (25%), Karongi (25%), Nyamasheke (20%) and Ruzizi (25%) districts. This region is also severely affected by chronic child malnutrition, with 50% of children stunted in the districts of Rutsiro, Nyabihu, Rubavu and Ngororero.

Figure 3 below illustrates the food insecurity situation in the study area.

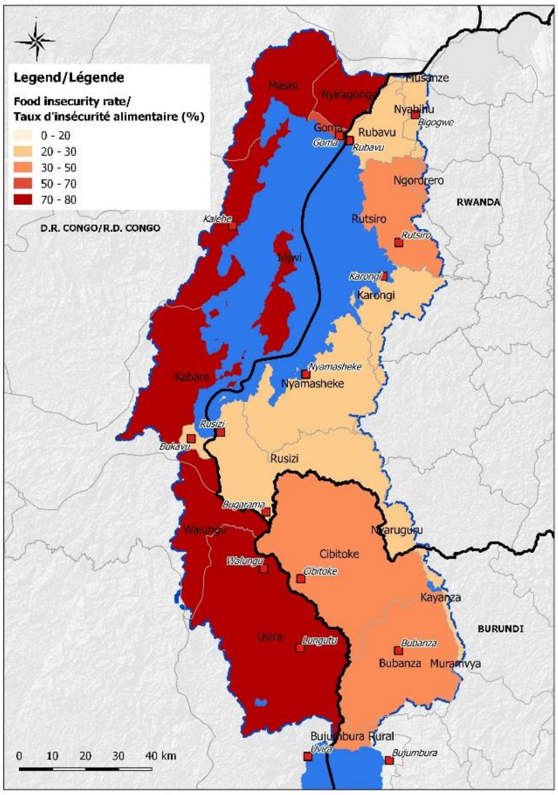


Figure 3. Level of food insecurity in the study area

6. Physical environment

6.1. Topography and geomorphology

The topography of the study area is very mountainous. It exceeds 3,000 m in altitude in the northern part of the basin, reaching 3,058 m, 3,470 m and 4,507 m respectively at the summits of the Nyamulagira, Nyiragongo and Mount Karisimbi volcanoes, constituting the northern limit of the basin within the Virunga range. To the northwest of Bukavu, the Kahuzi and Biega Mountains are also high points of the basin, at altitudes exceeding 3,000 m, within the Mitumba Mountains chain which marks the western limit of the basin. The Congo-Nile ridge, whose peaks reach 2,500 m, is the eastern limit of the basin.

Lake Kivu, at an average altitude of 1,462 m, is a volcanic dam lake whose flooded shores are divided into numerous bays, capes and islands, of which Idjwi is the largest. The outflow of Lake Kivu is the Ruzizi, which flows southwards through the basalt piles, carving gorges, to empty into Lake Tanganyika, after draining a vast plain.

The altitude of the Lake Kivu basin is between 1,462 and 4,507 m, while that of the Ruzizi River basin is between 770 and 3,400 m. The Ruzizi plain, located within the eponymous basin, extends over approximately 1,345 km² at an altitude of between 770 and 950 m.

The generally very hilly relief in the north of the basin is reflected in the often steep slopes, frequently exceeding 60%. From a geomorphological point of view, the basin is divided into the highlands at altitudes above 2000 m, the zone of plateaus, hills and lowlands between 1000 and 2000 m, and the plain zone at an altitude below 1000 m.

Figure 4 shows a simplified view of the topography of the catchment area and the main peaks.

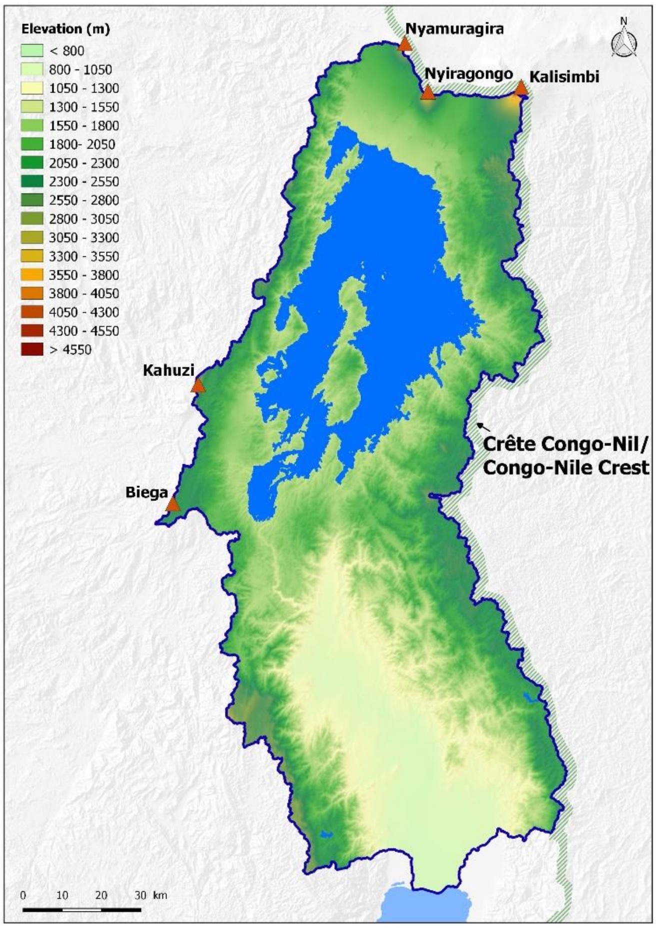


Figure 4 : Map of the topography of the catchment area and the main peaks.

Maps No. 004 and 005, in the appendix, illustrate the topography of the study area and the slope classes observed.

6.2. Soil Types

The soils of the basin are grouped into six main groups: Umbrisols, Leptosols, Ferralsols, Gleysols, Acrisols and Andosols, according to the classification of the IUSS Working Group WRB (2014). These soils are described below and presented in Figure 5:

- Umbrisols have a dark topsoil layer rich in organic matter. These soils, developed under vegetation cover that has been little degraded, can be observed in the cool and humid sectors of the Congo-Nile ridge;

- Leptosols, skeletal and shallow soils, are generally found on steep slopes that generate permanent erosion. They can also be found on erosion-resistant slopes, where rock weathering is slow, such as on quartzite ridges;
- Ferralsols result from weathering in humid, tropical climates. They have a reddish-brownish colour and are rich in hydroxides and oxides of iron and aluminium, but are depleted in weathering minerals. In the basin, they are developed on magmatic rocks rich in magnesium and iron, mainly basalts and gabbros, as well as on schist metasediments;
- Gleysols correspond to a group of soils developed from different unconsolidated materials, mainly of river and lake origin. They occupy areas of depression with very low slopes, and are mainly observed in the Ruzizi plain;
- Acrisols are characterised by their great depth and a kaolinite content that increases with depth. They develop on magmatic rocks rich in feldspar and poor in ferromagnesian minerals;
- Andosols are young and fertile soils formed on volcanic terrain with a degree of development which, as the dating of the basalts on Idjwi Island shows, is a function of the age of the volcano (from the Eocene, i.e. 49 Ma, to the present day).

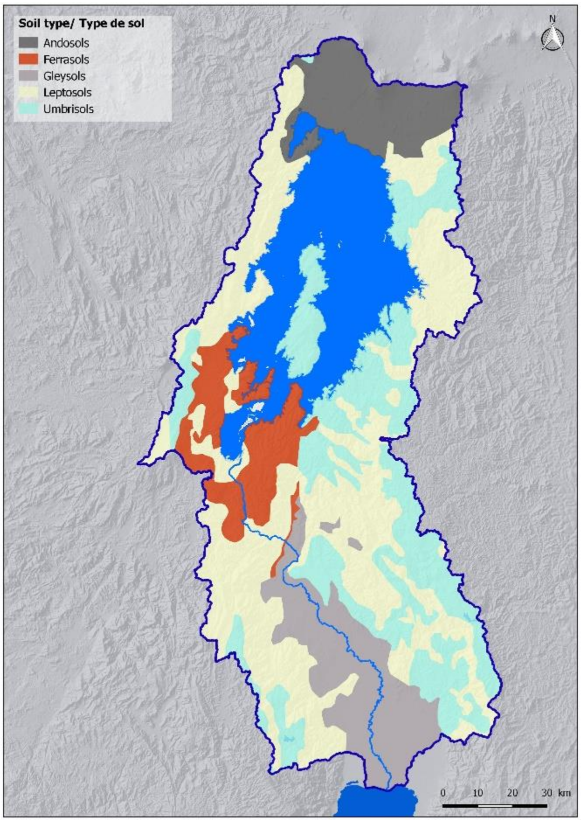


Figure 5: Map of soil types in the basin.

Map No. 006 in the appendix illustrates the types of soil found in the basin.

6.3. Geological context

The geological configuration of the basin of Lake Kivu and the Ruzizi River is essentially made up of lithostratigraphic units of Precambrian age (more than 600 million years). The main units are the Ante-Burundian (Lower Proterozoic), which includes the Upper Archean and the Rusizian, and the Burundian (Middle Proterozoic).

The Ante-Burundian unit is mainly composed of metamorphic rocks of gneiss type, gneissic and micaschist complexes, of Archean and Rusizian age. They appear as an outcrop primarily in the Rwandan part of the study area, where they are intersected by numerous granitic intrusions of Burundian age. They are also found on the right bank of the Ruzizi plain in the DRC.

The Burundian unit consists of quartzites, quartzite and granitoid metasediments, schist metasediments and granitic intrusions. These lands cover a large part of the study area, on either side (east and west) of Lake Kivu and on the left bank of the Ruzizi plain as far as Lake Tanganyika.

In addition to these Precambrian rocks, the study area also includes Phanerozoic terrains. Among them, the main units are fluvio-lacustrine sedimentary deposits of Cenozoic age, as well as volcanic rocks also of Cenozoic age.

The volcanic rocks of the Cenozoic, which were formed from the Tertiary to the present day by successive volcanic eruptions, are mainly made up of basalt. They are found in the basin north of Lake Kivu (Goma, Virunga volcanoes area), south and south-west of Lake Kivu (Bukavu and Rusizi area), and along the upper Ruzizi river to Cibitoke.

The sedimentary terrains of the Cenozoic mainly correspond to the fluvio-lacustrine alluvial deposits of the Quaternary, sometimes very recent, filling the Rift Valley and the widest low valleys of the main sub-basins of the study area. They are mainly - and abundantly - found in the plain of the Middle and Lower Ruzizi. These sediments, which are particularly permeable and aquiferous at the level of the Ruzizi plain, are primarily composed of sand, clayey sand and gravel.

Figure 6 presents a simplified overview of the geology of the basin.

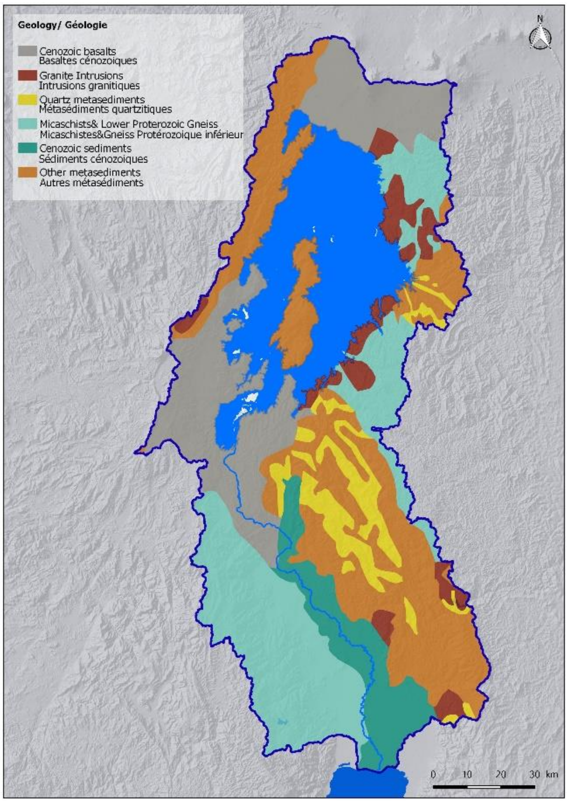


Figure 6: Simplified geological map of the basin.

Maps No. 007 to 009 in the appendix illustrate the geological context and aquifers of the study area.

7. Climate context

7.1. Current climate context

Burundi, DRC and Rwanda are part of Africa's Great Lakes region, whose landscapes bring together in the same space very high mountains, volcanoes, eroded land and lakes, including Lake Kivu in the study area. The topography, altitude and relief offer varied landscapes, marked by the greenness of the abundant vegetation of the equatorial high-altitude climate. However, the main feature of the landscape remains the presence of the Great Western Rift. Moreover, the position of the watershed, between 1.4 degrees and 3.4 degrees South, and the situation at the edge of the Indian Ocean monsoon shapes the specific climate of the study area. However, quantitative climate analysis is difficult because of the inadequacy of meteorological records over the entire catchment area.

7.1.1. Precipitation

The study area enjoys a tropical climate and benefits from two types of season, known as "dry" and "wet". The distribution of rainfall is not identical throughout the territory and is not equal in terms of duration. In fact, rainfall varies with altitude and follows a four-cycle regime. The uplands receive the most rain and the lowlands the driest. However, there are many local variations linked to the layout of the relief and the orientation of the slopes, to situations of exposure or shelter, to variations in altitude, and to valley or lake breezes. The highest parts of the mountains are not necessarily those with the highest rainfall, but rather the western slopes.

The seasonal regime consists of a long and a short dry season, and a long and a short rainy season with varying durations, as shown in the Table 2. Figure 7 shows an overview of the distribution of the average annual rainfall.

Table 2: Distribution of seasons in the study area by country

	North and South Kivu (DRC)	Burundi - Rwanda
Long dry season	June- July to August	
Short rainy season	September to December	
Short dry season	January	January to February
Long rainy season	February to June	March to May-June

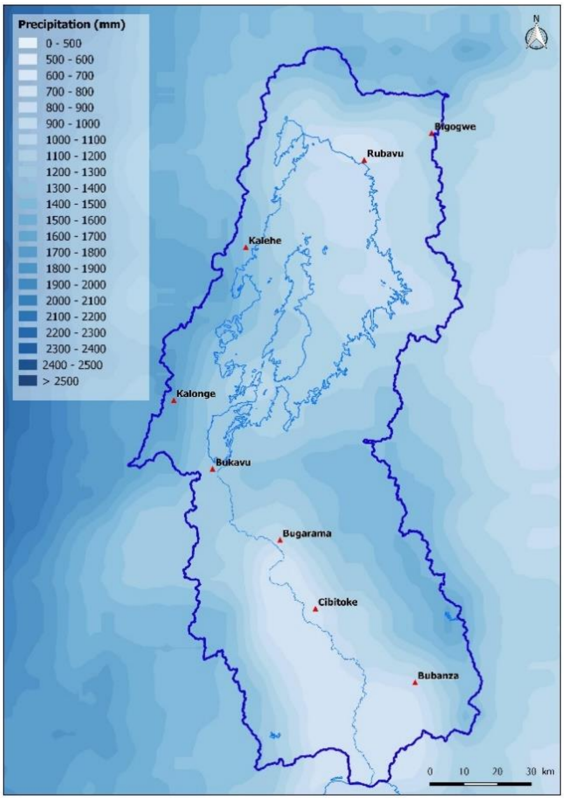


Figure 7: Average annual precipitation over 30 years (Source: processing CHIRPS data).

Map No. 012 in the appendix illustrates the average annual precipitation over 30 years.

7.1.2. Temperature

Temperatures are closely correlated with topography. The higher the altitude, the lower the temperatures (Table 3). It is important to note that daytime temperature differences are greater than annual differences. Between day and night, the temperature differences exceed ten degrees and are modified by the altitude according to the seasons: higher in the low altitudes, lower in the high altitudes and in the dry season.

7.1.3. Evapotranspiration

Evapotranspiration is also directly related to topography. For example, as the altitude of the Ruzizi plain is between 780 and 900 m, its evapotranspiration is the highest in the catchment area. Table 3 below shows the average values of temperature, rainfall and evapotranspiration for nine centres in the catchment area.

Table 3: Altitude, temperature, precipitation and evapotranspiration for nine urban centres in the catchment area.

City	Altitude (m)	Temperature (°C)	Precipitation (mm/year)	Evapotranspiration (mm/year)
Bubanza (Burundi)	1 063	22.5	1 120	1 900
Cibitoke (Burundi)	930	23.0	1 020	1 970
Mount Lungera (Burundi)	2 470	15.4	1 650	1 200
Bigogwe (Rwanda)	2 350	14.7	1 250	1 190
Bugarama (Rwanda)	970	23.0	1 160	1 990
Rubavu (Rwanda)	1 510	19.2	1 020	1 200
Bukavu (DRC)	1 550	19.4	1 400	1 260
Kalehe (DRC)	1 850	16.8	1 530	1 170
Kalonge (DRC)	2 165	15.1	1 830	1 250

The urban centres of Bubanza, Cibitoke and Bugarama are located in the Ruzizi plain. Mount Lugera is located in the Kibira forest, a few kilometres from the Congo-Nile ridge. The urban centre of Kalonge is on the edge of the Kahuzi Biega National Park, 25 km northwest of Bukavu.

Maps No. 010 and 011 in the appendix illustrate the mean annual distribution of temperatures and evapotranspiration. Map No. 012 shows the isohyets as well as ombro-thermal diagrams representative of the spatial variations in the catchment area.

7.2. Climate change

The availability of water resources in the long term is conditioned in particular by the impact of climate change on the water balance of the area. In the absence of specific data on the study area, both in terms of hydrology and climate, projections of monthly precipitation data in the study area were analysed for four scenarios of radiative forcing as proposed by the IPCC[21] . Sixteen global circulation models developed by the IPCC were used as references. The output data from these models are produced by the IPCC and available on their website. A description of the differences between these models is also available on their website. The results obtained for the study area show that there is a strong variation between the results of the 16 global circulation models. This variation between models increases with the 2050 modelling horizon (see Annex I).

Annual rainfall tends to increase slightly in all scenarios. This increase increases with the radiative forcing index from 0.1% by 2030 to 0.6% by 2050. Indeed, in the global circulation models, the water balance remains constant and the differentiation is made according to latitude. At the equator, these models tend to indicate a slight increase in annual precipitation. However, the variation in monthly precipitation is significant. Most of the scenarios show a drastic increase in rainfall in November, December and January from 11% (the most optimistic) to 19% (the most pessimistic) according to the

[21] The four scenarios are named according to the range of radiative forcing thus obtained for the year 2100: scenario RCP2.6 corresponds to a forcing of +2.6 W/m² and scenarios RCP4.5, RCP6 and RCP8.5 correspond respectively to a forcing of +4.5 W/m², +6 W/m² and +8.5 W/m².

average of the 16 models, by 2050. As for the month of July, a decrease in precipitation of around 2% is expected according to the four scenarios of radiative forcing. The number of rainy events could be modified, but due to lack of data, modelling is not possible. According to the CICOS status report, which is based on a wide range of assessed climate change projections, the results lead to the conclusion that drastic changes (in annual rainfall levels) are unlikely to occur in the future.

Concerning the near-surface atmospheric temperature, the 16 models indicate a significant temperature increase by 2050, regardless of the baseline scenario, optimistic or pessimistic. Temperature oscillations vary from 0.6°C to 2.3°C for the most favourable scenario and from 1.1°C to 3.2°C for the most unfavourable one. According to the CICOS status report, with regards to extreme temperatures (frequency of cold/hot days and nights), all models predict a drop/raise in temperature. According to the forecasts, an increase in hot days and nights is to be expected in the future, especially in the case of the pessimistic scenario.

However, it is unlikely that predicted changes in rainfall will lead to widespread water scarcity in the region. On the other hand, given the results of increased temperatures and a changed monthly rainfall distribution, the occurrence of prolonged and more frequent droughts is more likely.

To date, the variations induced by climate change combined with the effects of increased erosion in the sub-watersheds of Lake Kivu are already leading to significant soil degradation, with all the resulting negative impacts. This aspect will naturally be highlighted in the second part of the document.

8. Water resources

8.1. Catchment areas and surface waters

The time series available for the hydrographs of the different gauged rivers are presented in Annex II.

8.1.1. Watersheds and sub-basins

The watersheds of Lake Kivu and the Ruzizi River have surface areas of 7,392 km² and 6,057 km² respectively, for a total surface area of 13,449 km², representing the entire study area.

The division into sub-basins carried out for the purposes of the study includes a total of 128 sub-basins, of which 97 relate to rivers flowing into Lake Kivu, and 31 relate to tributaries of the Ruzizi River. Of these 128 sub-basins, 38 have a surface area of more than 80 km². The tables in Annex III describe the main physical characteristics of these 38 sub-basins. The above-mentioned sub-basins are grouped into 4 compartments and 12 sub-compartments, for the purpose of aggregating the results of the study (water balance, erosion rates, etc.) into different levels of spatial units. The Table 4 shows the compartments and sub-compartments defined for the aggregation of the 128 sub-basins. Figure 8 shows the location of the different compartments.

Table 4: Areas of the different compartments and sub-compartments in the study area.

<table>
<tr><th>Compartment</th><th colspan="2">Sub-compartment</th><th colspan="4">Surface area (km²)</th></tr>
<tr><td rowspan="4">Lake Kivu Basin</td><td rowspan="2">West</td><td>Upstream (KI_RD_HA)</td><td>1 188</td><td rowspan="2">2 228</td><td rowspan="4">4 603</td><td rowspan="11">13 449</td></tr>
<tr><td>Downstream (KI_RD_AV)</td><td>1 040</td></tr>
<tr><td rowspan="2">East</td><td>Upstream (KI_RG_HA)</td><td>1 244</td><td rowspan="2">2 735</td></tr>
<tr><td>Downstream (KI_RG_AV)</td><td>1 491</td></tr>
<tr><td rowspan="2">Ruzizi River Basin to Kamanyola</td><td colspan="2">West (KA_RD_HA)</td><td colspan="2">284</td><td rowspan="2">709</td></tr>
<tr><td colspan="2">East (KA_RG_HA)</td><td colspan="2">425</td></tr>
<tr><td rowspan="4">Kamanyola Ruzizi River Basin at Lake Tanganyika</td><td rowspan="2">West</td><td>Upstream (RU_RD_HA)</td><td>1 242</td><td rowspan="2">2 098</td><td rowspan="4">5 365</td></tr>
<tr><td>Downstream (RU_RD_AV)</td><td>855</td></tr>
<tr><td rowspan="2">East</td><td>Upstream (RU_RG_HA)</td><td>1 958</td><td rowspan="2">3 268</td></tr>
<tr><td>Downstream (RU_RG_AV)</td><td>1 310</td></tr>
<tr><td colspan="3">Lake</td><td colspan="3">2 412</td></tr>
</table>

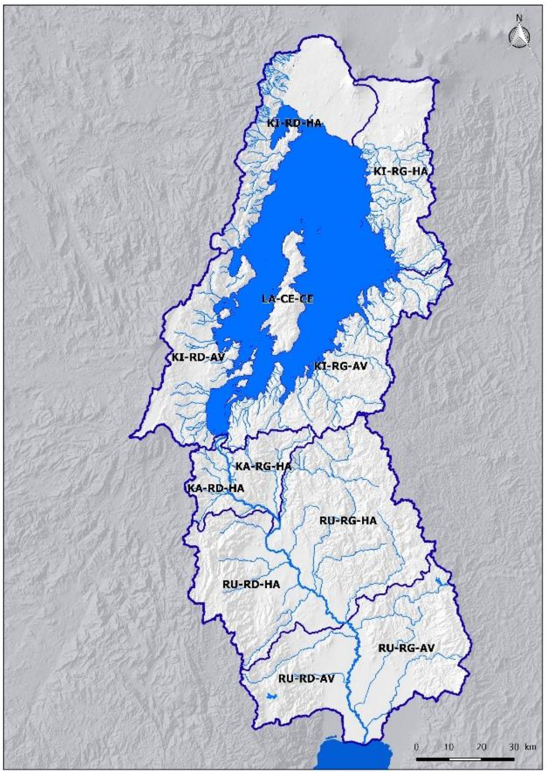


Figure 8: Map of the compartments and sub-compartments of the basin according to the hydrological model.

Map No. 013 in the appendix illustrates the location of the sub-basins in the study area.

8.1.2. Lake Kivu and its tributaries

Lake Kivu, with a surface area of 2,412 km², is located in the Albertine Rift Fault, which explains its great depth of 240 m on average, a maximum depth of 485 m and its steep sides. It is divided by the large island Idjwi (279 km²) and contains more than 560 billion m³ of water. Lake Kivu is situated at an altitude of 1,462 m above sea level and its surrounding watersheds can reach a maximum altitude of 4,507 m.

The hydrology of Lake Kivu directly determines the supply of the Ruzizi River at its outflow. Figure 9 shows the fluctuation of water levels in Lake Kivu over the last 70 years. These fluctuate from 1,461.8 m (February 2006) to 1,463.8 m (June 1963).

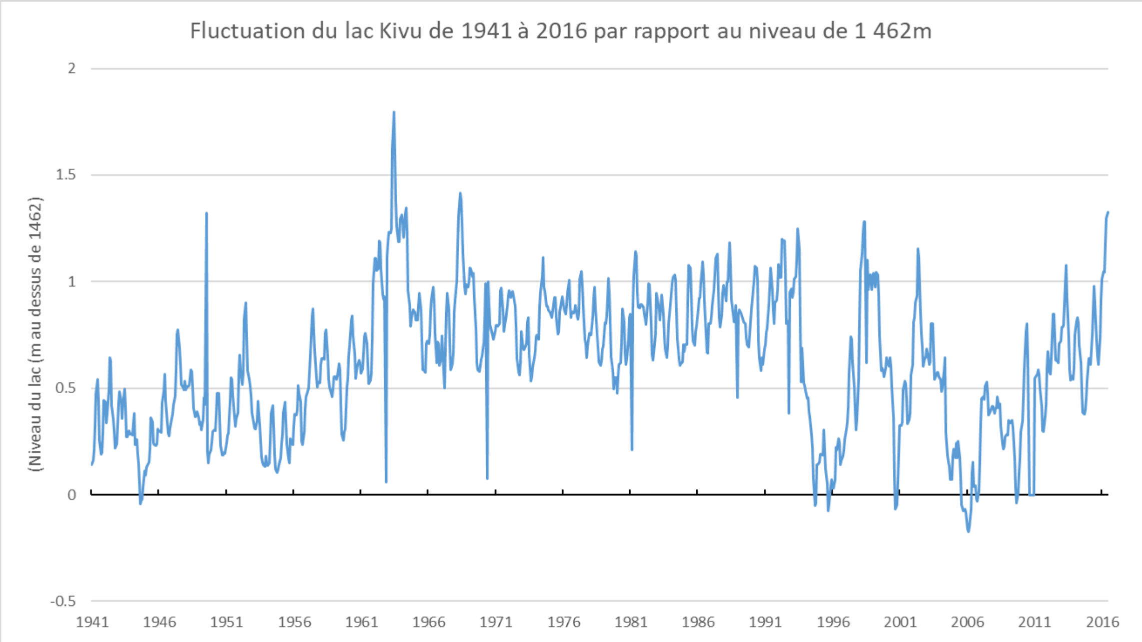


Figure 9: Fluctuations in the level of Lake Kivu from 1941 to 2016.

According to Muvundja and *al.* (2014)[22], there is a correlation between lake levels and rainfall in the catchment area, but it is not linear. Temperatures and thus evapotranspiration also play a key role and need to be taken into account. The physical process of Lake Kivu is particularly complex and therefore non-linear; many other climatic factors, in addition to rainfall, come into play.

Lake Kivu is a meromictic lake in the sense that surface and deep water never mix, mainly due to its great depth and low exposure to winds, as the lake is located between two mountain ranges. The water of the lake is relatively alkaline, the Ph varying between 9.47 at the surface and 6.02 at maximum depth, with a progressive acidification as one approaches the greater depths. The studies carried out indicate that the gases and elements dissolved in the water come from the interaction between the rock and the water and the chemical alteration of the volcanic rocks which are the main constituents of its foundation[23] .

The waters of Lake Kivu contain a volume of about 560 billion m^3 of water and a volume of dissolved gas equivalent to 300 billion m^3 of carbon dioxide (CO_2) and about 60 billion m^3 of methane (CH_4) as well as other gases including Hydrogen Sulphide (H_2S). Such a concentration of gas poses a threat to all animals and humans living on the shores, especially as the area is subject to frequent seismic and volcanic activity. These gases are greenhouse gases which, if emitted into the atmosphere, can reinforce ongoing climate change. Observations conducted have shown that these volumes of dissolved gases increase over the years for various reasons, including underground or surface magmatic

[22] Muvundja FA, Wüest A, Isumbisho M, Kaningini MB, Pasche N, Rinta P, Schmid M (2014) Modelling Lake Kivu water level variations over the last seven decades. Limnologica 47:21-33

[23]Tassi et al.: water and gas chemistry at lake Kivu (DRC) Geochemistry Geophysics Geosystems Article Volume 10 Number 2, 6 February 2009 American Geophysical Union

fluids related to volcanic activities. An abrupt rise of CO_2 to the surface, as was the case for Lake Nyos in Cameroon, remains an inherent risk that must be taken into consideration by the two riparian countries.

The characteristics of the lake are generally presented in the form of vertical stratification/gradients, the study of experts on Lake Kivu validated by the two riparian countries[24], dividing the lake into four zones namely:

- **The biozone** consists of an upper oxygenated zone of about 60 m rich in algal biomass (phytoplankton) that feeds zooplankton and fish. The depth of this zone varies according to the seasons, the zone is mixed and homogenised during the dry season and is strongly stratified during the rainy season with a reduced oxygenation up to about 45 m, accompanied by a reduction in temperature and (seasonal thermocline)[25] . The density of the water increases rapidly from 60 m to 85-120 m depth due to the increase in pressure but also to the concentration of dissolved gases such as hydrogen sulphide (H_2S), methane (CH_4) and carbon dioxide (CO_2) ;
- **The intermediate zone in** which the concentration of these gases increases significantly from (-120 m to -200 m) ;
- **The resource zone** from which the methane concentration is deemed to be exploitable (-200 m to about -270 m), is considered to contain the highest concentration of methane and is also rich in carbon dioxide, salts and nutrients;
- The gradients of the lake end with the **zone of low resources** beyond 270 m depth where the exploitation of the resources is no longer economically profitable.

However, this vertical stratification is not uniform over the entire surface of the lake, which can be divided into five zones with different pH concentrations linked to different concentrations of salts and gases. Thus a study was conducted by geophysicists from 2004 to 2007[26] examining the distribution of chemical and isotopic compositions of water and dissolved gases along vertical columns of water in five sub-basins of the lake, in the DRC part. This study indicates different chemical compositions vertically but also according to the different sub-basins due to: (i) the movement of the fluid system containing magmatic CO_2 which feeds the huge CO_2 (CH_4) reservoir contained in the deep waters of the lake, (ii) spatial and species variations in the distribution of biomass and (iii) solutions resulting from water-rock interactions. This study highlights the particularity of Kabuno Bay in DRC, which contains the highest rate of injection of magmatic fluids and which therefore constitutes the site that requires regular monitoring to prevent gas explosion risks that could be initiated by the volcanic activities of the Nyiragongo and Nyamulagira volcanoes located a few kilometres away.

Figure 10 illustrates the basin of Lake Kivu and its tributaries.

[24] Management prescriptions for the development of Lake Kivu gas resources, final version for general release 17 June 2009

[25] J.-P. Descy & Jean Guillard Biological baseline of Lake Kivu December 2014

[26] Tassi et al.: water and gas chemistry at lake Kivu (DRC) Geochemistry Geophysics Geosystems Article Volume 10 Number 2, 6 February 2009 American Geophysical Union

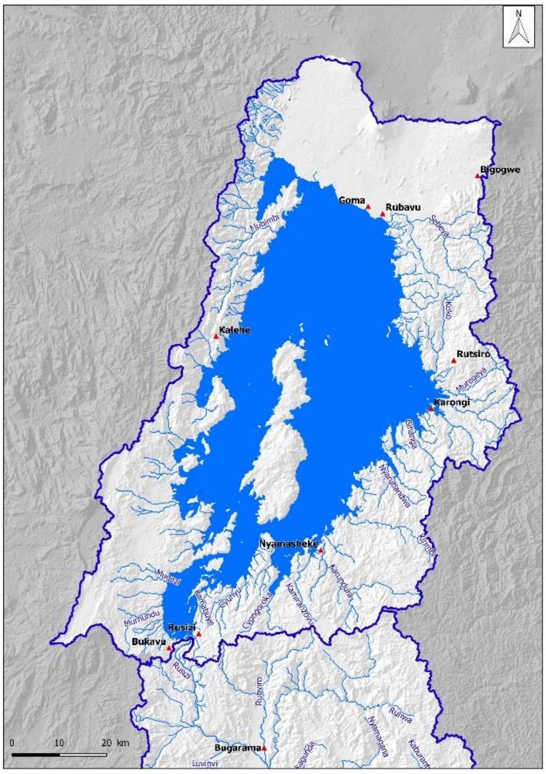


Figure 10: Map of the hydrographic basin of Lake Kivu.

The main tributaries of Lake Kivu are, from north to south:

- La Sebeya, Koko, Muregeya, Musogoro, Kirimbi, Karundula and Mwaga on the eastern part of Lake Kivu ;
- The Kyaraboze, Chabiringa, Mushuva, Mpungwe and Murhundu on the western part of Lake Kivu.

8.1.3. The Ruzizi river and its tributaries

The source of the Ruzizi River is located in the bay of Bukavu, in the southern zone of Lake Kivu, at an altitude of 1,462 m. The 168 km long Ruzizi River has an average annual flow of around 80 m^3/s.

It drains water from Lake Kivu to Lake Tanganyika and forms a natural border between Burundi, DRC and Rwanda. On its first 50 km long section from Lake Kivu to the locality of Kamanyola (upper river), the river carves between the steep, heavily deforested and bare watersheds of South Kivu in DRC and the District of Ruzizi in Rwanda. The river crosses an escarpment and the altitude decreases from 1,450 m to 962 m with numerous waterfalls (gorges), giving it a potential for hydroelectric power production estimated at around 500 MW[27] (see below).

After the escarpment zone, the Ruzizi River extends over a length of 118 km in the plain, gradually flowing from an altitude of 962 to 770 m with a gentle average slope. Before flowing into Lake Tanganyika, the Ruzizi River is fed by 17 tributaries, from upstream to downstream (Figure 11):

- The Rubyiro, Ruhwa, Nygakunda, Nyamagana, Muhira, Kaburantwa, Kagunuzi and Mpanda on the left bank of the Ruzizi ;

[27] FICHTNER (March 2010), Final report of the feasibility study for the development of the RUSIZI III hydroelectric project. EGL: Bujumbura - Burundi.

- The Bishalalo, Ruvinvi, Luvubu, Ruberizi, Shange and Kiliba, on the right bank of the Ruzizi.

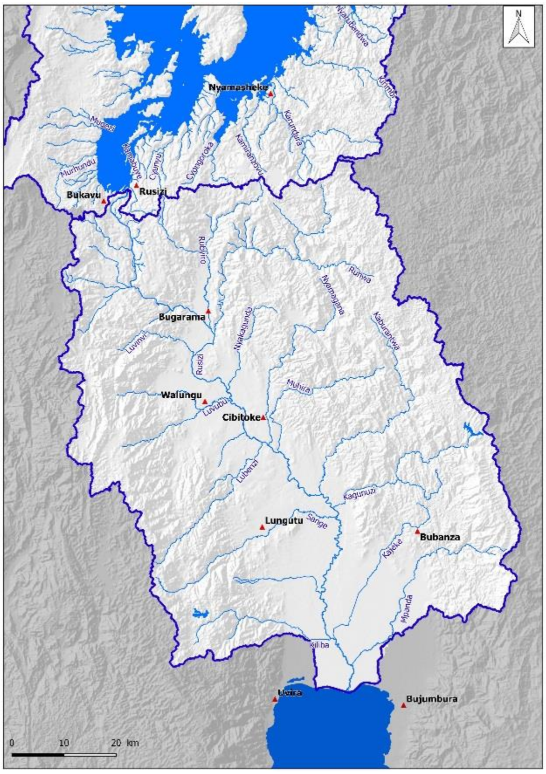


Figure 11: Map of the Ruzizi river catchment area.

The Ruzizi River and its tributaries are the main elements of the hydrography of the Ruzizi plain. The flow rate of the tributaries and the Ruzizi River are vary little from one month to another, which offers the potential for the exploitation of surface water in all seasons. Approximately 10 km before its mouth in Lake Tanganyika, the Ruzizi River is divided into two branches, the "Great Ruzizi" to the east and the "Small Ruzizi" to the west, delimiting, together with the northern coast of Lake Tanganyika, a small, partly flooded plain with a surface area of about 1000 ha.

Maps No. 014 and 015 in the appendix illustrate the hydrological and meteorological stations as well as the hydrographic network encountered in the basin.

8.2. Ground water

The basin is characterised by the presence of mostly Precambrian and Phanerozoic indurated terrains, composed of metamorphic rocks (schists, gneiss, quartzite), intrusive magmatic rocks (mainly granitic), and volcanic rocks (mainly basaltic).

In addition to these formations constituting the weathered and fissured base present throughout the basin, there are also loose formations consisting of fluvio-lacustrine alluvial deposits from the Quaternary period. These alluvial deposits are mainly found in the Ruzizi plain (middle and lower Ruzizi), as well as in the lower valleys of the most important sub-basins of the study area.

8.2.1. Types of aquifers

Within these geological formations, four main types of aquifers can be defined in the basin, based on their hydrodynamic properties and aquifer potential:

- Quaternary sedimentary aquifers corresponding to alluvial deposits (fluvio-lacustrine), mainly found in the alluvial plain of the middle and lower Ruzizi. The alluvial plains of secondary rivers can also constitute aquifers in the lower valleys, although their exploitation potential is more limited;
- Superficial aquifers located in the alteration zones of the metamorphic and crystalline Precambrian bedrock (granites, quartzites, gneiss, schists and psammites);
- Discontinuous and deeper aquifers located in fissured zones of metamorphic and crystalline Precambrian bedrock (granites, quartzites, gneisses, shales and psammites);
- Complex aquifers located in the volcanic terrains (basalt, pyroclastic deposits) of the Cenozoic.

8.2.2. Aquifer potential

The most important aquifer potentialities are found in the alluvial aquifer of the Ruzizi plain. This aquifer extends over the whole of the Ruzizi alluvial plain and at the level of the low valleys of its tributaries, over an area of approximately 1,700 km². The thickness of this aquifer can reach 50 to more than 150 m in the Ruzizi plain, and 10 to 30 m in the alluvial deposits of the lower inland valleys. Groundwater can be mobilised from boreholes, with an expected productivity of more than 10 l/s. This water table is encountered at a shallow depth, often less than 10 m below the ground surface, making it easily accessible from shallow structures. However, it contains high levels of iron and manganese, often exceeding drinking standards.

Interesting potential is also found in granite alteration, which can be particularly water-bearing and provide exploitation rates of up to 5 to 10 l/s from boreholes. Their thickness can reach 100 m.

Metamorphic formations offer more limited potential for exploitation, depending on the degree of alteration and cracking encountered, and on the nature of the rock, particularly its clay fraction. The potential for exploitation by drilling is generally more limited, and may not exceed 1 l/sec.

The aquifer potential of volcanic soils (Cenozoic basalts) is extremely variable and difficult to quantify, as the heterogeneity of this environment is so varied.

8.2.3. Groundwater exploitation

In the Burundian part of the Ruzizi alluvial plain, there are about fifteen boreholes used for rural hydraulics (IGEBU 2018 inventory). A few boreholes exploiting the aquifers of cracks in the crystalline basement are also identified in the basin, including boreholes in the urban area of Bubanza (granitic context) in Burundi.

Groundwater in the basin is mainly exploited from developed natural springs, mainly for drinking water supply in rural areas. In the Rwandan and Burundian parts of the basin, there are more than 550 springs for drinking water supply, as well as many natural springs (several thousand) that have not been developed but are nevertheless used by local populations without improved access to drinking water. In addition to these, there are also around 70 thermal springs in the basin.

An overview of the hydrogeological context, illustrated based on the basin's aquifer potential, is presented in Figure 12.

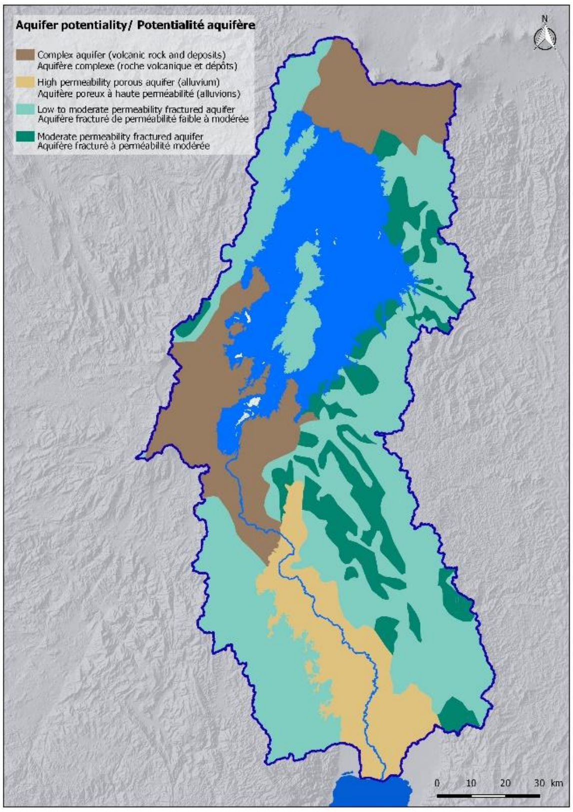


Figure 12: Hydrogeological map of the study area.

Maps No. 007 to 009 in the appendix illustrate the hydrogeological context encountered in the basin.

9. Land use and evolution

9.1. Current land use

Under the European Space Agency Climate Change Initiative (ESA-CCI), global land cover data have been available at a resolution of 300m since 1992 and at a resolution of 30m since 2016. In 2016, the catchment area was thus covered by 45% agricultural land, 30% forest area, 20% grassland, 3% shrubland and 1% urban area (see Figure 13).

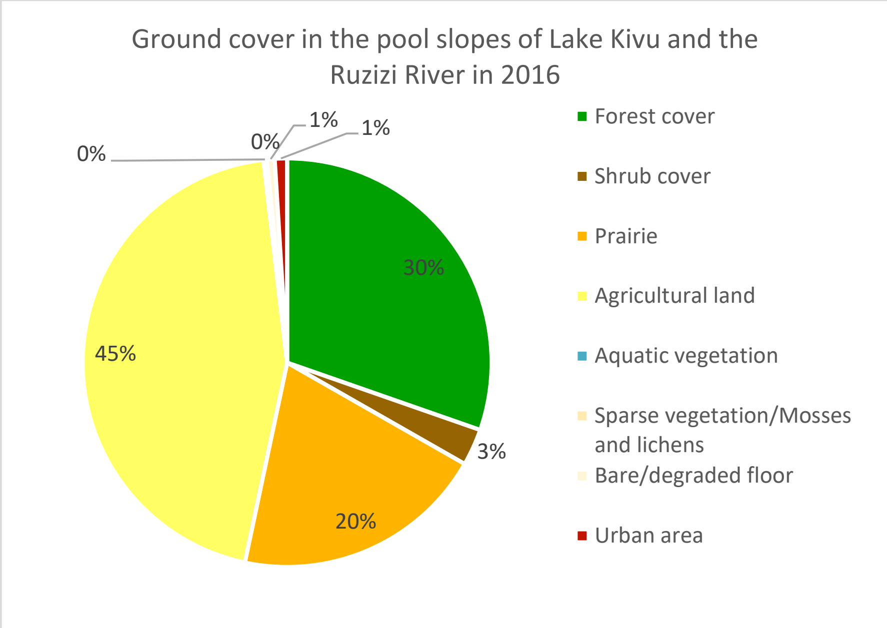


Figure 13: Land use in the Lake Kivu and Ruzizi River catchment area in 2016 (Source: extract from ESA-CCI 2016 data)

Forest areas with a particularly interesting biodiversity are also present in and near the study area:

- Within the watershed of Lake Kivu and the Ruzizi River, there are natural parks with remarkable biodiversity. To the north of the watershed, the Virunga National Park (DRC) and the Volcanoes National Park (Rwanda) are home to a number of species including primates such as mountain gorillas;
- To the east are the South Masisi Nature Reserve and the Kahuzi-Bieza National Park. The latter is one of the largest national parks in Congo and is also a habitat for lowland gorillas, among others. It has also been a UNESCO World Heritage Site since 1980. Further south is the protected nature reserve of the Massif d'Itombwe where only 55 km² are located in the watershed ;
- To the northwest is the Gishwati-Mukura National Park. This forest was once more than 1,000 km² and reached its smallest area in 2001, with 6 km². Currently, the forest has an area of 270 km² and a corridor is being replanted to connect it to Nyungwe Forest in the south;
- The Nyungwe Forest Transboundary National Park, created in 2002 (in Rwanda) and Kibira (in Burundi) also hosts primates such as chimpanzees, but also baboons, colobus, velvet and other monkeys ;
- At the extreme south of the catchment area, the Ruzizi Natural Park covers an area of 85 km² and is home to hippopotamuses and crocodiles, among others. It has been one of the RAMSAR sites (Wetlands of International Importance) since 1996. In the study area, the wetlands of the Virunga Park in DRC and the Nyungwe Park in Rwanda are also RAMSAR sites since 2002.

All these forests, parks and natural areas have a major impact on soil conservation, water resources and biodiversity and are part of a complex system of tropical forests in equatorial Africa, accounting for 30% of the watershed's land cover.

Agricultural areas cover almost half of the of the study area (45%). These agricultural areas are located on steep slopes, with the exception of those located in the Ruzizi plain. These two factors cause major environmental problems, including the loss of soil. Section 12(Environmental situation) explains in detail the issues related to this change in land use.

The meadow category is the third class represented. Grasslands are largely located on the periphery of the remaining forests and parks, as is the case around the Virunga Park, the Nyungwe-Kibira Forest and the Kahuzi-Biega Park and in the Ruzizi Nature Park.

9.2. Previous land use

The classification of land use, based on satellite images from the European Space Agency, could also be made for the year 1992.

In 1992, the dominant land use class was grassland (42%), followed by forest cover (35%), then agricultural land (16%) and then shrub cover (4%) (Figure 14). The category "urban areas" did not even represent 1% of the catchment area, nor did the classification "degraded soil".

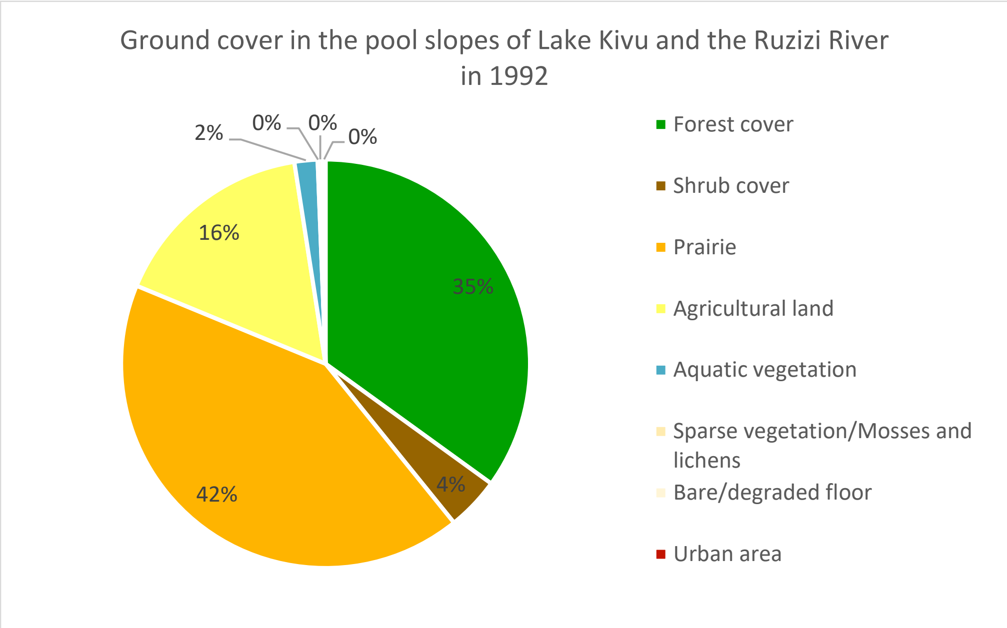


Figure 14: Land use in the catchment area of Lake Kivu and the Ruzizi River in 1992 (Source: ESA-CCI)

Table 5 below shows the differences in land use as a percentage and an area between 1992 and 2016. It should be noted that the spatial resolution between these two years is different and the differences, in percentage and km², are estimates.

Table 5: Percentage of land use in 1992 and 2016 (ESA-CCI 1992 and 2016)

Land use	1992	2016	Difference (%)	Difference (km²)
Forest cover	35.0%	30.3%	-4.6%	-532
Shrub cover	4.2%	2.9%	-1.3%	-150
Prairie	42.0%	20.1%	-22.0%	-2 528
Agricultural land	16.3%	44.8%	28.5%	3 278
Aquatic vegetation	1.8%	0.3%	-1.6%	-180
Sparse vegetation/Mosses and lichens	0.0%	0.0%	0.0%	-5
Bare/degraded soil	0.4%	0.6%	0.3%	30
Urban area	0.2%	1.0%	0.8%	86

In a quarter of a century, the area dedicated to agriculture has increased by 29%, corresponding to more than 3,200 km². Conversely, the forest area has decreased by 5% (530 km²) and that covered by grassland by 22% (2,500 km²).

9.3. Deforestation and extension of agricultural areas

Deforestation coupled with population growth and the extension of agricultural areas are strongly linked as illustrated in Table 5. The Gishwati-Mukura forest as well as the Nyungwe-Kibira forest or the Kahuzi-Biega National Park are striking examples of deforestation in favour of new agricultural areas. The latter have increased sharply in order to meet the needs of the growing population in the catchment area.

9.4. Extension of urban areas

Although urban land use represents only one percent of the study area in 2016, it is interesting to mention that from 2011 to 2020, the urban area increased by 43%, from 164 km² to 290 km². In less than 10 years, with an average annual growth rate of around 3%, cities are expanding. Goma and Gisenyi, have expanded considerably, with a doubling (47%) of their surface area, as have Cibitoke (58%), Buganda (43%) and Karenzu (60%), all benefiting from a relatively flat terrain. On the other hand, the city of Bukavu only increased its surface area by a quarter (25%), due to the rugged terrain surrounding the city (Figure 15). Urban centres have also emerged within the catchment area, such as the city of Mabanza in Rwanda. The main reasons for this urban sprawl are their economic attractiveness, which leads to rural exodus and a high annual population growth rate. In DRC, another reason is added, that of insecurity in the surrounding rural areas.

Figure 15: City of Bukavu

Maps No. 016 to 018 in the appendix illustrate land use in the basin for the years 1989, 2011 and 2016 respectively. Map No. 019 illustrates the location of national parks and forests.

10. Water Use

10.1. Introduction: NEXUS Water-Energy-Food (WEF) approach

Integrated Water Resources Management (**IWRM**) involves the coordination, development and management of water, land and related resources to produce economic and social well-being taking into account sustainability, and environmental and ecosystem aspects. It is in this perspective that the study integrates all these aspects, notably through the characterisation of the different water uses encountered in the basin and the interactions that may occur between these uses, whether in terms of water quantity or quality.

This study is also intended to be cross-sectoral, and in this sense it is in line with the approach of the **NEXUS** programme for water, energy and food (WEF - see Figure 16). This approach focuses on the interdependencies between these three sectors and the need to create synergies and regulate equitable trade-offs between competing uses of resources. It is particularly relevant in the Lake Kivu and Ruzizi River basin, which is characterised on the one hand by significant population growth, which means that the population's need for water is increasing, and on the other hand by economic development based on both agriculture and energy production (hydro-electricity and gas).

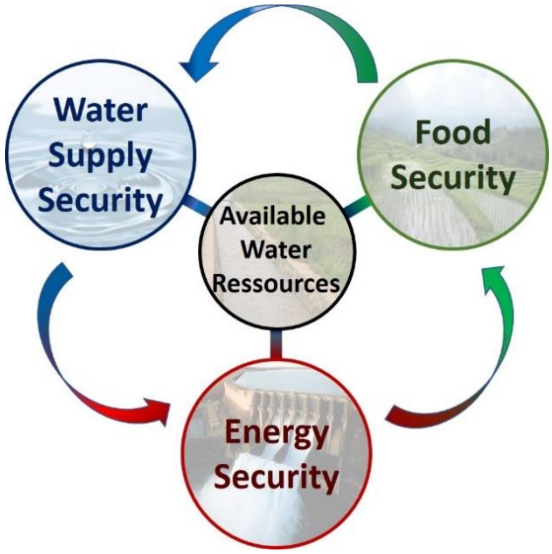


Figure 16: Representation of the NEXUS EEA approach.

10.2. Drinking water supply

In order to achieve sustainable development goal n°6 ("Clean Water and Sanitation") established by the United Nations, the population must have access to a minimum quantity of drinking water. Table 6 below shows these standards for the three countries[28].

Table 6: Consumption standards in the three countries, in urban and rural areas.

	Environment	
Country	**Rural (litres/person/day)**	**Urban (litres/person/day)**
Burundi	20	40
DRC	20	50
Rwanda	20	80

With regards to standards for the DRC in urban areas, this is a value commonly used in eastern cities. The use of these consumption standards, applied to the basin's estimated population in 2020 and population projected in 2050, leads to the following water needs for drinking water supply as illustrated in Table 7.

[28] The figures come from the Burundi Water Sector Programme, the Rwanda Water Resources Master Plan (2010) and the DRC WASH Cluster Guidelines.

Table 7: Estimated drinking water needs for the urban and rural population in 2020 and 2050.

Year	Type	Population (million inhabitants)	Water needs (million m³/year)
2020	Urban	2.5	49
	Rural	8.5	62
	Total	11.0	111
2050	Urban	6.5	125
	Rural	21 .0	152
	Total	27.5	277

Beyond these theoretical assessments based on water needs according to accepted standards, the question of drinking water distribution is acutely relevant in the basin, especially in the cities where it can become a serious concern. In Bukavu, for example, more than 50% of the inhabitants do not have access to drinking water. Water distribution is a strategic sector, like that of electricity. It is provided by public or para-public companies, such as REGIDESO in Burundi and DRC and WASAC in Rwanda, and mainly concerns cities. In rural areas, water supply networks are, depending on the country, managed by communal utilities supported by a ministerial agency (AHAMR, in Burundi), operated by NGOs, farmers' organisations or churches (DRC) or entrusted to private operators (Rwanda).

In the basin, drinking water is mainly supplied from spring catchments, with the exception of the large urban centres for which river or Lake Kivu catchments are used.

In the Burundian part of the catchment area, all drinking water consumed in urban areas comes from springs. At the rural level, most water is also collected from springs, although some boreholes exist in the Ruzizi plain (notably in Bubanza).

In the Congolese part of the catchment area,

- The city of Goma is supplied with water from the lake from 3 pumping stations (Turquoise, Lake Kivu and Keshero). In 2017, these pumping stations extracted an average of 15,000 m³/day from the lake[29]. New pumping sites are currently being planned. Two other pumping stations of very low capacity are located west of Goma and supply the refugee camps;
- The city of Bukavu is mainly served by water from the Murhundu River (the water treatment plant is currently being rehabilitated, theoretically producing 26,000 m³/d), supplemented by the catchment of two springs to the south-east of the city. A water intake is planned on the Mpungwe River (15,000 m³/d). The supply is and will nevertheless remain insufficient after this project and the inhabitants use and will continue to use many alternative sources (springs, wells, lake, rivers, etc.);
- No information is available for the centre of Kalehe. For the centres located in the Ruzizi plain, they are mainly supplied from springs and in some cases from boreholes.

In the Rwandan part of the catchment area, in the urban centres:

- The town of Gisenyi is supplied by the Sebeya and Pfunda rivers. The Gihira treatment plant treats an average of 8,000 m³/d (Figure 17). This plant is currently being rehabilitated to

[29] Master plan for the development of drinking water supply in the western districts of the city of Goma (North Kivu Province, Democratic Republic of Congo) - EkoCentric, BG and ICRC - December 2017

increase the flow of treated water up to 23,000 m³/d. As the Pfunda is slightly less loaded with sediment, its dilution with water from the Sebeya allows to reduce the sediment load of the water entering the plant;

- The town of Karongi is also supplied by many springs, as are the towns of Bugarama and Ruzizi ;
- Rural areas are supplied almost exclusively from springs.

Figure 17: Gihira Water Treatment Plant in Rwanda (October 2020)

All the water from these springs and rivers is then discharged into the catchment area and this does not therefore play a significant role in the water balance at the scale of the Lake Kivu and Ruzizi River basin.

In conclusion, the drinking water supply of most of the rural population of the basin depends on untreated water from springs: water is either drawn directly from springs, whether improved or not, or distributed by networks (generally without treatment).

Spring water constitutes the part of the groundwater resources which is accessible to the population without the need for expensive technical equipment. As springs will remain the basis for the water supply of the population of the basin in the future, they are an important challenge for meeting the water needs of the population, and their quantitative and qualitative characteristics deserve special attention.

Map No. 020 in the appendix illustrates the surface water abstraction points for drinking water supply in urban areas, as well as the sources developed for rural water supply. Map No. 021 in the appendix illustrates the distribution of drinking water demand in the basin in 2020, and the projection of this demand in 2050.

10.3. Agricultural water

10.3.1. Rain-fed agriculture on the slopes

Agriculture in the Lake Kivu basin relies almost entirely on rain-fed and subsistence farming; it is practised on sometimes steep slopes, highly exposed to erosion, and is associated with animal husbandry in stalls, particularly in Burundi and Rwanda.

In Burundi, in the foothills of the Mumirwa and on the Congo Nile ridge, agriculture is also practiced on sometimes steep slopes where food crops are grown, but also cash crops such as coffee and tea.

The economy of South Kivu is essentially oriented towards agriculture, livestock, trade and services. Agriculture is mainly practised by under-supported farm households on small plots of land, with rudimentary tools, unimproved seeds and obsolete cultivation techniques. Nevertheless, in recent years there has been a significant increase in the number of farmers' organisations thanks to NGOs that provide selected inputs, credit and appropriate supervision. Modern farms are rare. They are mainly oriented towards industrial farming, especially coffee, tea, sugar cane and cinchona.

The Western Province of Rwanda and in particular the districts of Rubavu, Musanze and Nyabihu, which benefit from very fertile volcanic land and abundant rainfall and produce 50% of the country's agricultural exports (tea, coffee, pyrethrum, horticulture), play a key role in the country's food security as more than 50% of agricultural products come from this region (potatoes, beans, maize, etc.) as well as livestock products. This agriculture is practised by a large part of the population on small plots of land with intensification approaches using improved seeds and organic and mineral fertilisers.

10.3.2. Irrigated agriculture in the Ruzizi plain

The total area of the Ruzizi plain is 177,905 ha with an agricultural potential of 125,713 ha. The Ruzizi basin contains within its plain a large number of developed irrigated areas with a total surface area of 59,287 ha, mostly shared between Burundi and DRC, but of which only a fifth (12,500 ha) is functional (Table 8).

Table 8: Surface area of all irrigated areas in the study area, by country.

Country	PI area (ha)	Percentage of total IP area (%)
Burundi	25 950	43.8
DRC	31 067	52.4
Rwanda	2 270	3.8
Total	59 287	100

These data come from the Master Plan of the Ruzizi plain which is based on the construction of a multi-criteria classification model, covering resource, physical, social, environmental, institutional and economic/financial aspects, in order to evaluate the irrigable potential of the plain. This analysis allowed classification of the potential into six classes such as IA (irrigation areas) of sugar factories, functional IA, Planned Priority 1 IA, Planned Priority 2 IA, projected IA and AIP zone (Annual Investment Plan zone) (Table 9).

The diagnosis of the existing hydro-agricultural developments highlights the lack of a coherent and coordinated development of the irrigation sector in the Ruzizi plain, since only 10% of the potential irrigation areas are functional. The irrigation areas suffer from several problems that hinder the development and exploitation of their potential. These problems, classified in two categories are:

- Technical problems :
    - Deterioration of the irrigation and water drainage network ;

    - Lack of water resource mobilisation works to meet the demand for irrigation water, especially in dry periods;
    - Lack of flood protection works;
    - Erosion problems;
- Social problems :
    - Demographic pressure on agricultural areas;
    - Urbanisation;
    - Boundary management conflicts (linked to the water rotation).

Table 9: The different categories of irrigation areas in the study area according to the three countries.

Irrigation area category (IA)	Country			Total area by category (ha)	Percentage of total IP area (%)
	Burundi (ha)	DRC (ha)	Rwanda (ha)		
Sugar Plant IA	2 331	4 371	-	6 702	11.3%
Functional IAs	5 726	-	-	5 726	9.7%
IA Planned Priority 1	6 022	8 642	2 270	16 934	28.6%
IA Planned Priority 2	2 493	12 631	-	15 124	25.5%
Projected IAs	9 378	2 383	-	11 761	19.8%
AIP Zone	-	3 040	-	3 040	5.1%
Total	25 950	31 067	2 270	59 287	100%

The catchment areas with the greatest irrigation potential, according to the planning and projections of the Master Plan, are respectively the catchment areas of the Kiliba (13,973 ha), the Mpanda (9,299 ha) and the Luvubu (8,513 ha) (Table 10).

Table 10: Categories of irrigation areas by catchment area (SDAR data)

Irrigation areas per catchment area	Category of irrigation areas	Surface area (ha)	Percentage of total IP area (%)
Kaburantwa (Burundi)	**Total**	**3 002**	**5.1%**
	Projected IAs	3 002	5.1%
Kagunuzi (Burundi)	**Total**	**1 992**	**3.4%**
	IA Planned Priority 1	838	1.4%
	IA Planned Priority 2	737	1.2%
	Projected IAs	417	0.7%
Kajeke (Burundi)	**Total**	**5 252**	**8.9%**
	Sugar Plant IA	2 319	3.9%
	Projected IAs	2 933	4.9%

Irrigation areas per catchment area	Category of irrigation areas	Surface area (ha)	Percentage of total IP area (%)
Kiliba (DRC)	**Total**	**13 973**	**23.6%**
	Sugar Plant IA	4 383	7.4%
	IA Planned Priority 1	4 716	8.0%
	IA Planned Priority 2	1 834	3.1%
	PAI Zone	3 040	5.1%
Luberizi (DRC)	**Total**	**2 027**	**3.4%**
	IA Planned Priority 2	1 121	1.9%
	Projected IAs	906	1.5%
Luvimvi (DRC)	**Total**	**1 604**	**2.7%**
	IA Planned Priority 1	1 092	1.8%
	IA Planned Priority 2	512	0.9%
Luvubu (DRC)	**Total**	**8 513**	**14.4%**
	IA Planned Priority 1	913	1.5%
	IA Planned Priority 2	6 803	11.5%
	Projected IAs	797	1.3%
Mpanda (Burundi)	**Total**	**9 299**	**15.7%**
	Functional IAs	1 400	2.4%
	IA Planned Priority 1	3 408	5.7%
	IA Planned Priority 2	1 756	3.0%
	Projected IAs	2 735	4.6%
Muhira (Burundi)	**Total**	**677**	**1.1%**
	Functional IAs	386	0.7%
	Projected IAs	291	0.5%
Nyakagunda (Burundi)	**Total**	**1 776**	**3.0%**
	IA Planned Priority 1	1 776	3.0%
Nyamagana (Burundi)	**Total**	**3 940**	**6.6%**
	Functional IAs	3 940	6.6%
Rubyiro (Rwanda)	**Total**	**2 270**	**3.8%**
	IA Planned Priority 1	2 270	3.8%

Irrigation areas per catchment area	Category of irrigation areas	Surface area (ha)	Percentage of total IP area (%)
Sange (DRC)	**Total**	**4 962**	**8.4%**
	IA Planned Priority 1	1 921	3.2%
	IA Planned Priority 2	2 361	4.0%
	Projected IAs	680	1.1%
TOTAL		59 287	100%

A monthly and annual water demand was determined for each of these irrigation areas. This demand was evaluated using crop coefficient data (Kc) for the usual crop mixes in the plain[30]. The cropping calendar was obtained from the data available on the Imbo plain for the main crops of rice, maize, market gardening, beans, sweet potato and tomato and extrapolated to all the irrigation areas. For each month, an average Kc was calculated for each of the crops, taking into account that each crop has two cropping seasons per year. These water demand values (in millions of m³ per year) are shown in the Table 11 below.

Table 11: Average annual water requirement by irrigation areas (millions of m³/year).

Irrigation areas per catchment area	Average annual water requirement (millions of m³/year)
Kaburantwa	24.5
Kagunuzi	16.2
Kiliba	114.3
Luberizi	16.9
Luvimvi	13.4
Luvubu	71.1
Mpanda	116.4
Muhira	5.6
Nyakagunda	14.8
Nyamagana	32.8
Rubyiro	18.9
Sange	40.9

In total, the estimated annual water needs for all the areas (functional, planned and projected) amount to 486 million m³. The annual water needs corresponding to the functional areas amount to 102 million m³. In the section 11 (Water balance) of this document, an analysis of the water balance, adequacy

[30] An average cultivation coefficient was calculated according to the crop cycles and crop rotation of the main crops on the plain.

between water availability and water needs, has been carried out. Figure 18 shows a simplified overview of the different irrigation areas.

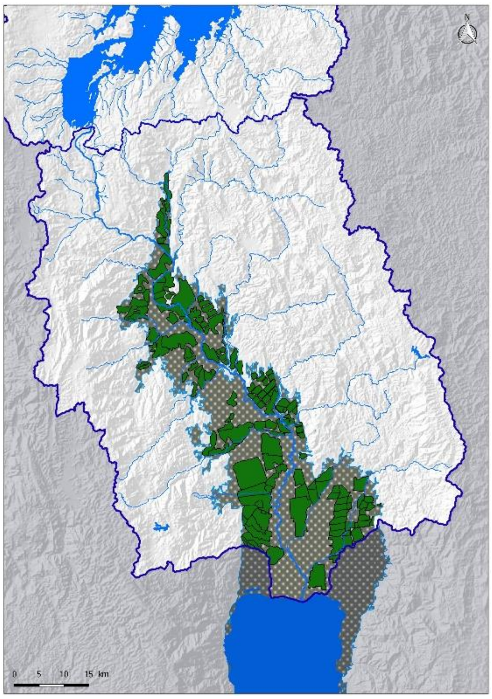


Figure 18: Map of irrigated perimeters in the Ruzizi plain.

In the Imbo plain in Burundi, farm irrigation is based on the hydrography of six rivers and Lake Dogodogo in Cibitoke province, namely the Nyamagana, Kaburantwa, Kagunuzi and Mpanda rivers, which cross a large expanse of marshland and communicate with the Mutimbuzi and Kajeke basins. These last two rivers, located in the low plain of the Ruzizi, are the only permanent tributaries of the Ruzizi River. As for Lake Dogodogo, in principle it is fed by the drainage waters of the adjacent areas (waters of the Nyakagunda and the Nyamagana) and by underground inputs.

The irrigation areas of the province of Cibitoke are mainly served by water from the Nyakagunda and Nyamagana rivers and some water intake works are being completed to increase the irrigation areas, notably from the Muhira and Kaburantwa rivers. Those in Bubanza provinces are mainly supplied from the Mpanda River or its tributaries, including the Kajeke (Figure 19).

Figure 19: Functional irrigation canal in the province of Cibitoke.

In the study area in the DRC, more than 4,300 ha of irrigation areas would be used to supply the Kiliba sugar factory. Other areas are planned and projected in order to reach a functional irrigable area of more than 31,000 ha, shared between the catchment areas of Kiliba, Luberizi, Luvimvi, Luvubu and Sange.

The main achievements in the field of irrigation infrastructure in the DRC were mostly made during the colonial period by the Anti-Erosive Mission (AEM) which had four concrete dams built to supply the rice fields and other cultural areas of the Congolese site (Nyakisasa, Kiliba, Tenge-Tenge and Kakamba dams). All these dams, built during the colonial period, only functioned partially and insufficiently after independence, and it was not until 1973 that the Ruzizi project, with financial assistance from China, began to repair them, as well as to regularise the river beds, clean the canals and rebuild the irrigation areas. Since then, three new dams have been built (Mukindw, Sange and Runingo dams).

In Rwanda, in Bugarama in the Ruzizi plain, rice is the main irrigated crop. The rice-growing area is subdivided into four zones of more than 2,200 ha, which are served by different irrigation works. The main Rubyiro canal serves the Byuviro dam. This canal feeds three zones. The secondary Kizura canal feeds the remaining area of zone 4; the Katabuvuga dam supplies the remaining area of zone 3; the Njambwe and Murundo dams feed the remaining area of zone 2.

Map No. 020 in the appendix illustrates the location of existing and planned hydro-agricultural developments in the Ruzizi plain.

10.4. Hydroelectricity

The three countries bordering the Ruzizi River decided several years ago to work together on the construction of a run-of-river dams along the river's steep zone.

The Ruzizi I power plant, operational since 1959, is managed and operated by the Société Nationale d'Electricité (SNEL), a Congolese public company that also owns it. The plant is located 3 km downstream from the outflow of Lake Kivu, with an installed capacity of 29.8 MW. The current available power is only 21.2 MW due to outdated equipment and insufficient maintenance. The Ruzizi II power station came into service in 1989, with an installed capacity of 43.8 MW, of which 36 MW is currently available for similar reasons. It is operated by the Société Internationale d'Electricité des Pays des Grands Lacs (SINELAC), an international public enterprise created in 1984 and owned by the three CEPGL member states.

The Ruzizi III hydropower plant will be the third hydropower development on the same Ruzizi River for which an agreement was signed between the three countries on 29 July 2019 in Kinshasa. The project will be developed as a public-private partnership (PPP) project with two companies namely Industrial Promotion Service - IPS (of the Aga Khan Group) and Sithe Global replaced by SN Power (Norwegian private company). The preliminary studies are for a hydropower plant with an installed capacity of 147 MW; it is expected that after the project agreements are signed, additional geological studies will be carried out, which could lead to an increase in the project's capacity up to 230 MW. The total cost of the project is expected to be between USD 644 and 700 million. The project itself is a run-of-river hydropower scheme which will also include a 1.9 million m^3 rockfill reservoir with an asphalt core and a maximum height of 30 m above the existing riverbed. By raising the water level, a useful volume of approximately 877,000 m^3 will be made available for stabilising energy production. At the level of the retaining structure on the Ruzizi III power plant, a minimum flow will be maintained in the Ruzizi river for ecological reasons. At a flow rate of 6.5 m^3/s, the micro-hydro power plant unit will allow a maximum production of approximately 1.3 MW at a head of 22 m. The micro-hydro power plant will be located in the discharge structure, between the main spillway and the regulating spillway.

In January 2020, the African Development Bank approved the financing of a project to prepare for the construction of a Ruzizi IV power plant which should be located between the Ruzizi II and Ruzizi III waterfalls, with an installed capacity of 287 MW.

Although the hydroelectric potential on the first 50 kilometres of the Ruzizi River is considerable as mentioned above, other sites have interesting potential. Table 12 below shows, according to the different compartments, the installed and potential hydroelectric power in the study area. The potential hydroelectric power of the right bank of the intermediate basin is 469 MW and therefore includes the future Ruzizi III and IV, among others.

Table 12: Installed and potential hydropower capacity by watershed groupings.

Compartment			Installed power (MW)	Potential Power (MW)
Kivu Basin	West	Upstream	-	-
		Downstream	-	5
	Sub-total		*-*	*5*
	East	Upstream	6	8
		Downstream	0	2
	Sub-total		*6*	*10*
	Sub-total Kivu		***6***	***15***
Intermediate basin (upper Ruzizi river)	Right Bank		57	469
	Left Bank		-	23
	Sub-total		*57*	*492*
Ruzizi river basin (tributaries)	Right Bank	Upstream	-	12
		Downstream	-	18
	Sub-total		*-*	*30*
	Left Bank	Upstream	-	81
		Downstream	19	63
	Sub-total		*19*	*144*
	Sub-total Ruzizi		***76***	***666***
Total			**82**	**681**

The left bank of the Ruzizi river basin has a hitherto little developed hydroelectric potential. Although it already has an installed capacity of 19 MW, its potential capacity is 145 MW. The watersheds concerned, with a high hydroelectric potential, are those of the Ruhwa (31 MW) and the Kaburantwa (44 MW), upstream, while on the downstream part, the major potential sites are on the Kagunuzi (26 MW) and the Mpanda (18 MW). The Rwegura power station, installed in the Kagunuzi basin, has a capacity of 19 MW.

These high powers, despite a limited river flow compared to that of the Ruzizi, are explained by relatively large catchment areas, the presence of forest cover on the upper parts and a very hilly relief. In fact, the Kaburantwa River, for example, has its source at an altitude of nearly 2,500 m in the Nyungwe-Kibira forest and ends in the Ruzizi River at 842 m, with average slopes of 33%. The Ruhwa

River has a similar profile since its catchment area has a maximum altitude of 2,934 m and a minimum elevation of 921 m, covering an area of 625 km².

In the Lake Kivu basin, the hydroelectric potential is much more limited. Despite the escarpment, the watersheds are not large enough to generate rivers with a large flow. In the eastern part of the study area, in Rwanda, there are a few power stations, such as Keya, Gisenyi, Gasashi, Cyimbili, Nkora, Murunda, etc., which are located in the eastern part of the country. Figure 20 shows a view of the pipelines of the Gisenyi power station.

Figure 20: View of the penstocks supplying the Gisenyi hydropower station.

Map No. 020 in the appendix illustrates the location of the main hydroelectric power stations in the study area.

10.5. Gas extraction in Lake Kivu

The estimated quantity of methane gas in Lake Kivu is estimated, according to different authors[31], to be about 60 km^3 of dissolved CH_4 (at 0°C and 1 atm) in the deep waters of the lake.

Rwanda has embarked on the exploitation of methane gas for power generation and distribution in the national grid. A committee of international experts mobilised by the governments of the DRC and Rwanda has recognised that the extraction of methane gas for energy production could be the most viable solution from a risk management, environmental and economic point of view, but only if it complies with the "Mandatory Guidelines[32]" validated by the two countries. The principle consists of pumping water and dissolved gases from a depth of 355 m (the resource zone) up to the surface, via a floating platform. At the surface of this platform, the gases are separated from the water by a separator and the CO_2 is separated from the CH_4 by a washing process. The CH_4 is then transported via a gas pipeline to the power station to be compressed and burned to produce energy converted into electricity. The question of the oxidation of H_2S in this whole process is still unknown, especially in oxygen-poor waters. The "Mandatory Directives" recommend that the water resulting from this

[31] Schmid, M., Halbwachs, M., Wehrli, B. & Wüest, A. (2005) Weak mixing in Lake Kivu: New insights indicate increasing risk of uncontrolled gas eruption. Geochemistry, Geophysics, Geosystems, 6 (1): 1-11, et Descy, J. P., Darchambeau, F., & Schmid, M. (Eds.). (2012). Lake Kivu. Limnology and biogeochemistry of a tropical great lake. Aquatic ecology series: Vol. 5.

[32] Management prescriptions for the development of Lake Kivu gas resources, final version for general release 17 June 2009

process should be re-injected into deep areas and not be mixed with the biozone water, at the risk of polluting it (gas, sediments, salts...). This process could be expensive due to the high energy requirement.

Two investments are already operational in Rwanda, namely:

- The KivuWatt project, a subsidiary of Contour Global (a US-based company), which entered into commercial operation on 31 December 2015 and operates at base load with a gross nominal capacity of 26 MW, and
- Symbion Power Lake Kivu Ltd, a subsidiary of Symbion Power LLC, which signed a 25-year power purchase agreement (PPA) with the Rwanda Energy Group (REG) on 8 December 2015 for a net capacity of 50 MW from a power plant to be located in the Nyamyumba sector in the Rubavu district. The first barge will provide 14 MW of electricity 15 months after the financial close of the project. The company has also acquired the barge for the Kibuye Power KP1 facility in Rubavu district and is working to mobilise funds to reopen the plant and increase its capacity to 25 MW.

The methane extraction units are shown on map No. 020 in the appendix.

10.6. Oil extraction

Like Lake Albert between DRC and Uganda, Lake Kivu is said to be teeming with oil in its subsoil. In 2017, the DRC and Rwanda signed an agreement for oil exploration in Lake Kivu. This exploration started in 2018 on the Rwandan side with a series of shallow drillings and geochemical tests in Lake Kivu. The geological structure in some parts of the lake would indicate a potential presence of oil. In order to best assess exploitation opportunities, Rwanda has reported to have temporarily suspended its call for bids for international oil operators.

10.7. Animal husbandry

Throughout the study area, livestock rearing is practised in the traditional way with a herd of three to five head of cattle (including a maximum of one to three large ruminants) reared on tethers or in stalls. Cattle raising is mainly for milk production and small ruminants for meat production.

In Burundi, the commune of Gihanga in the province of Bubanza is traditionally known for its dairy farming. The size of the herds reaches several dozen head of cattle. In recent years, population growth and pressure on pastures have led to increasing conflicts between herders and farmers. This situation forces herders to regularly move their herds, particularly to the Rukoko nature reserve, a protected area, or to other grazing areas, located in the DRC. A draft law on permanent livestock stalling was adopted in 2018 in Burundi, obliging herders in the area to move from extensive to intensive livestock farming with the introduction of a paddock system.

In Rwanda, the national herd has grown from 600,000 head of cattle before 1994 to over 1,390,000 to date. The highlands of the Congo Nile ridge in the west of the country and the shores of Lake Kivu account for about 25% of Rwanda's national livestock population. The Gishwati region, which extends into the districts of Rubavu, Nyabihu, Rustiro and Ngororero, is recognised as one of Rwanda's five major dairy basins. This region has the particularity of offering large areas of pasture allowing an extensive cattle raising system. Milk production forecasts for the Gishwati dairy basin (Figure 21), considered as a specific milk production area, are expected to have doubled between 2017 and 2022 from 15.7 to 31 million litres of milk per year.

Figure 21: Grazing in the Gishwati dairy basin, Rwanda (December 2018).

10.8. Fish farming and fishing

Fishing on Lake Kivu is still an artisanal activity today. In the pelagic zone, fishing is generally carried out at night, using a lifting net and a light source that attracts fish. Fishermen organised in cooperatives travel on board trimarans (assemblies of three large non-motorised pirogues) or motorised pirogues (Figure 22). Fishing on the coast is generally carried out during the day with various equipment such as beach seine nets, lines, longlines equipped with hooks, sparrowhawk nets, fish traps but also mosquito nets.

Figure 22: Trimarans on Lake Kivu

The main fish species in Lake Kivu are Isambaza (*Limnothrissa miodon)*, Nile Tilapia (*Oreochromis niloticus)*, Inkube or African Catfish (Clarias gariepinus) and *Haplochromis sp. of* the Cichlidae family.

Before the introduction of *Limnothrissa miodon* (Isambaza) into Lake Kivu in 1959[33], fishing was a marginal activity for the local population, with an estimated annual production of around 1,500 tonnes per year. Fish production gradually increased to reach an average annual production estimated at 6,000 T/year in 1999, confirmed by studies conducted from 2012 to 2014 by the LKMP. The bay of Bukavu is particularly prolific due to its shallow depth.

At present, the total number of people working in this sector can be estimated at between 6,500 and 7,000 in Rwanda and a similar population in the DRC, of which more than 50% are women responsible for cleaning and selling fish (in Rwanda, there are 2,249 fishermen organised in 37 cooperatives in the 5 districts bordering the lake). However, a growing number of non-regular and/or poorer fishermen using illegal fishing equipment, including nets with a mesh size that is too small, shows the existence of pressure on fishery resources. This is particularly noticeable in the bay of Bukavu where the number of fishing units has increased sharply in recent years.

Aquaculture is an alternative to overfishing in Lake Kivu. The Master Plan for Fishing in Rwanda of 2017 proposes the development of a total of 25 cage aquaculture parks on Lake Kivu, each park containing about 5,000 cages covering an area of 20 ha for an annual production capacity of 5,000 tonnes (1 T/cage). In 2020, nearly 211 cages of different capacities were installed for an area of 4.11 ha. The main factors limiting this activity are the high cost, the scarcity of floating fish feed (pellets) (to avoid polluting the lake) and the almost non-existent capacity of refrigerated storage and transport equipment.

Further south, in the Imbo plain in Burundi, there are a total of 2,091 fish ponds producing nearly 68 tons of fish annually. Although the river is known for its great diversity of fish, fishing is mainly conducted in Lake Tanganyika. Fishermen in the provinces of Bubanza and Bujumbura Rural are organised in a cooperative, COPEDECOBU, which has more than 8,000 members.

10.9. Industries

Industrialisation in the basin can be divided into three categories: food processing industries including beverage plants, cement works and pharmaceutical industries.

The basin includes multiple micro-industries of agri-food processing and livestock products (rice mills, coffee washing stations, tea factories (Figure 23), sugar production plants, milk collection and processing centres, slaughterhouses). Rice mills and sugar production units are mainly located in the Ruzizi plain. The Ruzizi Plain Regional Integrated Development Programme (PREDIR) plans to reinforce the infrastructures linked to these industries. The waste from these plants is generally recovered for animal feed (livestock or fish).

[33] G. Hanek and T.Baziramwabo. Fisheries development on lake Kivu - Credit system and fish marketing. In *Fisheries credit programmes and revolving loan fund: case studies*. FAO fishery industries division, 1989

Figure 23: Tea fields on the edge of Nyungwe Forest.

Coffee washing stations are present in large numbers on the slopes of the Congo-Nile ridge in Burundi and Rwanda, taking advantage of the presence of numerous rivers (Figure 24). A few tea factories are present in the basin. These factories are high energy consumers. Many of them have eucalyptus plantations but often have to rely on local wood production to process the tea leaves.

Figure 24: Coffee washing station on the shores of Lake Kivu.

There are two soft drink and beer production plants, BRALIMA in Bukavu and BRALIRWA in Rubavu. The BRALIMA brewery uses water from Lake Kivu for its production, while BRALIRWA is supplied by the Gihira water treatment plant. These plants have their own effluent treatment plants.

Cement works valorise limestone quarries or lava rock. Limestone rock is present in the south of the Kivu Basin and in the Ruzizi river basin. Three cement factories have developed there: CIMERWA, the Katana Cement Factory (Great Lake Ciment) and BUCECO. New cement plants are being developed in the northern part of the Basin, at the foot of the volcanoes, to exploit the volcanic rocks present in profusion. All these plants face the challenge of accessing sufficient energy. As with any large industry, environmental and social impacts must be assessed and management plans implemented.

Finally, Pharmakina is a pharmaceutical industry located in Bukavu that exploits cinchona bark for the production of medicines.

10.10. Mines

In Burundi, the exploitation of minerals takes place mainly in the bed of the Ruzizi tributaries. This activity, developed in an artisanal way but in places on a large scale (this is the case of the Muhira river in particular), causes a very strong degradation of the river beds and a conflict over the use of the resource, with river intakes and canals developed for irrigation being diverted in places for gold panning activities. The main mineral exploited is gold.

The main minerals exploited in North and South Kivu are gold, colombo tantalite (coltan), diamonds, wolfram as well as tin, monazite, limestone, cassiterite, methane gas and thermal waters. The mining sector has a few modern companies (SOMINKI, CIMENKI, ...) but also many artisanal miners who are poorly supervised, unorganised and where fraud is rife. Particular attention is paid to gold mines, which mobilise around 160,000 to 200,000 miners in a large number of artisanal small-scale mining operations (ASM).

Rwanda's Western Province has a number of mines including gold in Nyamasheke and Ruzizi; wolfram, cassiterite and coltan in Ngororero, Rutsiro and Karongi. Artisanal Small-scale mines (ASM) are still in the majority and are gradually being organised into cooperatives.

Map No. 022 in the appendix illustrates the main industrial and mining units identified in the basin.

10.11. Navigation

Lake transport on Lake Kivu is an essential activity for the local population.

In the DRC, a lake transport system exists for passengers and freight, linking the ports of Bukavu and Goma in three to eight hours, depending on the type of boat, compared to eight to ten hours by road (approximately 200 km) (Figure 25).

Figure 25: Boats on Lake Kivu in Goma.

On the Rwandan side of the lake, a professional water transport service has yet to be created. At present, there is a ferry between the major centres bordering the lake which carries only passengers. In addition, there are occasional boat services for passengers and freight between some centres although they do not run regularly.

A project supported by TRADEMARK East Africa is underway with the construction of four ports and shuttle facilities in Rwanda. This project foresees the development of lake traffic with an increase in passenger volume between 2017 and 2036 from 1.4 million to 2.7 million passengers in Ruzizi and 1.1 million to 2.1 million passengers in Rubavu. The same project is mobilising financing for the construction of ports on the DRC side, with a view to strengthening existing transport between the cities of Bukavu and Goma, whose passenger traffic volume should practically double between 2017 and 2036. The planned ferry system is expected to capture 90% of the market, with the remaining 10% being absorbed by the existing transport system.

Map No. 023 in the appendix illustrates the location of Lake Kivu's ports and navigation routes.

10.12. Tourism

The basin of Lake Kivu and the Ruzizi River has an interesting and very varied tourist potential. The green landscapes of the hills, the recreational banks of Lake Kivu, the cultural and ecotourism sites, the Ruzizi Natural Park and the proximity of the Nyungwe and Volcanoes National Parks are all assets to be exploited.

The main concentration of tourist infrastructure is in the northern part of the basin, in the cities of Goma and Rubavu. The transport infrastructures in place (air and road), the hotel capacity and the proximity of the Volcanoes-Virunga-Bwindi Park complex, rich in exceptional biodiversity, attract thousands of international tourists every year.

The southern part of the Lake (Bukavu and Rusizi towns) is experiencing slower tourist development. The scarce investments in recreation, cultural tourism and ecotourism are located on the banks of the lake. Bukavu offers about ten hotels of different categories and Rusizi a little less, including two of international class. The limited number of people qualified in the field of hotel services but also the insufficiency of basic services such as access to drinking water and efficient sanitation systems are the main constraints to the development of tourism. The Ruzizi National Park in Burundi, rich in biodiversity, offers a tourist potential that is still under-exploited.

In its Tourism Development Master Plan for the region bordering Lake Kivu (Kivu Belt), Rwanda aims to further strengthen the tourism infrastructure network which is still considered insufficient and transform it into an economically profitable value chain (Figure 26). The plan recommends the mobilisation of direct private investment worth a total of USD 250 to 300 million, including various infrastructures (hotels, roads, leisure) as well as the development of cultural and ecological tourism packages. On the Rwandan side, tourism could thus generate income equivalent to 36 million USD/year with an average of 2,500 to 5,000 permanent jobs.

Figure 26: Signs indicating the different routes of the Congo-Nile Trail, Rwanda.

10.13. Summary of the WEF NEXUS uses and water demand

Key figures for the uses of the basin corresponding to the Water-Energy-Food (WEF) Nexus as presented in the previous sections are given in Table 13.

Table 13: Current and projected water-electricity use and supply.

	Current and projected WEF use		Need for water
Drinking water supply	Needs 2020	11 million inhabitants	111 million m³/year
	Needs 2050	27.5 million inhabitants	277 million m³/year
Irrigation	Operational perimeters	12,500 ha	102 million m³/year
	Operational and planned perimeters	59,000 ha	486 million m³/year
	Irrigation potential of the Ruzizi plain	125,000 ha	1 billion m³/year
Hydroelectricity	Installed power	80 MW	n. a.
	Potential power	683 MW	

11. Water balance

11.1. Overview of the balance sheet methodology

A hydrological balance sheet was developed at the basin scale as part of the study. It enables the monthly water flows (inflows and outflows) to be determined for each of the 128 sub-basins in the study area, in a dry year, an average year and a wet year situation. The hydrological balance carried out thus allows the evaluation of the monthly volumes flowing at the level of each sub-basin, the total inflows into Lake Kivu, the outflows (such as direct evaporation from the lake and withdrawals for irrigation in the Ruzizi plain), as well as the flow of the Ruzizi river at three key points defined in the basin.

The methodology developed, on which the water balance is based, is presented in Annex IV.

The results of the hydrological model were grouped into four distinct compartments, conceptually representing the hydrological functioning of the basin:

- The Lake Kivu watershed (divided into 5 sub-basins), allowing the estimation of water flows (lateral inflows by runoff) from the sub-basins to Lake Kivu ;
- Lake Kivu, allowing the quantification of evaporation losses on the lake surface and to estimate the outflow from Lake Kivu to the Ruzizi River ;
- The catchment area between the outflow of Lake Kivu and the entrance to the plain at Kamanyola (divided into two compartments), making it possible to estimate the lateral inflows to this area and the flow of the Ruzizi at Kamanyola ;
- The catchment area corresponding to the Ruzizi plain between Kamanyola and Lake Tanganyika (divided into 4 compartments), making it possible to estimate the water consumption of the irrigation areas of the plain, the lateral contributions of the Ruzizi tributaries on this section, and the flow of the Ruzizi at its entry into Lake Tanganyika.

The arrangement of the different compartments is shown graphically in Figure 27.

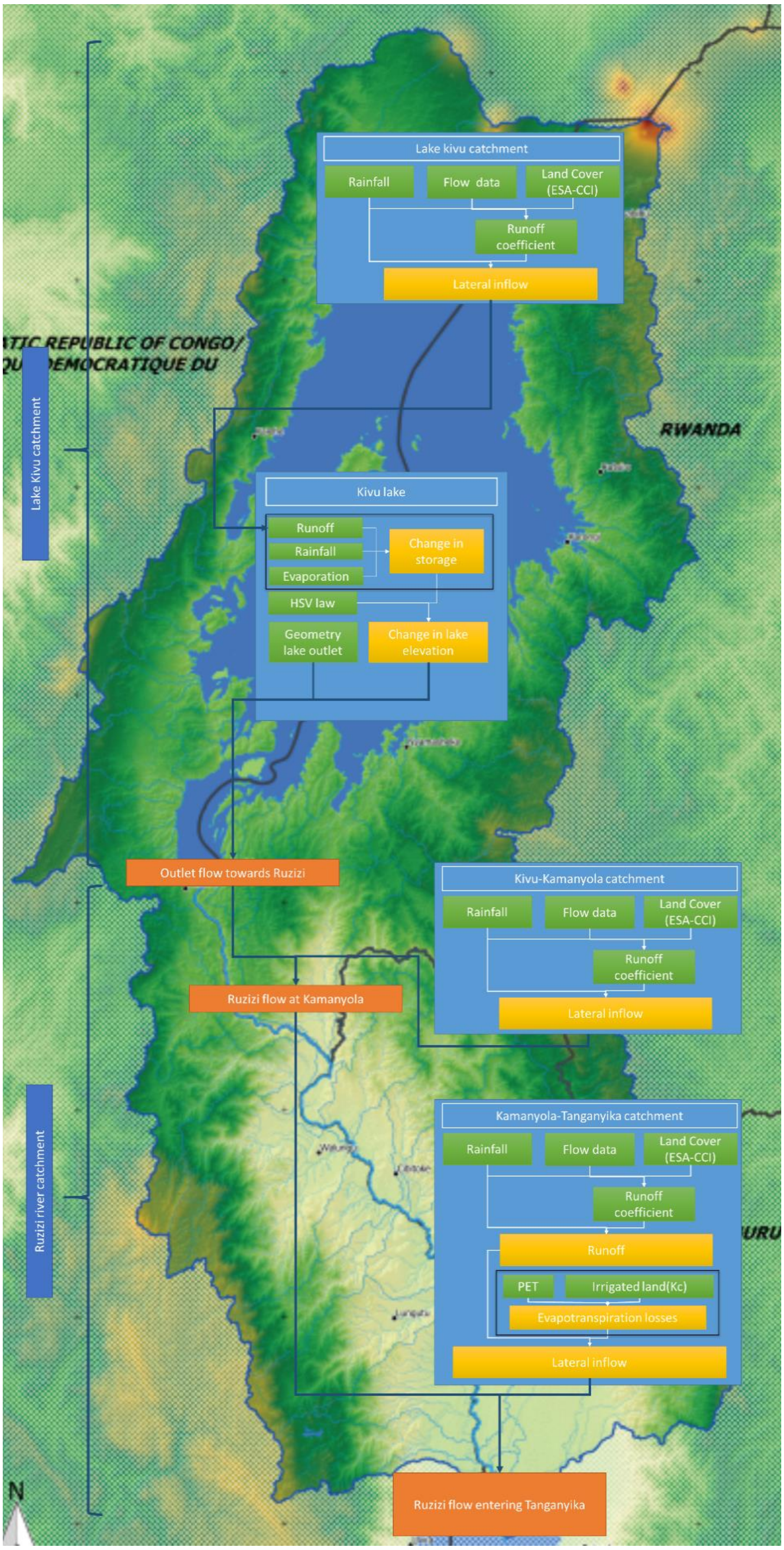


Figure 27: Diagram of the hydrological model.

11.2. Summary of the water balance results

Figure 28, Figure 29 and Figure 30 present the calculated average monthly flows of the Ruzizi River at the three key points defined in the basin: outflow of Lake Kivu, Kamanyola, and entry into Lake Tanganyika. The black line represents the flow in an average year, while the shaded areas represent the range of flows between dry and wet years.

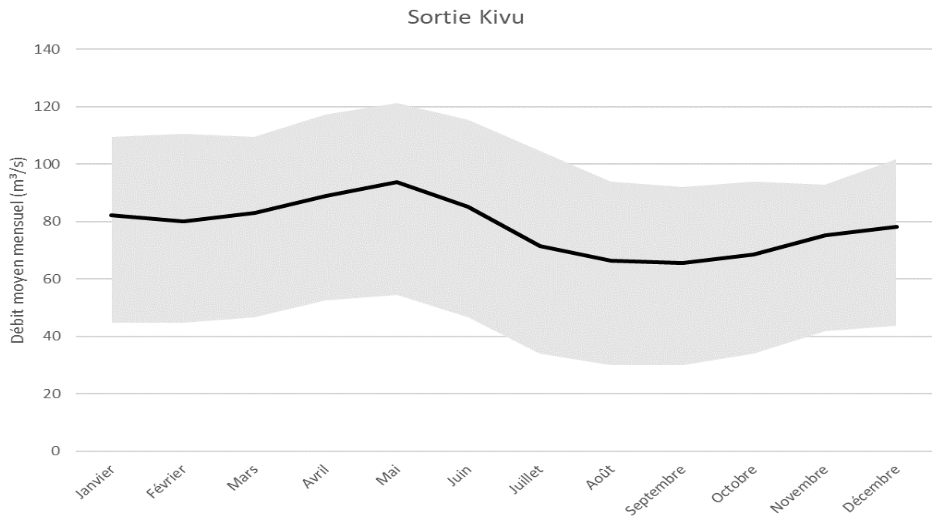


Figure 28: Average monthly flow of the Ruzizi River at the outlet of Lake Kivu.

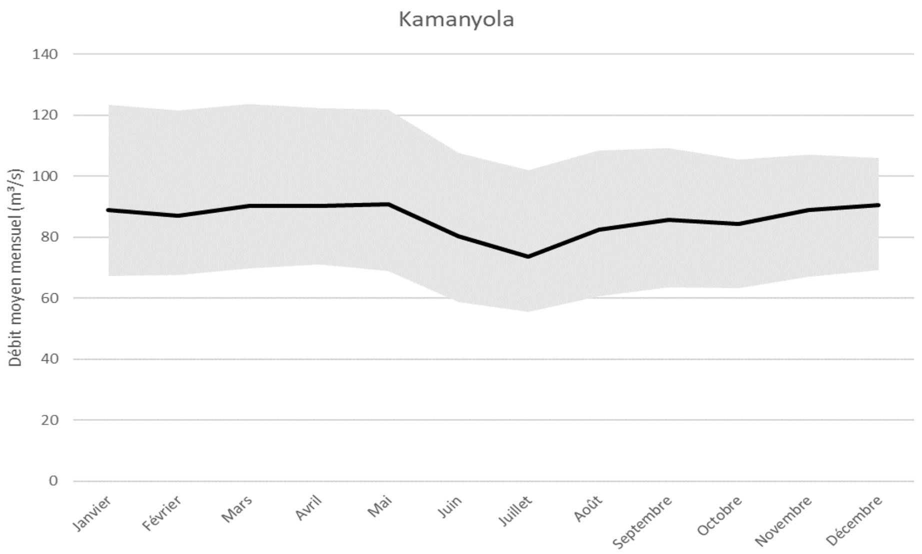


Figure 29: Average monthly flow of the Ruzizi River at Kamanyola.

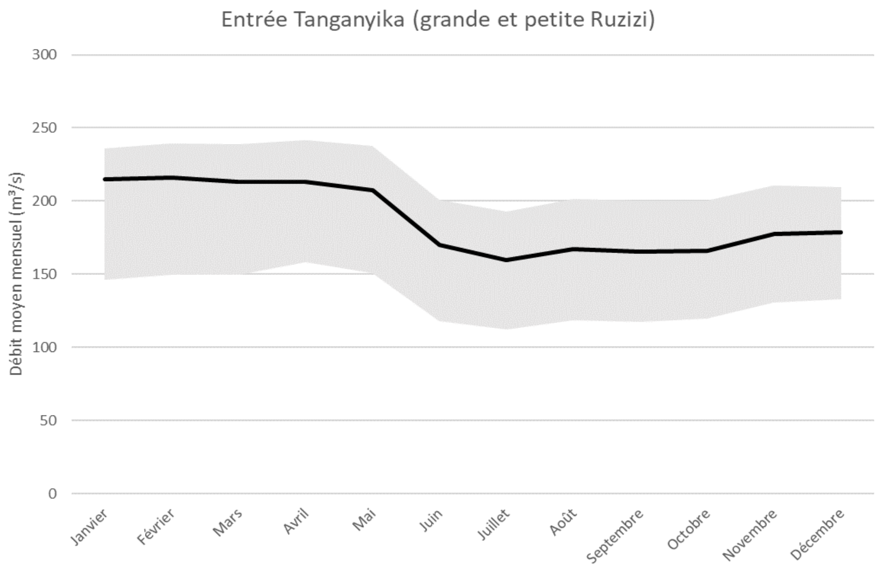


Figure 30: Average monthly flow of the Ruzizi River (large and small Ruzizi) at the entrance to Lake Tanganyika.

The average outflow from Lake Kivu to the Ruzizi River is around 71 m³/s in an average year, 53 m³/s in a dry year, and 98 m³/s in a wet year. At the level of Kamanyola, the average flow of the Ruzizi is estimated at 89 m³/s in an average year, 65 m³/s in a dry year, and 120 m³/s in a wet year. Downstream at its entrance into Lake Tanganyika, the Ruzizi has an average flow estimated at 206 m³/s in an average year, 139 m³/s in a dry year, and 227 m³/s in a wet year. The balance (expressed in million m³) of the different compartments is presented in the Table 14 below, for an average year.

Table 14: Average annual balance sheet (in millions of m³) according to the different compartments.

Compartment			Million m³ (average year)			
			Rain	Runoff	Irrigation	Evaporation
Lake Kivu Basin	West	Upstream	1 617	752		
		Downstream	1 683	740		
	East	Upstream	1 496	658		
		Downstream	2 000	863		
	Islands		421	186		
	Total		**7 217**	**3 199**		
Ruzizi River Basin to Kamanyola	West		386	209		
	East		592	322	19	
	Total		**979**	**532**	**19**	
Kamanyola Ruzizi River Basin at Lake Tanganyika	West	Upstream	1 544	825	101	
		Downstream	947	510	155	
	East	Upstream	2 791	1 692	78	
		Downstream	1 617	576	133	
	Total		**6 899**	**3 603**	**467**	
Lake			3 003			3 455
Total			**18 098**	**7 333**	**486**	**3 455**

Water inflows by runoff to Lake Kivu, from the rivers of the Lake Kivu basin, are estimated at about 3.2 billion m³ for an average year. This is in addition to the 3 billion m³ of direct rainfall at the lake level, while direct evaporation from the lake's open surface is estimated at 3.45 billion m³. On an annual basis, the water balance of the Lake Kivu catchment basin thus presents a net non-consumed volume of 2.75 billion m³.

Runoff water inflows into the Ruzizi River basin are estimated at around 4.1 billion m³, of which just under 500 million m³ are consumed for irrigation in the Ruzizi plain. On an annual basis, the water balance of the Ruzizi river basin shows a net non-consumed volume of 3.63 billion m³.

In total, water input by runoff over the whole basin is thus estimated at 7.3 billion m³ in an average year. On an annual basis, the water balance of the basin of Lake Kivu and the Ruzizi River thus presents a net non-consumed volume of 6.4 billion m³, corresponding to the water contributions of the Ruzizi River at its mouth at the level of Lake Tanganyika.

11.3. Conclusions of the water balance: adequacy between water availability and water needs of the basin

Analysis of the water balance results shows that, from a quantitative point of view, the basin's water resources are sufficient to satisfy all the identified uses, in a reference situation (2020) and for the different scenarios defined for 2050.

It should be noted, however, that based the WEAP modelling carried out and presented in section 20.4 of the report as well as in Annex VII, the monthly analysis of water needs for irrigation in the Ruzizi plain indicates locally a limitation of the available surface water resource for the July-August period, in the scenario of cultivation of all the existing, planned and projected areas combined with the dry climate year scenario (P80). However, this limitation does not exceed 5% of the estimated water needs for irrigation in this worst-case scenario.

On the scale of the basin and the main sub-basins, it can therefore be concluded that the availability of water resources is not a limiting factor in the socio-economic development of the intervention area, including in a situation of unfavourable climate change and significant population growth according to the established scenarios.

12. Environmental situation

12.1. Soil degradation

Small-scale peasant agriculture plays an important role in meeting the food needs of farm households. However, this type of agricultural production system is increasingly characterised by overexploitation of the natural resources on which it is based, as a result of rapid population growth. In the short and medium term, this overexploitation leads to soil degradation phenomena that in turn lead to a decrease in soil productivity, compromising the sustainability of agricultural production systems. In addition to this phenomenon of overexploitation, the very steep relief of the catchment area and climate change exacerbate this degradation. The consequences are numerous, such as less productive agriculture, an increase in natural disasters such as mudslides and landslides, an increase in the surface area of less fertile land, and a decrease in the quality and production of drinking water.

However, soil restoration measures can be implemented. These measures make it possible to limit a number of factors leading to soil degradation. Some types of measures are, for example, the establishment of progressive or radical terraces, crop strips, inter-crop strips, agro-forestry, and mulching. All these measures aim to increase soil cover during the months most exposed to erosion, to decrease the speed of water and thus increase its infiltration, which in turn decreases the amount of water and sediment removed flowing downstream into Lake Kivu and the Ruzizi River. The impact of these restoration measures can be quantified economically both in terms of the savings made in terms of increased productivity of the restored land or, for example, in terms of water treatment plants, as in the Sebeya and Murhundu catchment areas.

12.1.1. Estimating soil losses: RUSLE model

In order to quantify the annual soil loss within the study area and at the scale of each catchment, the Revised Universal Soil Loss Equation (RUSLE) model was used. A description of this model is provided in Appendix V. The rasters produced for each of the model parameters are provided in the appendices in digital format.

The results obtained give an average soil loss of 102 t/ha/year over the entire catchment area. For the Lake Kivu basin only, the model gives an average value of 116 t/ha/year, and for the Ruzizi river basin, an average of 91 t/ha/year. The slope factor is the dominant factor in the RUSLE equation and obtaining higher average rates in the Lake Kivu basin than in the Ruzizi basin is therefore relevant. Over the whole area, the figures are very high and reveal the major problem faced by the population, industries, authorities, etc., which is that the rate of erosion is very high in the Kivu basin. These figures are consistent with the rates of filling of reservoirs observed in these areas, particularly in the Kajeke catchment area, a tributary of the Mpanda.

The Chabiringa watershed has the highest average erosion rate with a maximum value of 170 t/ha/year. It is located in the Lake Kivu watershed. The other 46 average erosion rates that follow are also in the Lake Kivu basin or in the northern part of the Ruzizi River basin, where the slopes are very steep. At the level of the Ruzizi plain, the catchment areas of Muhira and Nyamagana have the highest average rates of erosion, with 109 and 108 t/ha/year respectively.

The highest erosion rate per hectare is locally around 290 t/ha/year and is located in the northern part of the Lake Kivu watershed, in the Chabiringa sub-catchment. This is explained by a young, poorly structured and friable volcanic soil type and a limited vegetation cover. Conversely, the rate of erosion on undisturbed forest land is generally very low, as in the Nyungwe-Kibira forest. However, other forests, reserves and national parks such as Gishwati, Virunga, South Masisi and Itombwe have severe erosion rates and reflect ecosystem disturbance. Canopy reduction, removal or alteration of understorey vegetation, mining, forest destruction, human-induced fires and soil compaction through grazing by domestic animals greatly increase the risk of soil erosion. Figure 31 presents an overview of the results of the RUSLE model.

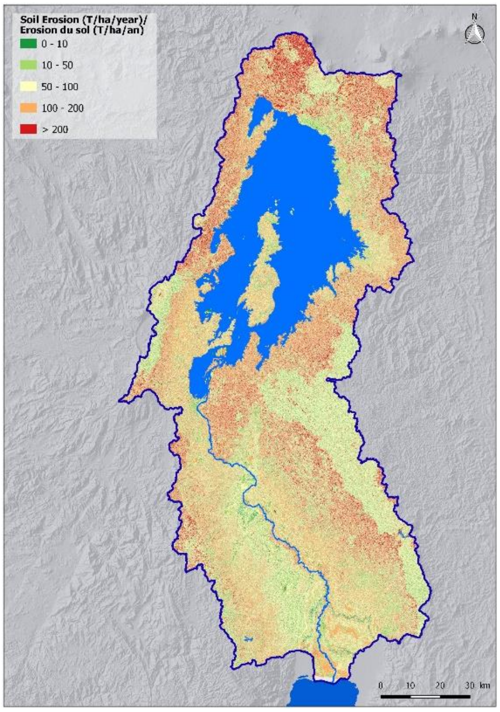


Figure 31: Map of RUSLE in t/ha/year.

Map No. 024 in the appendix shows the RUSLE model on the scale of the catchment area.

12.1.2. Anti-erosion measures: CROM model

Another model was used to determine the appropriate erosion control measures within the catchment area. This model, Catchment Restoration Opportunity Mapping (CROM), is based on 3 criteria: soil depth, soil cover and slope. Annex VI explains in detail on which parameters this model is based. These measurements are based on cultivation practices already present in the region. The following four types of anti-erosion measures are included:

- Radical terraces + agroforestry;
- Progressive terraces + agroforestry;
- Agroforestry;
- Afforestation.

For example, where the depth of soil and type of parent material allow, radical terraces may be the solution, provided it is accepted by the users. However, this solution cannot be implemented on all soil types, all depths and all slopes. Other types of layouts such as progressive terraces can be implemented (Figure 32). The implementation of terraces is ideally coupled with agroforestry to ensure slope stability, increase cover and biomass and provide additional income for farmers. Agroforestry consists of a mixture of fodder grasses and trees. On some plots with gentle slopes, agroforestry without terracing can be sufficient to ensure effective soil conservation. In contrast, on slopes that are too steep, only permanent forest cover can guarantee this.

Figure 32: Progressive terraces set up on steep slopes.

An overview of CROM's output is shown in Figure 33.

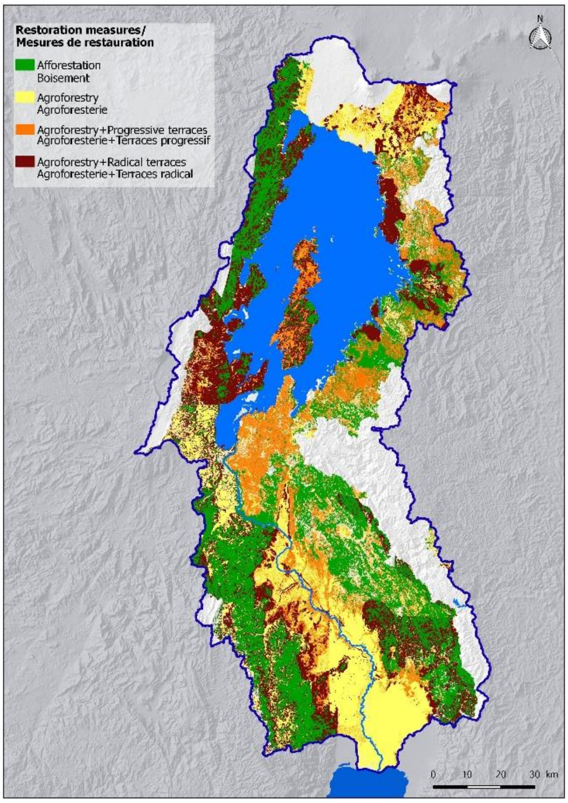


Figure 33: CROM map at the catchment scale.

Map No. 025 in the appendix illustrates the anti-erosion measures obtained from the CROM model.

12.2. Potential sources of pollution

The potential sources of pollution are diverse and can present a real danger for Lake Kivu and the Ruzizi River. Throughout the study area, there is no collective sanitation infrastructure, nor solid waste collection.

Bacteriological and chemical contamination due to inadequately treated, poorly treated or untreated domestic and industrial wastewater from rapidly growing urban agglomerations on lake shores adds chemicals, BOD and effluent to the lake and river.

In Burundi, in rural areas, the sanitation service is exclusively autonomous and is based on household self-investment. The Imbo plain is an area of intensive agriculture, and surface and groundwater are likely to receive large quantities of pesticides and fertilisers. However, no detailed studies exist that could show the extent of the problem and its geographical distribution.

In the DRC, the historic sanitation infrastructure of Bukavu is currently abandoned. There is no sewage disposal system in the city of Bukavu. Pit latrines are the main type of sanitation facility in the area; the few flush toilets with septic tanks are found in neighbourhoods with medium to high income levels. A significant part of the population uses open defecation. The city has no sites for the disposal of septic tank sludge and latrines. Solid waste is mainly collected by private individuals who dispose of it on open land about 2 km from the city limits. Due to the lack of adequate sanitation facilities, heavy contamination and pollution of streams, springs and wells throughout the city can be observed, although data are not available. In Goma, Kalehe and in the centres of the Ruzizi plain, no wastewater treatment plants exist.

In Rwanda, a project is underway to build four sewage sludge treatment plants, three of which are located in the study area, in Rubavu, Karongi and Ruzizi. This project, financed by the African Development Bank, should be completed in 2023. The construction and operation of a landfill and a sewage sludge treatment plant in these 3 cities will include the improvement of solid waste storage, collection, transport and disposal. This involves the development of a sanitary landfill site, the establishment of a disposal facility and the treatment of faecal waste (sludge), as well as the preparation of a complementary project on the option of recycling and reuse of solid waste. The expected capacity of the treatment plants by 2025 is 150 m^3/d for Rubavu and 30 m^3/d for Ruzizi and Karongi.

As far as solid waste is concerned, large urban agglomerations, in particular, lead to an accumulation of waste, including non-degradable plastic packaging that ends up in the lake and possibly the river.

In addition to the lack of sanitation and solid waste collection infrastructure, there is also pollution from industrial and mining sources. The small-scale agro-food industries in the basin are mainly those processing rice, sugar, maize, tea, coffee, but also animal products at the level of dairies, slaughterhouses and fish farms. These processing units, although small, can be a source of pollution when wastewater is discharged directly into watercourses. This is particularly the case for coffee washing stations, which are numerous in the area, milk collection centres and slaughterhouses. Mucilages, animal by-products or feed for fattening farmed fish discharged into the water can cause eutrophication of the water and a consequent increase in Biological Oxygen Demand (BOD).

The production plants present in the basin, and in particular in the Ruzizi basin, exploit the limestone quarries. Crushing activities can lead to air pollution and deposits on the leaves, which can impact agricultural productivity. The implementation of strict environmental standards has significantly reduced this kind of pollution that existed at the CIMERWA plant in Rwanda.

The beverage industries (BRALIMA in Bukavu and BRALIRWA in Rubavu) used to discharge their effluents directly into the lake. These two plants are now equipped with treatment plants, which allow them to reach acceptable discharge standards.

The PHARMAKINA factory (pharmaceutical industry) discharges its effluents directly into the waters of the basin; these waters are a source of significant pollution which adds to the sanitation problems of the city of Bukavu.

Mining activities in the region are dominated by artisanal mines which mobilise a young and poorly educated workforce; resources are exploited with very little investment to improve working conditions and environmental protection. The legislation in place is not really binding for these small-scale mines, which are a source of deterioration in the quality of surface water. Artisanal gold mining has developed strongly in the region, particularly in South Kivu province and in the rivers of Burundi. The processing of the ore involves washing with large quantities of water and, depending on the level of exploitation, may involve the release of mercury. This element presents a high risk of bioaccumulation and contamination of the food chain with a health impact for human beings.

Finally, other sources of pollution of the lake include shipping accidents that cause fuel and other plastic pollutants to be spilled into the lake waters.

12.3. Physicochemical quality of water

The major problem encountered in relation to surface water quality is the massive erosion observed in the basin, with an average soil loss value of around 100 t/ha/year in the basin. This erosion generates extremely high and widespread turbidity in most of the basin's watercourses. The phenomena of sediment transport in the watercourses and sediment accumulation, which are associated with the extreme turbidity observed, constitute the major problem facing the basin.

In addition to the alteration of surface water quality due to erosion and the massive transport of sediment to the rivers and Lake Kivu, the water resources of the basin are also threatened by various forms of pollution linked to urbanisation and industrialisation, especially in large cities such as Bukavu or Goma.

Other threats to the quality of the basin's water resources come mainly from mining and industrial discharges.

On the agricultural level, although the use of chemical fertilisers and phytosanitary products is globally moderate in the basin, their use may be locally more significant (especially in large farms in the Ruzizi plain) and may lead to surface and groundwater pollution in this area.

12.3.1. Lake Kivu and its catchment area

The water in Lake Kivu is of the soda-magnesian carbonate type, low in calcium and rich in potassium. The pH of the water is very high at the surface, with values of the order of 9, and decreases at depth tending towards neutralisation.

The waters of Lake Kivu are influenced by the salt content of the volcanic lava in the region and show consistent concentrations of soluble cations and anions that increase with depth.

Electrical conductivity and concentrations of major elements are relatively high at the surface of the lake, with electrical conductivity values of the order of 1000 to 1500 µS/cm and a salinity of the order of 1 g/l. Due to the permanent stratification of the lake and the existence of thermal springs at the bottom of the lake, these values increase with depth. Nitrates and nitrites become less abundant at depth, but phosphates are much more abundant than at the surface.

Very little data on the physicochemical quality of Lake Kivu is available, and the same is true for the rivers that form part of its catchment area: regular monitoring of the water quality (physico-chemical, bacteriological, biological) of the lake and its tributaries is very limited to date, with the exception of the data from Rwanda, which is included in the Rwanda Water Portal. Data from nine stations are thus available for Rwanda in the Lake Kivu watershed, six stations in rivers and three on the shore of the lake.

Table 15 below shows the average measured values of pH, electrical conductivity, dissolved oxygen and turbidity for the 6 river stations[34].

Table 15: Average measured values of pH, electrical conductivity, dissolved oxygen and turbidity for 6 river stations in the Lake Kivu basin.

		Rivers of the Lake Kivu catchment area					
Parameter	Unit	Sebeya to the Musabike sector	Sebeya before entering Lake Kivu	Karambo before its confluence with Sebeya	Karundura	Kamiranzovu	Cyunyu before entering Lake Kivu
pH	-	8.6	7.6	8.6	6.6	6.6	6.9
Conductivity	µS/cm	78	171	290	37	24	66
O2 (dissolved)	mg/l	6.2	5.7	5.6	6.8	7.1	5.6
Turbidity	NTU	792	569	704	980	185	219

The turbidity observed in the watercourses is generally very high, in relation to the significant erosion phenomena that characterise most sub-basins. This is the major problem encountered at the basin scale, in relation to water quality.

Table 16 below shows the average measured values of pH, electrical conductivity, dissolved oxygen and turbidity for the three Lake Kivu stations with data.

Table 16: Average measured values of pH, electrical conductivity, dissolved oxygen and turbidity for 3 stations in Lake Kivu.

		Lake Kivu		
Settings	Unit	City of Rubavu	Bralirwa	City of Kibuye
pH	-	9.1	8.8	7.5
Conductivity	µS/cm	1 751	1 708	1 180
O2 (dissolved)	mg/l	6.5	2.3	7.4
Turbidity	NTU	25	22	6

A generally basic pH and a high electrical conductivity exceeding 1000 µS/cm are observed.

[34] Data source: Rwanda Water Portal

12.3.2. The Ruzizi river and its tributaries

The hydrography of the Ruzizi plain is dominated by the Ruzizi River and its tributaries. The chemical composition of the water of the Ruzizi River is complex because it changes as a result of the contributions of its tributaries. The water quality of these rivers is controlled by the type of soil, geology and anthropological activities in the catchment area. The latter are a major source of environmental pollution and can cause a significant impact on public health.

In its upper course, in addition to the waters of the lake, the Ruzizi River collects the high salinity waters from the volcanic regions of South Kivu and the waters of the thermal springs. The Ruzizi River retains in its upper course many of the physicochemical characteristics of the water of Lake Kivu: pH close to 9, electrical conductivity of around 1000 µS/cm, high ionic concentrations (above 1 g/l), and low Ca/Mg ratio. Phosphates are observed in non-negligible quantities, while nitrate and nitrite concentrations are very low.

After crossing the volcanic areas and entering the plain, the salinity decreases from upstream to downstream, an effect due to the dilution by the tributaries of the low salinity Moyenne Ruzizi. The water of the Ruzizi is diluted along its course by the contribution of the waters of the tributaries, which are milder and much less mineralised. However, there is an increase in sulphates from upstream to downstream, which are thought to originate in the areas crossed by the Ruzizi and in the thermo-mineral springs located in the plain.

The water of the Ruzizi River shows strong seasonal variations in mineralisation, with the highest values being reached in the dry season. Indeed, in the rainy season, the inputs of low mineralised water from the tributaries of the Ruzizi River are more important and this results in a stronger dilution of the highly mineralised water coming from Lake Kivu.

The tributaries of the Ruzizi show, overall, pH values close to neutrality, and a very low electrical conductivity (rarely exceeding 200 µS/cm). The major ions are also present in low concentrations compared to the Ruzizi.

The primary source of the salinity of the Ruzizi River and the soils of the Ruzizi plain would therefore be linked to the volcanism of Kivu and the hydrothermalism of its watershed. Appreciable quantities of cations (Na, K, Mg and Ca) would come from the alteration of volcanic rocks. As for the anionic constituents, the primary source of the CO_3^{2-}/HCO_3^- would be the atmosphere while the ions $Cl^-$and SO_4^{2-} and part of the carbonates would be of hydrothermal and volcanic origin. Sulphates would also come from active hydrothermalism in the rift of Lake Tanganyika. Large quantities of ions are poured into the Ruzizi and eventually reach Lake Tanganyika. As the waters of the Ruzizi are in equilibrium with the water table of the Ruzizi plain, salts diffuse into the soil profile and are brought back into the surface layers by capillary rise. In the event of overflow during the rainy season, the soil becomes impregnated with salts and, in the dry season, the salts are brought to the surface by evapo-concentration. Factors such as the topography, the proximity of the lake, the semi-arid climate and poorly managed irrigation would facilitate the concentration of salts in the soils in Lower Ruzizi.

Ultimately, the Ruzizi would have the role of transporting ions whose primary source would be the meteoric alteration of basic rocks, hydrothermalism and the recent volcanism of South Kivu. Their accumulation in the soils of the Ruzizi plain would be accentuated by the combined effect of climate, topography and the proximity of the lake. The soils of the Ruzizi delta, due to its proximity to Lake Tanganyika, would be under the direct influence of the lake's waters and would receive, in addition to salts from the volcanism of South Kivu, salts from the sub-lacustrine hydrothermalism of Tanganyika.

In order to estimate the impact of anthropogenic activities on the surface water environment, a study of the water quality (physicochemical and bacteriological parameters) of the Ruzizi River and its major tributaries was carried out in 2018[35]. The results of this study highlight the following elements of surface water quality for the Ruzizi River and its tributaries:

- Very high turbidity, with measured values generally between 300 and 1000 NTU, regularly exceeding this high value;
- Very locally high values of Phosphates, Chlorides and Ammonium, without this problem being significant on the scale of the basin and the main sub-basins;
- High concentrations of iron and manganese;
- Dissolved oxygen in freshwater quality standards, generally in the range 4-9 mg/l ;
- Generalised and very high bacteriological contamination (total coliforms and E-Coli).

Apart from this one-off study, very little data is available on the physicochemical quality of the rivers in the Ruzizi catchment area: regular monitoring of water quality (physicochemical, bacteriological, biological) is very limited to date, with the exception of the data from Rwanda, which is included in the Rwanda Water Portal. Data from 4 stations are thus available for Rwanda in the Ruzizi catchment area.

Table 17 below shows the average measured values of pH, electrical conductivity, dissolved oxygen and turbidity for the 4 river stations[36].

Table 17: Average measured values of pH, electrical conductivity, dissolved oxygen and turbidity for 4 river stations in the Ruzizi basin.

		Ruzizi catchment area			
Settings	Unit	River Ruzizi upstream	Kamanyola River	Rubyiro River	Ruhwa River
pH	-	7.4	6.7	8.7	7.0
Conductivity	µS/cm	-	575	200	66
Dissolved O_2	mg/l	-	7	6,7	7,7
Turbidity	NTU	-	380	440	455

A basic to neutral pH and high turbidity are observed in relation to the very significant erosion phenomena that characterise most of the sub-basins in the area.

13. Natural hazards

The main natural risks identified in the study area are volcanic eruptions, earthquakes, gas explosions, floods and landslides. The risk of drought is considered to be low in the study area.

13.1. Volcanic eruptions

In the north of the study area, there are several volcanoes including Nyamulagira and Nyiragongo. The latter is an active volcano located at an altitude of 3,470 m, north of the city of Goma and is particularly well known for containing the largest lava lake in the world. As the lava is excessively liquid and the

[35] Strategic Environmental and Social Study (SESA) CEPGL, SMEC, April 2018

[36] Data source: Rwanda Water Portal

sides of the volcano are steep, the lava flows at speeds of up to 50 km/h. These two factors combined are a real danger for the cities of Goma and Rubavu, which during the eruptions of 1976 and 2002 saw tens of people perish and thousands of others displaced.

13.2. Seismic risks

The study area is located in the Albertine Rift where more than 28 earthquakes of magnitude greater than 4 have occurred in the last 15 years. The most powerful of these 28 was recorded in August 2015 with a magnitude of 5.8 in the locality of Kabare in DRC. These earthquakes can cause landslides in addition to human and material losses.

Map No. 026 in the appendix illustrates the earthquakes and volcanic eruptions in the study area.

13.3. Risk of gas explosion

Lake Kivu is highly stratified and its deep waters contain an enormous quantity of dissolved gas (3/4 carbon dioxide, 1/4 methane). In its static state, the lake is stable and harmless. However, a major disturbance from the volcanic activity of Nyiragongo located on the north shore of the lake or from the underwater volcanic cones (Ross *et al* 2014) could cause the deep waters loaded with dissolved gas to rise. These waters would then release a quantity of asphyxiating gas, either in the form of limited and localised emanations, or in the form of a cataclysmic explosion affecting a large part of the lake, threatening the safety of millions of people. Methane gas is the detonator of the time bomb represented by the enormous volume of dissolved carbon dioxide. In terms of assessing this risk, the extraction of methane means defusing this detonator and thus making the lake safe.

13.4. Floods

Floods and flash floods linked to torrential rains have become particularly frequent and devastating in Western Rwanda and Eastern Kivu. These floods depend on the intensity of the rains but also on the size and shape of the catchment area, its land use and topography. The frequency and intensity of these flash floods are intensifying due to climate change, urbanisation and the context of land degradation linked in particular to land pressure.

The main damages caused by floods are destruction of houses and infrastructure, loss and degradation of crops, soil erosion, landslides, injuries and loss of life. The impact on the food security of farming households is significant. In some cases, floods also lead to population displacement[37].

In April 2020, the flooding of the river Ruzizi caused by run-off water affected around 6,000 households west of Bujumbura, causing extensive material damage and population displacement. On the DRC side, nearly 20,000 farming households and 10,000 ha of food and market gardening crops were devastated[38].

13.5. Landslides

The slopes of the Albertine Rift on the shores of Lake Kivu are particularly prone to landslides and the number of events has been increasing since the 2000s. The predispositions are both natural (uneven relief, clay soils, intense rainfall, regional seismicity) and anthropogenic (reduction of plant cover,

[37] Communication MIDIMAR (Ministry of Disaster Management and Refugee affairs), floodlist.

[38] OCHA, Situation Report, South Kivu Province, 2020.

constructions and developments due to socio-economic activities). Rural centres, agricultural feeder roads, fields and watercourses are directly or indirectly threatened by mass movements.

According to the 2014 Mateso & Dewitte study carried out in Eastern DRC, [39]250 landslides have been recorded in the Kalehe Territory, 46 in the Kabare Territory north of the city of Bukavu and 13 landslides on the island of Idjwi, representing 0.6% of the area of the whole zone. Predisposing factors identified are slopes of more than 30 degrees, altitudes between 1400-2400 m, distance to the drainage network and soil types: Ferrasols, Umbrisols and Acrisols.

According to the Ministry of Disaster and Refugee Management (MIDIMAR), 40% of the Rwandan population is vulnerable to landslides with a higher risk in the districts of Ngororero, Nyabihu and Rutsiro.

13.6. Drought

The occurrence of drought is considered to be low in the coming decades in the study area[40]. As the average annual rainfall will only be marginally affected by climate change, but rainfall events will be more intense and scattered, drought risks cannot be excluded.

The effects on the population and the economic impact that droughts can have are difficult to quantify, but periods of heavy rainfall followed by long periods without rain undeniably reduce the volume of crop production.

14. Overview of the basin's ecosystem services

Ecosystem services can be defined as the benefits that an ecosystem provides to society, either directly or indirectly. They occur at several scales, from climate regulation and carbon sequestration on a global scale, to flood protection, soil formation and nutrient cycling on local and regional scales. The Millennium Ecosystem Assessment (2005) identifies four types of ecosystem services:

1. **Supply services** include the production of basic goods such as crops and livestock, fresh water, fodder, timber and biofuels, genetic resources and chemicals.
2. **Regulating services** are the benefits obtained when ecosystem processes affect the biological world around them. These services include flood and coastal protection, pollination, regulation of water and air quality, modulation of disease vectors, waste absorption and climate regulation.
3. **Cultural services are** the non-material benefits that people derive from ecosystems through enrichment, cognitive development, reflection, recreation, and aesthetic and cultural experiences.
4. **Supporting services are** those necessary for the production of all other ecosystem services. Their impacts are indirect or extend over long time scales. They include the production of biomass through photosynthesis, soil formation, atmospheric oxygen production, and nutrient cycling. Supporting services are basic ecological processes that maintain ecosystems without necessarily directly benefiting people. The value of these services is reflected in the other three types of services mentioned above (Hein et al, 2005).

[39] Jean-Claude MAKI MATESO & Olivier DEWITTE. Towards an inventory of landslides and elements at risk on the slopes of the Rift Valley west of Lake Kivu (DRC). Geo-Eco-Trop, 2014, 38, 1, n.s.: 137-154.

[40] IGAD. Great Horn of Africa: Climate risk and Food Security Atlas.2006.

When the level of detail of the information available at ecosystem level is sufficient, the analysis can be accompanied by an assessment of the cost related to their degradation or their economic value in comparison with an alternative economic valuation (e.g. agriculture, urban development or other). The following sections present the services provided in the study area with regards to three particular ecosystem types.

14.1. Aquatic Ecosystem

A description of surface waters (lakes and rivers) is included in the previous sections. This section presents the ecosystem services and the challenges encountered in maintaining the capacity of the ecosystem to provide these services.

Lake Kivu is a reserve of 560 km^3 of partially saline and alkaline water, of which the volume varies only slightly from season to season and over the years. Due to its physicochemical characteristics, but also to its bacteriological and possibly chemical contamination, the lake and river waters are unfit for human or animal consumption. The lake nevertheless constitutes a reserve of fresh water that could benefit the populations under specific conditions of exploitation.

14.1.1. Food supply

Although poor in nutrients, the lake contains a sufficient planktonic population to allow a fish production equivalent today to about 3,000 T/year in Rwanda and about 4,700 T/year in DRC for an income varying between USD 770,000 and USD 1,000,000 per year to the benefit of the riparian populations. Currently, the lake supports a fishing population estimated at around 2,250 people, but also all those involved in the processing and marketing of fish, the majority of whom are women. The total number of people working in this sector can be estimated at between 6,500 and 7,000 people in Rwanda and a similar population in DRC. In parallel to fishing, several fish farms have also been set up in recent years, mainly producing Tilapia. Fishing is much less developed on the Ruzizi River. There are also a few fish ponds in the Ruzizi plain.

Given the density of population living along the lake, maintaining and developing the lake's aquaculture production is crucial to ensure adequate protein supplies. The management of fish stocks is also critical for maintaining the income of the fishing populations.

14.1.2. Energy production

14.1.2.1. Exploitation of methane gas

As mentioned above, it is estimated that there are about 60 km3 of dissolved CH4 (at 0°C and 1 atm) in the deep waters of the lake. Two infrastructures are already in production on the Rwandan side, for a total installed capacity of 76 MW. The appropriateness of gas exploitation has been debated for a long time and due to the accumulation of gas volume, it is considered that its exploitation remains interesting despite high production costs.

While the exploitation of the lake's methane gas is a rare ecosystem service specific to Lake Kivu, the approaches used and the risks of disturbing the different water layers by pumping and especially the discharge of wastewater must be carried out with the utmost care, bearing in mind that a natural disaster or one linked to poor handling is not impossible.

The Rwandan government in partnership with REG and the companies already exploiting methane gas have set up the Lake Kivu Monitoring Programme which is operational only in the Rwandan part, with some collaborative projects with research centres in the DRC[41] . Given the dangerousness of the lake's exploitation programme and even the presence of dissolved gas in the deep layers, it would be desirable that a Danger Study and an Emergency Plan in case of an accident be prepared and implemented with the participation of all stakeholders in the basin.

14.1.2.2. Hydropower

Energy production is the main ecosystem service of the Ruzizi River, since its concentration of dissolved salts does not allow for other uses without prior treatment (agricultural use, livestock farming or drinking water supply). Other rivers with hydropower potential (see Section 10 Water) are in most cases also exploitable for drinking water or irrigation.

14.1.2.2.1. Sediment and pollution

The particular configuration of the natural lake upstream of the river offers a considerable advantage in terms of suspended solids in the turbined water. Indeed, the lake acts as an extremely efficient natural sand trap. The sediments carried by the Ruzizi are therefore mainly those brought by the direct tributaries, between the lake outflow and the last power plant. Given the land pressure in Bukavu, the current structures do not, however, operate at their maximum capacity; reductions in production can be attributed in particular to operations to clear the water intakes.

At the level of the tributaries of the lake and the Ruzizi, the situation is more problematic. The absence of a natural sand trap has a direct impact on the filling of reservoirs when they exist or on the production level of power plants when run-of-river intakes are involved. The power plants installed on the Sebeya River are therefore frequently experiencing production drops or shutdowns due to the high turbidities observed during heavy rains.

The cleaning of dams and intakes is costly and complicates a continuous maximum production level. As an example, the annual cost and lost revenue associated with sediment problems at the Gihira power plant (GIHIRA HPP operated by the Rwanda Mountain Tea factory) with a capacity of 1.8 MW was US$1,143,543 in 2008. The loss of income for populations without electricity is also high. The cities of Bujumbura, Uvira, Bukavu, Kalehe and Goma experience recurrent problems of power outages and high fuel costs for the operation of generators.

The vulnerability of hydropower works to sediment issues can be directly related to the sensitivity of the catchment area to erosion and to the average sediment production in t/ha/year. As indicated in section 12, while this sensitivity varies within the ABAKIR perimeter, it is globally very high (around 100 t/ha/year).

14.1.2.2.2. Dam failures

The Ruzizi III power station, foresees the construction of a dam 30 m high above the current river bed with a volume of 1.9 million m³. The potential impacts of such a large quantity of water in the reservoir represent a significant risk for the riverside populations living downstream and for the crops. A Danger Analysis and Accident Contingency Plan is being prepared as part of the studies related to the

[41] Notably a collaboration between the LKMP, the University of Volcanological Observatory of Goma (DRC) and the INES (Institute of Applied Sciences) in Ruhengeri (Rwanda) on the study on the geodynamics of the lake and its basins and mapping of systemic risk or a collaboration between the Institut Supérieur Pédagogique de Bukavu and the University of Rwanda on the evaluation of fish stocks.

construction of the Ruzizi III and should include modelling of the risks of dam failure. This analysis remains relevant also for the reservoirs built on the tributaries.

14.1.2.2.3. Hydro-ecological discontinuity

The diversion works constitute hydro-ecological discontinuities. These structures (mainly in the case of the Ruzizi River) constitute a barrier for fish migration, in particular *Barbus altianalis sp.* the only fish identified so far to migrate from Lake Tanganyika to Lake Kivu, with possible breeding grounds in some tributaries of the Ruzizi River. Fish ladders have been built on the first two power stations but need to be rehabilitated and similar structures should also be built on the power stations under design.

14.1.3. Drinking water supply

The aquatic ecosystem naturally ensures the supply of drinking water to the population living in the basin. As described in Section 10 (Water Use), the water consumed comes from rivers, lakes, springs or boreholes. The protection of watersheds to guarantee the quality of the water consumed is a major public health and economic issue. Given the quantities withdrawn for drinking water (and moreover returned through sanitation), the level of potential conflicts between drinking water and other uses remains limited. Nevertheless, quality aspects are crucial, as shown in the examples below:

- Some towns get their water from river intakes. This is notably the case of Rubavu (from the Sebeya) and Bukavu (from the Murhundu for the moment and from the Mpungwe in the future). The degradation of these catchment areas leads on the one hand to an increase in turbidity and on the other hand to a decrease in low water flows. The resource therefore diminishes over time and the cost of its treatment increases significantly. As an example, the additional cost linked to the exploitation of the Murhundu river compared to a river with better quality water (the Mpungwe) is estimated at almost 80,000 USD per year for the city of Bukavu alone. On the Rwandan side of the lake, WASAC's production costs are estimated at almost US$100,000/year (excluding energy) and are increased by frequent shutdowns of the stations during periods of heavy rainfall;
- Rural areas and small centres are supplied mainly from springs. In the plain, a few places are supplied from boreholes. The establishment of protection perimeters for these sources is for the moment limited to the immediate perimeter and is not systematically respected. The establishment of close and distant protection perimeters with restrictions, particularly in terms of agricultural activities (phytosanitary products and fertilisers), grazing or the installation of latrines for example. In the case of springs on the slopes, this mainly concerns bacteriological contamination. In the case of boreholes and springs located in the Ruzizi plain, it can be a question of physicochemical contamination for which more detailed studies for the delimitation of protection perimeters would be worthwhile. The conclusions of these studies could possibly indicate that these springs or boreholes cannot be exploited for human consumption and that other solutions for potable water supply (PWS) must be found through broader planning.

14.2. Forest Ecosystems

The basin of Lake Kivu and the Ruzizi River is delimited over a large part by high mountains resulting from tectonic ridges covered with dense primary forests at high altitude. The following tables present a summary of protected areas and forests for each country.

Table 18: Protected areas in Burundi

Forest	Altitude (m)	Surface area (ha)	Comments	Status
Kibira National Park	1 600 - 2 800	40 600	Mountain forest heavily disturbed by human activity.	Nature reserve
Ruzizi National Park	775	5 932 – 10 673	RAMSAR site	Nature reserve

Table 19: Protected areas in DRC

Forest	Altitude (m)	Surface area (ha)	Comments	Status
Mitumba Range Kahuzi-Biega National Park-	Kahuzi: 3,310 Biega: 2,790	60,000 ha Kahuzi-Biega Forest + ecological corridor linking forest 600,000 ha Maiko	Mountain forest disturbed by human activity, especially in its north-eastern part. Habitat of the Mountain Gorilla	UNESCO Heritage ICCN Protected Natural Park
Mitumba Chain Itombwe Forest	3 000	573 200	Forest disturbed by human activity, Habitat of the Grauer's gorillas	Nature reserve
Masisi Reserve				
Virunga National Park	2,400 and 4,507	125 000	Mountain forest disturbed by human activity	UNESCO Heritage. ICCN Protected Natural Park

Table 20: Protected areas in Rwanda

Forest	Altitude (m)	Surface area (ha)	Comments	Status
Volcanoes National Park	2,400 and 4,507	15 000	Mountain forest disturbed by human activity but protected.	National Park recognised by IUCN (category II)
Gishwati Forest	2 000 - 2 991	28 000	Mountain forest heavily disturbed by human activity.	Gishawti-Mukura National Park (IUCN)
Mukura Forest	2 300 - 2 696	2 000	Mountain forest disturbed by human activity but protected.	Gishwati-Mukura National Park (IUCN)
Nyungwe National Park	1 700 – 2 949	101 300	Mountain forest little disturbed by human activity and protected.	National Park (IUCN) managed by African Parks
TOTAL		142 000		

Table 21: Other (unprotected) areas such as forests in the basin.

Forest	Altitude (m)	Surface area (ha)	Comments
The relic forest of Sanza.	1 600 – 1 650	20	Forest disturbed by human activity. Difficult to conserve.
The relic forest of Busaga.	1 900 – 2 000	151	Aspect of apparently dense forest. Forest disturbed by human activity but protected.
Natural forest relic of Cyamudongo.	1 700 – 2 140	300	Effort to conserve this forest despite the ineffective protection which is reflected in the abundance of cut trees and considerable clearing on the edge.
TOTAL	-	471	

These areas represent an area equivalent to 30% of the basin, and in the case of the mountain National Parks, these forests are reinforced by afforestation mainly consisting of Eucalyptus and Pinus or even tea plantations in the buffer zone (Rwanda and Burundi) equivalent to 3% of the basin.

14.2.1. Supply services

Almost all the forests in the basin are water towers for the existing hydrographic networks. The forest cover, with its deep roots, allows the recharge of the underground water tables and slows down surface runoff. The majority of these forests (Nyungwe-Kibira forests, Kahuzi-Biega forests and the forests of the Virunga Volcanoes) are Afro-mountain rainforests, i.e. forests whose entire vegetative surface captures rainfall from mist or clouds and adds it, in the form of drops or runoff along the trunks, to the water balance of the catchment area. These forests contain species such as bromeliads, orchids, ferns, lichens and epiphytes.

The volume of water captured by these forests varies significantly according to rainfall regime, topographic location, cloud frequency or persistence, and the amount of wind-driven clouds. It can be in the order of 15-20% in areas receiving 2,000-3,000 mm of rainfall per year, and up to 50-60% in exposed ridges and areas of low rainfall[42].

Many of these forests are the main source of wood supply for domestic energy (biomass) but also for other uses. Plant resources are a significant source of food and medicine, particularly for local populations.

14.2.2. Climate regulation services

The regulating services of these forests are multiple. It must be noted that because of their altitude and their wide occupation in the area, these forests constitute a barrier to violent winds and are one of the reasons why Lake Kivu experiences very little mixing of the water layers. The presence of these high-altitude forests could explain the temperate climate in the northern part of the basin, which is a few degrees south of the equator[43].

[42] FAO, Studies No. 155 Forests and Water. 2005.

[43] Guillaumet J-L, 2009. The vegetation of the Rift Mountains. In "Le Rift est-africain : une singularité plurielle", IRD, Montpellier.

Forests contain large amounts of carbon dioxide (CO_2) that can be released into the atmosphere if they are felled or burned and replaced by permanent agriculture and grazing land. The economic value of forests is assessed according to the volume of CO_2 that is not emitted because it is currently stored in above-ground biomass. According to various researchers in the field[44], each hectare of old-growth tropical rainforest generally contains 120 to 400 tonnes of carbon equivalent in the above-ground vegetation and even more if we consider the underground biomass. The value of a tonne of carbon equivalent varies on the global market but is estimated to be 20 US dollars (USD) in 2020[45] . For the calculation principle alone, if the value is set today at USD 20 per ha, the value in tonnes of carbon equivalent of nearly 1,545,100 ha of primary forests would be estimated at USD 31 million.

14.2.3. Support service (nutrient cycling) and regulation in the face of climate change

Due to the deep and vigorous root bases as well as the different levels of plant cover and their covering canopy, forests provide the best cover to reduce all kinds of surface erosion and especially sheet erosion. The forest cover also constitutes the most suitable land cover to resist landslides, at least if they are only superficial.

The Nyungwe-Kibira complex on the peaks of the Congo-Nile Ridge, the Itombwe forest and the Kahuzi-Biega National Park play a key role in preventing erosion on the slopes and sedimentation of Lake Kivu and the tributaries of the Ruzizi River. These forests play a resilience role in the face of climate change in a context where climate projections indicate an increase in temperatures but also extreme climatic phenomena by 2050[46].

Any disturbance of this forest complex has serious consequences on the watersheds. For example, in the 1990s, substantial increases in sediment transport were observed in the Sebeya basin in Rwanda due to ongoing deforestation in the Gishwati-Mukura forests, with a notable increase in water turbidity as far as Lake Kivu.

Artisanal exploitation of minerals in the forests of Itombwe, Kibira and Kahuzi-Biega is a source of deforestation of protected areas and watershed degradation.

14.2.4. Cultural and tourist services

All of the parks in the region have a unique and endemic wealth of biodiversity that makes them sites of global importance. As such, three forest massifs have UNESCO World Natural Heritage Site status, namely Virunga National Park, Kahuzi-Biega National Park and Gishwati-Mukura National Park in Rwanda.

The Virunga-Volcanoes-Mgahinga National Park complex is known to generate annual revenues estimated at nearly US$9 million per year for the three parks, mainly because of the biodiversity they contain (the emblematic animal remains the Mountain Gorilla).

Indigenous populations used to live in all the forests of the basin and the riparian populations do not always understand the importance of conserving natural forests if a benefit-sharing approach is not put in place as well as mechanisms to enable them to access some specific services of the National Parks

44 Frangi & Lugo 1985, Rai & Proctor 1986, Brown & Lugo 1992, Fearnside 2000, Houghton et al. 2000, Hughes et al. 2000, Nascimento & Laurance 2002, Zheng et al. 2006

45 https://carboncreditcapital.com/

46 Intergovernmental Panel on Climate Change (IPCC) 2020 Report

(medicinal plants, water...). Thus, certain indigenous populations generally remain on the periphery of these forests, sometimes living from activities related to ecotourism, beekeeping or sometimes, as in the case of Kahuzi-Biega NP, from timber exploitation or poaching. In the latter case, collaboration between the NP and the local population remains problematic, in a general context disturbed by the presence of armed groups.

14.3. Agricultural, forestry, pastoral and urban ecosystems

This ecosystem covers the entire area between the forest massifs, most of which are protected areas, and the aquatic ecosystem (Lake Kivu). It is in this zone that the majority of the population resides and conducts activities. Any soil degradation in this basin area does not allow this ecosystem to play its role effectively and to guarantee services in the basin itself and downstream. The conservation of the buffer zones around Lake Kivu or the banks of the main rivers is not always respected, especially in the development zones of the cities, which leads to high risks of water pollution and destruction of the banks which are also fish breeding areas.

14.3.1. Urbanisation and spatial planning in the basin

From an ecological point of view, when urbanisation is planned, it theoretically makes it possible to concentrate basic services (energy, water, sanitation) and to limit the impact on the surrounding ecosystem. Urbanisation also makes it possible to limit land pressure on agricultural land. This process can be carried out effectively if certain conditions are met, particularly in terms of economic opportunities in cities. As mentioned above, with the exception of two large urban centres (Bukavu and Goma), the majority of urban centres are small. The surface area occupied by urban spaces in the basin so far represents only 1% of the territory of the basin, while the population, with an average growth rate of 3%, already amounts to almost 10 million people. Two other cities located in the delta of the Ruzizi river have a major influence on the basin, namely the urban centre of Uvira and the city of Bujumbura. The development space in the basin is limited by the presence of mountain ranges and forests in the east and west.

In order to effectively support urbanisation, spatial planning and urban development plans are necessary, based on realistic projections of demographic and economic growth. The present basin has definite potential for development once the energy and agriculture sectors are fully developed, as well as tourism and lake transport. This development should be accompanied by controlled urbanisation with, in the best case scenario, a decongestion of the cities of Goma and Bukavu through the creation of secondary towns with all the necessary urban facilities. In the case of Rwanda, the towns of Rubavu, Karongi and Ruzizi have been identified as secondary towns intended to provide the populations of the basin with urban infrastructure and services. These three cities have urban development plans and land use plans which unfortunately are not well followed, as a number of agricultural plots have been converted into urban land.

Certain challenges are particularly acute in the area of urbanisation:

- The absence of urban development plans and spatial planning plans is a hindrance to the structured development of the basin. It is essential to better manage the available space to ensure food security for the population, industrial development and the development of residential areas while ensuring basic services. The development of sanitation systems is urgent in all the cities in the basin, particularly those with a large population, bearing in mind that the consequences of a lack of adequate sanitation are paid for by the poorest populations in terms of medical care and lost income;

- Climate projections indicate an increase in temperature and rainfall intensity. These conditions present a risk of increased impact in terms of erosion and watershed degradation. The majority of the cities are located in areas vulnerable to erosion and landslides since they are at the foot of the foothills. Cities themselves will have to adapt by integrating into the design standards of infrastructure (roads, drainage networks...) standards that allow for resilience to extreme weather conditions.

14.3.2. Agriculture

Two particular production areas can be identified in the catchment area, namely irrigated agriculture in the Ruzizi plain and rain-fed agriculture on the slopes.

14.3.2.1. Irrigated agriculture in the Ruzizi plain

The sustainability of irrigation schemes depends, on the one hand, on the maintenance of the infrastructure against sedimentation and destruction and, on the other hand, on the management and conservation of soil in the catchment areas supplying the irrigation intakes. Maintenance is partly effective in Burundi and Rwanda but much less so in DRC. The management of erosion in the catchment basins remains a common issue in all three countries. A final challenge, encountered mainly on the Burundian side, concerns the availability of the resource and the organisation of water towers in the irrigated perimeters. The level of intensification of agriculture also leads to contamination of surface and underground water. These different points are discussed below:

- The silting up of canals is in the case of functional perimeters effectively managed by water users' associations, through sand removal works and dredging operations. However, the main cause remains the input of sediment from rivers, which is directly linked to the degradation of catchment areas and river beds. With regards to the degradation of catchment areas, restoration actions can be carried out within the framework of a CROM-type analysis, in order to promote an agriculture allowing a more efficient conservation of soils and possibly also of buffer zones around watercourses. With regards to river beds, many rivers are subject to more or less intensive gold panning, which is often the main cause of the presence of sediment in the water. National legal frameworks rarely authorise this type of exploitation, but control remains problematic;
- In the Imbo plain, there is a recurrent conflict for access to water in the irrigated areas between farmers, with some blocks being more irrigated than others, but also between farmers and livestock breeders, particularly in the dry season, when pasture and water are scarce upstream of the basin. This livestock can degrade the canals by trampling. However, the combination of livestock breeding and irrigated agriculture is a winning practice when it is well managed (livestock breeding in permanent stalls), the use of organic fertilisers improves soil quality and allows better use of chemical fertilisers);
- Although few study data are available at present concerning water and soil contamination, it is expected that concentrations in drainage water of irrigated areas are highly elevated in compounds from fertilizers (nitrates, phosphates) or phyto-sanitary [47] products. The

[47] According to Rwanda's national fertiliser policy (2014), the target was to use 45kg of fertiliser/ha by 2017.

accumulation and migration of these contaminants can cause various problems ranging from water eutrophication to contamination of the food chain.

The maintenance of intensive irrigated agriculture in the plain implies the simultaneous implementation of monitoring measures and preventive and remedial actions for each of the points raised above.

14.3.2.2. Agriculture in the catchment areas

Agriculture in the catchment areas represents the main economic activity for almost 90% of the catchment area's population. The practice of associating agriculture and livestock farming has long existed in the basin, particularly because of the small size of family land. This agriculture is mainly subsistence farming that depends on climatic conditions. Cash crops are also present in the basin, mainly tea and coffee.

Agricultural practices on the slopes are, however, a source of soil degradation. Deep ploughing and total weeding of plots of land at the beginning of the rainy season leaves the soil bare or with crops that do not cover the soil sufficiently, such as potatoes. Mulching is little practised. As mentioned in the previous sections, soil conservation and erosion control are essential not only to enable farmers on sensitive land to maintain their productive capacity, but also to ensure downstream ecosystem services.

15. Synthesis of challenges and opportunities in the basin and for ecosystem services

Table 22: SWOT analysis method for the Lake Kivu and Ruzizi River basin.

STRENGTHS	WEAKNESSES
Predominantly young population (average age 18 years) => Large available labour force **Rapid urbanisation in the Basin** => Concentration of socio-economic infrastructures and presence of an important market for food and manufacturing products. Labour-intensive and productive **agricultural and livestock activities due to** good soil quality (volcanic and sedimentary), dynamic farmer organisations and access to factors of production (organic and chemical fertilisers, pesticides). **Major investments in watershed protection** through the dissemination of anti-erosion, agroforestry and reforestation practices in parts of the basin. **Strategic electricity production** for the three countries. **Large drinking water reserve in Lake Kivu and an abundant hydrographic network** sufficient to supply drinking water to the entire population, electricity production and the development of industrial and mining activities. **Presence of forests** that play an important role in climate regulation, soil retention and resilience to climate change. **Regulations in place for the protection of internationally registered protected areas** (3 Ramsar sites (Virunga NP, Nyungwe NP and Ruzizi NP). 3 UNESCO World Heritage natural sites (Kahuzi-Biega NP, Virunga NP and Gishwati-Mukura NP). **Regulations in place in countries** for the prevention of environmental and social degradation (ESIA) and for the implementation of IWRM.	**High population density and high level of poverty** => insufficient employment opportunities, deforestation due to increasing domestic energy demand, illegal occupation of land in protected areas and illegal fishing and mining practices. **Insufficient water supply and sanitation infrastructures in urban centres** (rainwater, wastewater and solid waste) => high cost of maintenance of the Ruzizi hydroelectric plants, degradation of the basin's tourist potential. **Insufficient or no urban development plans based on real population growth** => high land speculation on urban land in some countries, inappropriate land use and land degradation, lack of urban social infrastructure and health degradation. **Inappropriate agricultural practices on steep slopes** => significant erosion on the slopes despite anti-erosion practices, high cost of water treatment for water supply and operation of micro hydropower plants, increased vulnerability to climate change, chemical pollution of transboundary water resources and impact on aquatic biodiversity. **Inappropriate industrial and mining practices** => chemical, sedimentary and organic pollution of water resources, degradation of watersheds and risks to the health of populations. **Insufficient application of the regulation in place for the conduct and implementation of ESIAs for socio-economic activities in the basin** => Sedimentary and chemical pollution of the lake and high bacteriological load, degradation of the tourist value of the lake and the Ruzizi National Park, risks to the health of the populations. **Insufficient application of the regulations in place for the implementation of IWRM in the countries** => insufficient knowledge of the water resource in the basin (quality and quantity), absence of regulations for the prevention of transboundary pollution and monitoring mechanisms, absence of transboundary regulations for the protection of the banks of shared rivers and lakes and monitoring. **Insufficient management and protection measures for certain protected areas and** risks of degradation of watersheds and ecosystem services in the catchment area, increased vulnerability to climate change, particularly of cities located at the foot of mountain ranges.

OPPORTUNITIES	THREATS
Development of the exploitation of mineral resources following certification and traceability of origin procedures in accordance with regional and international standards and existence of practices reducing the use of heavy metals, particularly in gold panning. **Development of sustainable agriculture** based on irrigated **agriculture** in the Ruzizi Plain and the catchment areas based on professionalization of farmers, control of the use of agrochemicals and anti-erosion practices and continuous supervision. **Potential development of the industry** based on more accessible electric power, compliance with national and international standards for the protection of the environment and social conditions. **Development of the tourism sector in the basin** also based on the sustainable conservation of globally important Protected Areas and based on the respect of national and international standards for the protection of the environment and social conditions, as well as on an improvement of IWRM and water quality in the basin. **Development of river transport** promoting the exchange of goods and people and opening up the basin. **Existence of a framework for cross-border cooperation** in basin management, for sharing knowledge of water resources and monitoring the sources of pollution and degradation of the catchment area.	**High vulnerability of the basin to climate change** which requires strengthening the conservation of protected areas but also the acquisition of knowledge on water resources for the integration of technical standards for adapting infrastructures to climate change (urban, transport, energy or irrigation infrastructures). **Recurrent politico-military insecurity and ethnic tensions** that require political will and regional cooperation for conflict resolution. **Basin located in an active volcanic and seismic zone** that requires constant monitoring and the implementation of early warning mechanisms. **High concentration of toxic gases in the lake** which requires constant monitoring and highly controlled exploitation of the methane gas present.

Part 2: Basin management and evaluation framework options

16. Hydrometeorological monitoring networks in the basin

16.1. Identification and characterisation of existing monitoring networks

16.1.1. Climatology

Within the study area and in the immediate vicinity, a total of thirteen functional weather stations with time series data are available (see Map No. 014). This figure does not include the few stations located in the DRC for which data is not available or for which data is too fragmentary.

These stations produce at least the following data:

- Average daily maximum temperature (°C) ;
- Average daily minimum temperature (°C) ;
- Average relative humidity (%) ;
- Average wind speed (km/day) ;
- Average hours of sunshine (day) ;
- Average solar radiation (MJ/m²/day) ;
- Monthly rainfall (mm/month) ;
- Actual monthly rainfall (mm/month) ;

Global databases such as those used by CLIMWAT (FAO) provide reference rainfall and evapotranspiration values at monthly time steps (calculated by the Penman-Monteith method). In terms of geographical coverage, the existing stations satisfactorily cover the eastern part of the ABAKIR perimeter, but little or no information is available for the western side (DRC).

16.1.2. Surface water

16.1.2.1. Hydrometric networks

In terms of surface water monitoring, an overview of the current situation was established during the field work organised as part of the study (Figure 34). In the study area, on the Burundian side, the eight existing stations were visited. The Geographic Institute of Burundi (Institut Géographique du Burundi - IGEBU) has a network of technicians who read limnimetric scale levels twice a day.

Figure 34: Limnimetric scale on the Ruhwa River, Burundi (October 2020).

In the Congolese part of the catchment area, no limnimetric station has been reported.

In Rwanda, in the study area concerned, seven stations have been identified as well as a non-functional lake water level measurement station. Five additional stations are listed in the Sebeya basin on the water portal site, some functional (2), others old and disused (3). New hydrological stations have been installed on the Rwandan side and are not yet fully functional (work in progress or real-time data transmission not yet effective). The measurement time step of these new stations is typically 15 to 30 minutes, which allows for detailed hydrological monitoring, particularly in terms of studies, forecasting and risk management related to flash floods.

Figure 35: Hydrological station on the Pfunda River, Rwanda (October 2020).

Map No. 014 in the appendix illustrates the location of the hydrometric stations.

16.1.2.2. Monitoring of surface water quality

Monitoring of surface water quality is relatively limited in the basin and varies greatly from one country to another.

In Rwanda, 15 quality monitoring stations are listed in the study area on the Water Portal site, but they are currently not subject to periodic monitoring: since 2015, only a few scattered data have been recorded. The parameters measured at these stations are pH, TDS, TSS, temperature, electrical conductivity, dissolved oxygen and turbidity. Among these stations, three concern the quality of Lake Kivu's water, while the others are located on rivers.

No surface water quality monitoring stations are listed in Burundi and DRC.

Map No. 014 in the appendix illustrates the location of surface water quality monitoring stations.

16.1.3. Ground water

Regular groundwater monitoring is very limited in the basin. There are only four groundwater monitoring stations in the entire basin, all located in Rwanda. These are automatic groundwater level monitoring stations, based on pressure probes, installed in 2016. There are no groundwater monitoring points in Burundi or DRC. Concerning the monitoring of groundwater quality, no point has yet been identified in the basin.

Three piezometers located within the basin perimeter on Rwandan territory are monitored for water level, conductivity and temperature. These piezometers are located respectively in Rubavu (Cyanika and Kabushongo) and Karongi (Kimigenge). A fourth piezometer has been abandoned (Karongi, Kimana). The data concerning these piezometers are freely available on the water portal site. Map No. 008 in the appendix illustrates the location of the groundwater monitoring stations.

16.2. Recommendations for optimising existing monitoring networks

16.2.1. Climatology

Over the last few decades, many stations have enabled the acquisition of climate data in a more or less complete and continuous manner. Some of these stations are now disused. The conclusions discussed below relate to the stations that are currently operational.

There is a significant imbalance between the eastern part of the basin with often long and complete historical data and the western part for which very little data is available. In view of this disparity in coverage and the availability of global data sets, it is recommended to operate as follows :

- Maintenance of existing meteorological stations. The existing networks allows for global dataset correction therefore, no specific densification of the network is required;
- Exploitation of global data sets (CHIRPS and GLOBAL-PET of the CGIAR-CSI) possibly corrected on the basis of the few ground stations in relation to regional specificities not taken into account in the global data sets (e.g. the Ruzizi plain for which FTE is globally underestimated in the GLOBAL-PET). These datasets are available free of charge on a global scale and on a daily time step basis. The balance sheet model developed in the study of the initial situation was based on these corrected data.

Daily time series and the corresponding decadal, monthly or annual statistics can be updated at a given frequency (e.g. monthly or annually) to take account of climate change.

16.2.2. Surface water

Like the climate monitoring network, the hydrometric monitoring network has evolved over the last few decades. Some stations are no longer functional today. The functional stations as well as the potential sites for new stations were visited as part of this study. These proposed stations or sites are presented in the digital appendices in KMZ format (viewable in Google Earth).

The hydrometric monitoring network must be densified. Unlike climate data, it is not possible to use global data sets. It is therefore imperative to plan a series of new stations and to maintain the quality of the data currently produced on the rivers being monitored.

As part of the establishment of the balance model (cf. study of the initial situation), six main stations (one tributary of the lake, the Sebeya and five tributaries on the left bank of the Ruzizi river) were used to evaluate the runoff contributions. More detailed hydrological monitoring is required with the installation of limnimetric scales on the DRC side and complements on the Rwandan rivers.

This study identified potential sites for the installation of new hydrological stations have been identified (Table 23). These sites have been chosen in ordrer to provide information on all major rivers with a sufficient distribution throughout the catchment area. These sites are shown on Map No. 014 and in the KMZ file (descriptive sheets).

Table 23: Potential sites of hydrological stations located during the field visit (October 2020).

Country	Name of the river	Province
Burundi	Muhira	Cibitoke
Burundi	Little Rusizi	Bujumbura Rural
Burundi	Ruzizi (Kavimvira)	Cibitoke
Burundi	Great Ruzizi	Bujumbura Rural
DRC	Bishalalo	South Kivu
DRC	Chabiringa	North Kivu
DRC	Kiliba	South Kivu
DRC	Kyaraboze	South Kivu
DRC	Luvubu	South Kivu
DRC	Mpungwe	South Kivu
DRC	Murhundu	South Kivu
DRC	Mushuva	South Kivu
DRC	Ruberizi	South Kivu
DRC	Ruvinvi	South Kivu
DRC	Ruzizi	South Kivu
DRC	Shange	South Kivu
DRC	Bidagara/Lwiro	South Kivu
Rwanda	Karundula	Western Province
Rwanda	Kirimbi	Western Province
Rwanda	Koko	Western Province
Rwanda	Muregeya	Western Province
Rwanda	Musogoro	Western Province
Rwanda	Mwaga	Western Province
Rwanda	Ruzizi	Western Province

On the Burundian side, the limnimetric scale located on the Muhira has recently been torn away by the river and therefore needs to be replaced. In the Congolese and Rwandan parts of the watershed, future stations are to be placed on the main rivers flowing into Lake Kivu and the Ruzizi River, where no stations have yet been installed in the case of Rwanda.

There are, however, two priority stations to be installed throughout the catchment area. These are to be placed on the Petite Ruzizi and on the Ruzizi, at the outflow of Lake Kivu. These would substantially improve the quality of the balance models.

The opportunity to transfer data in real time is relevant. This is the case on part of the stations on the Rwandan side. The existing stations on the Burundi side be improved. In the case of the DRC, it is suggested to first have simple liminimetric stations, so as to be able to evaluate after one or two years of acquisition of measurements the importance of equipment for real-time transmission.

16.2.2.1. Water quality

16.2.2.1.1. Quality of watercourses

As indicated in the first part of the report, one of the critical points in the management of the catchment area is the problem of erosion. Systematic measurement of soil losses at catchment level is complex to implement. An indirect indicator of watershed erosion is the turbidity of the water flowing out of the watershed. Turbidity is a simple parameter to measure. In qualitative terms, measuring turbidity provides crucial information on the suitability of water for different uses (drinking water supply, irrigation, hydropower, fish farming, etc.). On the quantitative level, it is possible to link turbidity values to transport values by carrying out spot measurements of suspended load.

As far as possible, this type of analysis should be carried out initially at the level of the sub-basins with the highest values of sediment transport by erosion, identified in the first part of the report. Turbidity measurements could be carried out daily on these basins, in order to obtain time series reflecting inter- and intra-annual variations and thus the level of degradation or the impact of restoration projects in a basin.

Periodic monitoring of the water quality of the Ruzizi River is also proposed, from the plain to the mouth of Lake Tanganyika. This monitoring aims to characterise the potential impact of hydro-agricultural activities in the plain on the water quality of the Ruzizi River, with regards to the risks of contamination of the latter that may result from the drainage of irrigation water loaded with residues of agricultural inputs (nitrogen compounds, phosphates, pesticides). Quarterly sampling of the Ruzizi River is recommended at two distinct points, namely at Cibitoke and at the mouth of Lake Tanganyika. The monitoring parameters proposed in the first approach are: nitrogen compounds, phosphates, sulphates, chlorides, pesticides, pH, electrical conductivity, dissolved oxygen and turbidity.

16.2.2.1.2. Water quality of Lake Kivu

A monitoring of the physico-chemical quality of the water of Lake Kivu is recommended, on a quarterly basis (in order to characterise the intra-seasonal variations), on the lake's shoreline waters in the towns of Bukavu / Ruzizi, Kalehe, Goma / Rubavu, and Karongi.

Quarterly monitoring of the physico-chemical quality of the lake water at these four points would cover the following elements: pH, electrical conductivity, total dissolved solids (TDS), temperature, redox potential, suspended solids (SS), dissolved oxygen, biological oxygen demand (BOD), chemical oxygen demand (COD), Chlorides, Sulphates, Phosphates, Nitrogen, Phosphorus, Nitrites, Nitrates, Ammonium and heavy metals.

16.2.2.2. Inventory of impoundments

No exhaustive data concerning the characterisation of water retaining structures exists. This characterisation could typically relate to the production of height-surface-volume curves as well as balances (including leakage flows) for each of the retaining structures, regardless of its purpose (hydro-agricultural, hydro-electricity, mixed use).

16.2.2.3. Other types of data

Free satellite data with interesting spatial and spectral resolutions are increasingly available. This is particularly the case for SENTINEL images (spatial resolution of 10 m) for which, in addition to raw images, preliminary analyses are also available. Indicators such as a moisture or vegetation index (NDVI) also make it possible to understand the level of functionality of certain hydro-agricultural infrastructures or the level of filling of reservoirs, for example. The acquisition frequency of these images is almost two images per month, which provides an ideal observation frequency for a precise understanding of the spatio-temporal evolution of water uses. An example of the type of images available is shown below (Figure 36). The exploitation of these data is possible under GIS, with the possibility to extract time series, etc.

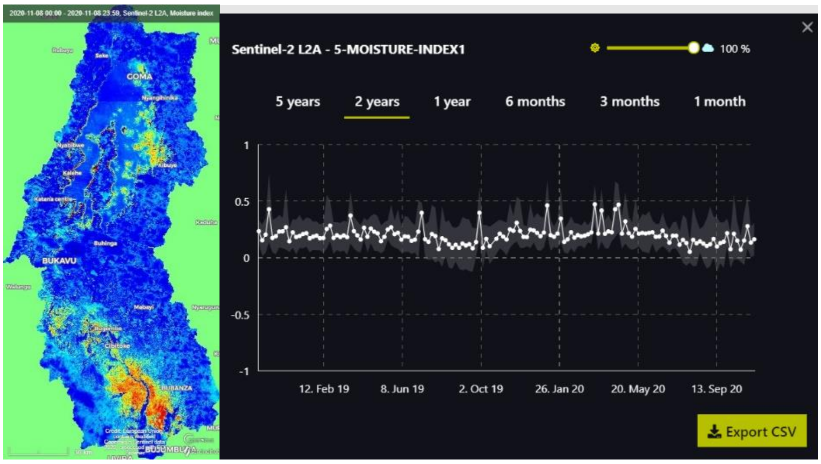


Figure 36: Moisture index obtained from sentinel images (https://apps.sentinel-hub.com/eo-browser/)

The evolution of land cover is also available free of charge each year through ESA-CCI products. This information, available at a spatial resolution of 300 m since the 1990s, makes it possible to monitor changes in forest cover and urbanised areas. Annual monitoring of the available data would allow to increase the level of knowledge of land cover in the basin at low cost.

16.2.3. Ground water

Periodic monitoring of groundwater levels in the basin is to date extremely limited, and no periodic monitoring of groundwater quality has been identified (see section 16.1.3).

The groundwater resources of the alluvial aquifer of the Ruzizi plain in Burundi and DRC are characterised by a very high exploitation potential, linked to the very favourable hydrodynamic properties of this aquifer (high hydraulic conductivity, significant extension and high renewable reserve, high recharge). It is the most productive aquifer in the basin, and its spatial extension offers interesting prospects for exploitation with a view to the development of the basin. These groundwater resources are also very vulnerable in relation to anthropogenic activities on the surface, given the generally shallow depth of the water table and the permeability of the land cover. Given the development of hydro-agricultural activities in this area, the risks of contamination of this water table by leaching of agricultural inputs (fertilisers and pesticides) are not negligible.

The establishment of a network to monitor the levels of the alluvial groundwater in the Ruzizi plain, and to monitor the quality of this groundwater, is recommended. This network would essentially aim to better understand and monitor the spatio-temporal evolution of the dynamics of the accumulation of agricultural inputs (nitrates and pesticides) in the water table.

This network would be made up of four observation points (piezometers) located in the Ruzizi plain, equipped with combined pressure-conductivity temperature probes (CTD probes) allowing the automatic and simultaneous measurement of groundwater level, electrical conductivity and temperature. Weekly time step measurements are recommended, using the automatic probes installed in the piezometers.

Periodic monitoring of the physico-chemical quality of the aquifer would also be ensured from these four observation points, by taking samples and analysing the following physicochemical parameters: pH, electrical conductivity, temperature, iron, manganese, nitrate, sulphate, phosphate, sodium, potassium, chlorides and pesticides. Two sampling campaigns per year are recommended.

The proposed location of the four points for monitoring the quality of the alluvial water table of the Ruzizi plain are shown on Map No. 007 in the appendix.

17. Legal framework in the basin

17.1. Legal framework for the management of water resources

Burundi, the DRC and Rwanda have legislative frameworks for water management in the form of various laws, codes and ministerial decrees. These countries also have strategic documents for the implementation of the legal framework (Table 24).

17.1.1. Situation in Burundi

The management of water resources is governed by law n°1/02 of 26 March 2012 on the water code. This law lays down the fundamental rules and the institutional framework intended to ensure the rational and sustainable management of water resources, of hydraulic installations and works of public interest, to allow the conservation and protection of this resource and its rational exploitation according to the different needs. More specifically, this law defines :

- General provisions including management principles and definitions
- The institutional framework for water resources management
- The financing of water management
- The protection (quantitative and qualitative) of water resources
- The combat against the harmful effects of water (pollution, floods, etc.) as a priority.
- Sewage and rainwater drainage
- The different uses of water in the public hydraulic domain

In addition, the country has a National Water Policy (2009), a National Water Strategy (2011) and a National Sanitation Policy (2013).

17.1.2. Situation in the DRC

The legal provisions of the water sector in the DRC has been made up for a long time of scattered texts dealing with the management and protection of water, springs, rivers, lakes and the delimitation of the territorial sea. These texts were unsuitable and had shortcomings in terms of their applicability in relation to the provisions of the current Constitution.

Since 31 December 2015, the DRC has had Law No. 15/026 on water, which is based on Articles 9 and 48 of the Constitution. It also includes the provisions of Articles 203(16) and 204(26) relating to concurrent constitutional powers and those exclusively devolved to the provinces; as long as it respects the universal principles of water resource management and public water service.

The purpose of this law is to:

- Establish the rules and instruments necessary for the rational and balanced management of water resources;
- Establish rules of accountability for public water and sanitation services;
- Resolve the problem of an inadequate legal and institutional framework and the low rate of access to drinking water;
- Protect water resources and regulate their use

The important innovations introduced in the framework of this law are, in particular:

- Emphasis on the priority uses of water and taking into account the option exercised by the government to further develop growth-generating sectors; Covering the water needs of all categories of consumers; Creating a framework setting out clear tariff rules according to the principles of true pricing, equality, equity and non-transferability of charges;
- The establishment of a dispute settlement mechanism
- The protection of consumers with regards to the potability of water
- The obligation to protect the environment for all development projects in the sector. In particular, it reinforces the requirements for an environmental and social impact assessment prior to the concession and the withdrawal of water resources.

The Water Law mentions a national policy and plans for the development and management of water resources at the river basin level, but these have not yet been drawn up.

17.1.3. Situation in Rwanda

The recent law n°49/2018 of 13/08/2018 which governs the use and management of water resources in Rwanda repeals the law n°62/2008 of 10/09/2008 that laid down rules for the use, conservation, protection and management of water resources.

This new law comprises seven chapters subdivided into several sections and 42 articles, and also sets out :

- General provisions and definitions of natural and artificial water,
- Management and use of water resources through guiding principles, water resources management institutions and water resources planning (master plans, information systems, ownership, control and use of water resources),
- Protection of water resources,
- Flood and drought management,

- Administrative sanctions, offences and penalties,
- Transitional and final provisions.

This law is supplemented by ministerial orders relating to the management of large river basins (Order 002/16.01 of 2013) and procedures for the declaration, authorisation and concession of water use (Order 007/16.01 of 2013).

Rwanda also has a national water resources policy (2011) and a water resources master plan (2015) for the period 2010-2040 that quantifies water availability and demand at the national level and for the nine basins. An irrigation master plan was developed in 2010 and an irrigation policy in 2015.

17.2. Legal framework for environmental management

Water resource management is part of a broader legal framework for natural resource management and environmental protection described specifically for each country below. In addition, these three countries have ratified various international conventions on environmental protection and biodiversity, including the Convention on Biological Diversity (1992) and the United Nations Framework Convention on Climate Change and the Convention to Combat Desertification (2012). They have also developed their own national policies, strategies and action plans related to environmental management and the protection of natural resources and biodiversity (Table 24).

17.2.1. Situation in Burundi

In Burundi, the main laws are Law n°1/010 of June 2000 defining the environment code supplemented by the decree of 07/10/2010 on environmental impact assessments.

There are also law n°1/11 of 2010 on the navigation and river transport code, law n°1/10 of 2011 on the creation and management of protected areas, law n°1/13 of 2011 on the revision of the land code, law n°1/21 of 2013 on the mining code, law n°1/07 of 2016 revising the forestry code and decree n°1/06 of 1980 on the creation of national parks and nature reserves.

In 2003, Burundi, DRC, Tanzania and Zambia signed a convention on the sustainable management of Lake Tanganyika. Only Burundi and Tanzania ratified it in 2004.

17.2.2. Situation in the DRC

The law of 09/07/2011 lays down the fundamental principles relating to the protection of the environment in accordance with article 123 of the Constitution of 18 February 2006. It aims to promote the sustainable management of natural resources, to prevent risks, to combat against all forms of pollution and nuisance, and to improve the quality of life of populations while respecting the ecological balance.

This law lays down the general principles which serve as a basis for the particular laws to govern the various sectors of the environment, including in particular law n°14/003 of 2014 relating to nature conservation, law n°14/011 of 2014 on the electricity sector, law n°11/022 of 2011 on the main fundamentals of agriculture, law n°11/2002 on the forestry code, law n°75/024 of 1975 relating to the creation of safeguarded sectors, law n°82/002 of 1982 relating to the regulation of hunting.

17.2.3. Situation in Rwanda

In Rwanda, Law No. 48/2018 of 13/08/2018 sets the modalities for the protection, conservation and promotion of the environment in accordance with the 2015 constitution especially in its articles 22, 53, 64, 69, 70, 88, 90, 91, 106, 120, 121, 168 and 176. It defines the fundamental principles of conservation of the natural and built environment; the obligations of the state, decentralised entities and communities, acts and sanctions and inspection in environmental matters.

This law is supplemented by law n°47bis/2103 which governs the management and use of forests in Rwanda, law n°70/2013 on biodiversity and law n°32/2003 on the creation of the Rwandan Office of Tourism and National Parks.

17.3. Legal framework for spatial planning, urbanisation and agricultural development

Land use planning is governed by the laws on land and town planning.

In Burundi, the land code revised in 2011 (Law n°1/13) governs land ownership and exploitation. Master plans for development and urban planning have been drawn up by province and for certain administrative entities.

In the DRC, law n°80/008 of 1980 modifies and completes law n°73/021 of 1973 on the general property regime, land and real estate regime and security regime. No policy to guide land use has been developed to date. Land management in the east of the country remains mainly based on customary law. In the fragile context of the country, the lack of an effective management framework and control systems for land management poses significant risks to the environment and its resources, including water, soil and forests.

In Rwanda, Law No. 43/2013 on land tenure and Law No. 10/2012 on the town planning and construction code constitute the legal framework. The National Land Policy was revised in 2019. Master plans at national and decentralised level have been drawn up. In 2017, Rwanda defined a national transformation strategy and district development strategies (2018-2024) that guide economic and social development programmes. Several national sectoral policies are also being revised (land, agriculture, ...).

In all three countries, agricultural development is governed by National Agricultural Investment Plans (NAIPs) or the Strategic Plan for Agricultural Transformation (PSTA IV) in Rwanda (Table 24).

Table 24: Laws, decrees, national strategies and action plans by country in relation to environmental and natural resource management.

		Laws and decrees	National strategies and action plans
Burundi	Management of natural resources and the environment	Law n° 1/01 of 30 June 2000 on the environment code in Burundi. - Decree 100/22/ of 07/10/2010 on the environmental impact assessment procedure. - Decree n°1/6 of 03/03/1980 on the creation of national parks and nature reserves Law n°1/07 of 15 July 2016 revising the Burundi Forestry Code. Law n°1/21 of 15/10/2013 on the Burundi Mining Code. Law n°1/13 of 09/08/2011 revising the land code Law n°1/10 of 30/05/2011 on the creation and management of protected areas Law n°1/11 of 16/05/2010 on the code of navigation and lake transport. Convention on Biological Diversity (1992). United Nations Framework Convention on Climate Change (2012). Convention on the Sustainable Management of Lake Tanganyika (2003)	- National Strategy to Combat Land Degradation (2011-2016) ; - National Strategy for the Environment - National Policy - National Action Programme for Adaptation to Climate Change (NAPA) (2007) ; - National Biodiversity Strategy and Action Plan (2000) ;
	Water resources management	Law n°1/02 of 26 March 2012 on the water code	- National Water Policy (2009) - National Water Strategy (2011-2020) - National Sanitation Policy (2013)
	Spatial planning, rural development	Law n°1/13 of 09/08/2011 revising the land code of Burundi	- Strategic Framework for Growth and Poverty Reduction II (2016) - Burundi National Development Plan (2018-2027) - National Agricultural Investment Plan (PNIA) (2012-2017). - Sector Strategy for the Energy Sector in Burundi (2011) - 12 Provincial land use plans and 5 master plans for development and urban planning
DRC	Management of natural resources and the environment	Law n°11/009 of 09 July 2011 on fundamental principles relating to environmental protection. - Ministerial Decrees 013/2005 and 043/2006 on the environmental and social assessment of the PMURR. - Decree 043/2006 on provisions relating to the obligation to carry out environmental and social assessment of projects in the DRC; - Decree 044/2006 on the creation, organisation and functioning of the Congo Environmental Study Group. Law n°14/003 of 11/02/2014 relating to nature conservation Law n°11/2002 of 29/08/2002 on the forestry code. Law n°75/024 of 22/07/1975 relating to the creation of safeguarded sectors.	- National Strategic Development Plan (2016-2050) - National Environmental Action Plan (1996) - National Programme Environment, Forests, Water and Biodiversity (2013-2023) - National Action Programme for Adaptation to Climate Change (NAPA) (2006) - National Action Programme to Combat Desertification (NAP) (2006)

		Laws and decrees	National strategies and action plans
		Law n°82/002 of 28/05/1982 on hunting regulation Law n°14/011 of 17/06/2014 relating to the electricity sector Law n°11/022 of 24/12/2011 on the main fundamentals of agriculture Convention on Biological Diversity (1992). United Nations Framework Convention on Climate Change (2012)	
	Water resources management	Law n° 15/026 of 31 December 2015 relating to water.	
	Spatial planning, rural development	Law n°80-008 of 18/07/1980 modifying and supplementing law n°73-021 of 20/07/1973 on the general property regime, land and real estate regime and security regime.	- Provincial Territorial Development Plans ; - Local land use plans ; - National Agricultural Investment Plan (PNIA) (2014-2020)
Rwanda	Management of natural resources and the environment	Law n°48/2018 of 13/08/2018 on the modalities of protection, conservation and promotion of the environment. - Decree 003/2008 of 15/08/2008 on the requirements and procedures for environmental impact assessments; Decree 004/2008 of 15/08/2008 establishing the list of works, activities and projects subject to environmental impact assessment. Law n°70/2013 of 02/09/2013 governing biodiversity in Rwanda. Law n°32/2003 modifying and supplementing the decree-law of 26/04/1974 on the creation of the Rwanda Tourism and National Parks Office. Convention on Biological Diversity (1992). United Nations Framework Convention on Climate Change (2012)	- National Policy on Environment and Climate Change (2019) - Strategic Plan for Environment and Natural Resources (2018-2024) - National Forest Policy (2018) - National Energy Policy (2015) - Mining Policy (2010) - Biodiversity Policy (2011) - Protected areas management and conservation policy (2013) - *Green Growth and Climate Resilience Strategy* (2011) - National Action Programme for Adaptation to Climate Change (2006) - National Strategy and Action Plan for Biodiversity Conservation (2003)
	Water resources management	Law n°49/2018 of 21/09/2018 on the use and management of water resources in Rwanda. - Ministerial Order n°007/16.01 of 24/05/2013 determining the main visions of water management of the large hydrographic basins in Rwanda. - Ministerial Order n°002/16.01 of 24/05/2013 on procedures for declaration, authorisation and concessions for water use..	- National Policy for Water Resources Management (2011). - National Policy and Strategy for Water Supply and Sanitation Services (2010). - Rwanda's National Water Resources Master Plan (2015) - Irrigation policy (2015) - *Rwanda irrigation master plan* (2010)
	Spatial planning, rural development	Law n°43/2013 of 16/06/2013 on land tenure in Rwanda. Law n°10/2012 of 02/05/2012 relating to the code of town planning and construction in Rwanda.	- Vision 2050 (2021-2024) - National Transformation Strategy (2017-2024) - District Development Strategies (2018-2024) - National Land Policy (revised) (2019) - National Urbanization Policy (2015) - *National land use and development Master plan* - *Sectorial land use Masters plans* - *Kigali city and District land use master plans (2013-2017)* - National Agricultural Policy (2018)

		Laws and decrees	National strategies and action plans
			- Strategic Plan for Agricultural Transformation-4 (2018-2024) - Tourism policy (2009)

17.4. Analysis of the strengths and weaknesses of national regulations and mandates on water use, abstraction and discharges

A legal and regulatory framework is in place in the three countries for environmental management and the prevention of natural resource degradation, especially since the three countries have ratified numerous international conventions listed in the annexes, including the Convention on Biological Diversity, the United Nations Framework Convention on Climate Change and the Convention to Combat Desertification. However, the implementation of regulations is unsatisfactory in many areas and the commitments at the international level do not always result in the establishment of the required policies and regulations, nor in the mobilisation of sufficient funding for the implementation of national plans and strategies. However, the momentum in place in Rwanda is to be commended as it has made it possible to publish its commitments to reduce greenhouse gases within the framework of the Paris Convention on Climate Change and has implemented an important action of its strategic plan on biodiversity through the restoration of the Gishwati forest and the establishment of the Gishwati-Mukura National Park.

Thus, the environmental code in the three countries retains several fundamental principles of environmental conservation (precautionary principle, polluter pays principle and sustainable management of resources), with clear indications of the projects that must be subject to prior environmental impact studies in order to limit the negative impacts of these activities. In the Lake Kivu and Ruzizi Basin area, it must be noted that :

- **The prevention of water pollution by organic and chemical substances and the monitoring of water quality are unsatisfactory;** Although in all three countries, activities such as mining or hydro-agricultural development projects must be subject to an environmental assessment and must implement impact mitigation measures, including in the use of fertilisers and pesticides, these are not always followed. The execution of environmental assessments for economic activities such as mining, quarrying or for all forms of industries but also the supervision of mitigation measures should be systematic in all three countries. In the agricultural sector, the increasing use of fertilisers and pesticides in the basin does not always comply with the regulations in place and farmers do not have protective equipment.
- There is no **collaboration between countries to** prevent banned fishing practices or the use of dangerous pesticides or to protect river and lake banks from degradation. Similarly, there is no agreement for the conservation of transboundary primary forests (Nyungwe NP and Kibira NP) or transboundary wetlands. For example, at the level of the Ruzizi delta, the boundaries of the Rusizi NP in Burundi no longer meet the specifications of its creation in 1990, as large portions have been converted into agricultural areas. On the other side of the delta, Congolese organisations want to protect the biodiversity of this site but do not have the necessary institutional and financial support.
- **Laws and decrees are still needed to harmonise the Land Code, the Water Code and the Environment Code**. For example, in Burundi's 2011 Land Code, irrigations areas and developed marshlands are state property (private or public state domain) unless the operators have taken steps to appropriate them and can prove that they have been using them for more than 5 years, which is difficult for them to prove. The Water Code in Rwanda and Burundi specifies that no construction is authorised beyond the water resource protection zone (buffer zones), namely 10 m for rivers, 20 m for marshes and 50 m for lakes in Rwanda, and 25 m for rivers and 150 m

for the shores of Lake Tanganyika in Burundi. A similar regulation does not yet exist in Congolese legislation and compliance with this regulation for other countries still leaves something to be desired. The objective related to the establishment of a buffer zone has not been achieved, given that their role is to mitigate sedimentation of watercourses and the transfer of contaminants of agricultural, mining or other origin to aquatic environments and the conservation of aquatic habitats including fish spawning areas.

- **Integrated Water Resource Management IWRM is embedded in all water regulations and must involve stakeholders at the most decentralised level.** This approach is difficult to achieve because in most cases decentralised entities have little technical and financial capacity. In the case of Rwanda's new Water Code, basin management has been emphasised and decentralised entities have seen their responsibilities in water resource management strengthened. In Burundi, the establishment of water commissions at the level of basins and sub-basins recommended by Article 31 of the Water Code is not yet operational. In the DRC, the new legal framework (law n°15/026 on water) provides, in accordance with IWRM principles, for the decentralisation of water management with, in particular, the creation of catchment committees at basin level and the responsibility for the construction of water supply infrastructure allocated to decentralised entities. However, the decentralisation policy is being implemented and structures at provincial level are still being set up and to date no watershed management committee has been set up, at least in the area concerned by ABAKIR. Furthermore, the national policy and development plans for water resources management provided for in the Water Law have not yet been developed.
- **Land management**: despite the dynamics of regulatory and institutional reform in the three countries, only Rwanda has carried out a land reform (2005) and set up a centralised digital land service that has made it possible to secure land titles and improve women's access to land. In Burundi and the DRC, land management is still hampered by several constraints, including the lack of customary law, the absence or inadequacy of land security, land fragmentation and the precariousness of women's access to land. With regard to irrigation, land laws in the Democratic Republic of Congo and the Republic of Rwanda do not allow farmers to practise irrigation without prior authorisation from the relevant authorities. On the other hand, in Burundi, irrigation is not subject to any restrictions. This can generate conflicts between populations from the three countries, using the same water resource for agricultural activities in the Ruzizi plain (case of the Ruhwa river shared between Rwanda and Burundi, for example).

17.5. Development of legal bases: recommendations for the improvement and harmonisation of the legal framework on water resources and environmental management in the basin.

17.5.1. Harmonisation of policies and regulations related to environmental management

Economic activities subject to environmental assessment and supervision of mitigation measures should be harmonised in the three countries and decentralised entities should have more responsibility for supervising the risks of pollution or inappropriate abstraction of water resources.

17.5.2. Harmonisation of policies and regulations related to agricultural development and the use of agrochemicals and pesticides

Countries should agree on the type and maximum amount of fertilizer to be used per sub-basin, depending on land cover and soil degradation, on the policies to support irrigation and on watershed protection. The list of registered plant protection products should be harmonised and measures for the promotion of biological control methods strengthened.

17.5.3. Harmonisation of policies and regulations related to water resource conservation

Regulations on standards for withdrawals and discharges should be harmonised for shared resources and be based on agreed physicochemical standards and available data for all stakeholders in the basin. Conservation measures for the buffer zones around the rivers and the lake should be harmonised for Rwanda and Burundi and integrated into Congolese legislation. Measures for the protection of fish spawning areas need to be put in place and should include the conservation of natural vegetation on the Ruzizi River or on the shores of Lake Kivu.

17.5.4. Harmonisation of regulations related to sanitation on the shores of Lake Kivu

The hotel and industrial infrastructures built on the banks of Lake Kivu must include autonomous wastewater treatment systems in order to limit any risk of serious pollution of water resources.

17.5.5. Harmonisation of regulations related to the management of protected areas

Harmonisation and consolidation of regulations on international collaboration is recommended, so that collaboration mechanisms between the institutions in charge of protected area management are strengthened.

17.5.6. Strengthening IWRM mechanisms

The strengthening of IWRM mechanisms would be based on a harmonisation of decentralisation in favour of decentralised entities and local organisations for watershed management. Strengthening would involve transferring IWRM responsibilities and supervision of sources of degradation to decentralised entities. This strengthening of responsibilities should be accompanied by the transfer of technical and financial capacities to these decentralised entities.

18. Institutional framework in the basin

18.1. Government institutions in charge of natural resource management

18.1.1. Situation in Burundi

The management of natural resources is attributed since 2018 (decree n°100/087) to the Ministry of the Environment, Agriculture and Livestock (MINEAGRIE) through):

- the Directorate General for the Environment, Water Resources and Sanitation (DGEREA) composed of :
    - The Directorate of Water Resources and Forestry, whose role is to plan development and IWRM, particularly with regional and international institutions; to implement

cooperation programmes on water and cross-border forests; to participate in the respect of the water code and the implementation of the national water policy and the forestry code; to restore and protect the perimeters of water points and protected areas.

  - The Directorate of Sanitation and the Environment whose function is to implement national policies on the environment, anti-erosion and sanitation; to participate in the elaboration and control of the quality of water resources and effluents; to elaborate environmental standards; to participate in the analysis of environmental and social studies, to build capacities in the field of sanitation and water pollution control.

- the Directorate General of Agriculture (DGA), through its provincial and communal offices for the environment, agriculture and livestock (BPEAE). These offices monitor activities related to crop production, livestock development, rural engineering, water and sanitation, forests and the environment.
- the Geographic Institute of Burundi (IGEBU), a body mandated to manage the hydrographic network.
- the Burundian Office for the Protection of the Environment (OBPE).

Figure 37 illustrates a simplified organisational chart of the MINEAGRIE.

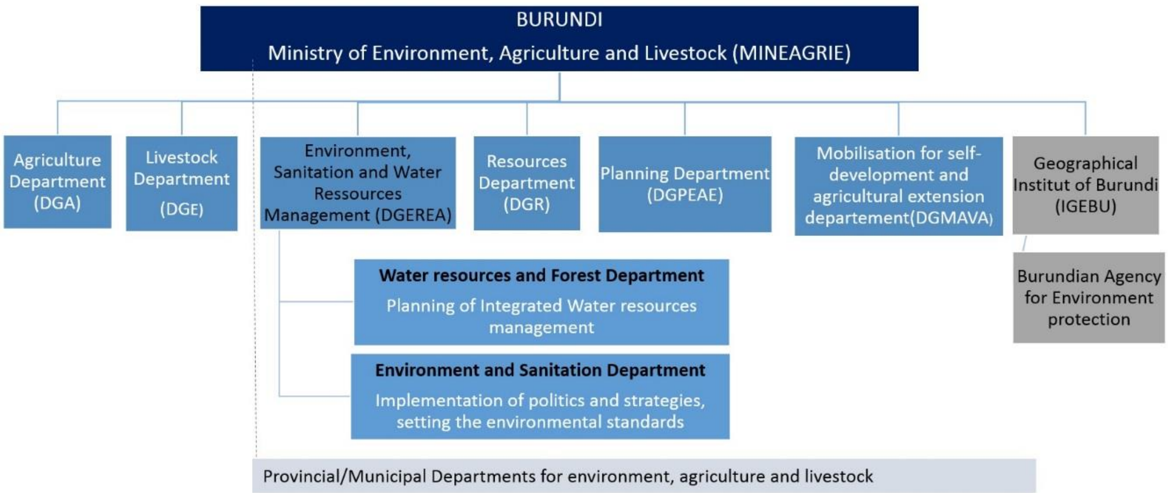


Figure 37: Organisational chart of the Ministry of Environment, Agriculture and Livestock in Burundi

Concerning the water sector, the Ministry of hydraulics, Energy and Mines (MEM) is in charge of the planning, construction and management of hydraulic, energy and basic sanitation infrastructures. It is organised in two directorates:

- the Directorate General for Drinking Water and Basic Sanitation (DGEPA). This includes the Agency for Hydraulics and Sanitation in Rural Areas (Agence pour l'Hydraulique et l'Assainissement en Milieu Rural - AHAMR), created in 2015 and responsible for the execution of drinking water supply and basic sanitation programmes and projects in rural areas. The Water Distribution Company, officially known as REGIDESO, is responsible for building infrastructure to strengthen water supply and electricity distribution systems in urban centres.
- the Directorate General for Energy (DGE), in charge of designing strategies and studies in the electricity sector and supervising new State investments in this field.

- The management of the mines is assigned to the Burundian Office of Mines and Quarries (Office Burundais des Mines et Carrières - OBM).

18.1.2. Situation in the DRC

The water sector is an area that involves several ministries and state bodies including :

- The Ministry of the Environment and Sustainable Development (MEDD) through its General Secretariat (revised by ministerial order 016/ME/MIN-FP/2017) and more specifically its General Directorate for Forestry and its General Directorate for the Environment and Living Environment (DGECV). This directorate comprises four directorates involved in the water sector:
    - the Water Resources Department (DRE) responsible for the quantitative and qualitative management of water resources throughout the national territory. It guarantees the appropriate use of water according to uses and the survival of aquatic ecosystems,
    - the Sanitation Directorate (DAS) which draws up standards and regulations on sanitation and supports decentralised territorial entities in sanitation work,
    - the Department of Human Settlements and Environmental Protection (DEHPE) assesses the impact of human activities on the environment and monitoring systems,
    - the Department of Nature Conservation (DCN) protects wildlife and fish resources.

Two specialised bodies, the Congolese Agency for Environment (Agence Congolaise de l'Environnement - ACE) created in 2019 for environmental and social assessment, and the Congolese Institute for Nature Conservation (Institut Congolais pour la Conservation de la Nature - ICCN) in charge of the protection of parks and natural reserves, are attached to MEDD. The Congolese Agency for Ecological Transition and Sustainable Development was also created in February 2020.

Figure 38 illustrates the structures involved in the Ministry of Environment in DRC

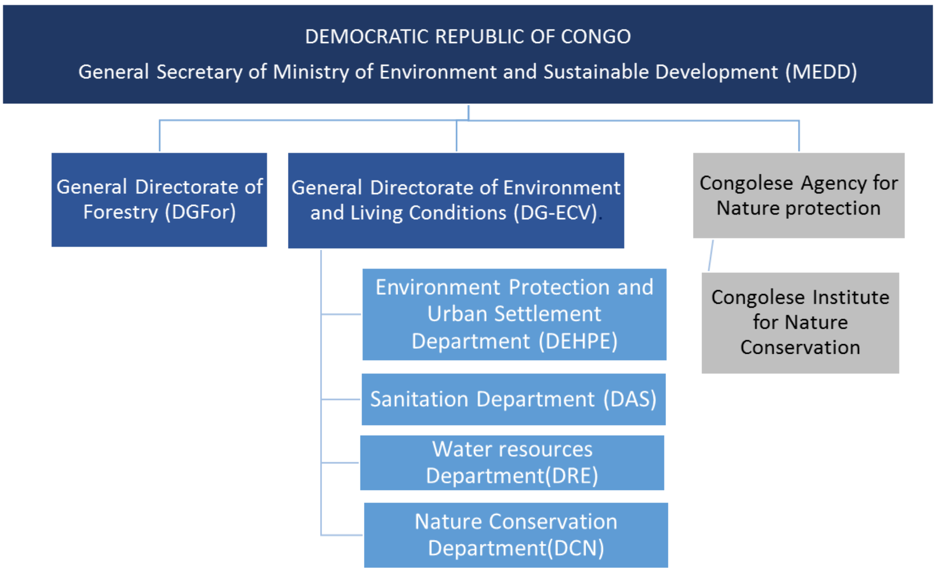


Figure 38: Organisational chart of the Ministry of the Environment and Sustainable Development in the DRC

- The Ministry of Energy and Water Resources (MERH) is responsible for the policy, management and distribution of drinking water and electricity. It also ensures the management of energy resources. REGIDESO is the public company in charge of drinking water distribution in urban and rural areas,
- The Ministry of Health sets the health standards for the environment in collaboration with the MEDD,
- The Ministry of Planning through its National Water, Hygiene and Sanitation Action Committee (CNAEHA) and its Provincial and Territorial Water, Hygiene and Sanitation Action Committees (CPAEHA and CTAEHA) created in 2015 (decree n015/039). This public service is responsible for coordinating the reform of the drinking water, hygiene and sanitation sector and ensuring the implementation of rehabilitation and development programmes for the drinking water, hygiene and sanitation sector.

18.1.3. Situation in Rwanda

The protection of the environment, the sustainable management of natural resources and the fight against climate change is entrusted to the Ministry of the Environment (MoE), formerly MINIRENA, whose organisation was reviewed in October 2020 by ministerial order n°108/03. It is comprised of various departments and specialised agencies including :

- the Department of Environment and Climate Change which ensures the development of policies, strategies and programmes relating to environmental protection, climate change and pollution control,
- the Rwanda Forest Authority (RFA) in charge of forest management and reforestation,
- the Rwanda Environmental Management Authority (REMA), mandated to facilitate the implementation of the environmental policy including the respect of environmental standards and the follow-up of environmental impact studies,
- Rwanda Meteorology Agency (Meteo Rwanda), an agency that provides weather forecasts and various information related to water and climate.

Figure 39 illustrates a simplified organisational chart of the Ministry of Environment in Rwanda.

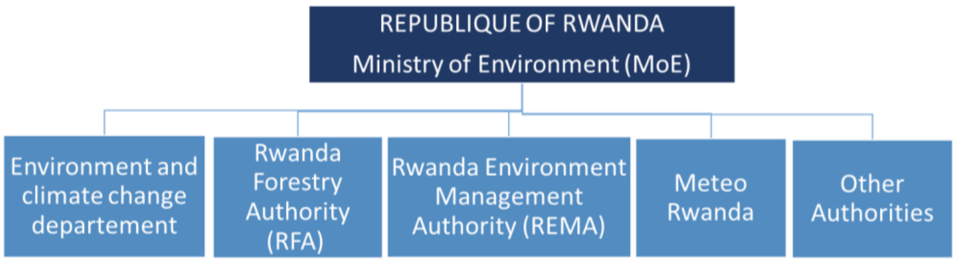


Figure 39: Organisational chart of the Ministry of Environment in Rwanda

Other ministries and authorities are also involved in the management of natural resources and more specifically in the field of water. These include :

- the Rwanda Water Resources Board (RWB). Created in 2020 and placed under the authority of the Prime Minister, it is the specific body that ensures the availability, quality and good management of water resources,

- the General Directorate for Water and Sanitation of the Ministry of Infrastructure (MININFRA) and its Public Service provider for Water and Sanitation (WASAC) which ensures the population's access to water,
- the General Directorate of Energy of MININFRA and its Public Service provider of Energy (REG) which ensures the population's access to energy.
- the Ministry of Agriculture through the Rwanda Agriculture and Animal Resources Development Board (RAB) also includes a department in charge of land use planning and irrigation,
- the Rwanda Mining, Oil, and Gas Board (RMB). This Government of Rwanda body was established in February 2017 and is responsible for implementing and advising the government on issues related national policies, laws and strategies related to mines, petroleum and gas.

18.2. Territorial organisation in the Basin

18.2.1. Provincial organisation in Burundi

The territorial administration is divided into provincial and municipal administration. Each municipality is organized into several zones and subdivided into collines (rural environment) and quartiers (urban environment). Figure 40 illustrates the territorial organisation in Burundi.

Figure 40 : Territorial organisation in Burundi

The Provinces are administered by a Provincial Governor supported by a chief of cabinet and four counsellors (appointed by decree), as redefined by the organic law of February 2020[48]. The Governor is responsible for the design, coordination and monitoring of development activities at the provincial level. It also exercises political, administrative and financial supervision over the municipalities.

The Provincial Governor chairs a provincial council which is made up of representatives of the municipalities, appointed by the Ministry of the Interior, and plays an advisory role in the provincial administration. The cabinet relies on the provincial technical services which have role of implementing national policies and strategies.

The municipalities are managed by an elected council of 15 members including a Municipal Administrator who is responsible for the implementation of the Municipal Community Development Plan and the deliberations of the municipal council. This includes various committees including the Economic and Development Commission responsible for studying everything relating to development work. It is supported by the municipal community development committee.

This committee is made up of individuals involved in community development. It is an advisory body established by the municipal council on behalf of the Municipal Administrator which brings technical expertise on planning, implementation and monitoring of municipal community development plan[49].

[48] Burundi organic law of 100/117 of December 14, 2020 on the provincial adminisration.

[49] Burundi organic law of 1/04 of February 19, 2020 revising some dispositions of the communal administration law of Nov 2014.

Similar to the municipal level, the colline / quartier is administrated by a council made up of five members elected. It is supported by an advisory body: the colline/quartier development council.

18.2.2. Provincial Organisation in the provinces of North and South Kivu in DRC

Territorial administration in the DRC is organised around a provincial administration subdivided into districts and towns. The districts are subdivided into territories that are divided into cities, sectors and chiefdoms [50] which are in turn divided into neighbourhoods and groupings. The groupings are a set of villages. Cities are subdivided into municipalities, which are divided into neighbourhoods and groupings[51]. Figure 41 illustrates the territorial organisation in DRC.

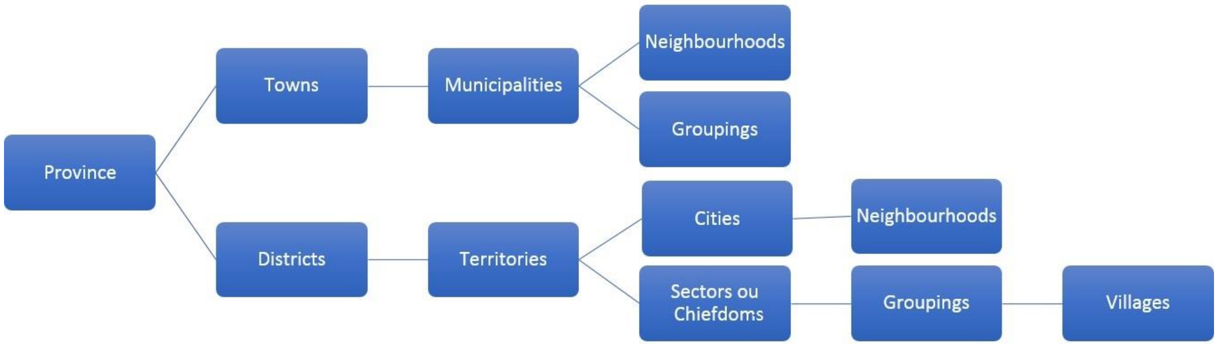


Figure 41: Territorial organisation in the DRC

The province is a decentralised administrative entity with legal personality headed by a Provincial Government with a Governor and a Vice-Governor, both elected by the Provincial Assembly[52].

The Provincial Government has 10 Provincial Ministers appointed by the Governor of the Province and heading the following departments: (i) Interior, Justice and Relations with Parliament, (ii) Public Works, Development of Decentralised Administrative Entities, (iii) Finance and Budget, (iv) Planning, Economy and Trade, (v) Transport and Communication, (vi) Mines, Energy and Hydrocarbons, (vii) Primary, Secondary and Professional Education, Culture and New Technologies, (viii) Public Health and Social Affairs, (ix) Industry and Employment, (x) Agriculture, Rural Development, Environment and Tourism.

Concerning water resources, the government and the provincial government organise committees at the level of basins or sub-basins, for their management, development and monitoring of water resources. These basin or sub-basin committees are technical and advisory bodies. Basins and sub-basins that cover more than one province are the responsibility of the government (Water Law of 2015).

Agriculture, rural development and spatial planning are the responsibility of the decentralised administrative entities:

- actions relating to provincial agricultural development and the improvement of living conditions for rural populations, including water development, rural water supply and rural sanitation programmes.
- the organisation of fish farming;

[50] The chiefdom comprises a generally homogeneous set of traditional communities organised on the basis of custom and headed by a customary chief designated by custom, recognised and invested by the public authorities. The sector is made up of a heterogeneous set of small, independent traditional communities organised on the basis of custom, which are demographically too weak to develop harmoniously and are headed by a sector chief appointed from among civil servants.

[51] Decree-Law 081 of 02/07/1998 on the territorial and administrative organisation of the Democratic Republic of Congo.

[52] Law 08/012 of 31/07/2008 laying down fundamental principles relating to the free administration of the provinces.

- the elaboration of agricultural and rural development programmes and their implementation according to the plan established by the government, in accordance with the standards of the national agricultural policy and the philosophy of rural development defined by the central power;
- the marketing of mass consumption food products, particularly cassava, maize and rice, because of their impact on the supply of large urban centres;
- agricultural projects initiated by decentralised administrative entities using local resources;
- the execution of development plans;
- construction and maintenance of secondary roads and related stormwater drainage infrastructure of provincial, urban and local interest ;
- the award and acceptance of works financed by the decentralised administrative entities, their monitoring and control during implementation;
- the construction and maintenance of erosion control structures;
- development and construction of ports and riverbanks

The central government remains responsible for:

- the design, organisation, reorientation and planning of national agricultural and rural development policy;
- projects of plant, animal or fish management or production of national interest requiring foreign or national participation;
- the organisation of research institutions in the field of agriculture and rural development;
- the design and planning of rural housing policy;
- projects linked by bilateral and multilateral agreements;
- agricultural, cooperative and rural development legislation;
- the design and preparation of spatial development plans either on the government's initiative or on the basis of proposals made by the decentralised administrative entities;
- monitoring and control of the execution of all civil engineering projects ordered on behalf of the State and public companies;
- intervention in the construction and maintenance of major structures;
- construction and maintenance of priority national and provincial highways and associated river drainage structures;

18.2.3. District Organisation in Rwanda

The territorial administration is divided into provinces, districts, sectors, cells and villages. Figure 42 illustrates the territorial organisation in Rwanda.

Figure 42 : Territorial organisation in the Rwanda

The province is the body that aims to ensure the coordination, efficiency and effectiveness of planning, implementation of national strategies at the decentralised level and supervision of decentralised services.

The district is an autonomous administrative entity with legal status and administrative and financial autonomy. The district is administered by the district council through which policies are formulated and adopted. The day-to-day affairs of the district are managed by the executive committee headed by a mayor and two deputy mayors. These Local councils are the most legitimized participatory structures composed by elected representatives and regulated by the law governing the functioning of decentralized entities. Each district has a development plan covering priority sectors including water and sanitation, energy, environment and natural resources.

Following the Decentralization Policy of 2012[53], the Government has established mechanisms aiming to strengthen the planning function in the local government system to enhance evidence-based planning, bottom-up needs identification and priority setting. Performance contracts ("Imihigo"), is a participatory framework which ensures that citizen priorities are identified by themselves from the household level and that they are taken into account in the District annual list of priorities. At the District level, local priorities are consolidated with national priorities from Central Government (Ministries) and are then approved by the District Council, before they are signed by the Mayor and the President of the Republic of Rwanda.

The sector is the administrative entity below the district. It is administered by the sector council. Each sector also has a strategic development plan in different areas including water and sanitation, environment and energy. Each Sector is organized in several cells divided into villages ("Imidugudu"). Cell elected leaders are organized into Citizen Assemblies.

18.3. Identification of stakeholders in IWRM and the NEXUS approach

Table 25 presents the stakeholders identified at the level of the ABAKIR perimeter.

Table 25: Identification of IWRM/NEXUS stakeholders.

Institutions/organisations	Description/role
Regional institutions	
Lake Kivu and Ruzizi River Basin Authority (ABAKIR)	To implement a cooperation policy for sustainable development and stabilisation of the Great Lakes Region through the integrated management of the water resources of the Lake Kivu and Ruzizi River basin, in all its dimensions (energy, agriculture, fishing, lake transport, tourism, biodiversity, etc.).
State institutions	

[53] Rwanda National Decentralization Policy, June 2012

Institutions/organisations	Description/role
Burundi	
Directorate General for Environment, Water Resources and Sanitation (DGREA) of MINEAGRIE	Develop and implement the strategy for sustainable land management and use in Burundi, the national anti-erosion policy; the code of conduct and environmental standards. Implement conventions for the conservation and protection of natural resources; Implement the national water policy and elaborate development strategies in this sector.
Provincial and Municipal Offices of the Directorate of Environment, Agriculture and Livestock	Implementing the national policy for marshland management, soil protection and fertilisation. Ensuring food security for the population by promoting food crops and animal production, supervising environmental interventions in agro-sylvo-zootechnical and fisheries matters.
Agency for Hydraulics and Sanitation in Rural Areas (AHAMR)	Rural Water and Sanitation Officer. Carries out/supervises work and studies in this field.
REGIDESO	In charge of portable water supply and electrification in urban areas
Geographical Institute of Burundi (IGEBU)	Collection of meteorological and hydrological data. Rehabilitation of observation networks, groundwater research.
DRC	
Ministry of Environment and Sustainable Development (MEDD)	In charge of drawing up hygiene and environmental standards; monitoring environmental and social impact studies; controlling industrial pollution and sanitation.
Ministry of Energy and Water Resources	Management and distribution of drinking water and electricity
REGIDESO	In charge of portable water supply in urban areas
The Provincial and Territorial Action Committees for Water, Hygiene and Sanitation	Ensuring the implementation of rehabilitation and development programmes for the drinking water, hygiene and sanitation sector
Provincial Ministries of South and North Kivu	To implement the conventions for the conservation and protection of natural resources.
National Satellite Meteorology Agency (METTELSAT)	Collection of meteorological data.
Rwanda	
Ministry of the Environment	In charge of developing and implementing policies and strategies on environmental protection; establishing standards and practices for natural resource management and evaluating their implementation.
Rwanda Water Resources Board (RWB)	Ensure the availability and proper management of water resources.

Institutions/organisations	Description/role
Rwanda Environment Management Authority (REMA)	Mandate to organise and carry out the monitoring recommended by the ESIAs.
Directorate General for Water and Sanitation and WASAC	In charge of the drinking water distribution network.
Rwanda Agriculture and Animal Resources Development Board (RAB)	The RAB manages irrigation and marshland development programmes.
Rwanda Development Board (RDB)	Responsible for approving ESIA reports.
Rwanda Standards Board (RBS)	In charge of the development and publication of national standards and carrying out research in terms of standardisation.
MeteoRwanda (Rwanda Meteorological Agency)	Collection of hydrological and meteorological data.
The Lake Kivu Monitoring Programme (LKMP)	A government programme operational since 2006 whose objective is to ensure safe and sustainable methane gas extraction.
Districts and decentralised administrative entities	Control pollution and its regulation.
Private sector and public utilities	
ContourGlobal, Symbion Power Lake Kivu and GazMeth	Private methane gas exploitation companies.
SINELAC, REGIDESO, SNEL, REG	Regional and national energy power utilities.
Hotels industries	Hotels on the waterfront or near protected areas in the basin.
Mining, Industries and small factories	Factories exploiting natural resources in the basin or with potential risks to pollute natural resources in the basin.
Cooperation agencies and international organisations	
GIZ (German Development Cooperation)	Executes projects in Burundi, DRC and Rwanda in the fields of IWRM (Nile Basin Initiative, ProSecEau) and energy (EnDev).
SNV (Dutch Development Organisation)	Executes projects in the field of IWRM (Water For Growth, Sebeya basin restoration in Rwanda).
International Union for Conservation of Nature (IUCN)	Assists the Governments of Burundi, DRC and Rwanda in the conservation of the integrity and the biodiversity of the nature and the good governance of natural resources.
ENABEL (Belgian Development Agency)	Executes projects in support of the agricultural sector, hydro-agricultural development, watershed protection and support to water users in Burundi, DRC and Rwanda.
UNICEF	United Nations organisation that finances and implements water, hygiene and sanitation projects.
UNDP	Collaborates with Governments and partners to build institutional capacity for sustainable development.

Institutions/organisations	Description/role
FAO/WFP	Support to the Government and collaboration with other UN agencies, NGOs, local communities and civil society to promote agricultural production and food security.
Water, Hygiene and Sanitation Cluster	This cluster brings together a set of national and international organisations that implement water, hygiene and sanitation projects. This cluster is particularly active in the provinces of North and South Kivu in DRC.

18.4. Ongoing projects in the basin

18.4.1. Support for the integrated management of water resources of Lake Kivu and the Ruzizi River (EU/BMZ, implemented by GIZ)

GIZ is currently implementing a project to provide "Support to the integrated management of water resources of Lake Kivu and the Ruzizi River", initiated in the framework of support from the European Union (EU Delegation to Rwanda) and the German Federal Ministry for Economic Cooperation and Development (BMZ). This two-year project (2019-2020) for an amount of EUR 2.5 million aims to improve the operational and hydraulic management of Lake Kivu and the Ruzizi River based on the NEXUS approach of integrated, cross-sectoral and cross-border resource management. The main partner of the project is ABAKIR, the regional authority in charge of the sustainable development of the basin's water and related resources. Through the promotion of regional cooperation, this project also aims to promote political and security stability in the region. The present document has been elaborated within the framework of this project.

18.4.2. Sebeya Basin Restoration and Integrated Water Resources Management Project

The Government of Rwanda through the Rwanda Water Resources Board, in collaboration with the International Union for the Conservation of Nature (IUCN) and the Dutch Development Cooperation (SNV) launched an integrated water resources management project in the Sebeya river catchment started in June 2019. This project includes the restoration of landscapes and the promotion of a sustainable and evolutionary management of the resources through a community participatory approach. This project is a continuation of the Water for Growth programme, which ended in mid 2019, and which had carried out several studies and certain developments, particularly in the Sebeya catchment area.

18.4.3. Ruzizi Regional Hydroelectric Power Plant Project.

Two hydroelectric dams (Ruzizi I and Ruzizi II) were built on the Ruzizi River in 1958 and 1989 respectively. The hydroelectric energy produced by these dams is equitably distributed to the three CEPGL States mainly to cover socio-economic needs (water, hospitals, local industry) and is one of the key drivers of industrial production in the Great Lakes area.

In July 2019, an agreement was signed between the three CEPGL countries for the construction of Ruzizi III and studies are underway for Ruzizi IV. The Ruzizi III regional hydropower project is part of the Programme for Infrastructure Development in Africa (PIDA) financed by the African Development Fund (ADF). It is in the final phase of development by Electricité des Grands Lacs (EGL), the entity responsible for tripartite energy cooperation within the institution. It consists of the construction of a run-of-river dam (located downstream of the Ruzizi II hydroelectric dam), a 147 MW power plant and a distribution substation. In addition, feasibility studies for the Ruzizi IV hydropower project are being financed by the European Development Fund, KFW and ADB. The Ruzizi IV project is all the more justified in view of the prospect of setting up mining and agro-industry with an expected energy demand of 80 MW in Burundi, 60 MW in Kivu in Eastern DRC and 60 MW in Rwanda.

18.4.4. KivuWatt Project

The Lake Kivu methane project was developed by KivuWatt Limited, a branch of the US company ContourGlobal, which in 2009 was awarded a licence to exploit Lake Kivu gas for electricity generation in Rwanda. The first phase of the project started in 2016 and consisted of the construction of a gas exploitation plant with a capacity to produce 26 MW of electricity to supply the local grid. The next phase of the project is the construction of nine additional generators to achieve a total capacity of more than 100 MW at a cost of US$200 million.

18.4.5. Kivu-56 and Kibuye Power

Symbion Power Lake Kivu Ltd, a subsidiary of the American company Symbion Power LLC, signed a 25-year power purchase agreement (PPA) on 8 December 2015 with the Rwanda Energy Group (REG) for a net capacity of 56 MW from a power plant to be located in the Nyamyumba sector in Rubavu district. The first barge will provide 14 MW of electricity 15 months after the financial close of the project. The company has also bought the barge from the Kibuye Power KP1 facility in Rubavu district and is working to mobilise funds to revive this methane gas power plant and increase its capacity from 3.6 MW to 25 MW.

18.4.6. Lake Kivu Monitoring Programme - LKMP

The Lake Kivu Monitoring Programme (LKMP) has been operational since 2006. Its main objective is to ensure that the extraction of methane gas is carried out in a safe and sustainable manner. It is the designated body to monitor the ecological impact of industrial developments of gas resources in Lake Kivu, Rwanda. In 2008, when the first pilot methane gas extraction plant began operations on Lake Kivu, the Ministry of Infrastructure (MININFRA) established a unit to monitor the impacts of methane gas extraction on the lake, known as (LKMP). From the outset, it was supported by the Government of Rwanda and various donors to carry out its tasks. Since 2014, it has been integrated into the Rwanda Energy Group (REG) / Energy Development Corporation Limited (EDCL). The LKMP was funded by the Netherlands from August 2013 to June 2019, with a budget of €8.9 million. The programme is therefore currently seeking funds to continue and expand its monitoring programmes and consultancy work.

18.4.7. Regional Programme for the Integrated Development of the Ruzizi Plain - PREDIR

The Regional Programme for the Integrated Development of the Ruzizi Plain (PREDIR), financed by the ADB and implemented by the CEPGL (2015-2019). Within the framework of this programme, the Master Plan for the Development of the Ruzizi Plain (SDAR) was developed and is in line with the long-term vision of the CEPGL and in particular the Regional Economic Programme (PER) which advocates the intensification and modernisation of a regional agriculture integrated into the world market and adapted to climate change.

This master plan, accompanied by the strategic environmental and social study (SEAS) and the feasibility studies (APS/APD) of a priority tranche for the development of irrigation areas, will constitute a planning tool and a regional intervention framework for all investments for the coming years. Five specific short-, medium- and long-term objectives have been defined, namely (i) to develop the irrigable potential, (ii) to ensure the sustainable development of water and natural resources, (iii) to contribute to integrated and inclusive sustainable socio-economic development, (iv) to protect and preserve the environment, (v) to strengthen institutional capacities for good governance.

The implementation of the master plan by the CEPGL and other agricultural development actors is planned to cover the period up to 2040. The total investment cost amounts to USD 1.6 billion, of which USD 345 million is for the Priority Programme consisting of short-term actions.

18.4.8. Great Lakes Regional Integrated Agriculture Development Project (PRDAIGL) and Integrated Project for Agricultural Growth in the Great Lakes (PICAGL)

PRDAIGL and PICAGL are two projects that are part of a regional multi-stakeholder programme financed by the World Bank for a period of 5 years (2016-2021) that aims to increase the productivity and competitiveness of selected agricultural value chains for the benefit of local communities in the project area in Burundi and DRC, and to strengthen regional economic integration between the two countries.

PRDAIGL focuses on the maize, rice and milk sectors in the provinces of Bubanza, Bujumbura, Cibitoke, Makambe and Rumonge in Burundi. The project targets 55,000 beneficiaries who are mainly small farmers (owning less than 0.5 ha), dairy producers and also vulnerable groups living in the targeted area. Activities include, among others, distribution of seeds and inputs, rehabilitation of irrigation systems, livestock vaccination campaigns.

PICAGL is implemented in the Provinces of South Kivu and Tanganyika in the DRC, particularly in the Bukavu-Uvira-Kalemie corridor (Bukavu, Ruzizi plain and the coastal plain of Baraka-Fizi-Kalemie). It focuses on the development of the rice, cassava and milk sectors, as well as fishing and animal production, and covers the aspects of production, storage, processing, transport and marketing of products. Another component of the project is devoted to the rehabilitation of irrigation systems and 540 kilometres of agricultural feeder roads, as well as access to credit for around 200 small and medium-sized enterprises. This project is expected to reach 200,000 beneficiaries.

The budget allocated to this regional programme by the World Bank amounts to 225 million USD, of which 150 million USD for the Congolese part (PICADGL) and 75 million USD for the Burundian part (PRDAIGL).

18.4.9. IWRM Rwanda Programme

The Rwanda Water and Forestry Authority (RWFA) commissioned a baseline study in 2019 to establish the basic water quality of some 36 selected water bodies in the country. The study was conducted in the nine level 1 catchments. A set of sixteen (16) parameters was selected for this monitoring activity for each sampling site. These parameters are: Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), potential of hydrogen (pH), Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Turbidity, Chloride (Cl^{-}), Sulphate (SO_4^{2-}), Nitrate (NO_3^{-}), Total Nitrogen (TN), Total Phosphorus (TP), Total Dissolved Inorganic Nitrogen (DIN), Total Dissolved Inorganic Phosphorus (DIP), Fecal Coliforms (F.C) and *Escherishia coli* (*E.coli*). The negative impact on surface water quality comes from the sedimentation of water bodies, mainly due to soil erosion, as well as microbiological contamination that can be linked to poor sanitation systems and practices. The study recommended further and regular studies. One line of thought proposed by this study is the Payment for Ecosystem Services (PES) approach (see below).

18.4.10. LATAWAMA Project - Lake Tanganyika Water Management

The "Lake Tanganyika Water Management" project aims to sustainably improve the management and control of the transboundary waters of Lake Tanganyika. This four-year project is entrusted to the Belgian Development Agency (ENABEL) and is financed by the European Union as part of a regional programme. The project aims to support the Lake Tanganyika Authority (LTA), an institution bringing together Burundi, the Democratic Republic of Congo, Tanzania and Zambia, in its mandate and duties to promote the protection and proper management of the water resources of the lake and its tributaries. Rwanda is also involved in this project as it borders the Ruzizi River, which eventually flows into Lake Tanganyika. To strengthen the role of the LTA, the project will develop tools to control and monitor the quality of the lake's water, put in place a series of pilot actions to reflect and share experiences and, in some cases, replicate similar actions in the project's target cities and along the lake, and strengthen the capacity of the LTA in its role of coordinating and supporting actors in water resource management.

19. Cross-border and international management framework

19.1. Regional organisations

19.1.1. The Economic Community of the Great Lakes Countries - CEPGL

The role of the Economic Community of the Great Lakes Countries (CEPGL), created in 1976 by Burundi, DRC and Rwanda, and under the direction of its Permanent Executive Secretariat, is generally to identify strategic axes and facilitate and lead inclusive development projects between the three member countries. In order to achieve the objectives of regional integration in the Great Lakes sub-region, in cohesion with the development prospects of the three Member States, in the field of energy and the electricity sub-sector, the CEPGL has set up two specialised bodies, namely : (i) the CEPGL Energy Organization for the Great Lakes (EGL), in 1979, and the International Electricity Corporation for the Great Lakes (SINELAC), established in 1983 (among other specialized bodies of the CEPGL, such as the Development Bank of the Great Lakes States).

The CEPGL, which was relaunched in 2007, is a new framework for Agreement and Integration aimed at revitalising political dialogue and economic integration through five priority axes: (i) peace and security, democracy and good governance; (ii) agriculture and food security; (iii) energy, infrastructure and communication; (iv) education and scientific research; (v) investment.

On July 6, 2011, within the framework of the CEPGL, the ministers in charge of water of the three member countries signed an agreement to set up an Authority in charge of managing the water resources of the basin in an integrated, sustainable and equitable manner. Pending the signature and ratification of a convention by the three member states, a transitional structure of ABAKIR was created in November 2014.

19.1.2. The Economic Community of Central African States - ECCAS

The treaty of the Economic Community of Central African States was signed in October 1983 by 11 countries [54]including Burundi, DRC and Rwanda. The fundamental objective of this organisation is to promote and strengthen harmonious cooperation and dynamic, balanced and self-sustained development in all areas of economic and social activity in order to achieve collective self-reliance and increase the standard of living of the populations. It defines an economic and political area of free movement of citizens. ECCAS has three specialised institutions: the Regional Commission of Fisheries of the Gulf od Guinea (COREP), the Commission of Central African Forests (COMIFAC) and the Central African Power Pool (Pool Energétique de l'Afrique Centrale - EAC).

The Member States signed a Protocol of Cooperation on Natural Resources in 1983. More recently, ECCAS adopted in 2009 a regional water policy and in 2014 a Regional Action Plan for IWRM (PARGIRE-AC) which includes six programmes: i) Provision of water governance instruments to member countries and access to WATSAN in rural areas, ii) Operationalisation of the institutional mechanism for water management at regional level, iii) Support to transboundary basin organisations and local governance, iv) Preservation of the resource and improvement of access to drinking water in urban areas, v) Development of water resource development projects for the production of economic goods and vi) Proposal of actions for the long term.

19.1.3. International Conference on the Great Lakes Region - ICGLR

The International Conference on the Great Lakes Region (ICGLR) was established in 2006 with the signing of the Pact on Peace, Security, Stability and Development in the Great Lakes Region. This intergovernmental organisation has 12 members which are Angola, Burundi, Central African Republic, Republic of Congo, Democratic Republic of Congo, Kenya, Rwanda, Sudan, South Sudan, Tanzania, Uganda and Zambia. Through its main programmes, which are (i) peace and security, (ii) economic development and regional integration, (iii) humanitarian and social issues, (iv) democracy and good governance, the ICGLR aims to promote (i) a prosperous and integrated economic space, (ii) the development of common infrastructure in the field of energy, transport and communications, and (iii) regional integration through the strengthening of cooperation and multisectoral solidarity between populations at the borders of neighbouring countries.

Its economic development projects include the cross-border development basin project, the certification of natural resources and the exploitation of methane gas in Lake Kivu. In 2005, the ICGLR contributed to the feasibility studies for the exploitation of gas in Lake Kivu through the bilateral entity SOCIGAZ, which led to the development of the KivuWatt Power project.

19.2. Basin management organisations relevant to the Basin

19.2.1. Lake Tanganyika Authority - LTA

The Convention on the Sustainable Management of Lake Tanganyika was signed on 12 June 2003 and ratified in November 2007 by the governments of the Republic of Burundi, the Democratic Republic of Congo, the United Republic of Tanzania and the Republic of Zambia. The objective of this Convention

[54] Republics of Chad, Central African Republic, Cameroon, Equatorial Guinea, Sao Tome and Principe, Gabon, Congo, Angola, Burundi, DRC, Rwanda

is to ensure the protection and conservation of biodiversity and the sustainable use of the natural resources of Lake Tanganyika and its basin by the signatory States based on integrated and cooperative management.

The Lake Tanganyika Authority, established in 2007, is responsible for coordinating the implementation of the Convention.

The Secretariat is the executive body of the LTA. It is headed by the Executive Director and is composed of the following four directorates: Administration and Finance; Fisheries; Environment; Monitoring and Evaluation. The LTA Secretariat became fully operational in January 2009. A Management Committee comprising four members from each of the Contracting States representing the fisheries, environment, water and finance sectors oversees and evaluates the activities of the Secretariat. This Committee meets annually.

19.2.2. International Commission of the Congo-Oubangui-Sangha Basin - CICOS

The International Commission of the Congo-Oubangui-Sangha Basin (CICOS) is a specialised agency of the Economic Community of Central African States (ECCAS) created following the Agreement signed on 21 November 1999 establishing a uniform river regime with the aim of promoting inland navigation. In 2007, the mission of CICOS was extended to include IWRM functions (Addendum of 22/02/2007).

It is composed of six Member States: the Republic of Cameroon, the Republic of Congo, the Central African Republic, the Democratic Republic of Congo, the Gabonese Republic and the Republic of Angola.

CICOS is a primarily implementation-oriented Commission with several functions ranging from harmonisation of legislation to basin-wide IWRM planning, optimisation of water allocations and benefit sharing. However, navigation remains the Commission's core function. The legal framework of CICOS consists of the multilateral international agreement establishing the international commission and a uniform regime for navigation in the basin signed in 1999.

19.2.3. The Nile Basin Initiative - NBI

The Nile Basin Initiative was initiated in 1999 with the signing by the ten member states (Burundi, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Tanzania, Uganda and DRC) of a series of agreements defining a common vision "to achieve sustainable socio-economic development through equitable utilisation of, and benefit from the common Nile Basin Water water resources". The objectives of the NBI are threefold: (i) to provide a platform for basin cooperation and policy dialogue, (ii) to provide Information Systems-based water resources planning and management services, and (iii) to facilitate the implementation of transboundary projects.

A new agreement to transform the NBI into a Nile Basin Commission and establish new rules for sharing the waters of the Nile has been under negotiation for almost two decades by member countries. This initiative is met with strong resistance from the downstream countries, Egypt and Sudan. In 2010, the Cooperative Framework Agreement (CFA) in the Nile River Basin (CFA) was finalised and signed by six countries (Burundi, Ethiopia, Kenya, Rwanda, Tanzania, and Uganda) but ratified only by Ethiopia, Rwanda and Tanzania. The CFA will enter into force after the ratification by the six member states. Egypt suspended its membership of the NBI in disagreement with the process. The current NBI strategy is to continue high-level political commitment to break the deadlock and accelerate the process of transforming the NBI into a permanent institution (NBI 2017). However, the current situation has greatly weakened the NBI's momentum and is hampering the coordination process that existed.

19.2.4. International Convention relating to the integrated management of water resources of the Lake Kivu and Ruzizi River basin - ABAKIR

The Convention was signed on 04 November 2014 by Burundi, DRC and Rwanda but has still not been ratified by the three countries. Its objective is the protection and conservation of the basin's water resources based on an integrated and sustainable management. In order to achieve this objective, the States Parties undertake to :

- Cooperate in the development of a common strategic vision for basin management and the implementation of the resulting action programmes;
- Cooperate in the design and implementation of harmonised rules and standards for the management of water resources in the Basin;
- Pay particular attention to the current and future riparian communities so that they benefit from the sustainable use of the Basin's resources and developments.

The Convention is based on international water law principles such as the Precautionary Principle, the Polluter-Pays Principle and the Subsidiarity Principle and proposes in its article seven different means to achieve the desired Cooperation, including the exchange of information and data on the quantity, quality and use of the water resources of the Basin.

In order to preserve and protect the environment of the Basin, the States Parties undertake in Article 9 of the Convention, to various initiatives and in particular to (i) take all useful measures for the maintenance and protection of installations, developments and other works having an impact on the water resource of the Basin and (ii) ensure the management and financing of activities inherent to the maintenance of the beds of the Ruzizi River and Lake Kivu as well as their banks (Figure 43).

Pending ratification of the Convention by the three Member States, a transitional structure of ABAKIR has been set up.

Figure 43: Ruzizi River between DRC and Rwanda.

20. Basin management options

20.1. Role of ABAKIR

20.1.1. The international convention on the integrated management of the water resources of the Lake Kivu and Ruzizi River Basin

The "International Convention on Integrated Water Resources Management in the Lake Kivu and Ruzizi River Basin" was signed on 4 November 2014 by representatives of the three riparian countries: Burundi, DRC and Rwanda. However, the three countries have not yet ratified the agreement.

The mission of ABAKIR is to promote economic, industrial and social development in each of the member countries in order to optimise the benefits of water resources and increase the use of water resources for energy production and all other beneficial uses while preserving the environment.

The preface to the Agreement reiterates the principles listed in several international conventions to which it fully subscribes.

Article 2 of the agreement states that its objective is to ensure the protection and conservation of water resources in the watershed of Lake Kivu and the Ruzizi River through integrated and sustainable management.

Article 2 adds that in order to achieve this objective, the parties to the agreement must:

- Cooperate in the development of a common strategic vision for the management of the basin and the implementation of the resulting action programmes,
- Cooperate in the design and implementation of harmonised rules and standards for water resources management in the basin,
- Pay particular attention to current and future riverside communities so that they benefit from the sustainable use of natural resources and basin management.

20.1.2. The establishment of ABAKIR

ABAKIR is headquartered in Rubavu, Rwanda.

A temporary structure has been mandated to undertake preliminary actions in order to ratify the agreement to create ABAKIR.

The temporary structure is currently composed of a Director Coordinator, a Co-Director in charge of Operations, and a Co-Director in charge of Administration and Finance.

The following paragraphs are taken from Annex II of the financing agreement for the creation of ABAKIR.

The project for the creation of the Lake Kivu and Ruzizi River Basin Authority, ABAKIR, aims to contribute to the following overall objective: "Contribute to the sustainable development and stabilisation of the Great Lakes region by stimulating economic development through integrated management of all aspects of the water resources of the Lake Kivu and Ruzizi River Basin (electricity production, transport, tourism, biodiversity, etc.).

More specifically, the project aims to support the establishment of the trilateral ABAKIR authority.

This action is perfectly in line with the sectoral policy and strategy of Burundi, DRC and Rwanda, which aim to strengthen regional collaboration around the management of natural and energy resources, while protecting the environment. The sustainable management of water resources in the Kivu-Ruzizi drainage basin is a prerequisite for the sustainable use of the resource and for maximising the overall long-term economic benefits of its use. Similarly, good management of water resources in terms of quantity and quality will facilitate adaptation to the potential effects of climate change at the regional level (e.g. changes in precipitation and evaporation parameters).

At the political level, the action will promote regional stability and good governance by strengthening relations between Member States and thus contribute to the maintenance of peace, as the management of shared resources is often a source of conflict between countries when it is not structured and regulated. This stabilisation will help to avoid the repetition of mass movements of people and the violence that accompanies them.

Three expected results have been identified to achieve the specific objective:

- The activities of the first result, R1, are aimed at setting up the temporary structure of ABAKIR and making it operational (operating rules, procedure manual, etc.) and facilitating the rapid implementation of the definitive structure. The result is stated as follows: R1: The legal framework for the executive body of ABAKIR is put in place.
- The activities of the second result, R2, aim to improve knowledge of water resources (in the broadest sense: its characteristics, actual and planned uses, major constraints, etc.) and to establish a strategic plan and an action plan based on this knowledge. The result is stated as follows: R2: The operational and sustainable framework of the executive body of the Trilateral Authority is set up and based on a better knowledge of the resource.
- The activities of the third result, R3, concern the elaboration of common rules on the use of water resources, the development and monitoring of the regional implementation of a system for the analysis and qualitative and quantitative control of the water resources of the basins and the development of various partnerships. The result is stated as follows: R3: Priority regulatory and institutional collaboration frameworks for the integrated management of lake and river water resources are developed, proposed and approved by the competent decision-making bodies.

As part of R2, the progressive acquisition of a better knowledge of the basin's water resources will be achieved through three activities:

- The first activity, which is essential, will be to carry out a preliminary inventory of the situation of water resources and their current uses. This activity will enable the temporary structure to draw up general guidelines for priority actions.
- The second activity will be to develop an action plan, a strategic plan and a preliminary financing plan based on the preliminary inventory.
- The third activity will be to launch the comprehensive baseline studies of the basin that will serve to update the Authority's strategic plan and medium-term financing plan.

20.2. Definition of ABAKIR's strategic orientations

The vision described below is that of ABAKIR as an operational entity once it is up and running, which will of course take a number of years to fully realise.

ABAKIR is operational and issues guidelines for water management in the basin.

A river basin must be managed and regularly monitored to ensure that it is developed in harmony and in accordance with the principles of Integrated Water Resources Management (IWRM).

In its article 1, the ABAKIR agreement defines IWRM as *"the management of water resources which takes into account the whole resource and the sectors of activity associated with water and their impacts in a given river basin".*

For cross-border basins, a specific structure bringing together the governments sharing the basin must be set up and entrusted with the cross-border management of the basin and its water resources. The Member States have achieved this by drawing up and signing the ABAKIR agreement, which must be followed by its ratification.

However, each Member State must continue to manage and use its part of the basin, but in accordance with the terms of the agreement *"In accordance with the principle of State sovereignty, each party is free to use its own resources; however, in the case of transboundary resources shared under this agreement, they must be used in strict compliance with the terms of the agreement". "Each Party reserves the right to use and benefit from the use of water resources in accordance with this Agreement"*.

The principles to be respected by the Member States are listed in Article 6 of the Agreement, in particular the "*principle of subsidiarity whereby decisions are taken at the most appropriate level*".

As a result, the legal and institutional framework of each State applies to its part of the basin, provided that it is not necessary to move to the higher level of the framework defined by the agreement.

If necessary, management will be entrusted to the higher level of the agreement framework in order to develop common rules that can be applied in the basin in the three countries. The European Union finds itself in a similar situation when drawing up its directives, which must then be transposed into the legal and institutional framework of its Member States. The European Union has developed the Water Framework Directive (WFD), which has led to considerable progress in sustainable basin management in its Member States. Another example is the Senegal River Water Charter which is an international legal instrument that applies to the Member States (the two Guineas, Mali, Mauritania and Senegal) of the Senegal River Basin[55].

Article 9 of the ABAKIR agreement lists a number of commitments. These commitments are effectively reflected in the legal framework of the three Member States:

- Develop, adopt, implement and enforce appropriate legal, administrative and technical measures to protect and preserve the ecosystems of the basins, taking into account the natural areas protected either by national regulations or by international agreements;
- Avoid, not take or authorise any decision that could lead to a deterioration of water resources or environmental quality, and take the necessary protective measures;
- Take all relevant measures to maintain and protect facilities, developments and other structures that have an impact on the water resources of the basin;
- Manage and finance the maintenance activities of the beds and banks of the Ruzizi River and Lake Kivu ;

[55] More information on the Senegal River Water Charter : http://www.omvs.org/content/charte-des-eaux

- Set up common regulatory bodies to regulate water resources and ensure enforcement; the implementation of these rules is the responsibility of each Member State ;
- Assess the impact of the non-application of these rules and decide on sanctions;
- Define threshold levels for the flows of the Ruzizi River and the water levels of Lake Kivu ;
- Implement measures to combat soil erosion throughout the basin;
- Give priority to taking appropriate legal, administrative and technical measures to prevent all causes of erosion;
- Ensure the implementation of legal, administrative and other measures requiring water resource impact assessments for all projects planned in the basin;
- Ensure the proper application of all conditions relating to water resource use authorisations that are imposed to protect the resource.

The legal and institutional framework of the Member States is strengthened

The legal and institutional framework of each Member State applies to its part of the basin, provided that it is not necessary to refer to the higher level of the framework defined by the agreement.

The legal and institutional framework in each Member State must be sufficiently robust to ensure sound and sustainable management of the environment and water resources. The aim is not to stop development in the region, but to ensure that the development of the basin respects the environment and the water balance. It is also important that water resources are equitably shared between users, including the aquatic environment, which must retain the share (reserve flow, environmental flow) it needs to maintain biodiversity.

The legal and institutional framework of each Member State changes regularly. ABAKIR has a particular interest in it in order to be able to propose, if necessary, improvements, in particular with regard to the basin.

ABAKIR must regulate regional actions and measures by fully implementing the agreement and agreeing with the Member States on directives to be implemented by each of them and transposed into their national legal framework at least for the part of their country that is in the basin.

In addition, a financing mechanism for ABAKIR should be discussed and agreed between the Member States and formally incorporated into their legal and institutional framework.

The precious nature of water and the environment is recognised and accepted by all Member States.

The recognition of the precious nature of water and the environment has become (one could say it has become) a cultural issue. As such, everyone must respect water resources and the environment and ensure their preservation.

To this end, ABAKIR, through its Member States, should develop and implement a communication strategy based on an information, education and communication (IEC) approach.

ABAKIR is responsible for the monitoring and evaluation of the basin.

In order to manage the basin properly, its situation must be monitored regularly and the implementation of the recommended measures must be evaluated. The Member States of the basin are fully aware of this fact and have entrusted ABAKIR with this monitoring and evaluation.

The resources that ABAKIR needs to fulfil its role should be provided and a sustainable funding mechanism ensures that it can continue to fulfil its tasks in the future.

ABAKIR supports the harmonious development of water resources in the basin.

Water is life, and the development of the basin depends on the potential offered by its water resources. However, this development must be sustainable and respectful of the environment.

To this end, ABAKIR supports the development of water resources in the basin while ensuring that all precautions are taken to preserve the resource. ABAKIR should be systematically consulted and should give its opinion on the significant developments planned in the basin and make recommendations to ensure compliance with IWRM principles.

ABAKIR is a financial agency for the basin.

It is not enough to identify the deterioration of water bodies. It must be remedied through the application of appropriate measures. These measures have a cost and should be financed. To this end, ABAKIR, when operational, should have at its disposal revenues from charges and taxes levied for water abstraction and pollution, part of which could be used to support remedial measures. This approach, which has been successfully applied by French water agencies for years, should be successfully implemented in the basin.

ABAKIR sets the course through a river basin management plan and a programme of measures.

ABAKIR must put in place an ambitious strategy to ensure that the water bodies in the basin are in good condition or have good potential. To this end, it should developed rolling water resources master plans that examine the state of the basin by water body and identify the objectives sought at the end of each period. To achieve this objective, the river basin management plan should be accompanied by a programme of measures, which are aimed at solving the problems and sources of pollution identified. Thanks to the fees and taxes it collects, ABAKIR should finance a significant part of the measures within the framework of the ABAKIR financing programme, which covers the same period.

Member States and all stakeholders involved in water resources and environmental management in the basin should be involved in the development of the river basin management plan and the associated programme of measures. Extensive consultative activities should ensure that views are shared. Technicians and economists should work together to recommend measures that are both technically and financially feasible given ABAKIR's investment capacity and that of its Member States.

In this way, the river basin management plans and their programmes of measures will be accepted by all and the need to implement them will take on a legal character. Failure to comply with the recommendations of the master plan may lead to sanctions depending on the conclusions of ABAKIR.

ABAKIR's seven proposed strategic orientations should therefore be summarised as follows:

- **Strategic orientation 1:** Create a stable and operational trilateral institution for integrated water resources management (IWRM) in the Lake Kivu and Ruzizi basins.
- **Strategic Direction 2:** Develop the institution's capacity to advise the three Member States on harmonised legislation and regulation of the different uses and protection of water resources in the Lake Kivu and Ruzizi basin.

- **Strategic orientation 3:** Establish a sustainable system of advocacy and clear communication within communities around the good management and protection of water resources in the Lake Kivu and Ruzizi basin.
- **Strategic Direction 4:** Regular monitoring and evaluation of the basin
- **Strategic Orientation 5:** ABAKIR aims to support the harmonious development of water resources in the basin.
- **Strategic Orientation 6:** ABAKIR aims to become a financial agency on the basin
- **Strategic Direction 7:** ABAKIR aims to set the course through a river basin management plan and a programme of measures

	OS1	OS2	OS3	OS4	OS5	OS6	OS7
Name	Setting up a basin authority	Development of advisory capacity to Member States	Raising awareness on good water management and protection	Monitoring and evaluation of the basin	Supporting the development of water resources in the basin	ABAKIR aims to become a financial agency of the basin	ABAKIR is designed to set the course by means of an RBMP and a programme of measures
Motivation	IWRM must become operational	IWRM - Harmonisation of the implementation framework	IWRM - Raising awareness of the need to respect water resources	IWRM - Knowing the state of the water in the basin to be able to act	Basin development according to IWRM principles	IWRM - Financial autonomy for efficiency.	IWRM - Achieving good status or good potential of water bodies
Objectives	Operational implementation of ABAKIR	Upgrading the legal and institutional framework of the Member States	Raise awareness and develop everyone's responsibility for the preservation of water and the environment	Organise regular monitoring and reporting on the quantity and quality of water in the basin.	Ensure that developments follow IWRM principles	Ensure that ABAKIR becomes a financial agency of the basin. Collection of royalties.	Cyclical development of the RBMP and PoM to remedy malfunctions
Requirements	Ratification of the ABAKIR Convention	Ratification of the ABAKIR Convention	Ratification of the ABAKIR Convention The Executive Secretariat is operational	Ratification of the ABAKIR Convention The Executive Secretariat is operational	Ratification of the ABAKIR Convention The Executive Secretariat is operational	Ratification of the ABAKIR Convention The Executive Secretariat is operational OS2	Ratification of the ABAKIR Convention The Executive Secretariat is operational OS2, OS6
Responsible entities	3 Member States + support from development partners	3 Member States + ABAKIR + support from development partners	ABAKIR Executive Secretariat + support from Member States	ABAKIR Executive Secretariat and technical services of the Member States	All ABAKIR bodies in consultation with Member States	3 Member States in consultation with ABAKIR + support from development partners	ABAKIR in consultation with the 3 Member States
Chronology	1 year after ratification of the ABAKIR Convention	2 years after ratification of the ABAKIR Convention	Activity continues to start as soon as the Executive Secretariat is operational.	Activity continues to start as soon as the Executive Secretariat is operational.	Activity continues to start as soon as the Executive Secretariat is operational.	2 years after ratification of the ABAKIR Convention	Continuous activity possible once the ABAKIR has reached cruising speed.
Performance indicators	The Executive Secretary is operational Initial results of the recommended measures	Harmonisation of the legal and institutional framework of the Member States in accordance with the ABAKIR Convention	Increased awareness of the need to respect water and the environment	Monitoring of the data actually collected and banked. Effective evaluation of the measures implemented.	WR development projects are submitted to ABAKIR for advice. ABAKIR issues an opinion and makes recommendations on these projects.	ABAKIR's financing mechanism is established and operational	Development and implementation of the IWRM Master Plan. Elaboration of the first RBMP and its PoM.

20.3. Options for structural reinforcement of ABAKIR

A strengthening of ABAKIR's capacity to implement its mandate, and the missions associated with it, could materialise through :

- The establishment ABAKIR of (i) a Planning and Studies Unit, to ensure the implementation and monitoring of studies and projects within the framework of a planned process, (ii) an "Observatory of water resources and associated environments of the basin" (see section 23.2.2), to ensure the management, exploitation, capitalisation and sharing of data for monitoring water resources and associated environments in the basin and (iii) Technical Committees composed of representatives of the Member States and aimed at dealing with specific matters (erosion, water quality, natural risks, etc.).
- The establishment of data exchanges between the three member states and ABAKIR, based in particular on the definition of standardised exchange processes and the designation of national focal points;
- The use of external technical expertise, in support of the development of data management and exploitation tools, the undertaking of specific studies on the basin, the implementation of projects, and the strengthening of ABAKIR's capacities (training modules).
- A proposal for the structural strengthening of ABAKIR, based on the elements presented above, is illustrated in the organisational chart in Figure 44.

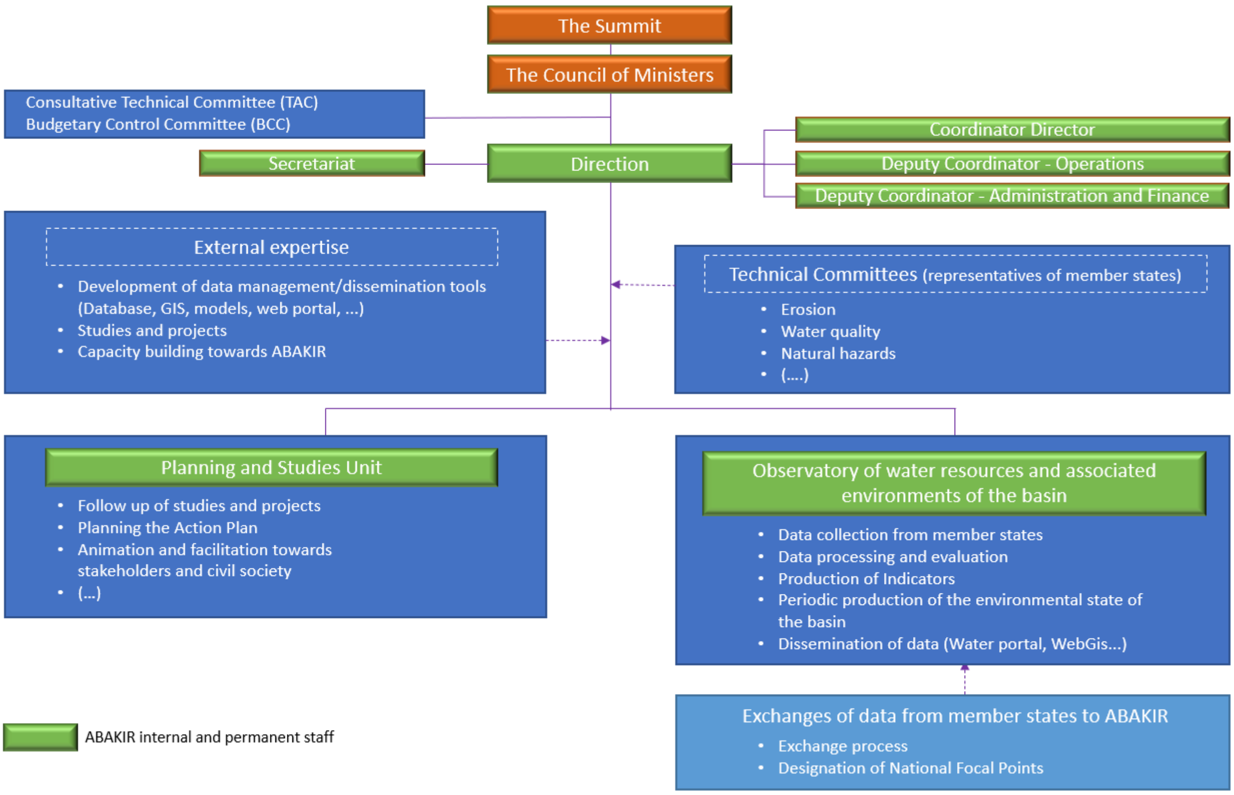


Figure 44: Proposed organisational chart for a structural strengthening of ABAKIR.

The Technical Committees are composed of representatives of the three member states, who are staff members of the Ministries in charge of the matters concerned. They are therefore not permanent internal staff of ABAKIR.

20.3.1. Establishment of a Planning and Studies Unit within ABAKIR.

In its mandate to promote tools for permanent consultation between the stakeholders in the development of the basin and to promote the implementation of IWRM, ABAKIR's involvement of all stakeholders, from grassroots populations to national and regional bodies, in each of its actions, is preponderant.

It is proposed to set up a Planning and Studies Unit within ABAKIR. This would be an internal and permanent structure within ABAKIR, with technical staff specialized in planning and project management, to be assigned to the permanent staff of ABAKIR.

The Planning and Studies Unit would in particular be responsible for planning and monitoring the basin action plan, monitoring studies and projects, and of animation and facilitation activities towards stakeholders and civil society. It would be composed of permanent technical staff of ABAKIR.

20.3.2. Establishment within ABAKIR of an Observatory of the water resources of the basin and associated environments.

It is proposed that an Observatory of Water Resources and Associated Environments be set up within ABAKIR. This would be an internal and permanent structure within ABAKIR, with technical personnel specialized in water resources management and environment, to be assigned to the permanent staff of ABAKIR.

In accordance with ABAKIR's mandates, the specific objectives of this initiative are to :

- Support the emergence of ABAKIR by making the Observatory of Water Resources and Associated Environments a multi-sectoral operational tool of the Authority ;
- To enable ABAKIR to establish a diagnosis of water needs and the resource actually available as well as the environmental situation of the basin, and to set up an information and communication tool (such as Geoportail);
- Produce and quantify governance and technical indicators relevant to the basin;
- Contribute to decision-making, with a view to:
    - Define priorities and options for the sustainable management of the basin;
    - Anticipate the negative impacts of the management of the basin's water resources.

It can be considered that the first part of this study constitutes the inventory of the environmental situation of the basin; in this sense, the first objective of the process of setting up the Observatory can be considered as achieved.

The Observatory's operational objectives can be defined as follows:

- Organise the collection, processing and analysis of the data required to monitor the basin's environment by connecting the data producers;
- Produce aggregated indicators and comprehensive information on the state of water resources and the environment in the Lake Kivu and Ruzizi river basin;
- Ensure wide dissemination of the information collected and disseminate the results of environmental monitoring in appropriate forms (publication of periodic status reports, feeding a geoportal);
- Measure and/or evaluate the environmental impacts of past, current or planned actions;
- Analysing information and detecting situations requiring an alert from the Emergency Management Centres related to natural risks (floods, earthquakes, volcanic eruptions);

- Monitor progress and trends towards sustainable development of the basin.

The operationalisation of the Observatory will be based on the development and implementation of basin management tools, which are presented in the following section.

20.3.3. Recommendations for a protocol for the exchange of information relating to the hydrometeorological and environmental monitoring of the basin

At present, no data is shared from the member states to ABAKIR. Some data (meteorological or hydrometric data in the case of Rwanda) are nevertheless available online and therefore easily accessible.

With regard to the modalities of collection and capitalisation by ABAKIR of the data collected and consolidated at national level by the member states, it is recommended :

- The designation of National Focal Points in each of the three Member States. The national focal points would be responsible for the periodic transmission of data to ABAKIR.
- The definition of a standardised data exchange protocol, defining in particular the type and format of data, the periodicity of exchanges, as well as the modalities of data transmission. A standardised digital format for data exchange between member countries and ABAKIR will allow for easy integration into the centralised database to be adopted by ABAKIR.

20.4. Development of basin management tools

20.4.1. Identification and strategy for the development of basin management tools

The development of basin management tools (see proposals below) aims at setting up information, communication and decision-making tools within ABAKIR, and the Observatory in particular. This component thus contributes to the operationalization of the Observatory and responds to the commitment of the States parties to the convention to cooperate closely for the rational and sustainable development of the water resources of the Lake Kivu and Ruzizi River Basin, based in particular on the regular exchange of data and information. This data and information change would be based on clearly established processes adopted by each of the parties. A series of information, data management, communication and decision support tools have been identified to be implemented within the Observatory. These include, in order of priority

- The implementation of a GIS application and adjoining database. In order to guarantee the durability of the tool, it is recommended to opt for software with a free license. For the management of the cartographic data and associated datasets, we recommend the use of PostgreSQL/PostGIS for the cartographic database to be created, and QGIS for the exploitation of the cartographic data. The combination of PostgreSQL/PostGIS with QGIS is indeed very robust and widely developed in many projects around the world. It could be deployed within the framework of ABAKIR's activities. Moreover, these are open-source products and therefore free. QGIS is a free and open-source GIS (Geographic Information System) mapping software capable of managing both raster and shapefile images as well as several databases. PostgreSQL is a free and open source relational and object database management system (RDBMS) that supports much of the SQL language. PostGIS is the spatial module that gives PostgreSQL the status of a spatial RDBMS, usable as a database in GIS software such as QGIS. In conclusion, the combination of PostgrSQL/PostGIS with QGIS is the solution that we recommend for the management and exploitation of thematic data relating to the subjects treated by ABAKIR.Sharing and dissemination to the stakeholders and the public of the information capitalised at ABAKIR within the GIS application concerning the hydrometeorological and environmental situation of the basin: development of a "Water Geoportal" type solution including a data query tool and a WebGIS tool, accessible online (internet), and Geoserver / web services type solutions for access to cartographic data.

- The use of hydrological and water resource planning models, in particular the Water Evaluation and Planning (WEAP) model developed in this study.
- The exploitation of models for the evaluation of erosion and the identification of anti-erosion measures, such as CROM and RUSLE used in this study.
- The use of an IWRM toolkit and its sharing on the Water Portal to be created.
- The establishment of an observation and early warning system:
    - Impact of particular hydrometeorological conditions on agricultural and energy production ;
    - Impact of meteorological conditions on possible landslides (more fragile areas, etc.), undertaking a detailed diagnosis, integration of risk and impact concepts on key structures (dams/dams, irrigated perimeters, water intakes for drinking water treatment) and inhabited areas.

20.4.2. Elaboration of a tool for managing and planning water resources in the basin

Among the tools proposed above for the operationalisation of ABAKIR's missions, those aimed at the sustainable management and planning of the basin's water resources occupy a predominant place. It is based on this observation that such a tool was developed, at an initial stage and through the use of WEAP (Water Evaluation And Planning) software, within the framework of the present study.

The management and planning of the basin's water resources, both in terms of quantity and quality, can indeed be advantageously supported by the use of the WEAP software developed by the SEI (Stockholm Environment Institute).

WEAP makes it possible to quantify and plan the allocation of water resources for the different uses encountered (drinking water supply, irrigation, industry, livestock, hydropower), at the basin and sub-basin scales, and to characterise the adequacy between these uses and the available water resource. Different scenarios can be established, notably based on a variation in water demand (population growth, industrial development, development of irrigation, etc.), and on a variation in water resource availability (climate change, successive dry years, changes in land use, etc.).

As part of this study, an initial WEAP conceptual model of the Lake Kivu and Ruzizi River basin was carried out (Figure 45).

The WEAP model is parameterised at the scale of the 11 sub-compartments defined in section 11.1 and also used for the establishment of the water balance: the water resources that can be mobilised, as well as the water uses (withdrawals), are therefore represented in the model at this scale. The time step considered for the parameterisation of the model and the production of the results is monthly.

The water demands considered for each of the 11 sub-compartments relate to domestic use (drinking water supply) in urban and rural areas, agricultural use (irrigation), and industrial use.

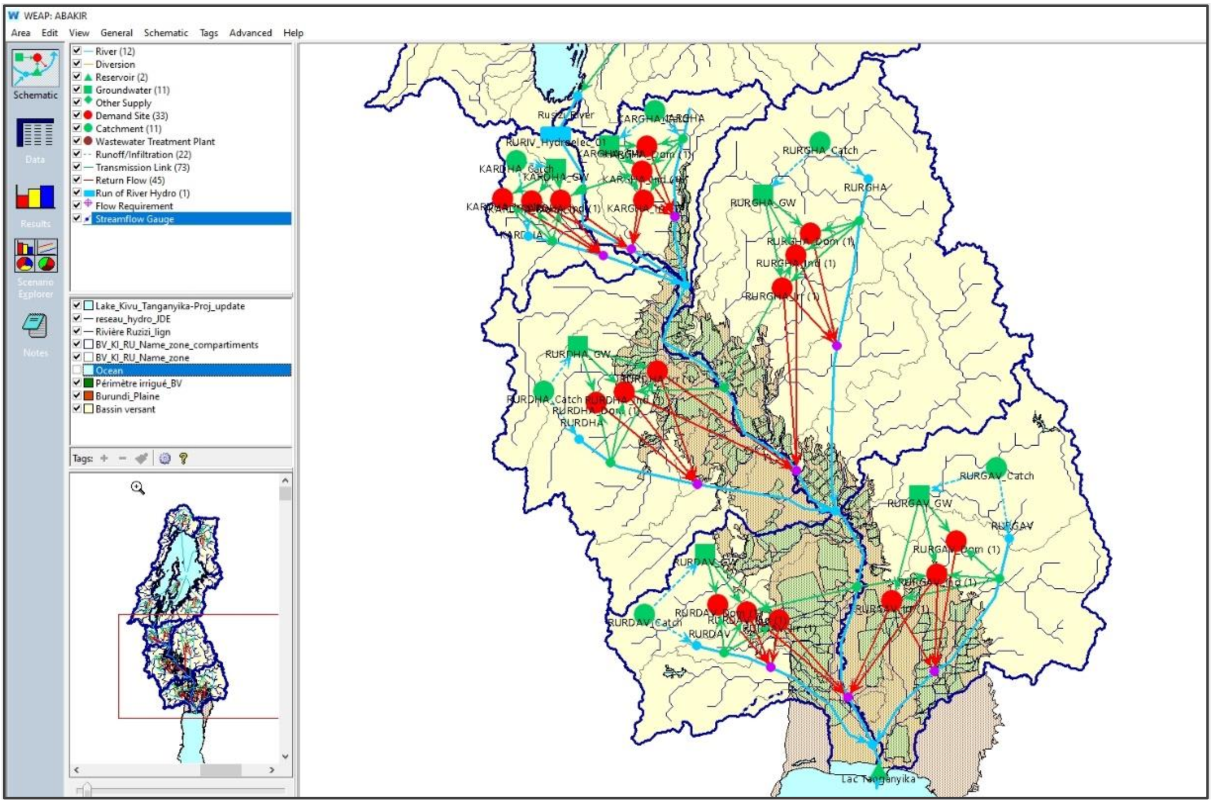


Figure 45: Schematic illustration of the WEAP model carried out on the basin of Lake Kivu and the Ruzizi River (view of the Ruzizi plain)

The scenarios defined in the study, and used in the WEAP model, are as follows:

1. Reference situation: population year 2020, climate average year (P50)[56], irrigation according to operational perimeters in activity;
2. Increase in drinking water needs by 2050: using the annual population growth rates defined for the three countries (BUR, DRC, RWA) in rural and urban areas;
3. Improving the rate of access to drinking water by 2050: definition of a function to increase the annual per capita demand for drinking water in rural and urban areas;
4. Increase of irrigated agriculture in the Ruzizi plain: increase of irrigation areas from the reference situation (operational areas currently in activity) to a situation of cultivation of all current and projected areas;
5. Climate change: taking into account the reference climate situation (P50), and a climate change towards a drought situation corresponding to the P80 level defined in the water balance.

The detailed description of the conceptual model, the model parameterisation (water resources and uses), the defined scenarios, and the main results obtained, is included in Annex VII of the report.

The analysis of the WEAP modelling results shows that, from a quantitative point of view, the water resources of the basin make it possible to satisfy all the identified uses, in a reference situation (2020) and for the various defined scenarios.

[56] P20, P50, P80 refer to the probability of exceedance. P50 refers to a 50 % of exceedence which corresponds to the median value, P80 refers to a 80 % probability of exceedance which corresponds to a dry event. P20 refers to a 20 % probability of exceedance which correspondes to a wet event.

Water demand for drinking water supply in urban and rural areas is indeed met for all compartments, both on an annual and monthly basis, for all established scenarios.

The demand for water for irrigated agriculture in the Ruzizi plain is also globally satisfied, the only limitations observed being encountered in monthly analysis in the scenario of cultivation of all the areas (existing, planned and projected) combined with the dry climate year scenario (P80). These limitations of monthly availability of surface water are met for 3 compartments, over a short period (July-August) of the year. However, they do not exceed 5% of the estimated water needs for irrigation in this worst-case scenario combination. In this sense, they therefore do not represent a significant threat to the quantitative management of the basin's water resources and its hydro-agricultural development.

On the scale of the basin and the main sub-basins, it can therefore be concluded that the availability of water resources is not a limiting factor in the socio-economic development of the intervention area, including in a situation of unfavourable climate change and significant population growth according to the established scenarios.

20.5. Adoption of indicators

The monitoring of the situation of water resources and the state of the environment in basins by basin organisations is generally supported by the use of indicators. Most transboundary basin organisations have been using this type of tool for many years, particularly in Africa, and it therefore seems relevant to recommend their use to ABAKIR.

The International Network of Basin Organizations (INBO) and its regional network in Africa (the African Network of Basin Organizations - ANBO) have developed performance indicators relating to the implementation of IWRM principles in African transboundary basins[57]. These indicators could usefully be used within the framework of the activities of the ABAKIR Observatory, in particular to periodically establish the environmental status of the basin and the basin management framework.

Two groups of indicators are designed for basin organisations, which manage lakes, rivers or aquifers crossing international borders. The 20 **governance indicators,** assess the organisation of the basin organisation with regard to the main pillars of IWRM (political aspects, legal, institutional and organisational framework, financing mechanisms, participatory aspects, planning, information system and communication), whilst the 15 **technical indicators,** assess the results of the programmes and characterise the evolution of the "situation on the ground". They thus make it possible to evaluate the control obtained in the knowledge and management of water resources, uses and users of the basin. The set of indicators always depends on the context and must be interpreted according to the specific institutional structures of the basin (agreements, financing, functions, objectives), hydrological conditions, the state of progress of economic development, etc. All indicators can be widely applied at the basin scale, but some indicators will also work at a sub-basin level.

Among all these indicators, it is recommended that the following selection be taken into account as a priority, corresponding to the parameters deemed most relevant for the Lake Kivu and Ruzizi River basin and best suited to the current context of cross-border management of this basin.

[57] Manual for the use of key performance indicators for IWRM in African transboundary basins, INBO 2010

20.5.1. Governance indicators

Table 26 presents the governance indicators selected from the ANBO list.

Table 26: Governance indicators selected from the list elaborated by the African Network of Basin Organisations.

Code	Title	Description
Political process		
G01	Political commitment	Political commitment of the States in the governance and operation of the basin organisation
Legal framework		
G10	Legislation at the level of basin organisations	Legal framework relating to the mandate and structure of the basin organisation, financial mechanisms and water management at the regional level, adapted to IWRM requirements.
G11	Coherence between national/regional legislation	Reciprocal consistency of national water legislation with the texts carried by the basin organisation.
Planning and functional coordination		
G12	Planning process	A planning process with clearly defined objectives, mutually beneficial goals and development priorities, all set out in a long-term integrated basin management plan.
G15	Interface national/regional level	Design and operation of national relay structures
Information and communication system		
G18	Information management system	Shared information system (including its geographical component, environmental characterisation, etc.) for decision-making support.
G19	Information management protocols	Processes for specifying the type of information needed, how it should be presented and how information should be exchanged in the basin organisation's information management system

20.5.2. Technical indicators

Table 27 presents the technical indicators selected from the ANBO list. These are the most relevant technical indicators for the Lake Kivu and Ruzizi River basin, taking into account the configuration of this basin (physical environment, water resources, water uses, and environmental situation), among those included in the ANBO list.

Table 27: Technical indicators selected from the list developed by ANBO.

Code	Title	Description
Risk of overexploitation of water resources		
Ensuring and optimising water needs for irrigation		
T03	Share of irrigated agricultural land	The area of irrigated perimeters expressed as a percentage of the total area of agricultural land. Unit: percentage
Monitoring the evolution of water resources		
T05	Number of quantity monitoring stations for hydrological monitoring of the basin	Number of hydrometric stations enabling changes in the quantity of water resources in the basin to be measured.
Risk of water resource degradation		
Monitoring water quality		
T08	Number of water quality monitoring stations for basin monitoring	Setting up water quality monitoring stations to ensure a balanced and sufficient coverage of the hydrographic network in order to account for the impact of human activities and to have a reference system for the development or restoration of a watercourse.
Risk of deterioration in the living conditions of the basin's populations		
Improving the supply of drinking water		
T12	Proportion of the population with sustainable access to an improved water source	Access to an improved water source is characterised by the possibility of having an easier supply of drinking water. This access must also protect the drinking water source from external contamination. Unit: Percentage
Preventing natural risks		
T13	Number of sites at high risk of flooding	The basin organisation's regulations should set out the rules for determining the characteristics of high-risk sites and for taking the necessary measures to mitigate the risk.
Risk of environmental degradation		
T15/2	Land degradation	Approximate area of degraded land Unit: Km2
T15/3	Land degradation	Sub-basin erosion rates Unit: Tonne/ha/year

20.6. Integrating Payments for Ecosystem Services (PES) into basin management

Understanding the ecosystem services approach is fundamental to apply the concept of PES, which emerged as a response to the fact that many ecosystem services, even if they generate high economic values, cannot truly be traded at a defined price. This is the case, for example, for forests, whose ecosystem benefit is not easily quantifiable. There is a critical lack of incentives and funding for ecosystem conservation in river basins, which ultimately leads to the degradation and conversion of natural ecosystems into pasture, agricultural or other areas and the loss of ecosystem services.

PES is a mechanism to reverse this dynamic so that the guarantors of the functioning of ecosystem services (mainly upstream farmers or conservation authorities) are rewarded by the users of these services (e.g. water consumers in urban centres or hydropower projects). Based on findings from the assessment report on experiences and lessons learned in payment for ecosystem services (PES) in East Africa which was produced by the United States Agency for International Development (USAID), under the PREPARED Program carried out by the Lake Victoria Basin Commission[58] ; for a PES scheme to be effective, at least six key elements must be satisfied :

- The PES must involve at least one user of an ecosystem service and at least one provider;
- The process must be transparent and accepted by all parties;
- The provision of services and their payment, as well as the conditions under which such payments are negotiated and made, must be agreed between the two parties;
- PES should involve a clearly defined ecosystem service and specify a land use that is known to provide that service;
- The activities that are carried out on the area that produces the service must be able to be monitored and quantified;
- The PES must involve payment in cash or in kind to the User.

Within the framework of the Lake Kivu Basin and the Ruzizi River, ABAKIR could initiate and set up this PES mechanism by relying on existing national institutions in the three countries. The establishment of the PES mechanism could be done in several phases which are described here below.

20.6.1. Preliminary phase

Establishment of the institutional and legal framework of the PES

It is essential that an institutional and legal framework be established in the three countries in order to enable the funds mobilization from users of ecosystem services. The Regional Power Generation Institutions on the Ruzizi River, which work in close collaboration with the national utilities for the production and distribution of electrical energy, can be identified as the main user of the ecosystem services. Therefore, regulations will have to be set in place in Burundi, DRC and Rwanda, so that funding for the PES is collected from the energy billing of all consumers in the two provinces of North and South Kivu, Rwanda and Burundi. This regulation shall also indicate the institution in charge of managing this funding and distributing payment to ecosystem service providers.

The Legal Framework might further be extended with the establishment of an appropriate tax system aimed at raising funds from the hotel and tourism industry, and other industries benefiting from water resources.

[58] Tetra Tech and LTS Africa Experiences and lessons learned in payments for ecosystem services (PES) in East Africa, Jan 2018

Identification of ecosystem service providers

ABAKIR can identify the most relevant water catchments that will be the object of this PES mechanism on the basis of the WEAP water resources planning and management tools, and conduct broad consultations with all stakeholders in order to obtain their support and commitment to participate in the project. Thus the Conservation Authorities of the Volcanos NP, Kahuzi-Biega NP, Nyungwe NP, Kibira NP and/or Itombwe Reserve will be key beneficiaries and partners in the PES mechanism implementation, depending on the selected sub-catchment. Indigenous populations living in protected areas or in their vicinity should also be consulted and be included among stakeholders, with the aim of sharing benefits and sustainable conservation of protected areas.

The landowners located in the selected sub-watersheds will be identified and consulted as beneficiaries of the PES, individually if they own land titles or collectively through local structures such as collines/quartiers (Burundi) or rural and urban collectivities (DRC), and express their commitment through legal contracts.

Identification of criteria for monitoring and surveillance of the PES mechanism

The use of geo-referenced tools to identify all plots involved in the PES is recommended as well as the establishment of a monitoring network for parameters such as river turbidity is essential to measure the impact of the ecosystem service that may be rendered by upstream users.

Suppliers of services must commit to strengthening of the Basin Ecosystems Services through different actions including protected areas conservation, maintenance of forest plantations, implementation of anti-erosion measures on agricultural land or protection of the lake Kivu and the Ruzizi river banks.

Laboratories contracted to provide monitoring of water quality and institutions responsible for monitoring land use / land cover in sub-watersheds will provide progress reports to be used as reference for payments to ecosystem services providers on an agreed basis. Payments will be made on an individual basis to each supplier or collectively through construction of community infrastructure, access to micro-finance schemes... based on the agreements.

Mobilization of financing to set a favorable ground to the PES

In order for the PES system to be operational in the Lake Kivu basin and the Ruzizi river, the project of PSE will have to mobilize funding in order to significantly reduce the high level of pollution already observed at the entrance to the Ruzizi river (Bukavu Bay) as it is a significant operational shortfall for hydroelectric power stations in place or under construction. The funds should be used to support the city of Bukavu to set up a sustainable sanitation system (wastewater and faecal sludge treatment system, management of public dumpsite). For recall, the town of Rusizi in Rwanda is benefiting from support from the African Development Bank to establish similar infrastructure.

20.6.2. Phase 1 of the PES mechanism

Burundi, DRC and Rwanda will have adopted legislation allowing the financing collection of at source from energy consumers and giving clear powers to the regional institution in charge of managing these funds for the benefit of service providers. A well-defined amount (eg: 1-10 USD) can then be deducted from the bill of anyone benefiting from the electrical energy generated from the Ruzizi river.

All ecosystem service providers identified in each of the sub-watersheds will be consulted and informed of the conditions of their engagement individually or collectively in the PES mechanism.

The hydrological, ecological and socio-economic data of the sub-basins selected in the PES mechanism compiled and the reference situations of the indicators to be used for the monitoring and surveillance of ecosystem services will be defined in partnership with the monitoring and surveillance institutions in the three countries.

The payments will be based on monitoring and surveillance reports indicating the impacts of the conservation measures set in place by the service providers, including:

- the surface of land maintained in conservation or restored in protected areas and the surface of afforestation maintained or planted in the selected sub-basins;
- the level of sedimentation in the rivers (value of river turbidity) linked to anti-erosive measures in agricultural areas;
- the quality of the water including the level of nitrates, phosphates, chlorides and heavy metals concentration;
- the dissolved oxygen concentration and level of bacteriological contamination
- the surface of restored soil covered with perennial vegetation;
- the surface of rivers and Lake Kivu banks restored and covered with perennial and appropriate vegetation.

Payments do not necessarily have to be in cash but can be made in the form of investment into socio-economic infrastructures (dispensaries, markets, schools, etc.), facilitation in finding new markets for agricultural products, loans to advantageous conditions, authorization to harvest forest products, local recruitment of forest guards, support for youth initiatives, etc.

20.6.3. Phase 2 of the PES mechanism

The second phase of the PES could consist in offering better choices to local communities already involved into economic activities that degrade the environment. This is the case of artisanal mining activities, and quarries or brick making in the marshes. Identification of severely degraded sites or sites under exploitation should be conducted in the sub-basins and significant advocacy should be conducted with the participation of key stakeholders including local authorities and NGOs in order to offer profitable economic alternatives to populations involved while respecting the best environmental management standards.

21. Development of the legal and technical bases in the basin: summary of the proposed options

The development of the legal and technical bases of the basin is elaborated in the previous sections of this second part of the report. A summary is given below.

21.1. Legal basis

An analysis of the water and environmental legislation in force in the three countries, and the proposed development of legal bases for the Lake Kivu basin and the Ruzizi River, are included in chapter 17 of this report. A summary is given below.

Harmonisation of policies and regulations related to environmental protection and water resources management

Basin management should involve the harmonisation of policies and regulations related to environmental protection and water resource management. This harmonisation should be achieved by strengthening the capacities and responsibilities of decentralised entities but also of organisations in charge of watershed management and institutions in charge of the management of protected areas. It should also be achieved through the harmonisation of agricultural, livestock and fisheries policies in the basin as well as regulations related to the practice of these activities in order to limit practices that are harmful to the environment and the health of populations, particularly in the use of agrochemicals. Similarly, the harmonisation of policies and regulations related to environmental assessment would prevent environmentally damaging investments and the use of hazardous chemicals, whether in agriculture, industry or mining. The establishment of common sanitation rules would prevent uncontrolled development of urban centres and hotel infrastructure and the provision of appropriate sanitation infrastructure.

Implementation of Payment for Ecosystem Services mechanisms

Establishing mechanisms for Payments for Ecosystem Services in sub-basins requires a good knowledge of the ecosystem services provided at the sub-basin level, the identification of beneficiaries of payments based on land tenure data and the establishment of a mechanism for collecting fees from service beneficiaries. This should be harmonised in the three countries.

21.2. Technical bases

The options proposed for the development of the technical bases in the basin were presented in detail in chapters 16 and 20 of the report.

These options relate mainly to the elements summarised below.

Strengthening and optimising existing hydro-meteorological monitoring networks in the three countries.

The proposed strategy for optimising climatological monitoring consists of maintaining existing meteorological stations, combined with enhanced use of global climate data sets (CHIRPS and GLOBAL-PET from the CGIAR-CSI) corrected based on of ground stations.

Concerning surface water, a reinforcement of the hydrometric monitoring network is proposed. 24 potential sites have been identified during field visits (see Table 23 in section 16.2.2).

A strengthening of the monitoring of surface water quality is also proposed; it includes, as a priority, the monitoring of turbidity in the sub-basins most exposed to erosion phenomena, as well as the monitoring of chemical parameters related to the potential impacts of agricultural inputs on the Ruzizi river at the level of the plain. A monitoring of the physicochemical quality of the water of Lake Kivu is recommended, mainly in relation to the potential impacts of wastewater and solid waste discharges from the main urban areas bordering the lake on the quality of the lake water.

Concerning groundwater, a reinforcement of the piezometric monitoring network and of the water quality monitoring network is proposed as a priority for the alluvial water table of the Ruzizi plain, in relation to the risks of contamination of this water table from hydro-agricultural activities.

The establishment of operational technical structures within ABAKIR

A structural reinforcement of ABAKIR is proposed, with the setting up of a Planning and Studies Unit on the technical level and internally, and on the other hand an "Observatory of water resources and associated environments of the basin".

The definition of a protocol for the exchange of information and data between the member states and ABAKIR.

The strengthening of the modalities of information and data exchange between the three member states and ABAKIR would be based in particular on the definition of standardised exchange processes (standardised protocol), as well as on the designation of national focal points.

The development of basin management tools

The tools identified and recommended for the management of the basin, to be implemented within ABAKIR, consist primarily of :

- a relational and object database accessible by client cartographic software (such as QGIS) as well as by WebGIS ;
- hydrological and water resources planning models (WEAP), and erosion assessment models (CROM and RUSLE) ;
- a IWRM toolbox.
- an observation and early warning system.

The development of information and extension tools

The information and popularisation tools proposed as initial measures consist in setting up a Water Geoportal, and the publication of a summarised and popularised version of the state of the basin's water and environmental resources.

The adoption of indicators

It is proposed that governance and technical indicators be adopted to monitor the implementation of IWRM principles within the basin.

22. Recommendations for the elaboration and prioritisation of an action programme

Measures aimed at the sustainable management, preservation and restoration of water resources and associated environments of the basin are necessary, through enhanced cooperation between Member States. Under the coordination and with the support of ABAKIR, an action programme is thus proposed to achieve these objectives. A prioritisation of actions is then proposed, taking into account the main risks and issues identified in the basin.

22.1. Proposals for an action programme in the basin

It is proposed to implement an action programme consisting of the following six types of measures:

1. Knowledge enhancement measures ;
2. Resource monitoring measures and data transmission ;
3. Measures to reduce pressure on the environment ;

4. Natural risk management measures ;
5. Institutional support measures for ABAKIR ;
6. Measures to develop the legal bases in the basin.

These measures are described below.

22.1.1. Knowledge enhancement measures

The inventory carried out in the first part of this study shows that knowledge of water resources and water use in the basin could be improved.

The improvement of knowledge would concern in particular the following elements:

- **Hydrology**: Extensive characterisation of the hydrological context of the sub-basins, based on the setting up of additional hydrometric stations to reinforce the current network and on a detailed hydrological analysis ;
- **Hydrogeology**: the hydrogeology of the basin is insufficiently studied and poorly documented. The efforts to be made are mainly aimed at drawing up an inventory of the aquifers and their characteristics. These efforts should provide more information on aquifer potentialities, renewable reserves, sustainable exploitation flows, and groundwater quality. They should also make it possible to define measures to protect the most vulnerable aquifers, such as the alluvial groundwater of the Ruzizi plain.
- **Water abstraction and wastewater discharges**: the location and quantification of the volumes abstracted in the three Member States from surface water (Lake Kivu and rivers) and groundwater (springs and boreholes) for the various significant uses are still insufficiently known. The improvement of knowledge on these elements, and the setting up of periodic monitoring, could be supported by the activities of the Observatory of water resources and associated environments to be set up within ABAKIR, and by the modalities of data exchange facilitated by the designation of national focal points. The same applies to the location and quantification of waste water discharges into Lake Kivu and the main rivers of the basin. An initial inventory should be undertaken by each of the three member states, followed by periodic data exchange for the benefit of ABAKIR.
- **Potential sources of pollution**: The identification and characterisation of the main potential sources of pollution in the basin, addressed within the present study, should be deepened, in particular in relation to a better knowledge of the sites of extractive activities (mines and quarries), the sites of solid waste storage (essentially in urban and peri-urban areas), and the industrial sites likely to generate solid and liquid discharges. The data collected in the framework of the present study would indeed deserve to be completed, through the transmission of information by the national focal points to be designated.
- **Quality of the basin's water resources**: The assessment of the quality of surface water (river and Lake Kivu) and groundwater, carried out within the present study on the basis of the available information, would deserve to be deepened. In this sense, proposals have been made to improve the monitoring networks of surface and groundwater quality. Concerning surface water, the problem of turbidity (resulting from erosion) is a priority, as is the physico-chemical quality of the water of Lake Kivu downstream of the large urban agglomerations. Concerning

groundwater, the problem of the impact of agricultural inputs on the alluvial water table of the Ruzizi, in the plain, is a priority.

- **Degradation of the basin**: The assessment of the environmental degradation of the basin, carried out within the present study, could be deepened on the scale of the main sub-basins that are characterised by a significant modification and impacting land use (deforestation, development of agriculture favouring erosion, urbanisation, etc.).
- **Natural risks:** Several types of risks existing in the basin have been identified and characterised. These are mainly flood risk, volcanic risk, seismic risk, and landslides, as well as risk of limnic eruptions. The flood risk, which is a priority, could usefully be the subject of more detailed analyses carried out on a more local scale, in the zones identified as being sensitive in relation to this issue.

22.1.2. Measures to monitor water resources

Surface water monitoring

A reinforcement of the hydrometric monitoring network is proposed in this study. 24 potential sites were identified during the field visits (see Table 23 section 16.2.2).

A strengthening of the monitoring of surface water quality is also proposed; it includes, as a priority, the monitoring of turbidity in the sub-basins most exposed to erosion phenomena, as well as the monitoring of chemical parameters related to the potential impacts of agricultural inputs on the Ruzizi River at the level of the plain. A monitoring of the physico-chemical quality of the water of Lake Kivu is recommended, mainly in relation to the potential impacts of wastewater and solid waste discharges from the main urban areas bordering the lake on the quality of the lake water.

Groundwater monitoring

Concerning groundwater, a reinforcement of the piezometric monitoring network and of the water quality monitoring network is proposed as a priority for the alluvial water table of the Ruzizi plain, in relation to the risks of contamination of this water table from hydro-agricultural activities.

22.1.3. Measures to reduce pressure on the environment

All infrastructure and equipment projects that reduce pressure on the environment and water resources are welcome and should be encouraged. Most of these measures are the domain of national governments, but ABAKIR should play a catalytic role. Regional cooperation among member states through ABAKIR is sure to attract donor funds for this purpose.

Once ABAKIR is operational, part of the royalties it will receive should be allocated to finance these measures in conjunction with other sources of funding (government, donors, etc.). The following measures have already been identified, but others will of course be necessary in the future.

Measures to reduce the use of firewood

As there is no alternative source of energy, people mainly use firewood or charcoal for cooking. Measures to increase the use of improved stoves can help to reduce the use of firewood and thus minimise the extraction of wood from forests. These measures protect the natural water reservoirs created by these forests and are therefore recommended.

Measures to improve access to electricity

Access to electricity reduces the use of firewood. In addition to improving the comfort of the population, widespread access to electricity helps protect the natural water reservoirs created by the forests. As long as the environment is respected in the implementation of these developments, measures to increase access to electricity are to be recommended.

Measures to improve access to water and sanitation

Access to safe drinking water (from an improved source) is an end in itself and every effort should be made to achieve this. It is equally important that people have access to adequate sanitation facilities.

In addition, excreta must be collected and properly treated or disposed of. Under no circumstances should excreta be dumped into the nearest gutter and end up in the river or lake.

The development of sewerage networks and wastewater treatment plants is strongly recommended to ensure the preservation of water resources.

Measures to improve solid waste management

All too often, solid waste is still dumped indiscriminately and, more often than not, into sewers and rivers in the hope that water will carry it away. Not only does this pollute rivers and lakes, it also poses a serious risk of waterborne diseases such as cholera and bilharzia. There is an urgent need to address this situation.

Measures to organise the collection and disposal of solid waste are therefore recommended.

Subsequently, a closer analysis should be made of the way in which waste is disposed of, especially when it is landfilled. Furthermore landfills are a source of surface and groundwater pollution through infiltration.

Measures for the protection of fishing and fish farming

An assessment of fishing and fish farming in Lake Kivu should identify measures that can ensure the sustainability of these practices. It would be interesting to create fish reserves on the shores of the lake to allow fish to reproduce and fry to develop. Poaching (illegal and illicit fishing) should be systematically controlled and sanctions strengthened.

Along the Ruzizi River, hydropower dams should be required to operate at the set environmental flows. Dams should be equipped with fish ladders that should never be de-watered. Once these conditions are met, local fish restocking measures can be taken, fishing by poisoning or blasting should be prohibited, and closed seasons for fishing should be defined and enforced.

Measures to combat soil degradation

The degradation of slopes through deforestation and the development of agriculture and livestock is not inevitable. There are a number of well-known techniques to protect soils from erosion, including the construction of levees and terraces in fields, weirs in gullies and replanting of trees on steeper slopes and along roads.

Member States, Rwanda in particular, are aware of the stakes and wish to continue to implement these erosion control measures. Efforts to stabilise land, conserve water and reduce siltation of rivers and lakes should be supported.

Measures for the treatment of excrements from intensive livestock farming

These measures should be understood more generally as protective measures against water resource degradation.

Following an inventory of intensive livestock farms, an inventory of the current situation should be drawn up for each site in order to highlight areas for improvement. Partnerships should be established with each polluting site in order to find technical and financial solutions to reduce the level of pollutants released into the environment.

Measures to improve industrial processes with regards to pollution

These measures should be understood more generally as protective measures against water resource degradation.

Following the factory inventory, a baseline should be taken of the current situation for each site to highlight areas where processes could be improved. Partnerships should be established with each polluting site in order to find technical and financial solutions to reduce the level of pollutants released into the environment.

It should be noted that a similar approach could be adopted with artisanal worker cooperatives.

Measures to improve mining processes with regard to pollution

These measures should be understood more generally as protective measures against water resource degradation.

As a follow-up to the mining site inventory, an inventory of the current situation should be drawn up for each site, in order to highlight areas where processes could be improved. Partnerships should be established with each polluting site in order to find technical and financial solutions to reduce the level of pollutants released into the environment.

It should be noted that a similar approach could be taken (i) with peatland operators and (ii) with quarry operators, including quarries that exploit material from minor riverbeds. It will then be necessary to identify, the quantities of material extracted and the impact of the extractions on the environment.

Measures to reduce pollution from tourism infrastructure, health infrastructure and schools

These measures should be understood more generally as protective measures against water resource degradation.

Following the inventory of the largest establishments, an inventory of the current situation should be drawn up for each establishment in order to highlight areas where processes could be improved. Partnerships should be established with each polluting site in order to find technical and financial solutions to reduce the level of pollutants released into the environment.

Measures to combat the degradation of water resources

The pressure of pollution on water resources comes from many sources. With population growth and the development of socio-economic activities in the basin, the degradation of this resource will worsen if nothing is done to remedy the situation. However, much development depends on water resources.

It is therefore necessary to put in place mitigation mechanisms to protect the resource. The ultimate objective is to prevent users from polluting water and to ensure that they use water rationally.

New developments must comply with environmental standards. To this end, environmental assessments must be carried out in accordance with the legal framework and recommended impact mitigation measures must be implemented.

It will be more difficult to change the situation for pre-existing uses. In this case, the solution lies in incentives and support measures. It is therefore essential to put in place a system based on the user and polluter pays principle. Part of the fees collected should be refunded in the form of incentives and support to users to help them improve their processes.

ABAKIR should therefore function as a water agency, able to collect water charges and reimburse part of them in the form of aid.

The implementation of this measure firstly requires a very detailed inventory to be carried out, as recommended in the above-mentioned measures to improve knowledge.

Measures to safeguard biodiversity

Measures to protect biodiversity should be promoted from the point of view of water resource conservation. Areas of high biodiversity must be maintained in good condition. They are generally located upstream of catchment areas, often covered by forests and wetlands.

It would be beneficial to protect forests in the upper basins, as they are natural reservoirs of water resources. The Ruzizi River flows through the lower areas of the escarpments which have a high tourist potential but are very hostile to human settlements, so conservation and ecotourism are the most appropriate means of promoting these areas. This would allow the preservation of endangered species such as baboon, cheetah, crocodile, hippopotamus, Nile watch lizards, snakes (pythons), rare birds, fish, etc.

22.1.4. Natural risk management measures

Human settlements in areas at high risk of natural disasters must be avoided at all costs. Natural risk management measures are needed. ABAKIR should make recommendations to its member states on mechanisms to prevent people from settling in areas at risk.

Prevention mechanisms based on zoning could be useful in this context.

22.1.5. Institutional support measures to ABAKIR

Once the agreement has been ratified and ABAKIR officially established, it will need technical support. This support will help ABAKIR to set up its financing mechanisms, based initially on donor funds, and then gradually through the introduction of royalties.

The technical support should help ABAKIR and the Member States to set up a means of collecting these fees.

It should also assist ABAKIR in preparing the terms of reference and specifications of the studies and other activities it will launch, as well as in procuring the necessary digital equipment and software as identified in this study (GIS, hydrological models, etc.).

22.1.6. Measures to develop the legal bases in the basin

Harmonisation of policies and regulations related to environmental protection and water resources management

Basin management should involve the harmonisation of policies and regulations related to environmental protection and water resource management. This harmonisation should be achieved by strengthening the capacities and responsibilities of decentralised entities but also of organisations in charge of watershed management and institutions in charge of the management of protected areas. It should also be achieved through the harmonisation of agricultural, livestock and fisheries policies in the basin as well as regulations related to the practice of these activities in order to limit practices that are harmful to the environment and the health of populations, particularly in the use of agrochemicals. Similarly, the harmonisation of policies and regulations related to environmental assessment would prevent environmentally damaging investments and the use of hazardous chemicals, whether in agriculture, industry or mining. The establishment of common sanitation rules would prevent uncontrolled development of urban centres and hotel infrastructure and the provision of appropriate sanitation infrastructure.

Implementation of Payment for Ecosystem Services mechanisms

Establishing mechanisms for Payments for Ecosystem Services in sub-basins requires a good knowledge of the ecosystem services provided at the sub-basin level, the identification of beneficiaries of payments based on land tenure data and the establishment of a mechanism for collecting fees from service beneficiaries that should be harmonised in the three countries.

22.2. Prioritisation of measures in the ABAKIR Action Programme

Among the options for the development of the legal and technical framework presented in this second part of the study, and in particular among the measures included in the action programme presented above, the following actions are recommended to be implemented as a matter of priority:

- Setting up of ABAKIR's internal technical units: Studies and Planning Unit, and Observatory of Water Resources and Associated Environments.
- Establishment of data exchange protocols between ABAKIR and the member states, notably through the designation of national focal points for data transfer.
- Operationalisation of ABAKIR's technical units by establishing and operating the proposed management tools: computer infrastructure, database, geographic information system, water resources planning model (WEAP), erosion assessment model (CROM and RUSLE).
- Implementation of communication tools, improving the visibility of ABAKIR within the member states and to share information on the basin with the general public. In particular, establishment of a Water Geoportal, and publication of a popularised version of the inventory of water resources and the environment of the Lake Kivu and Ruzizi river basin.
- Setting up pilot projects to combat soil degradation and erosion in sensitive sub-basins in the intervention zone.
- Improvement of the network for monitoring surface and groundwater resources.

- Implementation of measures to improve knowledge on (i) the hydrogeology of the basin (characterisation of aquifers, exploitation potential, vulnerability), (ii) water abstraction and discharges, (iii) the quality of surface and groundwater resources.

23. General conclusions

The current situation of management of water resources and associated environments in the Lake Kivu and Ruzizi River basin can be summarised in the form of a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis as shown below.

The main strengths characterising the basin and the current situation of management of its natural resources are the following:

- A basin well supplied with generous water inflow
- Hydrogeological potential with many exploitable water sources
- A large and beautiful lake in a very picturesque area with a remarkable tourist potential.
- Protected forests and remarkable biodiversity that enhance the tourist potential
- A dynamic socio-economic area with a fast-growing population
- High potential for fisheries and aquaculture
- Forests that protect the basins and provide firewood
- Fertile land for irrigated and rainfed agriculture
- High potential for electricity production (hydroelectricity, methane gas from Lake Kivu, other renewable energy sources)
- Rich mineral resources
- Infrastructures that are gradually developing
- A strategic situation because on the border between three countries (Burundi, DRC and Rwanda), or even four if neighbouring Uganda is included, a junction between Central and East Africa.

The main weaknesses characterising the basin and the current situation of management of its natural resources are the following:

- Landlocked countries
- Basin shared between three countries with different modes of governance, which complicates management; moreover, the surface area of the basin is very small compared to the total surface area of each of the three countries, which does not encourage national membership.
- Population growth that is difficult to control
- The water of Lake Kivu is alkaline and saline; the water of the Ruzizi River is saline, as is the water of some tributaries.
- The months of June, July and August are dry and during these months the river flows are low.
- The sources have limited flow rates
- The terrain of the basin is rugged, the land used for cultivation along the slopes is fragile and subject to erosion and landslides.
- Lack of hydro-meteorological monitoring in the basin

The opportunities for development of the basin, restoration and preservation of its natural resources are as follows:

- The conflict has practically ceased in the basin
- The three countries wish to cooperate and develop the basin
- Donors are ready to support the development of the basin and ABAKIR
- Cross-border projects strengthen regional cohesion
- A clear willingness of governments to preserve the environment

- The ABAKIR agreement has been signed by the governments
- The implementation of ABAKIR is in a provisional phase.
- All the countries concerned have updated their legal frameworks for sustainable water and environmental management.
- There are experienced researchers in the three Member States, including in the major cities of the basin, who could help to strengthen the knowledge base.

The threats to the socio-economic development of the basin and to the restoration and preservation of its natural resources are the following:

- Climate change could affect water supplies
- High natural risks: volcanic eruptions, limnic eruptions, strong seismicity, floods, landslides, etc.
- Agriculture and livestock farming on steep slopes cause soil erosion and landslides.
- Uncontrolled and unsustainable use of wood, forest clearing and bush fires lead to loss of biodiversity and erosion.
- Uncontrolled explosive urbanisation combined with a lack of sanitation and collection/treatment of solid and liquid waste
- Several industries that are not particularly environmentally friendly
- The exploitation of mines and quarries, often with little respect for the environment, and with little control.
- Extreme poverty of the populations living in the basin, putting a strong pressure on natural resources
- Overfishing in Lake Kivu and the Ruzizi River, and poaching in protected areas
- Delay in the ratification of the ABAKIR agreement
- Failure by members to pay their contributions to ABAKIR and the tripartite companies
- The provisional implementation phase of ABAKIR has been extended for a long time.

The main issues related to the management and preservation of the basin's water resources are globally linked to the quality of the water resources, rather than to the quantity. The control of environmental degradation, in particular with regards to soil erosion and the resulting significant turbidity of the watercourses, is one of the major issues encountered in the basin.

The threats to the quality of Lake Kivu's water, in relation to the uncontrolled development of the urban areas bordering the lake, as well as the industrial development - especially mining - which poses environmental threats to the surface waters of the basin, are all factors that require coordinated action at the scale of the basin and the most vulnerable sub-basins.

Finally, the need to control natural risks in the basin should not be overlooked particularly as the basin is exposed to extreme events such as floods, landslides, volcanic eruptions and seismic phenomena.

Faced with these threats, the challenges of sustainable management and preservation of water resources and associated environments in the basin can be met in a coordinated manner between the three countries, through the operationalisation of ABAKIR. The priority in this respect will be to give this structure the visibility and legitimacy that will enable it to strengthen the support of the authorities, populations and users of the basin's resources, prior to the implementation of measures that could be considered binding.

Bibliography

AUTHORITY OF THE VOLTA BASIN - 2009. *Observatories of water resources and associated environments. Executive summary*.

BALAGIZI A; AHOUANSOU M. S; NSHOMBO M; LALEYE P - 2018. *Characterization of Fishing In Lake* Kivu.

BITARIHO R., KASANGAKI A., TWINAMATSIKO M., BABAASA D - 2015. A Survey of Hydrological Systems in the Great Virunga Landscape: Water resources assessment and use in and around Mgahinga *Gorilla National Park and Echuya Central Forest Reserve, S.W Uganda.*

AFRICAN DEVELOPMENT BANK - 2015. *Ruzizi III Hydroelectric Power Plant, Summary of the Environmental and Social Impact Assessment.*

WORLD BANK - 2016. *Burundi Poverty Assessment.*

CAZENAVE-PIARROT A., NDAYIRUKIYE S., VALTON V. (coord.) - 2015, *Atlas of North Tanganyika Countries*. IRD Éditions, 144 pages.

CEPGL - 2014. *Regional Programme for the Integrated Development of the Ruzizi Plain. Master Plan for the Development of the Ruzizi Plain.*

CEPGL - 2018. *Etude Environnementale et Sociale Stratégique (EESS)*, SMEC, April 2018.

CICOS - 2016. CICOS Water Development and Management Master Plan*. Inventory of the premises. 2015.* Kinshasa, CICOS, 41 pages.

DESCY J.P. and GUILLARD J. - 2014. *Biological baseline of lake Kivu.*

EkoCentric, BG and ICRC - 2017. *Master plan for the development of drinking water supply in the western districts of the city of Goma (North Kivu Province, Democratic Republic of Congo).*

FAO - 2005. Studies n°155. *Forests and water.*

FICHTNER - 2010. *Final report of the feasibility study for the development of the RUSIZI III hydroelectric project*. EGL: Bujumbura - Burundi.

GIZ - 2014. *Integrated vulnerability analysis in Burundi, Volume I.*

Global Environnment Facility - 2020. *Lake Kivu and Rusizi River Basin Water Quality Management Project. Project Identification Form*. Consulté sur https://gefportal2.worldbank.org.

FURAHA G. 2018 *Comparative Analysis of Rice Value Chains in the Ruzizi Plain of the Economic Community of the Great Lakes Countries (CEPGL) Academic Thesis*.

INTER-GOVERNMENT FORUM (IGF) - 2017. *Mining Policy Framework (MPF). Assessment by the Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF).*

INTERNATIONAL ALERT - 2016. *Environmental assessment of mercury pollution in eastern Democratic Republic of Congo.*

INTERNATIONAL ALERT - 2009. Study on the role of natural resource exploitation in fuelling and perpetuating the crises in Eastern DRC.

ILRI/Ministry of Agriculture and Animal Resources of Rwanda- 2017. Rwanda Livestock Master Plan 2017/18-2021/22.

IUSS Working Group WRB - 2015. World reference base for soil resources 2014 - update 2015. World Soil Resources Reports No. 106. FAO, Rome.

KABONYI NZABANDORA V., SALMON M., ROCHE E.- 2011. The Kahuzi - Biega National Park (D.R. Congo), heritage in danger? The "High Altitude" sector, situation and perspectives.

KALOMBO PEMBA R., KUSINZA HERI B., MAFWELE MUNGIYA C.- 2020, Atlas de l'Accès à l'eau potable dans les 145 territoires de la République Démocratique du Congo. 61 pages.

K. von Grebmer, A. Saltzman, E. Birol, D. Wiesmann, N. Prasai, S. Yin, Y. Yohannes, P. Menon, J. Thompson, A. Sonntage - 2014. 2014 Global Hunger Index: The challenge of hidden hunger. Bonn, Washington D.C, and Dublin: Welthungerhilfe, International Food Policy Research Institute, and Concern Worldwide.

LINA ALEKE A.- 2016. Evaluation of the pollution loads (domestic and industrial) arriving at Lake Kivu in the city of Bukavu, RD. Congo University Thesis.

MASOZERA M. - 2008. Valuing and capturing the benefits of ecosystem services of Nyungwe watershed, SW Rwanda.

MWAMBA NYEMBA JP - 2019. Building on regional examples to speed up transboundary cooperation: establishing agreements and setting up transboundary basin organisations Experience of setting up the Lake Kivu and Ruzizi River Basin Authority (ABAKIR). Presentation made in Douala, on 07/11/2019.

MUVUNDJA FA., WUEST A., ISUMBISHO M., KANINGINI M.B., PASCHE N., RINTA P., SCHMID M. -2014. Modelling Lake Kivu water level variations over the last seven decades. Limnologica 47:21-33.

WORLD FOOD PROGRAMME - 2014. Global Analysis of Vulnerability, Food Security and Nutrition in Burundi.

PROGRAMME ALIMENTAIRE MONDIAL - 2018. Comprehensive Food Security and Vulnerability Analysis in Rwanda.

WORLD FOOD PROGRAMME - 2020. Analysis of Food Security in Emergency Situations in South Kivu, September 2020.

WORLD FOOD PROGRAMME - 2020. Analysis of Food Security in Emergency Situations in North Kivu, July 2020.

UNDP - 2009. Poverty profile and household living conditions. North Kivu Province. Summary.

UNDP - 2009. Poverty profile and household living conditions. South Kivu Province. Summary.

UNEP-2016. Environmental Assessment of Mercury Pollution in Eastern Democratic Republic of Congo.

UNEP - 2011. Water Issues in the Democratic Republic of Congo: Challenges and Opportunities. Technical Report.

REPUBLIC OF BURUNDI - 2018. Burundi National Development Plan (2018-2027)

REPUBLIC OF BURUNDI - Ministry at the Presidency in charge of Good Governance and Planning (MPBGP), Ministry of Public Health and the Fight against AIDS (MSPLS), Institute of Statistics and Economic Studies of Burundi (ISTEEBU), and ICF- 2018. Enquête Démographique et de Santé au Burundi 2016-2017: Rapport de synthèse. Rockville, Maryland, USA: ISTEEBU, MSPLS, and ICF.

REPUBLIC OF BURUNDI - Ministry of Water, Environment, Spatial Planning and Urban Development - 2013. Burundi National Sanitation Policy and Operational Strategy Horizon 2025.

REPUBLIC OF BURUNDI - Ministry of Water, Environment, Spatial Planning and Urban Development - 2012. National Water Strategy (2011-2020).

REPUBLIC OF BURUNDI - Ministry of Water, Environment, Spatial Planning and Urban Development - UNDP - 2015. National Habitat Report III.

REPUBLIC OF BURUNDI - Ministry of Agriculture and Livestock - 2011. National Agricultural Investment Plan in Burundi (2012-2017).

REPUBLIC OF BURUNDI - Institute of Statistics and Economic Studies of Burundi - 2019. National survey on the nutritional situation and food security in Burundi, December 2018.

REPUBLIC OF BURUNDI - Ministry of Finance and Economic Development Planning - ISTEEBU - 2008. General Census of Population and Housing.

REPUBLIC OF CONGO - National Strategic Development Plan (2016-2050)

REPUBLIC OF CONGO - 2016. National Biodiversity Strategy and Action Plans (2016-2020).

REPUBLIC OF CONGO - Ministry of Planning and Modernity Revolution - National Institute of Statistics - 2015. Statistical Yearbooks 2014. Kinshasa, INS.

REPUBLIC OF CONGO - Ministry of Planning - National Institute of Statistics - 2015. Statistical Yearbooks 2017. Kinshasa, INS.

REPUBLIC OF CONGO - National Institute of Statistics - 2020. Multiple Indicator Cluster Survey (MICS), 2017-2018, report of survey results. South Kivu, Democratic Republic of Congo.

REPUBLIC OF CONGO - Ministry of hydrocarbons / REPUBLIC OF RWANDA - Ministry of Infrastructures - 2010. Management Prescriptions for the development of lake Kivu gas resources.

REPUBLIC OF RWANDA. 7 Years Government Programme: National Strategy for Transformation (NST 1) 2017 - 2024.

REPUBLIC OF RWANDA - Ministry of finance and economic planning - ARTELIA/SHER - 2017. Inventory of water resources and uses in the Lake Kivu and Ruzizi River Basins. FINAL REPORT- R4.

REPUBLIC OF RWANDA - Ministry of Natural Resources - 2016. Assessment and Evaluation of the National land use and Development Master Plan implementation (2011-2016).

REPUBLIC OF RWANDA - MINIRENA/RNRA - 2015. Rwanda National Water Resources Master Plan.

REPUBLIC OF RWANDA - Ministry of Agriculture and Animal Resources - 2011. Master Plan for Fisheries and Fish Farming in Rwanda.

REPUBLIC OF RWANDA - National Institute of Statistics of Rwanda - 2012. Fourth Population and Housing Census.

RWANDA GOVERNANCE BOARD - 2018. Assessing GIRINKA Programme (2006-2016).

RWANDA WATER AND FORESTRY AUTHORITY - 2019. Water quality monitoring in Rwanda final report 2019.

RWANDA WATER AND FORESTRY AUTHORITY - 2018. Annual water status report 2016-2017.

RWANDA ENERGY GROUP - A. MUZANA & J. GUILLARD - Stock estimation of Limnothrissa miodon in Lake Kivu. 2014.

SEGUIN J.J. and GUTIERREZ A.- 2016. Water resources on the African continent: scarcity and abundance. Géosciences, the BRGM journal for a sustainable Earth, Volume 21, pp. 58-66.

SNOEKS J., KANINGINI B., MASILYA M.P, NYINA-WAMWIZA L. and GUILLARD J. - 2012. Fishes in Lake Kivu : Diversity and Fisheries. Aquatic Ecology Series, Volume 5.

TASSI *et al*. - 2009. *Water and gas chemistry at lake Kivu (DRC)*. Geochemistry Geophysics Geosystems,

TETRATEK & LTS Africa Ltd PREPARED PROJECT -2018 Experiences and lessons learned in payments for ecosystem services (PES) in East Africa.

WORLD BANK- 2016. "*Doing Business 2016: Measuring Regulatory Quality and Efficiency. Economic Profile 2016, Burundi*." The International Bank for Reconstruction and Development / The World Bank.

Annexes

I. Calculations and graphs of rainfall variations for the 2030 and 2050 horizons

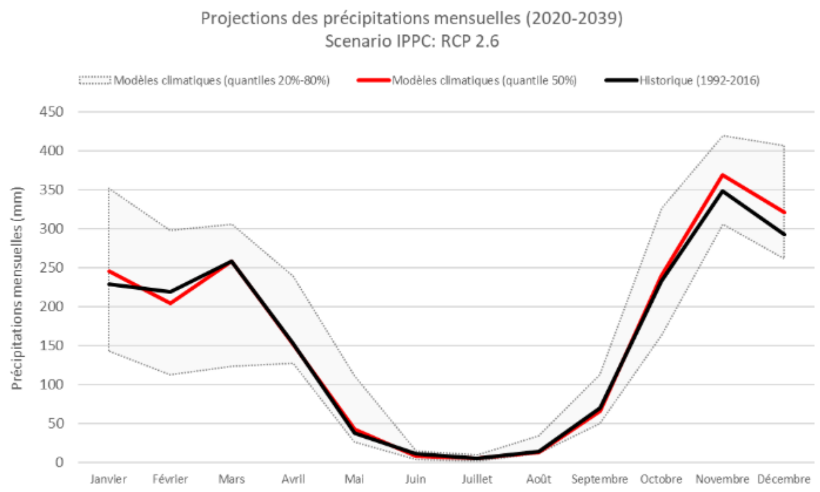
Appendix 1 - 001 - Tables of average precipitation (in mm) to 2020 - 2039 by model under RCP2.6 scenario

	année	bcc_csm 1_1	bcc_csm 1_1_m	ccsm4	cesm1_ cam5	csiro_m k3_6_0	fio_esm	gfdl_cm 3	gfdl_es m2m	giss_e2_ h	giss_e2_ r	ipsl_cm 5a_mr	miroc_e sm	miroc_e sm_che m	miroc5	mri_cgc m3	noresm 1_m	Modèles climatiqu es (quantile 20%)	Modèles climatiqu es (quantile 50%)	Modèles climatiqu es (quantile 80%)	Modèles climatiques (quantiles 20%-80%)
Janvier	2020-2039	227.9	242.4	277.1	248.4	34.2	373.0	143.5	187.2	159.8	141.7	365.8	318.5	309.1	427.7	124.6	351.7	143.5	245.4	351.7	208.2
Février	2020-2039	193.6	215.3	264.7	178.2	90.1	377.8	104.3	155.8	120.3	113.0	297.8	300.3	290.1	335.0	86.6	287.9	113.0	204.4	297.8	184.8
Mars	2020-2039	305.4	262.9	260.2	171.6	266.5	411.8	124.1	145.0	98.5	112.2	506.2	255.8	252.3	463.1	120.5	303.3	124.1	258.0	305.4	181.3
Avril	2020-2039	231.6	283.2	145.3	147.3	239.2	230.2	158.4	137.7	45.1	43.0	574.4	127.4	139.2	451.3	103.6	175.8	127.4	152.8	239.2	111.8
Mai	2020-2039	97.9	111.5	43.4	58.0	42.8	39.7	131.7	32.6	20.8	21.6	143.4	29.2	26.5	228.3	24.8	49.5	26.5	43.1	111.5	85.0
Juin	2020-2039	49.4	31.1	10.2	6.1	4.1	4.4	41.1	0.4	11.4	11.7	8.1	4.3	2.3	14.7	9.0	7.6	4.3	8.6	14.7	10.4
Juillet	2020-2039	32.8	18.6	7.5	4.5	2.6	1.7	18.3	0.1	9.8	10.0	6.5	2.5	1.7	6.6	1.3	3.5	1.7	5.5	10.0	8.2
Août	2020-2039	100.7	39.9	12.3	13.3	13.3	6.7	29.7	1.6	11.5	13.4	34.0	14.6	14.6	62.5	2.4	12.0	11.5	13.4	34.0	22.5
Septembre	2020-2039	243.1	179.3	68.0	97.0	74.8	64.9	65.5	6.7	25.0	25.9	112.7	65.8	66.5	332.1	50.7	50.4	50.4	66.1	112.7	62.3
Octobre	2020-2039	367.3	326.6	244.3	234.6	260.4	249.5	185.7	115.3	77.0	94.2	329.6	168.7	163.9	542.2	252.4	210.6	163.9	239.4	326.6	162.7
Novembre	2020-2039	377.0	328.5	360.8	316.2	419.5	405.4	321.1	432.5	161.7	181.1	623.9	305.7	302.7	623.3	378.7	381.8	305.7	368.9	419.5	113.9
Décembre	2020-2039	265.0	278.0	358.0	312.5	141.1	407.0	359.4	321.7	162.5	160.7	689.9	319.9	323.2	499.1	261.6	407.5	261.6	320.8	407.0	145.4

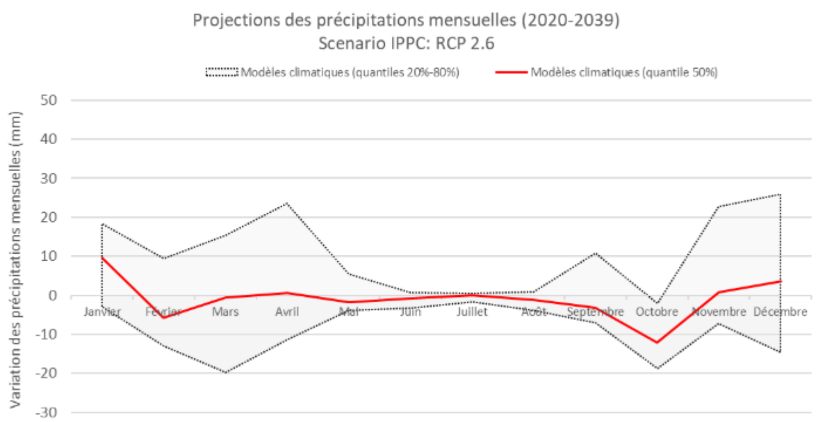
Appendix 1 - 002 - Tables of mean relative precipitation changes (in mm) to 2020 - 2039 by model under RCP2.6 scenario

	année	bcc_cs m1_1	bcc_cs m1_1_ m	ccsm4	cesm1 _cam5	csiro_ mk3_6 _0	fio_es m	gfdl_c m3	gfdl_es m2m	giss_e2 _h	giss_e2 _r	ipsl_c m5a_ mr	miroc_ esm	miroc_ esm_c hem	miroc5	mri_cg cm3	nores m1_m	Modèles climatiqu es (quantile 0%)	Modèles climatiqu es (quantile 0%)	Modèles climatiqu es (quantile 0%)	Modèles climatiques (quantiles 0%-0%)	Modèles climatiqu es (quantile 20%)	Modèles climatiqu es (quantile 50%)	Modèles climatiqu es (quantile 80%)	Modèles climatiques (quantiles 20%-80%)
Janvier	2020-2039	-2.8	15.4	-3.7	43.8	-6.5	9.7	6.0	16.3	-1.3	9.4	30.7	18.3	1.4	16.8	-10.3	42.8	-2.8	9.5	18.3	21.1	-2.3	7.8	14.9	17.2
Février	2020-2039	-21.1	-7.6	37.5	7.7	4.4	5.4	-3.7	-9.3	21.6	-10.0	-31.6	-9.7	-13.1	9.4	-13.4	18.9	-13.1	-5.6	9.4	22.5	-15.9	-6.8	11.4	27.2
Mars	2020-2039	29.4	12.1	14.1	-30.1	0.9	-34.2	-2.4	-18.9	-2.2	13.0	37.3	-24.9	-19.8	56.2	-12.0	15.4	-19.8	-0.7	15.4	35.2	-13.4	-0.5	10.5	23.9
Avril	2020-2039	23.6	32.8	-7.7	8.3	-4.8	8.9	5.1	-2.0	2.6	-17.7	61.0	-1.3	24.7	-36.4	-14.3	-11.5	-11.5	0.6	23.6	35.1	-8.7	0.5	17.8	26.5
Mai	2020-2039	-2.4	2.1	8.2	-0.9	5.4	7.3	-3.9	-2.8	-4.5	-3.5	28.1	-3.8	2.4	-1.1	-13.9	-5.2	-3.9	-1.8	5.4	9.3	-3.4	-1.5	4.7	8.1
Juin	2020-2039	6.5	-5.6	-1.4	0.7	0.6	0.3	-1.6	-0.2	-1.0	-3.3	-3.0	1.1	-0.4	-11.9	0.5	-3.6	-3.3	-0.7	0.6	4.0	-9.3	-2.0	1.8	11.1
Juillet	2020-2039	2.2	-1.7	0.2	2.2	-1.4	0.0	-9.0	-0.2	-0.5	0.3	-4.1	0.5	0.1	-11.6	0.0	0.5	-1.7	0.0	0.5	2.2	-22.5	-0.4	7.0	29.5
Août	2020-2039	13.1	-2.0	-2.2	-5.0	-1.2	2.9	-3.9	0.3	0.5	0.8	-8.9	-2.0	0.1	-7.6	-1.1	4.4	-3.9	-1.1	0.8	4.7	-11.3	-3.3	2.4	13.7
Septembre	2020-2039	-5.4	-4.2	-10.3	10.7	-14.5	11.9	-7.1	-4.2	-1.6	-5.8	-15.7	-2.3	13.5	28.4	9.9	10.8	-7.1	-3.3	10.8	17.9	-8.0	-3.7	12.4	20.4
Octobre	2020-2039	-8.1	-13.1	-2.0	19.4	1.4	1.6	-33.0	-11.2	-16.0	-7.8	-16.0	-21.7	-18.7	-68.5	-18.4	-7.7	-18.7	-12.2	-2.0	16.7	-15.5	-10.1	-1.6	13.8
Novembre	2020-2039	78.7	-0.2	-7.4	14.6	24.9	-10.2	-7.3	11.5	2.5	22.7	33.2	1.8	-5.8	-0.9	-16.1	-2.2	-7.3	0.8	22.7	29.9	-5.1	0.6	15.8	20.8
Décembre	2020-2039	-8.8	-5.4	38.6	25.2	-37.5	4.7	93.1	-18.8	-3.8	-14.6	25.9	22.4	10.5	-31.3	2.5	42.9	-14.6	3.6	25.9	40.5	-11.7	2.9	20.7	32.4

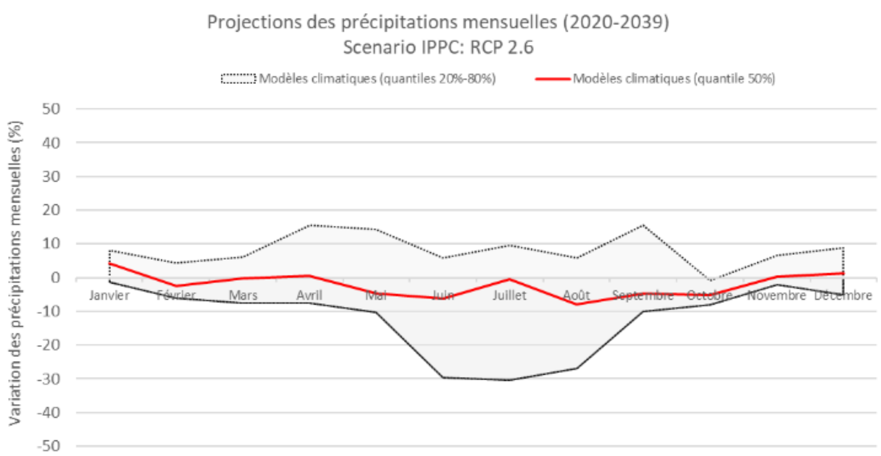
Appendix 1 - 003 - Monthly precipitation graphs to 2020 - 2039, by model, according to the RCP2.6 scenario



Appendix 1 - 004 - Graphs of changes in average annual precipitation by model for 2020 - 2039 under the RCP2.6 scenario



Appendix 1 - 005 - Graphs of changes in average annual precipitation by model for 2020 - 2039 under the RCP2.6 scenario



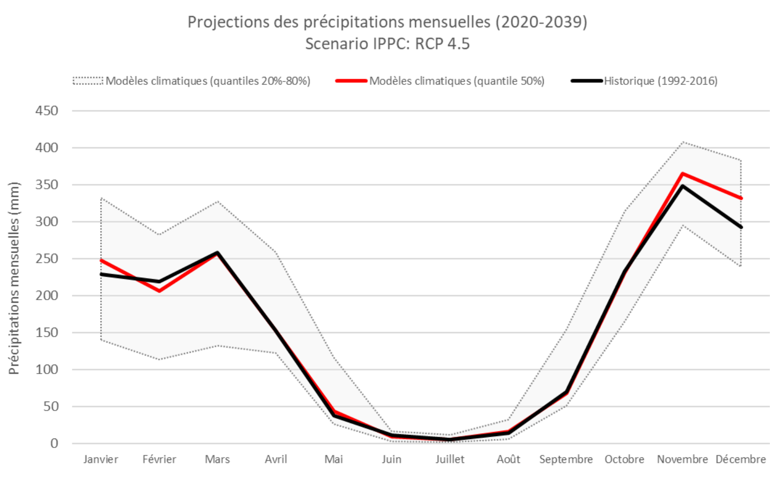
Appendix 1 - 006 - Tables of average precipitation (in mm) by model for 2020 - 2039, by RCP4.5 scenario

	année	bcc_csm1_1	bcc_csm1_1_m	ccsm4	cesm1_cam5	csiro_mk3_6_0	fio_esm	gfdl_cm3	gfdl_esm2m	giss_e2_h	giss_e2_r	ipsl_cm5a_mr	miroc_esm	miroc_esm_chem	miroc5	mri_cgcm3	noresm1_m	Modèles climatiques (quantile 20%)	Modèles climatiques (quantile 50%)	Modèles climatiques (quantile 80%)	Modèles climatiques (quantiles 20%-80%)
Janvier	2020-2039	262.1	213.2	317.0	233.2	49.2	438.5	148.7	208.2	140.4	139.7	409.7	308.3	314.6	427.2	130.8	332.0	140.4	247.6	332.0	191.6
Février	2020-2039	187.4	225.6	248.6	173.9	78.7	393.3	91.8	136.5	113.2	129.4	280.0	288.1	281.8	364.5	98.0	281.2	113.2	206.5	281.8	168.7
Mars	2020-2039	259.0	275.7	268.0	177.9	254.5	404.6	131.8	162.2	92.4	93.0	515.1	244.5	264.0	426.5	126.9	327.3	131.8	256.7	327.3	195.5
Avril	2020-2039	200.1	249.2	157.5	136.4	258.2	265.5	148.2	139.4	60.1	47.4	555.5	136.1	122.5	384.9	95.4	180.9	122.5	152.8	258.2	135.7
Mai	2020-2039	100.5	117.0	36.7	56.5	35.2	24.2	144.5	39.1	17.6	26.8	130.8	31.9	24.4	247.5	49.0	57.7	26.8	44.0	117.0	90.2
Juin	2020-2039	41.5	40.5	11.3	5.1	2.9	4.2	41.1	0.9	11.1	12.2	14.4	2.7	1.6	16.7	5.4	8.2	2.9	9.6	16.7	13.8
Juillet	2020-2039	29.8	11.5	8.5	2.1	4.0	1.9	21.6	0.2	10.4	9.9	7.5	3.3	3.2	14.0	1.6	3.3	2.1	5.8	11.5	9.5
Août	2020-2039	94.3	40.3	14.2	20.5	16.2	4.9	28.7	1.6	12.5	10.6	32.5	15.3	17.2	86.4	5.9	5.9	5.9	15.7	32.5	26.6
Septembre	2020-2039	240.1	168.2	71.8	104.3	95.5	65.1	77.1	14.9	29.3	27.7	154.0	60.6	62.6	337.0	50.8	64.6	50.8	68.4	154.0	103.2
Octobre	2020-2039	379.4	325.5	299.2	230.6	266.5	255.3	203.4	190.5	116.2	96.6	314.7	164.6	166.0	585.4	231.7	217.0	166.0	231.2	314.7	148.7
Novembre	2020-2039	315.5	361.6	399.1	294.4	405.2	407.7	321.8	440.5	168.7	182.9	644.0	274.4	300.1	617.7	375.7	368.1	294.4	364.9	407.7	113.3
Décembre	2020-2039	271.1	276.8	383.4	336.0	174.2	409.7	353.0	355.5	163.5	178.6	683.6	326.7	306.3	585.2	238.6	381.7	238.6	331.3	383.4	144.8

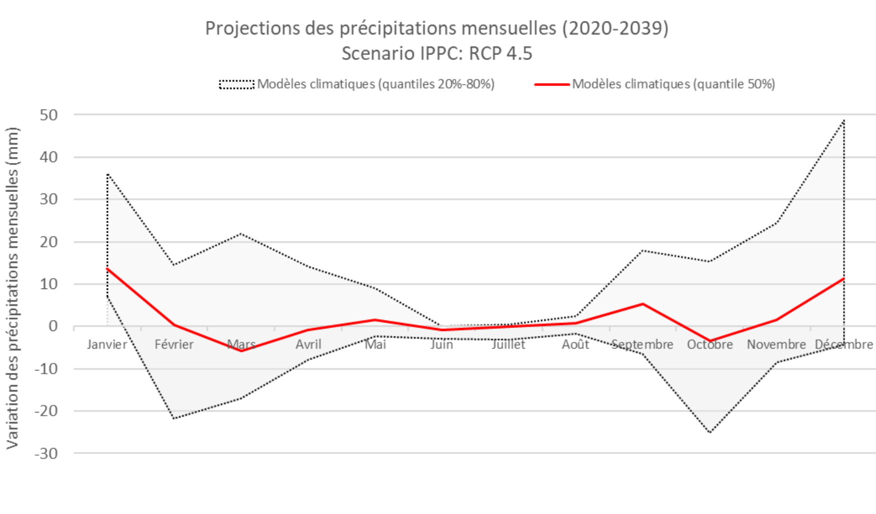
Appendix 1 - 007 - Tables of mean relative precipitation changes (in mm) to 2020 - 2039 by model under RCP4.5 scenario

	année	bcc_csm1_1	bcc_csm1_1_m	ccsm4	cesm1_cam5	csiro_mk3_6_0	fio_esm	gfdl_cm3	gfdl_esm2m	giss_e2_h	giss_e2_r	ipsl_cm5a_mr	miroc_esm	miroc_esm_chem	miroc5	mri_cgcm3	noresm1_m	Modèles climatiques (quantile 0%)	Modèles climatiques (quantile 0%)	Modèles climatiques (quantile 0%)	Modèles climatiques (quantiles 0%-0%)	Modèles climatiques (quantile 20%)	Modèles climatiques (quantile 50%)	Modèles climatiques (quantile 80%)	Modèles climatiques (quantiles 20%-80%)
Janvier	2020-2039	31.4	-13.8	36.3	28.6	8.6	75.2	11.2	37.3	-20.7	7.4	74.5	8.0	6.9	16.3	-4.1	23.1	6.9	13.8	36.3	29.3	5.6	11.2	29.5	23.9
Février	2020-2039	-27.3	2.7	21.4	3.4	-7.0	21.0	-16.2	-28.5	14.5	6.5	-49.4	-21.9	-21.3	38.9	-1.9	12.1	-21.9	0.4	14.5	36.3	-26.5	0.5	17.5	44.0
Mars	2020-2039	-17.0	24.8	21.8	-23.8	-11.1	-41.5	5.3	-1.7	-8.4	-6.2	46.2	-36.3	-8.1	19.6	-5.5	39.4	-17.0	-5.8	21.8	38.9	-11.5	-4.0	14.8	26.4
Avril	2020-2039	-8.0	-1.2	4.4	-2.6	14.2	44.1	-5.1	-0.3	17.6	-13.3	42.2	7.4	7.9	-102.7	-22.6	-6.4	-8.0	-0.8	14.2	22.2	-6.0	-0.6	10.7	16.8
Mai	2020-2039	0.2	7.6	1.5	-2.4	-2.3	-8.2	9.0	3.6	-7.7	1.6	15.5	-1.1	0.3	18.1	10.4	2.9	-2.3	1.6	9.0	11.3	-2.0	1.4	7.9	9.9
Juin	2020-2039	-1.3	3.8	-0.3	-0.3	-0.6	0.1	-1.6	0.3	-1.3	-2.9	3.2	-0.4	-1.0	-9.9	-3.1	-3.0	-2.9	-0.8	0.1	3.0	-8.1	-2.2	0.4	8.4
Juillet	2020-2039	-0.7	-8.8	1.3	-0.2	0.0	0.2	-5.7	-0.1	0.0	0.2	-3.1	1.3	1.6	-4.3	0.3	0.4	-3.1	0.0	0.4	3.5	-41.0	0.4	4.8	45.8
Août	2020-2039	6.6	-1.6	-0.2	2.3	1.6	1.1	-4.8	0.3	1.5	-2.0	-10.4	-1.3	2.7	16.2	2.5	-1.7	-1.7	0.7	2.5	4.2	-4.9	2.1	7.2	12.1
Septembre	2020-2039	-8.4	-15.3	-6.6	18.0	6.2	12.1	4.6	4.0	2.7	-4.0	25.6	-7.5	9.6	33.3	10.1	25.0	-6.6	5.4	18.0	24.5	-7.5	6.2	20.5	28.0
Octobre	2020-2039	4.1	-14.3	53.0	15.4	7.6	7.4	-15.3	63.9	23.1	-5.4	-30.9	-25.9	-16.6	-25.2	-39.0	-1.4	-25.2	-3.4	15.4	40.6	-20.9	-2.8	12.7	33.6
Novembre	2020-2039	17.2	32.9	30.9	-7.3	10.5	-7.9	-6.5	19.5	9.6	24.4	53.3	-29.5	-8.4	-6.5	-19.1	-15.9	-8.4	1.5	24.4	32.8	-5.8	1.1	17.0	22.8
Décembre	2020-2039	-2.7	-6.6	64.0	48.7	-4.3	7.3	86.8	15.1	-2.8	3.3	19.7	29.2	-6.3	54.8	-20.5	17.0	-4.3	11.2	48.7	53.0	-3.5	9.0	38.9	42.4

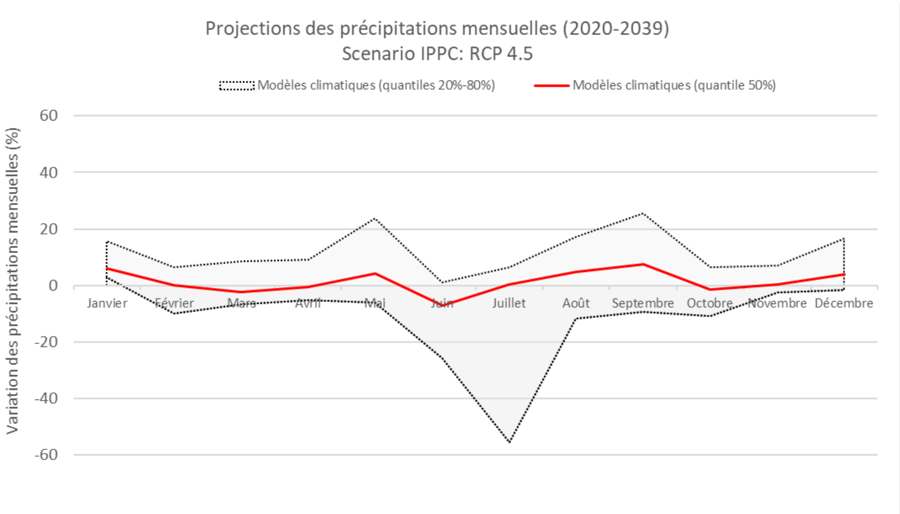
Appendix 1 - 008 - Monthly precipitation graphs to 2020 - 2039, by model, according to the RCP4.5 scenario



Appendix 1 - 009 - Graphs of changes in average annual precipitation by model for 2020 - 2039 under the RCP4.5 scenario



Appendix 1 - 010 - Graphs of changes in average annual precipitation by model for 2020 - 2039 under the RCP4.5 scenario



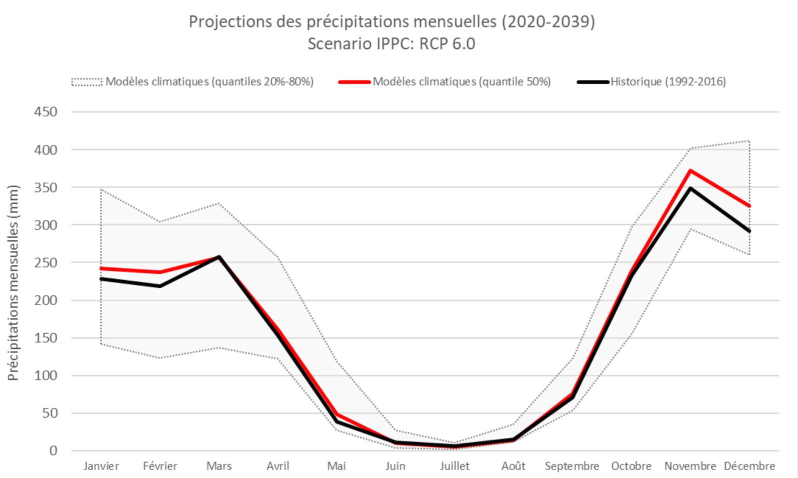
Appendix 1 - 011 - Tables of average precipitation (in mm) by model for 2020 - 2039, by model, according to the RCP6.0 scenario

	année	bcc_csm1_1	bcc_csm1_1_m	ccsm4	cesm1_cam5	csiro_mk3_6_0	fio_esm	gfdl_cm3	gfdl_esm2m	giss_e2_h	giss_e2_r	ipsl_cm5a_mr	miroc_esm	miroc_esm_chem	miroc5	mri_cgcm3	noresm1_m	Modèles climatiques (quantile 20%)	Modèles climatiques (quantile 50%)	Modèles climatiques (quantile 80%)	Modèles climatiques (quantiles 20%-80%)
Janvier	2020-2039	237.4	246.2	292.1	235.7	40.6	400.4	134.0	192.8	143.9	141.3	378.3	307.7	339.9	406.9	132.0	347.5	141.3	241.8	347.5	206.2
Février	2020-2039	244.3	229.9	263.9	165.5	83.2	395.0	100.4	155.7	135.8	113.5	302.7	304.8	309.2	392.0	123.3	283.2	123.3	237.1	304.8	181.5
Mars	2020-2039	268.5	273.4	259.3	179.8	254.7	416.2	118.6	156.2	84.6	91.6	520.2	252.8	270.1	464.7	136.5	329.1	136.5	257.0	329.1	192.6
Avril	2020-2039	221.4	247.5	141.0	131.1	257.8	258.8	167.3	153.6	46.2	48.4	626.9	121.8	142.1	393.4	97.5	199.9	121.8	160.4	257.8	136.0
Mai	2020-2039	88.7	119.6	38.2	61.7	50.5	33.6	150.4	45.2	19.1	22.5	205.7	25.5	27.0	251.6	30.2	53.2	27.0	47.8	119.6	92.6
Juin	2020-2039	53.7	40.0	10.9	8.5	3.1	4.6	45.2	2.7	11.2	12.5	13.2	3.2	3.6	27.4	8.6	8.3	3.6	9.8	27.4	23.8
Juillet	2020-2039	36.8	19.8	6.9	1.8	3.9	1.8	25.1	0.3	10.7	10.0	7.7	1.5	2.7	9.0	2.5	4.0	1.8	5.4	10.7	8.9
Août	2020-2039	92.8	40.9	14.6	14.1	12.0	2.3	34.6	3.1	12.3	11.5	33.8	13.1	19.1	68.8	4.0	11.0	11.0	13.6	34.6	23.7
Septembre	2020-2039	246.4	173.7	77.9	92.1	104.0	54.1	76.5	15.8	26.9	27.1	122.8	75.3	69.5	329.3	59.7	63.3	54.1	75.9	122.8	68.7
Octobre	2020-2039	389.2	336.6	253.0	224.8	251.1	252.2	211.7	123.3	87.1	107.9	297.8	155.2	184.9	583.2	252.0	220.9	155.2	238.0	297.8	142.6
Novembre	2020-2039	342.4	365.5	404.1	294.6	392.8	379.7	354.5	396.6	170.2	171.7	562.5	302.0	292.1	628.1	402.5	382.4	294.6	372.6	402.5	107.9
Décembre	2020-2039	276.8	309.5	357.1	322.5	143.4	412.1	350.7	350.6	178.5	157.9	710.7	303.4	329.2	552.3	260.2	428.4	260.2	325.8	412.1	152.0

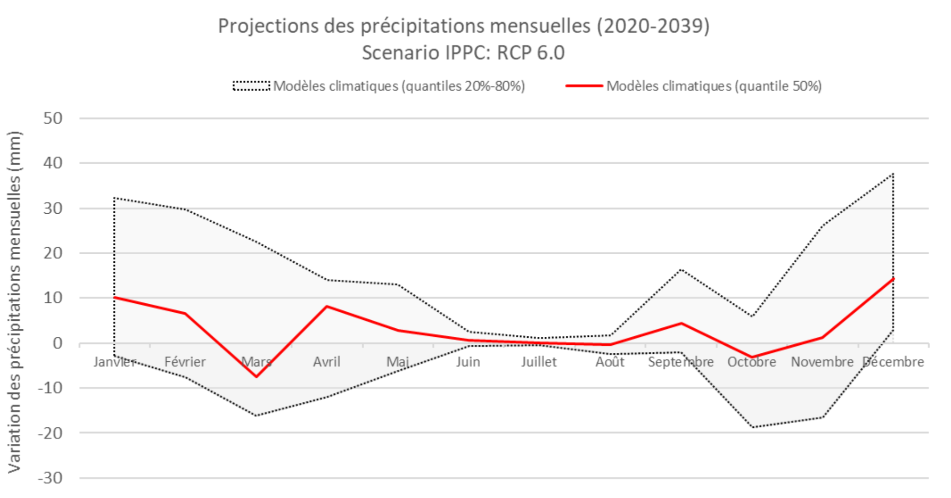
Appendix 1 - 012 - Tables of mean relative precipitation changes (in mm) to 2020 - 2039 by model under RCP6.0 scenario

	année	bcc_csm1_1	bcc_csm1_1_m	ccsm4	cesm1_cam5	csiro_mk3_6_0	fio_esm	gfdl_cm3	gfdl_esm2m	giss_e2_h	giss_e2_r	ipsl_cm5a_mr	miroc_esm	miroc_esm_chem	miroc5	mri_cgcm3	noresm1_m	Modèles climatiques (quantile 0%)	Modèles climatiques (quantile 0%)	Modèles climatiques (quantile 0%)	Modèles climatiques (quantiles 0%-0%)	Modèles climatiques (quantile 20%)	Modèles climatiques (quantile 50%)	Modèles climatiques (quantile 80%)	Modèles climatiques (quantiles 20%-80%)
Janvier	2020-2039	6.7	19.2	11.4	31.1	0.0	37.1	-3.5	21.9	-17.3	9.0	43.2	7.4	32.3	-4.0	-2.8	38.6	-2.8	10.2	32.3	35.1	-2.3	8.3	26.2	28.6
Février	2020-2039	29.7	7.1	36.7	-5.0	-2.5	22.7	-7.6	-9.4	37.1	-9.4	-26.7	-5.2	6.0	66.4	23.4	14.2	-7.6	6.5	29.7	37.2	-9.2	7.9	35.9	45.1
Mars	2020-2039	-7.5	22.6	13.1	-21.9	-10.9	-29.9	-7.9	-7.6	-16.2	-7.6	51.3	-27.9	-2.0	57.8	4.0	41.2	-16.2	-7.6	22.6	38.8	-11.0	-5.1	15.3	26.3
Avril	2020-2039	13.3	-2.9	-12.0	-7.9	13.8	37.4	14.0	13.9	3.7	-12.3	113.5	-6.9	27.5	-94.3	-20.5	12.5	-12.0	8.1	14.0	26.0	-9.1	6.1	10.6	19.7
Mai	2020-2039	-11.6	10.2	3.0	2.8	13.0	1.2	14.9	9.8	-6.3	-2.7	90.4	-7.5	2.9	22.2	-8.4	-1.5	-6.3	2.9	13.0	19.3	-5.5	2.5	11.4	17.0
Juin	2020-2039	10.8	3.2	-0.7	3.1	-0.3	0.5	2.5	2.1	-1.2	-2.6	2.0	0.0	1.0	0.8	0.0	-2.9	-0.7	0.6	2.5	3.2	-2.0	1.8	7.1	9.0
Juillet	2020-2039	6.3	-0.5	-0.3	-0.4	0.0	0.1	-2.2	0.0	0.4	0.4	-2.9	-0.5	1.1	-9.2	1.3	1.1	-0.5	0.0	1.1	1.5	-6.1	-0.1	13.8	19.9
Août	2020-2039	5.2	-1.1	0.2	-4.1	-2.5	-1.5	1.1	1.8	1.4	-1.1	-9.1	-3.5	4.6	-1.3	0.5	3.4	-2.5	-0.4	1.8	4.3	-7.3	-1.3	5.2	12.4
Septembre	2020-2039	-2.1	-9.8	-0.4	5.7	14.7	1.1	4.0	4.9	0.3	-4.6	-5.6	7.1	16.5	25.6	18.9	23.8	-2.1	4.5	16.5	18.6	-2.4	5.1	18.8	21.2
Octobre	2020-2039	13.8	-3.2	6.8	9.6	-7.8	4.3	-6.9	-3.3	-5.9	5.9	-47.8	-35.2	2.3	-27.5	-18.7	2.5	-18.7	-3.2	5.9	24.6	-15.5	-2.7	4.9	20.3
Novembre	2020-2039	44.1	36.7	35.9	-7.1	-1.8	-35.8	26.1	-24.4	11.0	13.2	-28.2	-1.8	-16.5	3.9	7.6	-1.5	-16.5	1.2	26.1	42.6	-11.4	0.8	18.1	29.6
Décembre	2020-2039	3.0	26.1	37.7	35.1	-35.2	9.8	84.5	10.1	12.2	-17.4	46.7	5.9	16.5	21.9	1.1	63.8	3.0	14.4	37.7	34.7	2.4	11.5	30.1	27.7

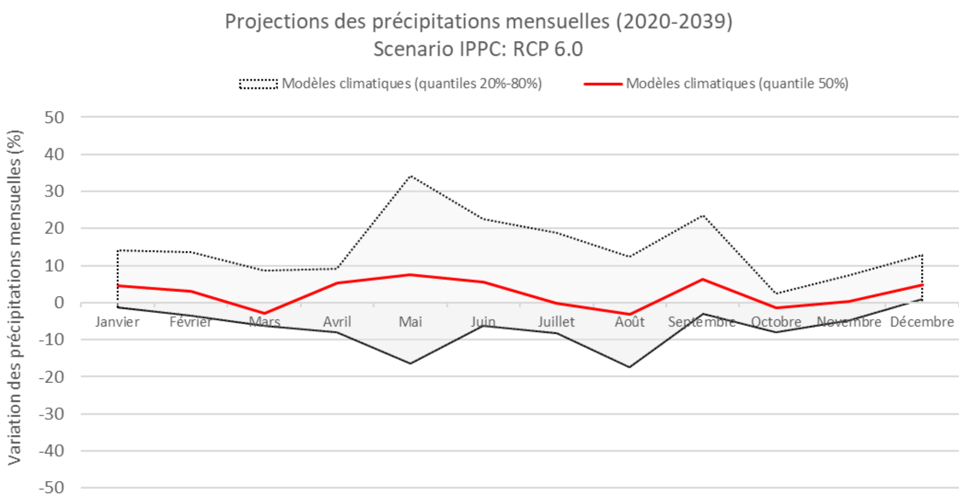
Appendix 1 - 013 - Monthly precipitation graphs for 2020 - 2039, by model, according to the RCP6.0 scenario



Appendix 1 - 014 - Graphs of Changes in Mean Annual Precipitation by Model for 2020 - 2039 under the RCP6.0 Scenario



Appendix 1 - 015 - Graphs of Changes in Mean Annual Precipitation by Model for 2020 - 2039 under the RCP6.0 Scenario



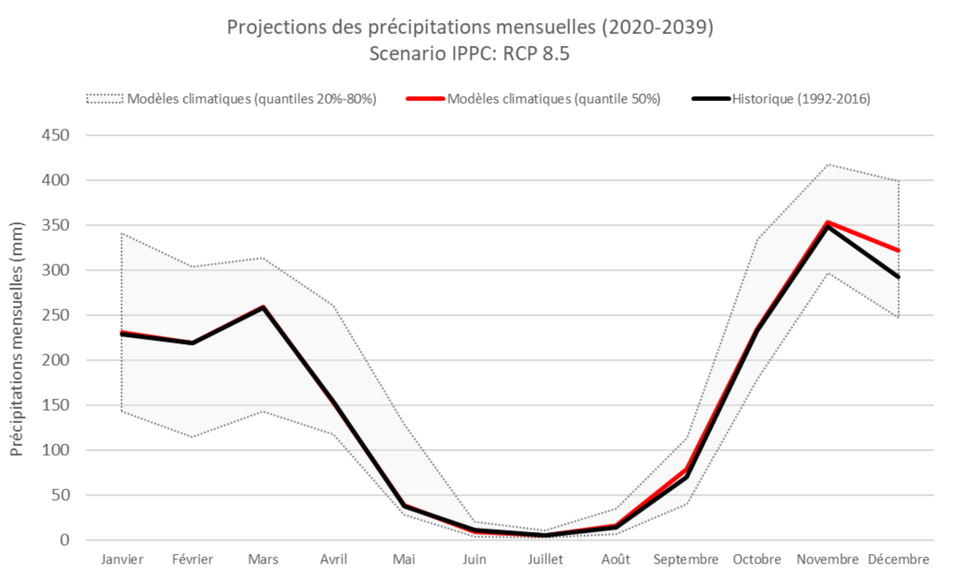
Appendix 1 - 016 - Tables of average precipitation (in mm) by model for 2020 - 2039, by model, according to the RCP8.5 scenario

	année	bcc_csm1_1	bcc_csm1_1_m	ccsm4	cesm1_cam5	csiro_mk3_6_0	fio_esm	gfdl_cm3	gfdl_esm2m	giss_e2_h	giss_e2_r	ipsl_cm5a_mr	miroc_esm	miroc_esm_chem	miroc5	mri_cgcm3	noresm1_m	Modèles climatiques (quantile 20%)	Modèles climatiques (quantile 50%)	Modèles climatiques (quantile 80%)	Modèles climatiques (quantiles 20%-80%)
Janvier	2020-2039	221.1	199.4	299.6	240.5	39.7	397.0	151.6	202.9	143.4	126.8	353.2	341.0	332.5	438.2	126.9	338.8	143.4	230.8	341.0	197.6
Février	2020-2039	194.9	243.3	253.7	172.1	77.5	398.8	112.9	152.7	115.4	114.7	310.6	304.1	302.2	391.6	111.9	282.7	114.7	219.1	304.1	189.4
Mars	2020-2039	284.0	285.5	245.9	204.4	271.6	408.1	130.9	175.7	105.2	108.8	477.5	273.6	244.0	461.0	143.5	313.2	143.5	258.7	313.2	169.6
Avril	2020-2039	201.5	261.0	117.6	145.7	282.9	243.6	146.3	158.1	54.3	57.2	527.1	118.5	151.4	405.6	98.5	152.6	117.6	152.0	261.0	143.4
Mai	2020-2039	113.6	129.1	51.4	50.4	30.3	28.6	139.5	30.7	18.1	27.8	148.0	34.8	24.4	258.6	37.6	40.3	28.6	39.0	129.1	100.5
Juin	2020-2039	48.6	37.9	12.7	5.6	6.3	4.1	50.5	1.1	12.1	12.6	10.4	1.9	3.0	20.2	6.1	9.2	4.1	9.8	20.2	16.2
Juillet	2020-2039	39.0	22.4	6.1	3.8	3.5	1.9	25.6	0.6	10.5	9.4	8.6	2.7	2.9	7.9	1.5	2.6	2.6	5.0	10.5	7.9
Août	2020-2039	112.9	51.9	16.0	25.3	15.7	6.7	34.6	1.8	12.8	12.0	35.6	20.7	16.9	89.2	1.6	5.7	6.7	16.4	35.6	28.9
Septembre	2020-2039	229.3	203.6	78.4	96.5	85.1	55.1	78.5	15.9	22.6	27.1	113.9	65.5	79.5	327.6	40.4	59.0	40.4	78.5	113.9	73.5
Octobre	2020-2039	375.9	350.5	237.6	221.8	258.1	237.6	204.3	137.4	70.3	96.4	334.4	179.5	186.0	585.6	271.5	231.9	179.5	234.8	334.4	154.9
Novembre	2020-2039	349.1	348.6	357.5	285.5	393.3	419.0	337.5	417.1	169.0	161.9	588.4	297.3	332.8	654.5	407.8	408.5	297.3	353.3	417.1	119.8
Décembre	2020-2039	272.5	313.5	368.7	305.0	134.1	421.7	317.5	344.0	168.1	174.5	680.1	326.0	329.7	530.5	247.3	398.5	247.3	321.7	398.5	151.2

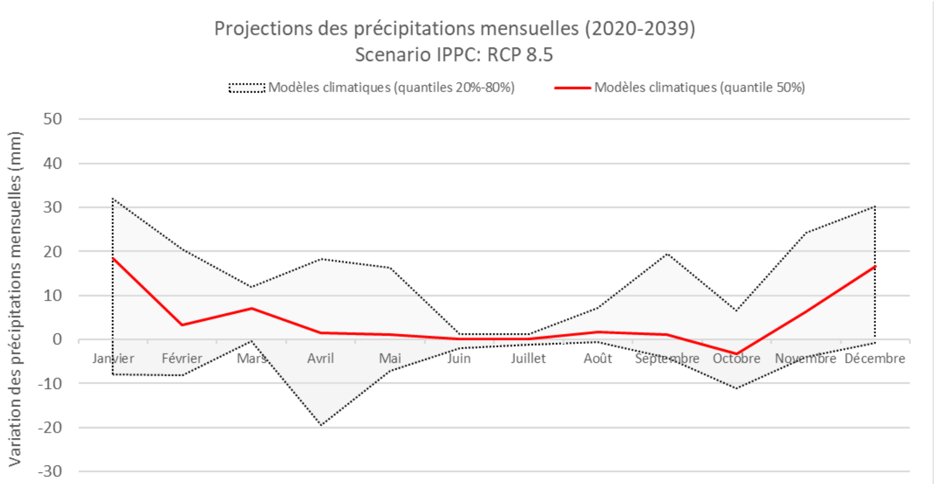
Appendix 1 - 017 - Tables of mean relative precipitation changes (in mm) to 2020 - 2039 by model under the RCP8.5 scenario

anomaly	année	bcc_csm1_1	bcc_csm1_1_m	ccsm4	cesm1_cam5	csiro_mk3_6_0	fio_esm	gfdl_cm3	gfdl_esm2m	giss_e2_h	giss_e2_r	ipsl_cm5a_mr	miroc_esm	miroc_esm_chem	miroc5	mri_cgcm3	noresm1_m	Modèles climatiques (quantile 0%)	Modèles climatiques (quantile 0%)	Modèles climatiques (quantile 0%)	Modèles climatiques (quantiles 0%-0%)	Modèles climatiques (quantile 20%)	Modèles climatiques (quantile 50%)	Modèles climatiques (quantile 80%)	Modèles climatiques (quantiles 20%-80%)
Janvier	2020-2039	-9.6	-27.7	18.8	35.9	-0.9	33.7	14.0	32.0	-17.8	-5.6	18.1	40.8	24.9	27.3	-7.9	29.9	-7.9	18.4	32.0	40.0	-6.5	15.0	26.0	32.5
Février	2020-2039	-19.8	20.4	26.5	1.6	-8.2	26.5	4.9	-12.4	16.7	-8.2	-18.8	-5.9	-1.0	66.0	11.9	13.7	-8.2	3.3	20.4	28.6	-10.0	4.0	24.7	34.7
Mars	2020-2039	8.0	34.6	-0.3	2.7	6.0	-37.9	4.4	11.8	4.4	9.5	8.6	-7.1	-28.1	54.2	11.1	25.2	-0.3	7.0	11.8	12.1	-0.2	4.8	8.0	8.2
Avril	2020-2039	-6.5	10.6	-35.4	6.7	38.9	22.3	-7.0	18.4	11.8	-3.5	13.7	-10.2	36.8	-82.1	-19.5	-34.8	-19.5	1.6	18.4	37.8	-14.7	1.2	13.9	28.6
Mai	2020-2039	13.3	19.7	16.2	-8.5	-7.2	-3.7	4.0	-4.7	-7.2	2.6	32.7	1.8	0.3	29.2	-1.0	-14.5	-7.2	1.0	16.2	23.4	-6.3	0.9	14.3	20.6
Juin	2020-2039	5.7	1.1	1.0	0.2	2.8	0.0	7.8	0.5	-0.3	-2.4	-0.7	-1.3	0.4	-6.3	-2.5	-2.0	-2.0	0.1	1.1	3.1	-5.6	0.2	3.2	8.8
Juillet	2020-2039	8.5	2.1	-1.1	1.5	-0.5	0.2	-1.7	0.3	0.2	-0.3	-2.1	0.7	1.3	-10.3	0.2	-0.3	-1.1	0.2	1.3	2.4	-14.6	2.3	16.6	31.2
Août	2020-2039	25.2	10.0	1.5	7.1	1.2	2.9	1.0	0.5	1.8	-0.6	-7.3	4.2	2.4	19.0	-1.8	-1.9	-0.6	1.7	7.1	7.7	-1.8	4.9	20.6	22.4
Septembre	2020-2039	-19.2	20.2	0.1	10.1	-4.2	2.1	6.0	5.0	-4.0	-4.6	-14.5	-2.6	26.5	23.9	-0.4	19.5	-4.2	1.1	19.5	23.7	-4.8	1.3	22.2	27.0
Octobre	2020-2039	0.5	10.8	-8.7	6.6	-0.9	-10.3	-14.4	10.8	-22.7	-5.6	-11.2	-11.0	3.4	-25.0	0.8	13.6	-11.2	-3.2	6.6	17.8	-9.3	-2.7	5.4	14.7
Novembre	2020-2039	50.9	19.9	-10.8	-16.1	-1.4	3.5	9.1	-3.9	9.9	3.4	-2.3	-6.5	24.3	30.3	13.0	24.5	-3.9	6.3	24.3	28.2	-2.7	4.4	16.9	19.6
Décembre	2020-2039	-1.3	30.1	49.3	17.7	-44.4	19.4	51.2	3.6	1.8	-0.7	16.1	28.5	17.1	0.0	-11.8	33.9	-0.7	16.6	30.1	30.8	-0.6	13.3	24.1	24.7

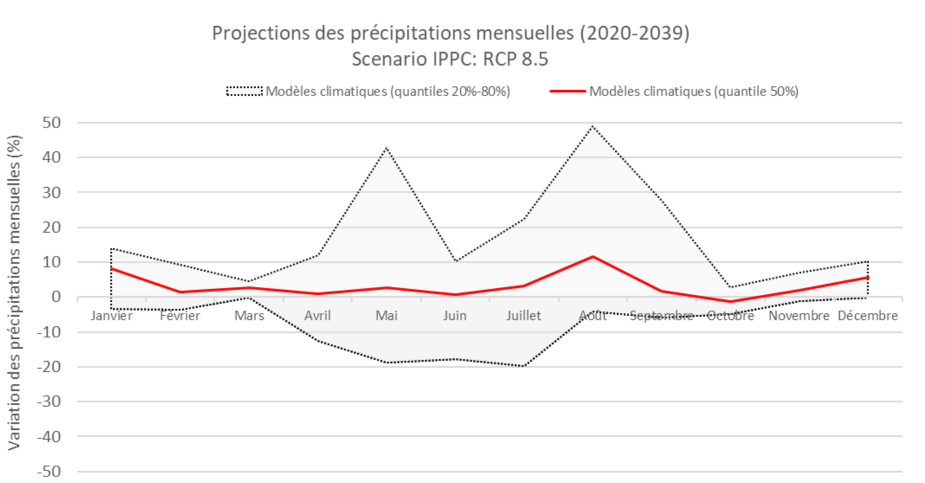
Appendix 1 - 018 - Monthly precipitation graphs for 2020 - 2039, by model, according to the RCP8.5 scenario



Appendix 1 - 019 - Graphs of changes in average annual precipitation by model for 2020 - 2039, by RCP8.5 scenario



Appendix 1 - 020 - Graphs of changes in average annual precipitation by model for 2020 - 2039 under the RCP8.5 scenario



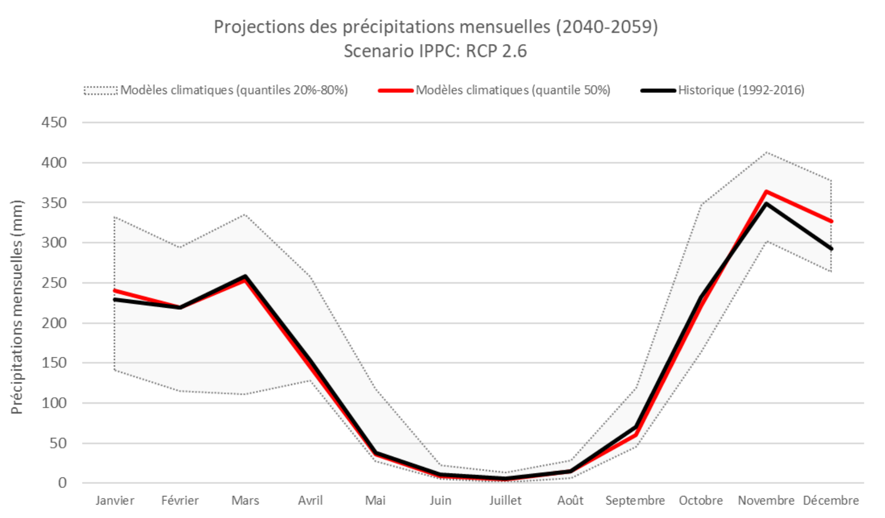
Appendix 1 - 021 - Tables of average precipitation (in mm) to 2040 - 2059 by model according to the RCP2.6 scenario

	année	bcc_csm1_1	bcc_csm1_1_m	ccsm4	cesm1_cam5	csiro_mk3_6_0	fio_esm	gfdl_cm3	gfdl_esm2m	giss_e2_h	giss_e2_r	ipsl_cm5a_mr	miroc_esm	miroc_esm_chem	miroc5	mri_cgcm3	noresm1_m	Modèles climatiques (quantile 20%)	Modèles climatiques (quantile 50%)	Modèles climatiques (quantile 80%)	Modèles climatiques (quantiles 20%-80%)
Janvier	2040-2059	246.7	221.7	278.2	234.1	20.3	365.3	168.3	204.1	141.4	125.2	473.3	312.5	303.5	431.1	130.7	332.8	141.4	240.4	332.8	191.3
Février	2040-2059	228.2	210.8	281.9	180.3	72.8	393.4	103.9	165.7	116.4	114.7	329.1	293.7	283.0	383.2	112.6	284.9	114.7	219.5	293.7	179.0
Mars	2040-2059	253.3	292.5	228.6	180.7	261.8	433.0	110.9	139.3	90.0	95.1	556.3	273.7	253.5	459.2	105.3	334.9	110.9	253.4	334.9	224.0
Avril	2040-2059	171.2	269.5	140.4	129.0	247.3	257.8	148.9	128.7	43.8	51.4	562.8	127.8	140.2	413.6	94.8	162.9	127.8	144.7	257.8	130.0
Mai	2040-2059	118.2	112.8	39.7	54.7	27.7	36.7	139.9	35.1	19.3	18.0	145.2	20.4	27.0	220.6	33.1	33.9	27.0	35.9	118.2	91.3
Juin	2040-2059	50.8	42.0	9.6	5.3	7.9	5.3	36.8	1.0	11.5	12.3	9.5	1.7	2.5	22.5	7.6	8.5	5.3	9.0	22.5	17.3
Juillet	2040-2059	24.5	19.3	6.9	1.9	1.4	1.9	17.9	0.9	10.8	10.0	13.6	2.3	1.8	7.7	0.5	2.6	1.8	4.8	13.6	11.8
Août	2040-2059	77.5	32.0	11.2	22.3	16.7	2.6	24.7	1.4	11.9	12.2	28.4	16.9	11.9	68.4	5.9	5.7	5.9	14.5	28.4	22.6
Septembre	2040-2059	228.4	147.1	63.4	96.0	61.3	57.2	68.1	9.5	22.9	25.9	119.0	53.8	58.7	288.1	45.9	55.0	45.9	60.0	119.0	73.0
Octobre	2040-2059	357.2	347.2	250.7	217.7	225.3	228.1	189.7	125.6	75.7	91.3	349.6	164.4	167.1	573.5	252.9	213.7	164.4	221.5	347.2	182.8
Novembre	2040-2059	309.6	355.6	397.9	302.4	403.3	413.1	324.8	438.1	172.5	166.0	580.8	304.0	287.1	646.0	372.6	373.4	302.4	364.1	413.1	110.7
Décembre	2040-2059	278.9	286.2	352.8	319.5	143.1	377.9	359.3	333.5	158.1	157.3	714.0	344.4	316.6	564.7	264.1	405.3	264.1	326.5	377.9	113.7

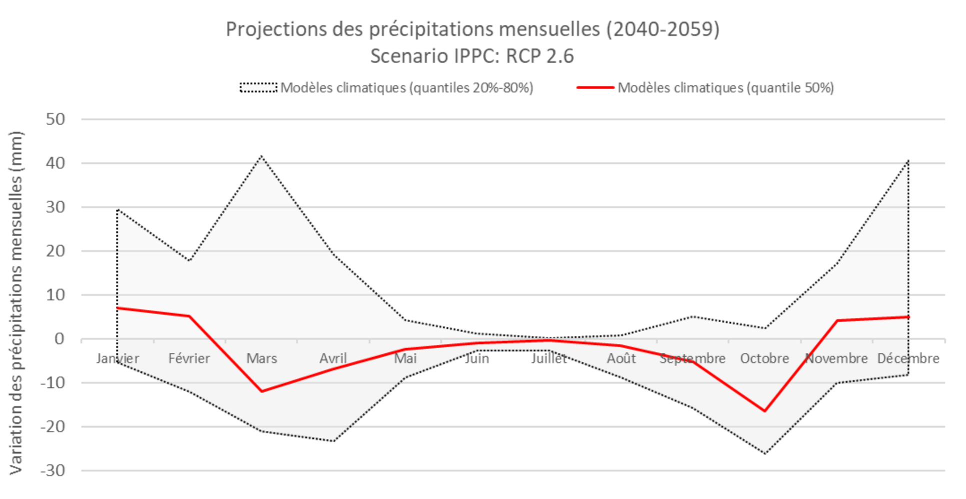
Appendix 1 - 022 - Tables of precipitation variations relative to the average (in mm) by model for the 2040 - 2059 horizon according to the RCP2.6 scenario

	année	bcc_csm1_1	bcc_csm1_1_m	ccsm4	cesm1_cam5	csiro_mk3_6_0	fio_esm	gfdl_cm3	gfdl_esm2m	giss_e2_h	giss_e2_r	ipsl_cm5a_mr	miroc_esm	miroc_esm_chem	miroc5	mri_cgcm3	noresm1_m	Modèles climatiques (quantile 0%)	Modèles climatiques (quantile 0%)	Modèles climatiques (quantile 0%)	Modèles climatiques (quantiles 0%-0%)	Modèles climatiques (quantile 20%)	Modèles climatiques (quantile 50%)	Modèles climatiques (quantile 80%)
Janvier	2040-2059	16.0	-5.3	-2.5	29.5	-20.3	2.0	30.8	33.2	-19.7	-7.2	138.1	12.2	-4.1	20.2	-4.1	23.9	-5.3	7.1	29.5	34.9	-4.3	5.8	24.0
Février	2040-2059	13.5	-12.0	54.7	9.7	-12.8	21.1	-4.0	0.6	17.7	-8.2	-0.3	-16.2	-20.2	57.6	12.7	15.9	-12.0	5.2	17.7	29.8	-14.6	6.3	21.5
Mars	2040-2059	-22.7	41.6	-17.5	-21.0	-3.8	-13.1	-15.6	-24.6	-10.8	-4.2	87.5	-7.0	-18.6	52.4	-27.2	47.0	-21.0	-11.9	41.6	62.7	-14.3	-8.1	28.3
Avril	2040-2059	-36.8	19.1	-12.6	-10.0	3.3	36.5	-4.4	-11.0	1.3	-9.3	49.5	-0.9	25.6	-74.1	-23.2	-24.4	-23.2	-6.9	19.1	42.3	-17.5	-5.2	14.5
Mai	2040-2059	18.0	3.4	4.5	-4.2	-9.8	4.4	4.4	-0.3	-6.0	-7.2	29.9	-12.5	2.9	-8.8	-5.6	-20.8	-8.8	-2.3	4.4	13.2	-7.8	-2.0	3.9
Juin	2040-2059	7.9	5.2	-2.0	-0.2	4.4	1.2	-5.9	0.4	-0.9	-2.7	-1.7	-1.4	-0.1	-4.0	-0.9	-2.6	-2.6	-0.9	1.2	3.8	-7.4	-2.6	3.3
Juillet	2040-2059	-6.1	-1.0	-0.3	-0.3	-2.5	0.2	-9.4	0.6	0.5	0.3	3.0	0.3	0.2	-10.6	-0.7	-0.3	-2.5	-0.3	0.3	2.9	-33.6	-4.1	4.2
Août	2040-2059	-10.2	-10.0	-3.3	4.1	2.2	-1.3	-8.8	0.1	0.9	-0.4	-14.4	0.4	-2.6	-1.8	2.5	-1.9	-8.8	-1.5	0.9	9.7	-25.6	-4.5	2.6
Septembre	2040-2059	-20.2	-36.4	-15.0	9.6	-28.0	4.2	-4.4	-1.4	-3.7	-5.7	-9.5	-14.3	5.7	-15.7	5.2	15.5	-15.7	-5.1	5.2	20.8	-17.9	-5.8	5.9
Octobre	2040-2059	-18.2	7.5	4.4	2.6	-33.6	-19.7	-28.9	-0.9	-17.3	-10.7	4.0	-26.1	-15.5	-37.2	-17.8	-4.7	-26.1	-16.4	2.6	28.6	-21.6	-13.6	2.1
Novembre	2040-2059	11.4	26.9	29.7	0.8	8.7	-2.4	-3.6	17.1	13.3	7.5	-9.9	0.1	-21.4	21.8	-22.3	-10.5	-9.9	4.1	17.1	27.0	-6.9	2.9	11.9
Décembre	2040-2059	5.1	2.8	33.3	32.2	-35.5	-24.5	93.1	-7.0	-8.1	-18.0	50.0	46.9	4.0	34.3	5.0	40.7	-8.1	5.1	40.7	48.8	-6.5	4.1	32.6

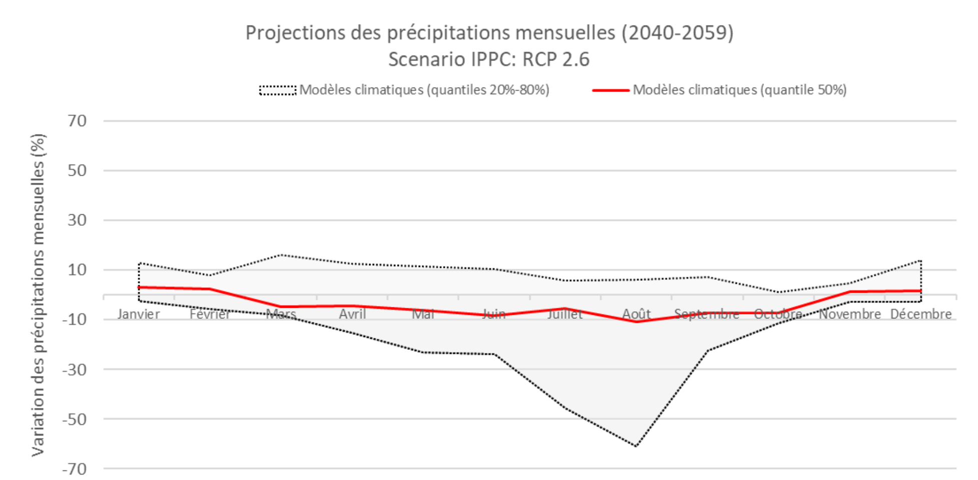
Appendix 1 - 023 - Monthly precipitation graphs by model for the 2040 - 2059 horizon, according to the RCP2.6 scenario



Appendix 1 - 024 - Graphs of variations in mean annual precipitation by model for the period 2040 - 2059, according to the RCP2.6 scenario



Appendix 1 - 025 - Graphs of variations in mean annual precipitation by model for the period 2040 - 2059, according to the RCP2.6 scenario



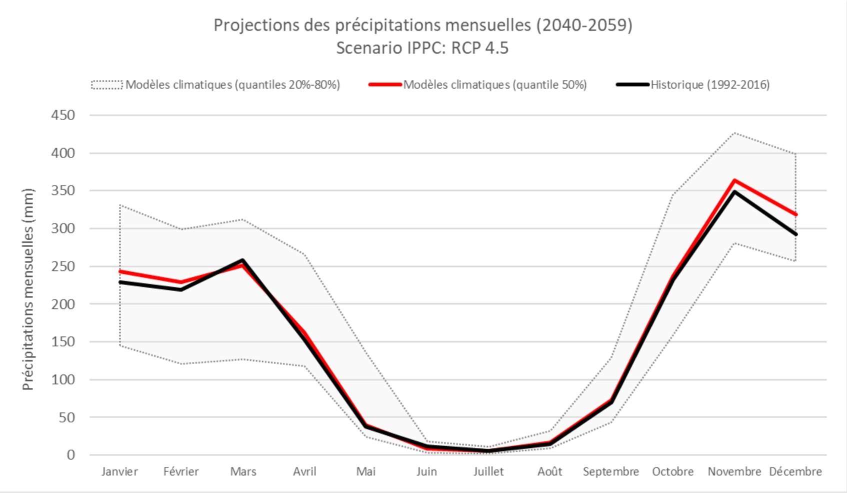
Appendix 1 - 026 - Tables of average precipitation (in mm) by model, by 2040 - 2059, according to the RCP4.5 scenario

	année	bcc_csm1_1	bcc_csm1_1_m	ccsm4	cesm1_cam5	csiro_mk3_6_0	fio_esm	gfdl_cm3	gfdl_esm2m	giss_e2_h	giss_e2_r	ipsl_cm5a_mr	miroc_esm	miroc_esm_chem	miroc5	mri_cgcm3	noresm1_m	Modèles climatiques (quantile 20%)	Modèles climatiques (quantile 50%)	Modèles climatiques (quantile 80%)	Modèles climatiques (quantiles 20%-80%)
Janvier	2040-2059	236.5	241.8	320.9	245.3	18.1	396.3	144.6	169.8	152.5	133.6	389.4	330.8	316.6	461.3	138.6	320.2	144.6	243.6	330.8	186.2
Février	2040-2059	244.8	213.7	293.6	191.7	73.2	364.5	105.4	138.2	121.2	132.7	301.8	290.5	293.6	370.3	102.2	299.3	121.2	229.3	299.3	178.2
Mars	2040-2059	278.5	273.3	246.8	203.2	268.8	433.7	126.8	141.8	91.1	86.8	572.5	248.4	254.3	448.9	119.2	311.8	126.8	251.4	311.8	185.0
Avril	2040-2059	220.7	286.4	147.5	130.2	265.3	245.3	142.7	177.6	49.9	51.3	662.2	128.4	117.8	419.4	107.1	192.5	117.8	162.5	265.3	147.6
Mai	2040-2059	112.1	136.1	41.4	55.7	36.6	26.4	159.9	52.5	21.7	21.0	185.1	23.7	24.1	234.8	34.8	38.5	24.1	40.0	136.1	112.0
Juin	2040-2059	45.6	32.6	9.3	8.0	3.3	4.1	41.8	3.3	11.5	11.7	14.3	2.6	1.7	18.2	7.5	6.0	3.3	8.7	18.2	14.8
Juillet	2040-2059	39.0	15.7	7.6	2.6	1.1	2.0	21.6	0.2	9.9	10.4	11.1	1.7	2.0	11.4	1.0	2.9	1.7	5.2	11.4	9.7
Août	2040-2059	61.0	30.6	24.2	25.3	10.3	3.8	32.7	0.4	12.5	12.6	43.0	19.9	14.0	111.2	1.7	8.7	8.7	17.0	32.7	24.1
Septembre	2040-2059	261.8	183.8	75.1	117.3	99.2	67.6	71.6	12.7	25.7	28.7	129.2	67.4	78.8	329.6	42.9	64.5	42.9	73.4	129.2	86.3
Octobre	2040-2059	376.6	344.6	302.8	224.1	250.8	283.0	186.9	130.5	78.5	89.0	367.6	158.5	161.5	585.5	246.5	227.7	158.5	237.1	344.6	186.1
Novembre	2040-2059	328.3	327.7	389.3	323.1	388.3	402.7	346.4	436.5	164.0	175.2	610.2	281.0	268.5	633.2	426.8	381.3	281.0	363.9	426.8	145.8
Décembre	2040-2059	269.0	294.9	368.2	332.0	112.9	423.2	344.0	340.5	185.8	179.9	680.0	305.6	290.4	529.0	256.2	398.7	256.2	318.8	398.7	142.5

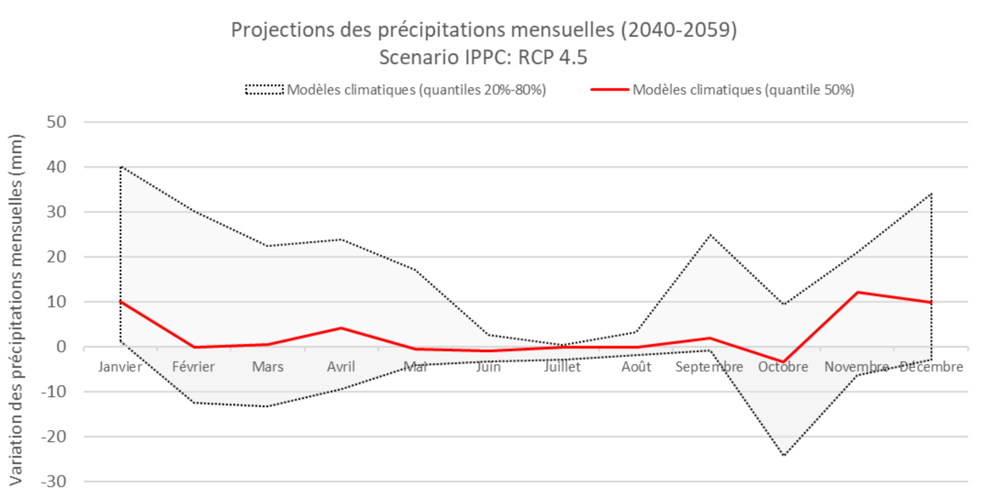
Appendix 1 - 027 - Tables of precipitation variations relative to the average (in mm) by model for the 2040 - 2059 horizon according to the RCP4.5 scenario

	année	bcc_csm1_1	bcc_csm1_1_m	ccsm4	cesm1_cam5	csiro_mk3_6_0	fio_esm	gfdl_cm3	gfdl_esm2m	giss_e2_h	giss_e2_r	ipsl_cm5a_mr	miroc_esm	miroc_esm_chem	miroc5	mri_cgcm3	noresm1_m	Modèles climatiques (quantile 0%)	Modèles climatiques (quantile 0%)	Modèles climatiques (quantile 0%)	Modèles climatiques (quantiles 0%-0%)	Modèles climatiques (quantile 20%)	Modèles climatiques (quantile 50%)	Modèles climatiques (quantile 80%)	Modèles climatiques (quantiles 20%-80%)
Janvier	2040-2059	5.7	14.8	40.2	40.7	-22.6	33.0	7.1	-1.0	-8.7	1.3	54.2	30.6	8.9	50.4	3.7	11.2	1.3	10.1	40.2	38.9	1.1	8.2	32.7	31.6
Février	2040-2059	30.2	-9.2	66.4	21.1	-12.4	-7.9	-2.6	-26.9	22.5	9.8	-27.6	-19.5	-9.6	44.7	2.2	30.3	-12.4	-0.2	30.2	42.6	-15.1	-0.2	36.5	51.6
Mars	2040-2059	2.5	22.4	0.7	1.5	3.2	-12.3	0.3	-22.1	-9.7	-12.4	103.6	-32.3	-17.7	42.0	-13.3	23.9	-13.3	0.5	22.4	35.7	-9.0	0.3	15.2	24.2
Avril	2040-2059	12.7	36.1	-5.6	-8.7	21.3	24.0	-10.6	37.9	7.4	-9.4	148.8	-0.3	3.2	-68.3	-10.8	5.1	-9.4	4.2	24.0	33.3	-7.1	3.1	18.1	25.2
Mai	2040-2059	11.8	26.7	6.3	-3.2	-0.8	-6.0	24.3	17.1	-3.6	-4.2	69.8	-9.3	0.0	5.4	-3.8	-16.3	-4.2	-0.4	17.1	21.2	-3.6	-0.4	15.0	18.6
Juin	2040-2059	2.8	-4.1	-2.3	2.6	-0.2	0.0	-0.9	2.7	-0.9	-3.3	3.1	-0.6	-0.9	-8.4	-1.0	-5.1	-3.3	-0.9	2.6	5.9	-9.3	-2.5	7.3	16.7
Juillet	2040-2059	8.5	-4.6	0.3	0.3	-2.9	0.3	-5.7	-0.1	-0.4	0.7	0.4	-0.3	0.4	-6.8	-0.2	0.0	-2.9	-0.1	0.4	3.2	-37.9	-1.0	4.7	42.6
Août	2040-2059	-26.6	-11.3	9.8	7.1	-4.3	0.0	-0.9	-0.9	1.5	0.0	0.1	3.4	-0.4	41.1	-1.7	1.1	-1.7	0.0	3.4	5.1	-5.0	-0.1	9.7	14.8
Septembre	2040-2059	13.2	0.3	-3.2	30.9	9.9	14.7	-0.9	1.8	-0.9	-2.9	0.8	-0.7	25.8	25.8	2.1	24.9	-0.9	2.0	24.9	25.8	-1.0	2.3	28.4	29.5
Octobre	2040-2059	1.2	4.8	56.6	8.9	-8.1	35.2	-31.8	3.9	-14.6	-13.0	22.0	-32.0	-21.1	-25.1	-24.2	9.3	-24.2	-3.5	9.3	33.5	-20.0	-2.9	7.7	27.7
Novembre	2040-2059	30.0	-1.0	21.1	21.4	-6.4	-12.8	18.0	15.5	4.8	16.7	19.4	-22.8	-40.0	9.0	31.9	-2.6	-6.4	12.2	21.1	27.5	-4.4	8.5	14.7	19.1
Décembre	2040-2059	-4.8	11.5	48.8	44.7	-65.7	20.8	77.8	0.0	19.5	4.6	16.0	8.1	-22.2	-1.4	-2.8	34.1	-2.8	9.8	34.1	36.9	-2.3	7.9	27.3	29.5

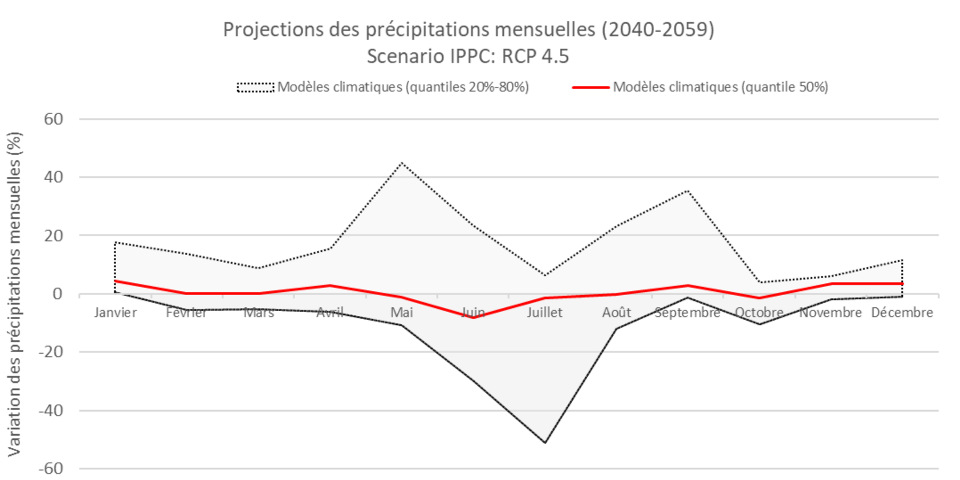
Appendix 1 - 028 - Monthly precipitation graphs to 2040 - 2059, by model, according to the RCP4.5 scenario



Appendix 1 - 029 - Graphs of variations in average annual precipitation by model for 2040 - 2059 under the RCP4.5 scenario



Appendix 1 - 030 - Graphs of variations in average annual precipitation by model for the period 2040 - 2059, according to the RCP4.5 scenario



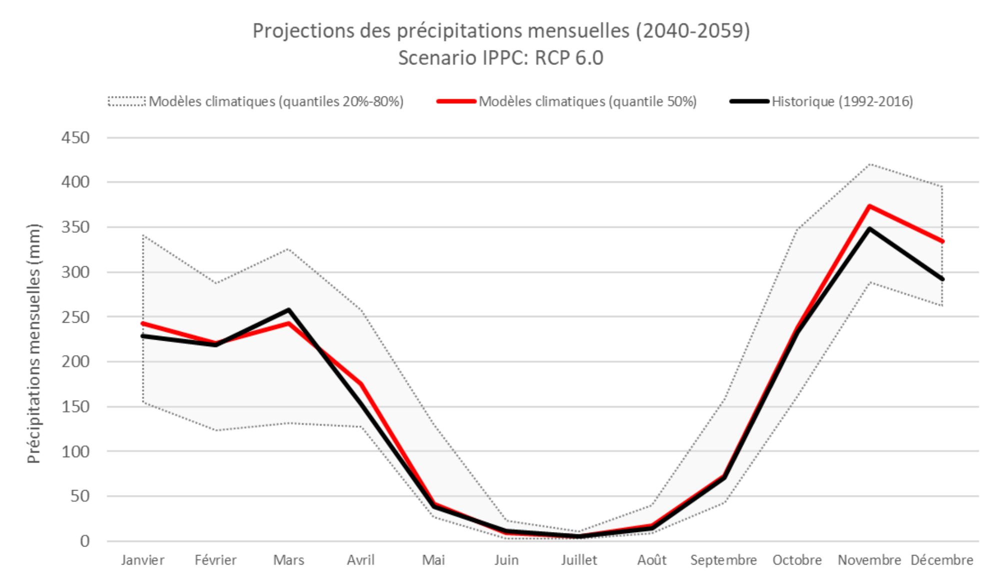
Appendix 1 - 031 - Tables of average precipitation (in mm) to 2040 - 2059 by model, according to scenario RCP6.0

	année	bcc_csm1_1	bcc_csm1_1_m	ccsm4	cesm1_cam5	csiro_mk3_6_0	fio_esm	gfdl_cm3	gfdl_esm2m	giss_e2_h	giss_e2_r	ipsl_cm5a_mr	miroc_esm	miroc_esm_chem	miroc5	mri_cgcm3	noresm1_m	Modèles climatiques (quantile 20%)	Modèles climatiques (quantile 50%)	Modèles climatiques (quantile 80%)	Modèles climatiques (quantiles 20%-80%)
Janvier	2020-2039	243.3	243.1	305.7	226.4	41.6	390.8	160.3	190.7	138.6	130.2	357.3	324.3	315.2	412.2	154.4	340.6	154.4	243.2	340.6	186.2
Février	2020-2039	242.4	199.6	247.8	177.0	85.6	374.9	104.1	147.8	127.6	123.6	295.1	274.2	288.1	389.0	102.0	278.6	123.6	221.0	288.1	164.4
Mars	2020-2039	280.2	254.5	245.7	196.8	264.1	417.0	112.1	153.7	98.1	83.3	496.5	239.8	239.6	405.2	131.2	326.3	131.2	242.8	326.3	195.1
Avril	2020-2039	203.8	292.5	174.3	150.1	257.1	207.5	176.4	152.7	59.3	43.4	555.5	127.4	127.3	434.3	101.6	178.0	127.3	175.4	257.1	129.8
Mai	2020-2039	89.9	130.5	34.9	75.0	32.6	27.3	138.5	37.7	21.4	22.3	181.2	28.9	21.3	233.8	45.2	55.9	27.3	41.4	130.5	103.3
Juin	2020-2039	33.3	34.6	9.3	6.7	2.9	3.7	43.3	1.5	11.7	13.4	9.2	2.5	1.9	22.9	5.6	12.7	2.9	9.2	22.9	20.0
Juillet	2020-2039	25.7	14.2	6.8	2.6	2.6	1.8	25.2	1.0	10.2	9.6	10.1	2.4	3.4	11.3	2.1	3.2	2.4	5.1	11.3	8.9
Août	2020-2039	78.1	40.1	18.1	30.4	8.8	4.4	38.0	1.1	13.8	11.7	44.7	20.9	16.4	78.1	4.8	10.7	8.8	17.3	40.1	31.3
Septembre	2020-2039	248.3	205.4	88.4	108.0	87.5	55.3	74.7	13.0	21.5	30.7	159.0	65.8	70.3	289.6	42.7	57.4	42.7	72.5	159.0	116.2
Octobre	2020-2039	373.6	347.4	280.4	220.1	258.9	233.3	184.8	134.5	80.8	100.0	363.2	161.0	175.2	561.1	243.2	253.8	161.0	238.2	347.4	186.4
Novembre	2020-2039	376.3	335.9	370.8	309.1	415.8	420.2	315.0	427.0	173.8	178.9	632.9	278.6	288.8	626.2	404.7	411.5	288.8	373.6	420.2	131.4
Décembre	2020-2039	280.2	291.2	380.6	336.2	148.3	424.4	357.7	344.8	179.9	168.7	736.9	311.2	332.9	548.3	262.1	395.7	262.1	334.6	395.7	133.6

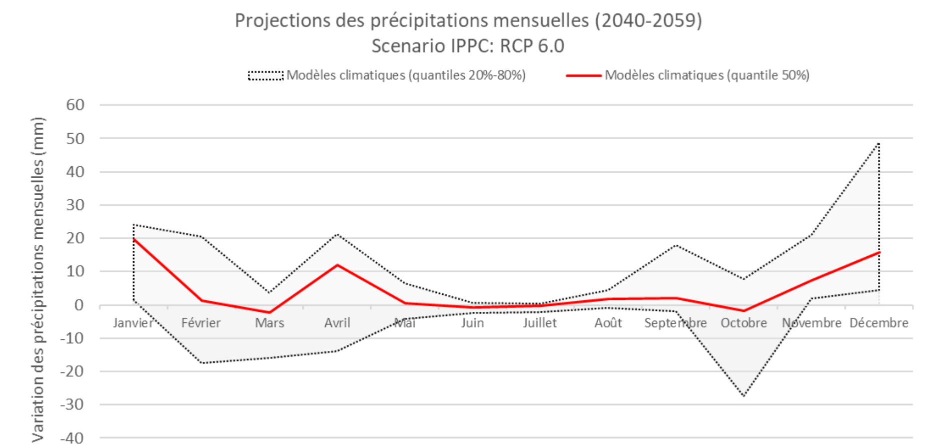
Appendix 1 - 032 - Tables of precipitation variations relative to the average (in mm) over the 2040 - 2059 horizon, by model under the RCP6.0 scenario

	année	bcc_csm1_1	bcc_csm1_1_m	ccsm4	cesm1_cam5	csiro_mk3_6_0	fio_esm	gfdl_cm3	gfdl_esm2m	giss_e2_h	giss_e2_r	ipsl_cm5a_mr	miroc_esm	miroc_esm_chem	miroc5	mri_cgcm3	noresm1_m	Modèles climatiques (quantile 0%)	Modèles climatiques (quantile 0%)	Modèles climatiques (quantile 0%)	Modèles climatiques (quantiles 0%-0%)	Modèles climatiques (quantile 20%)	Modèles climatiques (quantile 50%)	Modèles climatiques (quantile 80%)	Modèles climatiques (quantiles 20%-80%)
Janvier	2020-2039	12.6	16.1	24.9	21.8	1.0	27.5	22.8	19.8	-22.5	-2.1	22.2	24.0	7.5	1.3	19.5	31.7	1.3	19.7	24.0	22.7	1.1	16.0	19.5	18.5
Février	2020-2039	27.7	-23.3	20.6	6.5	0.0	2.6	-3.9	-17.3	28.9	0.7	-34.3	-35.7	-15.1	63.4	2.1	9.6	-17.3	1.4	20.6	38.0	-21.0	1.7	25.0	46.0
Mars	2020-2039	4.2	3.6	-0.4	-4.9	-1.5	-29.1	-14.5	-10.1	-2.7	-16.0	27.6	-40.9	-32.5	-1.7	-1.3	38.4	-16.0	-2.2	3.6	19.6	-10.8	-1.5	2.4	13.3
Avril	2020-2039	-4.3	42.1	21.3	11.1	13.0	-13.9	23.1	13.0	16.7	-17.3	42.2	-1.4	12.7	-53.3	-16.4	-9.4	-13.9	11.9	21.3	35.1	-10.5	9.0	16.1	26.6
Mai	2020-2039	-10.4	21.1	-0.3	16.1	-4.8	-5.1	3.0	2.3	-3.9	-2.9	65.9	-4.1	-2.8	4.4	6.5	1.2	-4.1	0.5	6.5	10.7	-3.6	0.4	5.7	9.4
Juin	2020-2039	-9.6	-2.1	-2.4	1.2	-0.6	-0.4	0.6	0.9	-0.7	-1.7	-2.0	-0.7	-0.7	-3.7	-2.9	1.5	-2.4	-0.7	0.6	3.0	-6.6	-1.9	1.7	8.3
Juillet	2020-2039	-4.8	-6.1	-0.5	0.3	-1.4	0.1	-2.1	0.7	-0.1	-0.1	-0.6	0.4	1.8	-7.0	0.8	0.2	-2.1	-0.1	0.4	2.5	-27.5	-1.6	5.7	33.3
Août	2020-2039	-9.6	-1.8	3.7	12.2	-5.7	0.6	4.4	-0.2	2.8	-0.9	1.8	4.4	2.0	7.9	1.4	3.1	-0.9	1.9	4.4	5.3	-2.7	5.5	12.7	15.4
Septembre	2020-2039	-0.2	21.9	10.0	21.6	-1.8	2.3	2.2	2.1	-5.1	-1.0	30.5	-2.3	17.3	-14.2	2.0	17.9	-1.8	2.1	17.9	19.7	-2.0	2.4	20.4	22.4
Octobre	2020-2039	-1.8	7.7	34.2	4.9	-0.1	-14.6	-33.9	7.9	-12.2	-2.0	17.6	-29.4	-7.4	-49.5	-27.5	35.5	-27.5	-1.9	7.9	35.4	-22.8	-1.6	6.5	29.3
Novembre	2020-2039	78.0	7.2	2.6	7.4	21.1	4.6	-13.3	6.0	14.6	20.4	42.2	-25.3	-19.7	2.0	9.8	27.5	2.0	7.3	21.1	19.2	1.4	5.1	14.7	13.3
Décembre	2020-2039	6.4	7.8	61.2	48.9	-30.2	22.1	91.4	4.4	13.6	-6.5	72.9	13.8	20.3	17.8	3.0	31.1	4.4	15.8	48.9	44.5	3.5	12.6	39.1	35.6

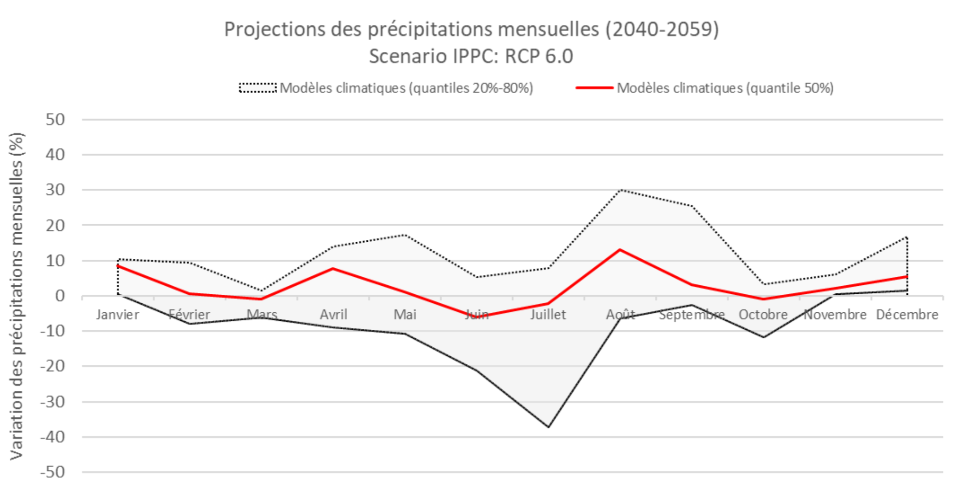
Appendix 1 - 033 - Monthly precipitation graphs by model for 2040 - 2059, by model, according to the RCP6.0 scenario



Appendix 1 - 034 - Graphs of variations in average annual precipitation by model for the period 2040 - 2059, according to the RCP6.0 scenario



Appendix 1 - 035 - Graphs of variations in average annual precipitation by model for the 2040 - 2059 horizon, according to the RCP6.0 scenario



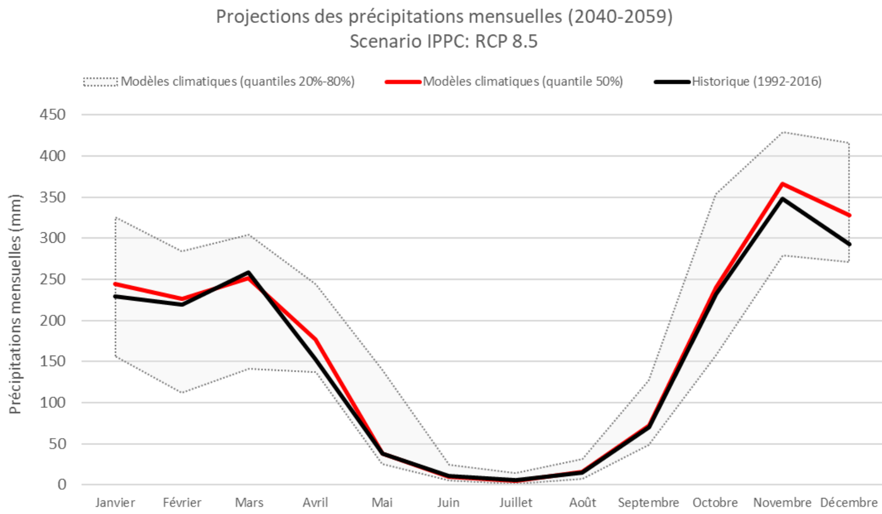
Appendix 1 - 036 - Tables of average precipitation (in mm) by model, by 2040 - 2059, according to the RCP8.5 scenario

	année	bcc_csm1_1	bcc_csm1_1_m	ccsm4	cesm1_cam5	csiro_mk3_6_0	fio_esm	gfdl_cm3	gfdl_esm2m	giss_e2_h	giss_e2_r	ipsl_cm5a_mr	miroc_esm	miroc_esm_chem	miroc5	mri_cgcm3	noresm1_m	Modèles climatiques (quantile 20%)	Modèles climatiques (quantile 50%)	Modèles climatiques (quantile 80%)	Modèles climatiques (quantiles 20%-80%)
Janvier	2020-2039	247.4	228.3	312.2	241.8	39.1	402.3	178.8	188.0	142.8	146.1	455.9	315.9	308.0	444.4	156.3	325.3	156.3	244.6	325.3	169.0
Février	2020-2039	205.6	247.9	268.9	184.9	99.3	415.3	111.7	167.5	122.2	111.0	281.4	273.0	284.2	352.4	107.6	305.0	111.7	226.7	284.2	172.6
Mars	2020-2039	281.3	278.1	258.3	170.9	263.8	426.6	130.1	169.8	84.6	90.3	500.1	244.1	238.8	462.8	141.2	304.1	141.2	251.2	304.1	163.0
Avril	2020-2039	237.2	286.2	161.7	136.9	243.7	228.3	159.0	192.4	54.1	56.1	601.4	139.5	146.3	394.2	104.6	192.9	136.9	177.1	243.7	106.8
Mai	2020-2039	87.6	141.3	35.3	67.9	36.8	31.6	142.5	42.1	19.1	21.0	139.9	27.4	25.1	232.6	25.7	39.5	25.7	38.2	139.9	114.2
Juin	2020-2039	63.4	31.2	10.5	6.2	8.3	5.3	40.9	3.3	11.3	12.1	13.1	2.3	2.2	24.2	6.1	8.2	5.3	9.4	24.2	18.9
Juillet	2020-2039	35.4	17.7	6.6	1.9	3.0	1.6	21.5	0.6	10.4	9.8	10.6	3.0	1.5	14.8	0.7	2.8	1.6	4.8	14.8	13.3
Août	2020-2039	59.4	32.0	19.9	13.3	27.8	7.4	25.1	3.2	14.0	12.9	35.6	15.0	16.0	85.8	2.3	4.2	7.4	15.5	32.0	24.6
Septembre	2020-2039	226.9	182.9	83.9	100.6	91.4	67.7	71.5	17.3	21.7	24.6	127.3	72.2	56.2	335.9	55.1	48.9	48.9	71.9	127.3	78.4
Octobre	2020-2039	394.0	353.3	287.8	231.6	248.8	265.0	161.9	97.4	75.9	87.5	409.1	182.8	157.1	556.1	269.9	228.4	157.1	240.2	353.3	196.2
Novembre	2020-2039	326.0	344.9	414.9	338.9	391.9	417.5	316.9	444.9	155.0	150.5	614.1	278.7	270.8	627.7	429.3	388.2	278.7	366.5	429.3	150.6
Décembre	2020-2039	274.2	305.2	416.0	336.2	145.5	428.6	363.1	368.9	170.4	158.5	708.9	320.1	313.2	548.1	271.3	380.8	271.3	328.2	416.0	144.7

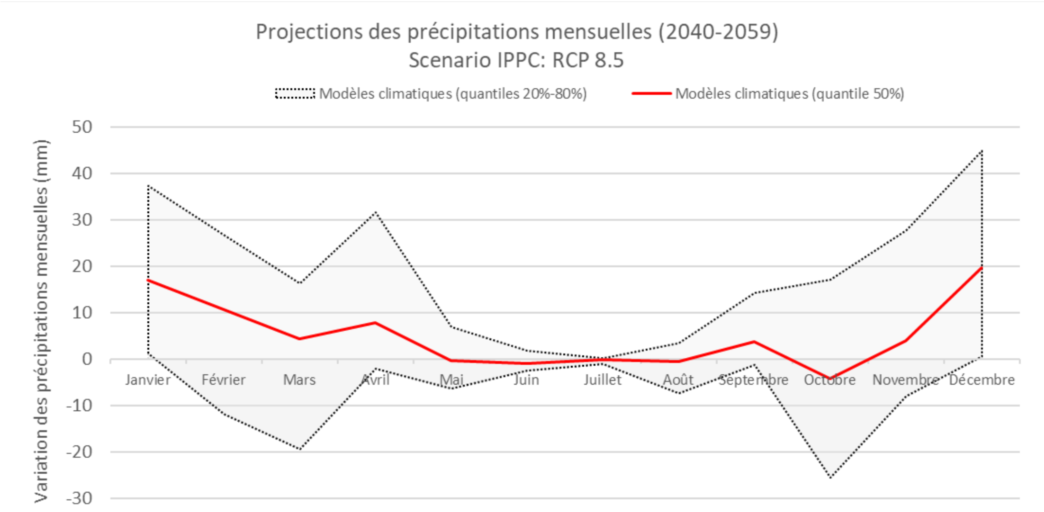
Appendix 1 - 037 - Tables of precipitation variations relative to the average (in mm) by model for the 2040 - 2059 horizon according to the RCP8.5 scenario

	année	bcc_csm1_1	bcc_csm1_1_m	ccsm4	cesm1_cam5	csiro_mk3_6_0	fio_esm	gfdl_cm3	gfdl_esm2m	giss_e2_h	giss_e2_r	ipsl_cm5a_mr	miroc_esm	miroc_esm_chem	miroc5	mri_cgcm3	noresm1_m	Modèles climatiques (quantile 0%)	Modèles climatiques (quantile 0%)	Modèles climatiques (quantile 0%)	Modèles climatiques (quantiles 0%-0%)	Modèles climatiques (quantile 20%)	Modèles climatiques (quantile 50%)	Modèles climatiques (quantile 80%)	Modèles climatiques (quantiles 20%-80%)
Janvier	2020-2039	16.7	1.3	31.5	37.3	-1.6	39.0	41.3	17.1	-18.4	13.8	120.7	15.6	0.4	33.5	21.4	16.4	1.3	16.9	37.3	36.0	1.1	13.8	30.3	29.2
Février	2020-2039	-9.1	25.0	41.7	14.3	13.6	43.0	3.7	2.5	23.5	-11.9	-48.0	-36.9	-18.9	26.8	7.7	35.9	-11.9	10.6	26.8	38.7	-14.4	12.9	32.5	46.9
Mars	2020-2039	5.3	27.2	12.1	-30.8	-1.8	-19.4	3.6	5.9	-16.2	-8.9	31.3	-36.6	-33.3	56.0	8.7	16.2	-19.4	4.4	16.2	35.6	-13.2	3.0	11.0	24.2
Avril	2020-2039	29.1	35.8	8.7	-2.1	-0.3	7.0	5.6	52.7	11.6	-4.6	88.0	10.7	31.7	-93.5	-13.4	5.6	-2.1	7.8	31.7	33.8	-1.6	5.9	24.0	25.6
Mai	2020-2039	-12.7	31.9	0.2	9.0	-0.6	-0.7	6.9	6.7	-6.3	-4.2	24.6	-5.6	1.0	3.2	-12.9	-15.2	-6.3	-0.2	6.9	13.2	-5.5	-0.2	6.1	11.6
Juin	2020-2039	20.6	-5.5	-1.1	0.8	4.9	1.2	-1.8	2.7	-1.1	-3.0	1.9	-0.8	-0.4	-2.3	-2.5	-3.0	-2.5	-1.0	1.9	4.4	-6.9	-2.7	5.4	12.2
Juillet	2020-2039	4.9	-2.6	-0.6	-0.3	-0.9	-0.1	-5.8	0.3	0.1	0.2	0.0	1.0	-0.1	-3.4	-0.6	-0.1	-0.9	-0.1	0.2	1.1	-12.3	-1.7	2.1	14.5
Août	2020-2039	-28.2	-10.0	5.5	-4.9	13.3	3.6	-8.5	1.9	3.0	0.3	-7.3	-1.5	1.6	15.7	-1.1	-3.4	-7.3	-0.4	3.6	10.8	-21.1	-1.2	10.3	31.4
Septembre	2020-2039	-21.7	-0.6	5.6	14.2	2.1	14.8	-1.0	6.4	-4.9	-7.0	-1.1	4.1	3.2	32.2	14.4	9.3	-1.1	3.7	14.2	15.3	-1.3	4.2	16.2	17.5
Octobre	2020-2039	18.6	13.6	41.5	16.4	-10.1	17.1	-56.8	-29.2	-17.2	-14.5	63.5	-7.7	-25.5	-54.6	-0.9	10.0	-25.5	-4.3	17.1	42.6	-21.1	-3.5	14.2	35.3
Novembre	2020-2039	27.7	16.2	46.7	37.3	-2.7	1.9	-11.5	23.9	-4.2	-7.9	23.4	-25.2	-37.7	3.5	34.4	4.3	-7.9	3.9	27.7	35.7	-5.5	2.7	19.3	24.8
Décembre	2020-2039	0.4	21.8	96.5	48.9	-33.0	26.3	96.8	28.5	4.1	-16.7	44.9	22.6	0.5	17.7	12.2	16.1	0.5	19.8	44.9	44.4	0.4	15.8	35.9	35.5

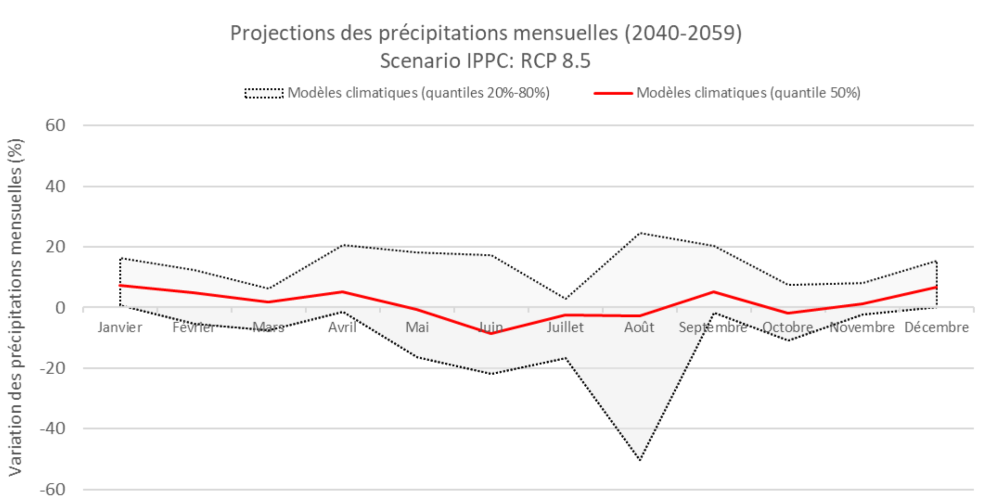
Appendix 1 - 038 - Monthly precipitation graphs to 2040 - 2059, by model, according to the RCP8.5 scenario



Appendix 1 - 039 - Graphs of variations in mean annual precipitation by model for the period 2040 - 2059, according to the RCP8.5 scenario

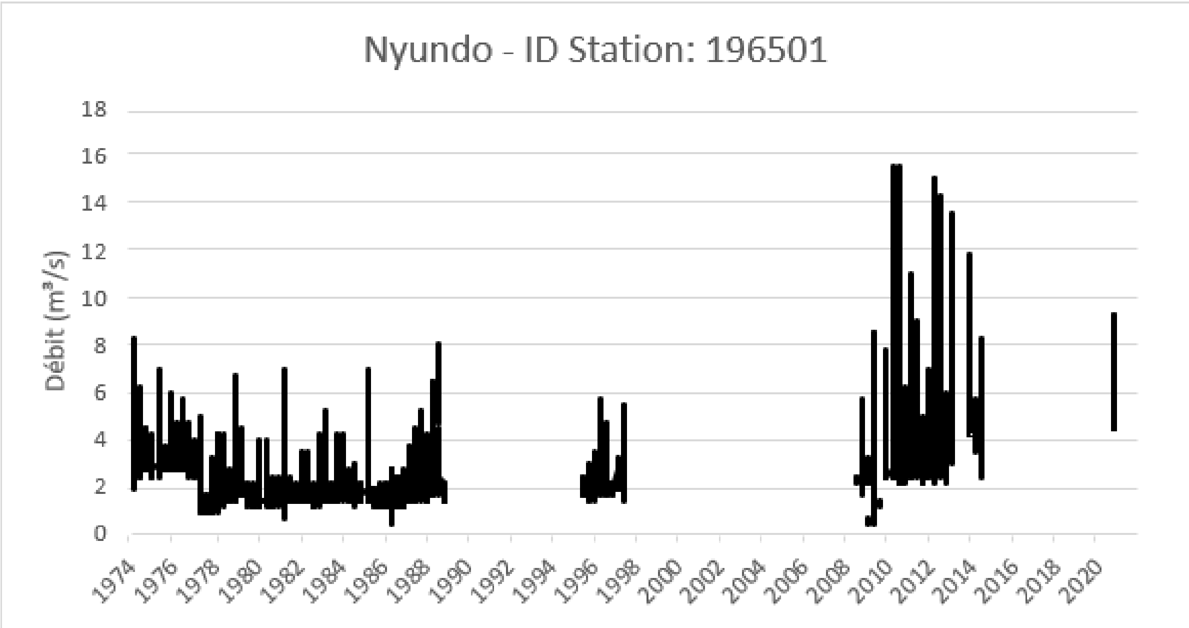


Appendix 1 - 040 - Graphs of variations in mean annual precipitation by model for the period 2040 - 2059, according to the RCP8.5 scenario

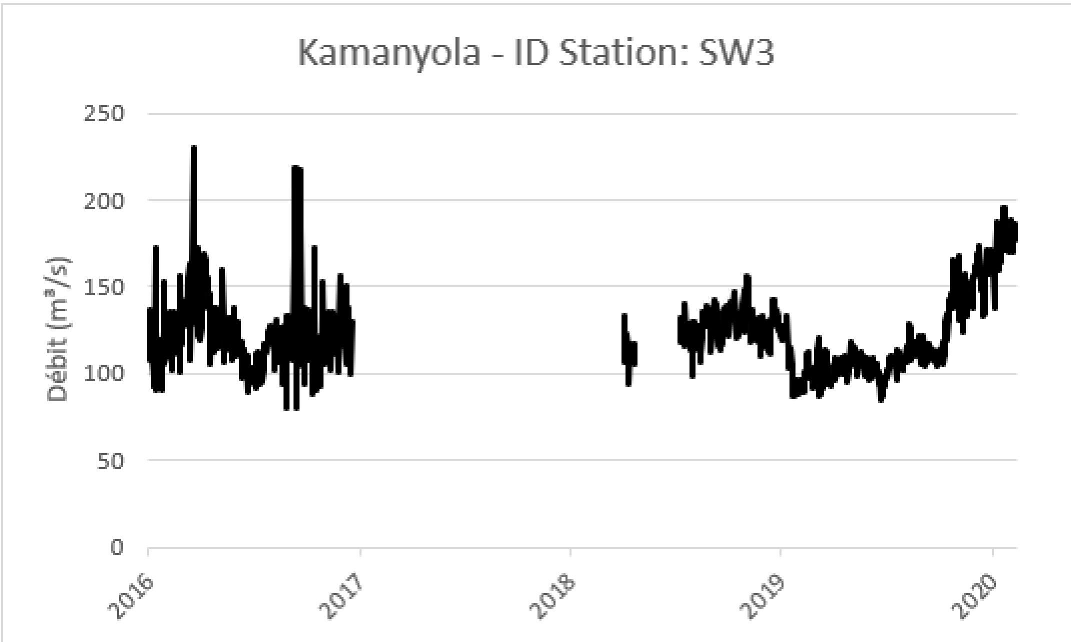


II. Hydrographs of key rivers

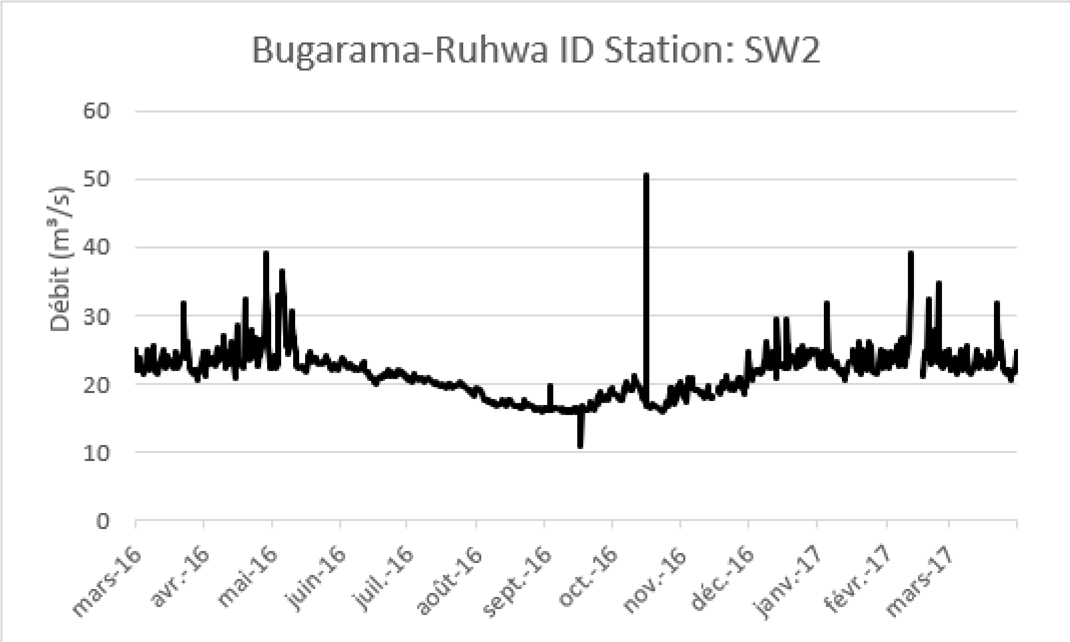
Appendix 2 - 001 - Hydrograph of the Nyundo River (195601), based on Waterportal data



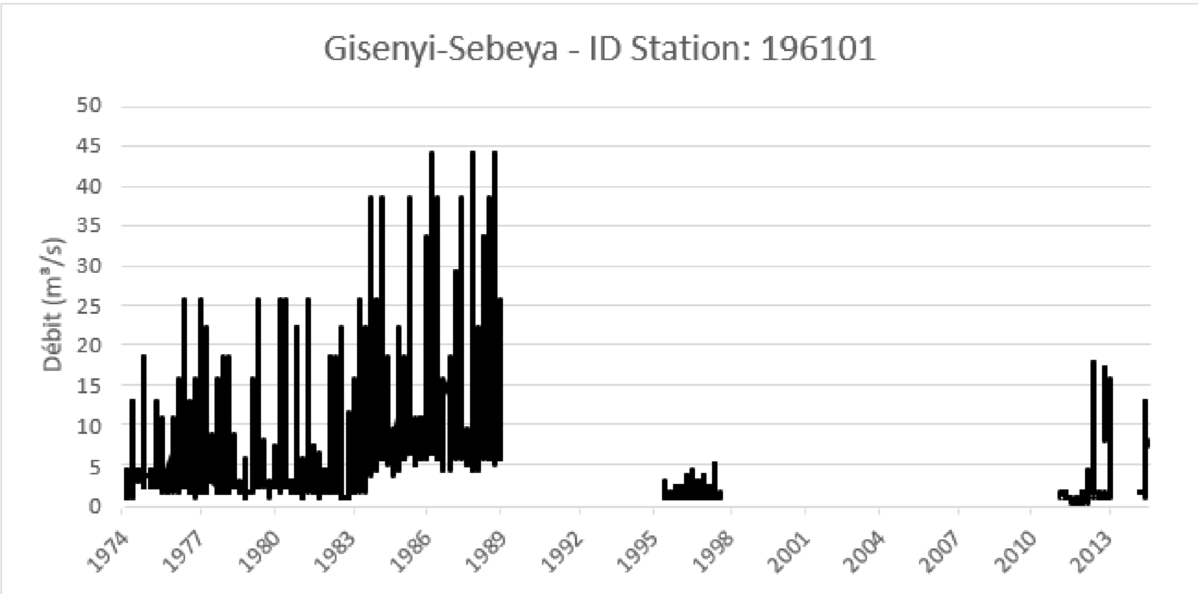
Appendix 2 - 002 - Hydrograph of the Kamanyola River (SW3), according to Waterportal data



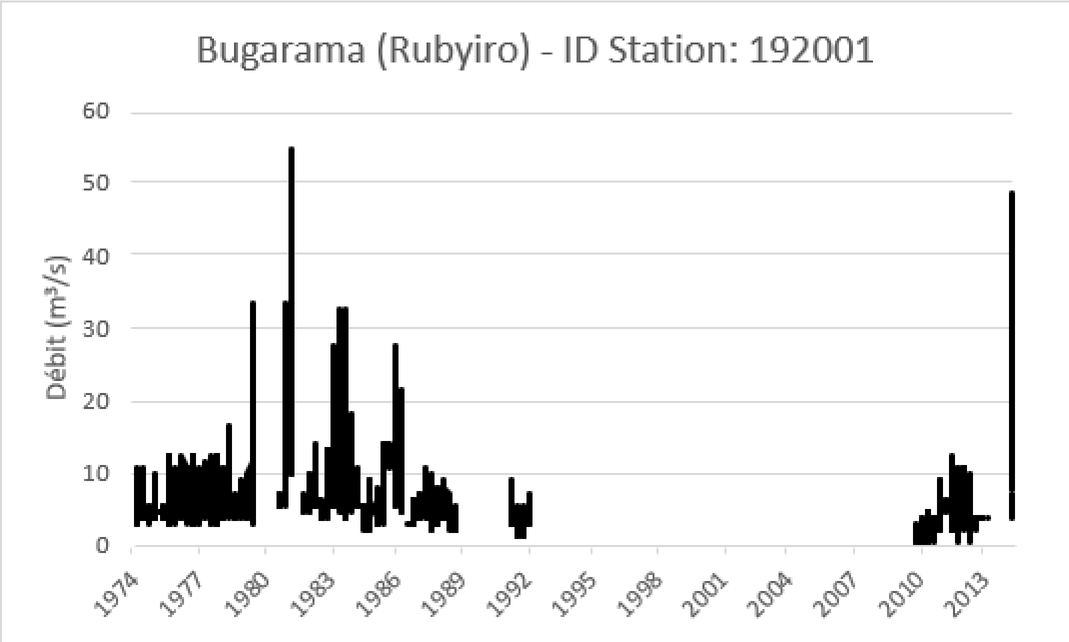
Appendix 2 - 003 - Hydrograph of the Bugarama-Ruhwa River (SW2), based on Waterportal data



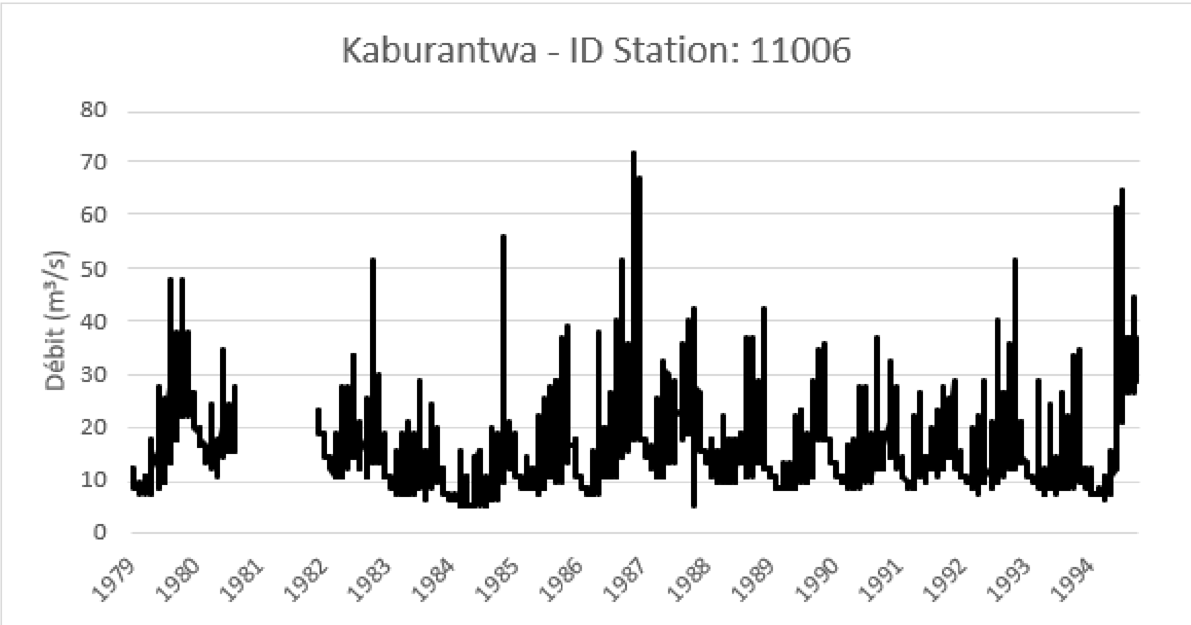
Appendix 2 - 004 - Hydrograph of the Gisenyi- Sebeya River (196101), based on Waterportal data



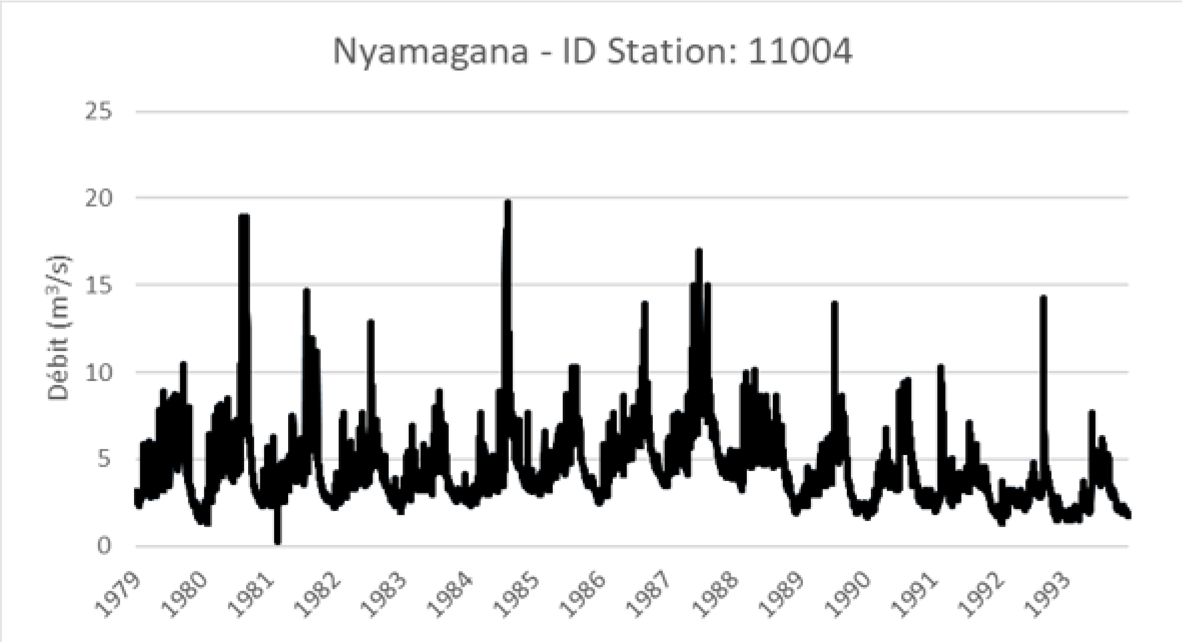
Annex 2 - 005 - Hydrograph of the Bugarama- Rubyiro River (192001), according to Waterportal data



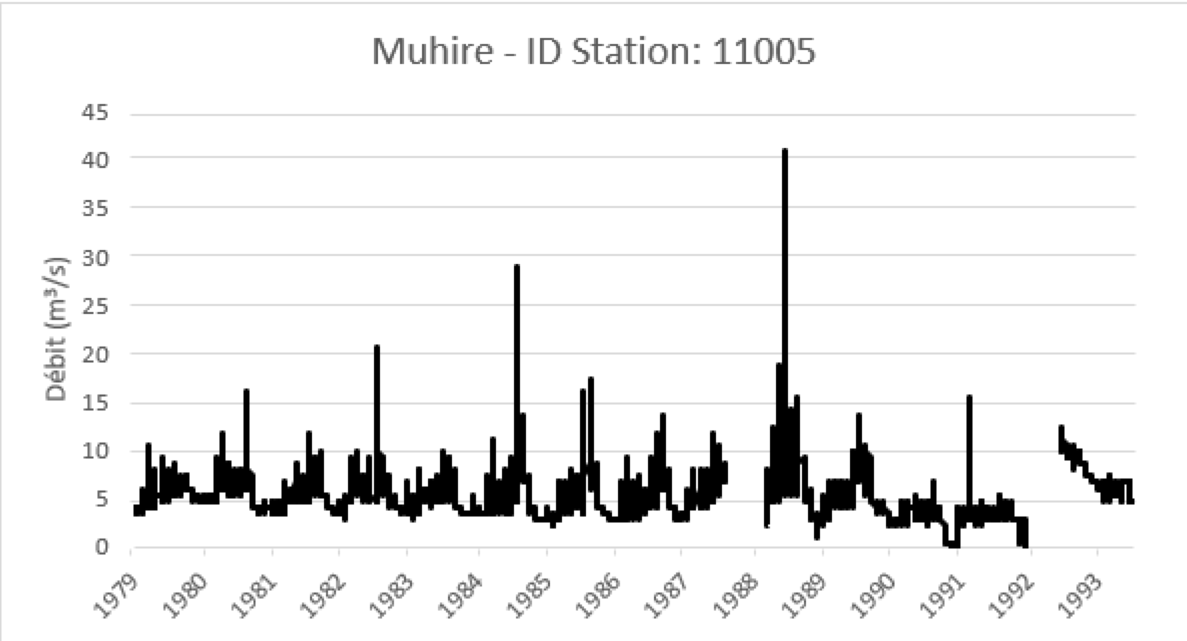
Appendix 2 - 006 - Hydrograph of the Kaburantwa River (11006), according to IGEBU data



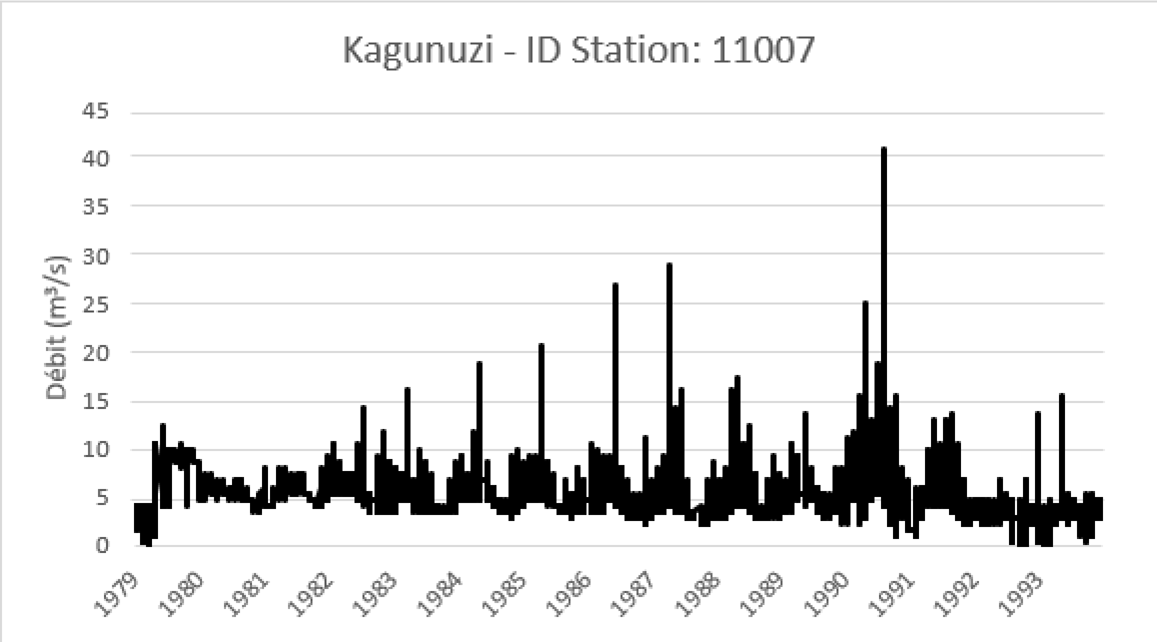
Annex 2 - 007 - Hydrograph of the Nyamagana River (11004), according to IGEBU data



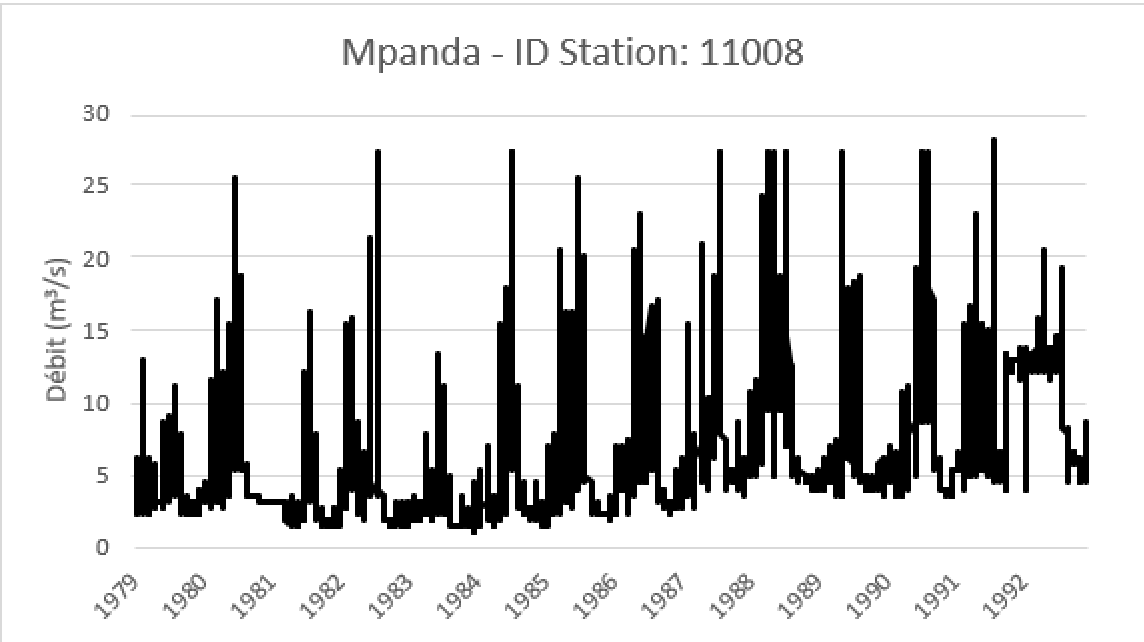
Appendix 2 - 008 - Hydrograph of the River Muhire (11005), according to IGEBU data



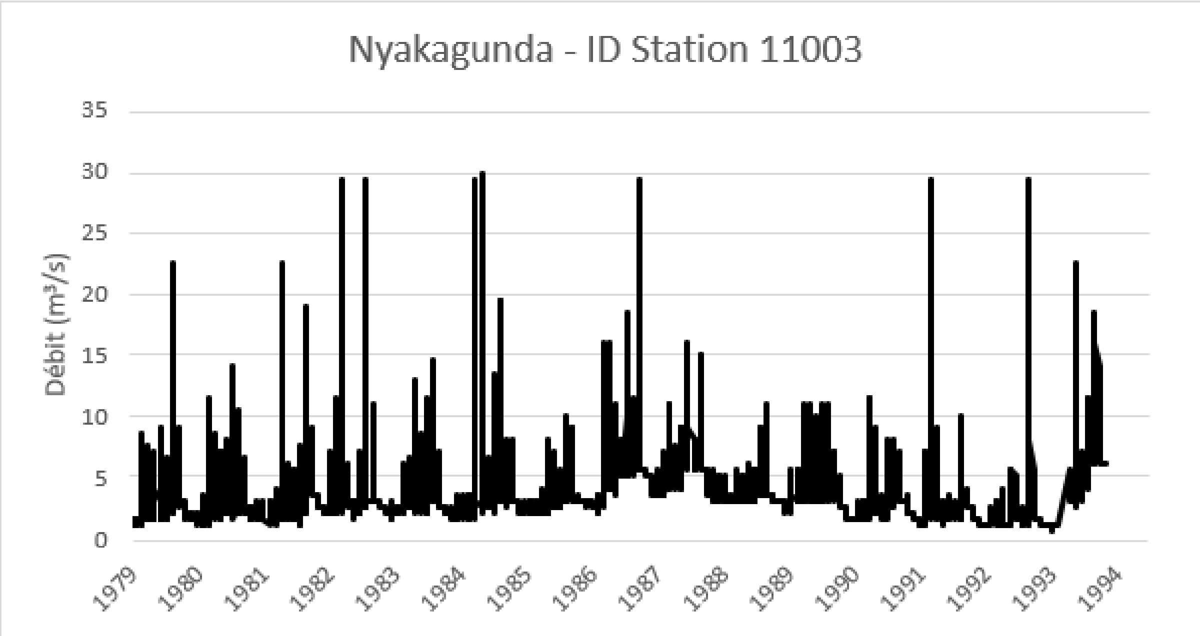
Appendix 2 - 009 - Hydrograph of the Kagunuzi River (11007), according to IGEBU data



Annex 2 - 010 - Hydrograph of the river Mpanda (11008), according to IGEBU data



Appendix 2 - 011 - Hydrograph of the Nyakagunda River (11003), according to IGEBU data



III. Characteristics of Catchment Areas

Annex 3 - 001 - Detailed characteristics of BVs

No. Compartment cement	Sub-Fund	ID	Name	Bassin	Rive	AMAV	Average slope (%)	Area (ha)	Soil losses (kt/year)	Precipitation (m³/year)	FTE (m³/year)	Runoff (m³/year)
1	KI-RG-HA	258	Seem	KI	RG	HA	13	29 596	3 971	380	355	175
1	KI-RG-HA	262	Sebeya	KI	RG	HA	30	37 036	4 456	444	438	194
1	KI-RG-HA	369	Muregeya	KI	RG	HA	36	13 471	1 532	161	157	69
1	KI-RG-HA	542	Koko	KI	RG	HA	34	13 446	1 500	160	156	69
1	KI-RG-HA	543	Nyawoza/Gatugunguru	KI	RG	HA	33	15 014	1 649	178	174	73
1	KI-RG-HA	-	other sub-basins of the compartment	KI	RG	HA	30	15 876	1 332	180	186	78
2	KI-RG-AV	279	Muso	KI	RG	AV	32	10 320	1 092	121	120	51
2	KI-RG-AV	281	Kabilizi/Gatore	KI	RG	AV	36	11 393	1 172	135	132	56
2	KI-RG-AV	295	Karundura	KI	RG	AV	36	29 071	2 786	425	345	183
2	KI-RG-AV	296	Kamiranzovu	KI	RG	AV	30	9 392	955	136	113	60
2	KI-RG-AV	374	Nyarubandwa	KI	RG	AV	37	8 222	1 072	108	95	46
2	KI-RG-AV	381	Cyongoroka	KI	RG	AV	26	10 891	1 250	154	133	66
2	KI-RG-AV	534	Kirimbi	KI	RG	AV	34	16 022	1 850	224	187	95
2	KI-RG-AV	-	other sub-basins of the compartment	KI	RG	AV	21	75 455	8 823	958	888	413
3	KI-RD-HA	98	Kyaraboze	KI	RD	HA	24	24 557	3 949	354	303	159
3	KI-RD-HA	261	xLac	KI	RD	HA	10	9 782	951	116	118	58
3	KI-RD-HA	310	Chabiringa	KI	RD	HA	8	26 156	4 505	348	318	167
3	KI-RD-HA	343	xLac	KI	RD	HA	42	8 525	1 182	125	102	54
3	KI-RD-HA	-	other sub-basins of the compartment	KI	RD	HA	32	49 750	5 919	673	600	314
4	KI-RD-AV	124	Murhundu	KI	RD	AV	23	8 388	902	137	106	58

No. Compartment cement	Sub-Fund	ID	Name	Bassin	Rive	AMAV	Average slope (%)	Area (ha)	Soil losses (kt/year)	Precipitation (m³/year)	FTE (m³/year)	Runoff (m³/year)
4	KI-RD-AV	128	Mugezi	KI	RD	AV	22	11 967	1 201	208	151	88
4	KI-RD-AV	148	Mush	KI	RD	AV	20	11 161	1 113	184	138	79
4	KI-RD-AV	-	other sub-basins of the compartment	KI	RD	AV	25	72 463	7 631	1 154	879	515
5	RU-RG-HA	14	Kaburantwa	UK	RG	HA	33	53 108	5 122	799	726	549
5	RU-RG-HA	444	Nyamagana	UK	RG	HA	34	23 655	2 569	330	363	179
5	RU-RG-HA	445	Muhira	UK	RG	HA	35	25 228	2 761	344	390	208
5	RU-RG-HA	491	Nyakagunda	UK	RG	HA	25	18 283	1 786	226	319	161
5	RU-RG-HA	503	Ruhwa	UK	RG	HA	37	62 514	5 247	958	802	521
5	RU-RG-HA	-	other sub-basins of the compartment	UK	RG	HA	7	13 044	1 162	133	257	73
6	RU-RD-HA	397	xplaine Imbo	UK	RD	HA	7	9 775	744	98	192	52
6	RU-RD-HA	483	Luberizi	UK	RD	HA	34	17 863	1 511	221	279	117
6	RU-RD-HA	485	xplaine Imbo	UK	RD	HA	9	8 120	585	77	161	41
6	RU-RD-HA	495	Luvubu	UK	RD	HA	32	56 718	4 953	730	908	389
6	RU-RD-HA	497	Luvimvi	UK	RD	HA	36	28 856	3 016	390	415	209
6	RU-RD-HA	-	other sub-basins of the compartment	UK	RD	HA	9	2 879	203	28	57	15
7	KA-RG-HA	435	Rubyiro	KA	RG	HA	27	35 654	3 567	498	526	270
7	KA-RG-HA	-	other sub-basins of the compartment	KA	RG	HA	27	6 869	871	95	91	52
8	KA-RD-HA	404	Bish	KA	RD	HA	30	18 046	1 901	250	233	133
8	KA-RD-HA	-	other sub-basins of the compartment	KA	RD	HA		10 360	901	136	147	76
9	LA-CE-CE	48	Ijwi	LA	EC	EC	24	31 651	2 719	419	367	184

No. Compartment cement	Sub-Fund	ID	Name	Bassin	Rive	AMAV	Average slope (%)	Area (ha)	Soil losses (kt/year)	Precipitation (m³/year)	FTE (m³/year)	Runoff (m³/year)
9	LA-CE-CE	-	other sub-basins of the compartment	LA	EC	EC	15	113	11	1	1	2
10	RU-RD-AV	464	Kiliba	UK	RD	AV	32	20 915	1 782	252	311	136
10	RU-RD-AV	465	xxKiliba	UK	RD	AV	13	26 959	1 857	268	505	143
10	RU-RD-AV	470	Sange	UK	RD	AV	28	28 859	2 345	344	457	184
10	RU-RD-AV	-	other sub-basins of the compartment	UK	RD	AV	7	8 811	854	84	170	48
11	RU-RG-AV	447	Kagunuzi	UK	RG	AV	34	43 216	4 441	650	625	199
11	RU-RG-AV	457	Mpanda	UK	RG	AV	21	68 805	5 577	780	1 188	276
11	RU-RG-AV	466	xplaine Imbo	UK	RG	AV	12	11 364	996	109	220	59
11	RU-RG-AV	-	other sub-basins of the compartment	UK	RG	AV	11	7 641	745	78	148	42

Appendix 3 -002 - Summary of the various sub-funds

Compart-ment no.	Sub-Fund	Area (ha)	Average slope (%)	Soil losses (kt/year)	Precipitation (m^3/year)	FTE (m^3/year)	Runoff (m^3/year)
1	KI-RG-HA	124 440	27	14 440	1 503	1 466	658
2	KI-RG-AV	149 053	32	16 736	2 004	1 761	863
3	KI-RD-HA	118 770	24	16 506	1 617	1 441	752
4	KI-RD-AV	103 979	24	10 847	1 683	1 275	740
5	RU-RG-HA	195 833	32	18 647	2 791	2 856	1 692
6	RU-RD-HA	124 213	29	11 013	1 544	2 013	825
7	KA-RG-HA	42 523	27	4 438	592	617	322
8	KA-RD-HA	28 406	29	2 802	386	380	209
9	LA-CE-CE	31 764	24	2 730	421	368	186
10	RU-RD-AV	85 544	22	6 838	947	1 442	510
11	RU-RG-AV	131 025	24	11 758	1 617	2 180	576
	Total	**1 135 550**	**27**	**116 754**	**15 106**	**15 802**	**7 333**

IV. Description of the hydrological model

Description of the hydrological model

This annex presents the water balance model developed to determine the flow of the Ruzizi River at various key points, namely the outlet of Lake Kivu, the entrance to the Imbo plain at Kamanyola and the entrance to Lake Tanganyika between Bujumbura and Uvira.

Input parameters

The input parameters used for the model are as follows:

- Topography data: delimitation of catchment areas based on the SRTM 1-arc second ;
- Land cover data: ESA-CCI global dataset of 2016 (20 m spatial resolution) ;
- Meteorological data: Artificial time series (dry, wet and average years) derived from statistics on global data sets (CHIRPS daily rasters and ETP-CGIAR). These global data are corrected from ground weather station data. These global input data are thus available over the entire study area with the same level of accuracy. The raster data are aggregated at monthly time steps and extracted in the form of statistics at the level of each sub-catchment area of interest;
- Hydrological data: daily flow values for a series of rivers gauged over periods of several years up to 40 years and more. Statistical analysis of rainfall and flow data pairs (aggregated at monthly time steps) to extract rainfall and flow rates for dry, wet and average years and the corresponding runoff coefficients. These coefficients are extracted for each basin gauged monthly and for the different cases studied (dry, average, wet). With the exception of the irrigated perimeters in the Imbo plain, evapotranspiration is included in these coefficients. In the specific case of the Imbo plain, the gauges being partly located upstream of the water intakes, these needs are also included in these coefficients;
- Irrigation: The delimitations of irrigated perimeters as well as their status (functional, to be developed, to be rehabilitated, etc.) were extracted from the SDAR data. In order to determine the corresponding water needs, a simulation of development using a mixture of crops typically used in the Imbo plain made it possible to determine monthly values of crop coefficients (values from CROPWAT) ;
- Specific data on the lake: surface area, volume (and average depth), geometry of the outlet ;
- Calibration data: flow data on some tributaries (available), flow data on the Ruzizi (available in Kamanyola, but over short periods of time).

When reference is made to a dry year, this refers to an annual rainfall exceeded four years out of five and potential evapotranspiration exceeded one year out of five. An average year corresponds to a median rainfall and potential evapotranspiration. A wet year corresponds to an exceeded rainfall in one year out of five and an exceeded potential evapotranspiration in four years out of five.

Different compartments of the model :

The different compartments of the model are as follows:

- Lake Kivu watershed :
    - Starters : rain ;
    - Outputs: determination of runoff from rainfall data and average monthly runoff coefficients based on gauged basins (in this case, mainly the Sebeya) and land use. Evapotranspiration and evaporation are taken into account through the runoff coefficient ;
    - Three sub-compartments: East bank, West bank and islands ;
- Lake Kivu :

- Inputs: lateral inputs by runoff (Lake Kivu watershed) and rainfall ;
- Outputs: evaporation and outlet flow from Lake Kivu ;
- Storage and output flow rate: in the absence of a height-volume surface curve, it is considered that the surface does not vary with height. The outlet flow rate is determined from the water height according to a hydraulic relationship (Manning) based on the geometry of the river ;

- Catchment area located between the exit of Lake Kivu and the entrance to the plain at Kamanyola :
    - Starters : rain ;
    - Outputs: determination of runoff from rainfall data and average monthly runoff coefficients based on gauged basins (in this case, mainly Nyamagana) and land use. Evapotranspiration and evaporation are taken into account through the runoff coefficient;
    - Two sub-compartments: left bank and right bank ;
- Catchment area corresponding to the Ruzizi plain (between Kamanyola and Lake Tanganyika) :
    - Input: rain, evapotranspiration on the irrigated perimeters;
    - Outings :
        - Determination of runoff from rainfall data and average monthly runoff coefficients based on gauged basins (all basins are gauged on the East side, and on the West side, using Nyamagana data) and on land use. Evapotranspiration and evaporation are taken into account through the runoff coefficient;
        - Determination of the consumption of the irrigated perimeters (evapotranspiration) from the average monthly Kc and evapotranspiration data;
    - Four sub-compartments: left bank downstream and upstream and right bank downstream and upstream.

V. Model description RUSLE

Description of the RUSLE model

The degradation of the Lake Kivu and Ruzizi River watershed is closely linked to the increasing expansion of cultivated land, deforestation and urbanisation, which increase soil erosion, causing landslides, greatly increasing the influx of minerals and nutrients downstream, but also increasing flooding with the risk of a decrease in the low-water flow.

The latter consequence is also directly linked to soil degradation. A degraded catchment area does not retain water, does not allow water to infiltrate as a wooded surface does. The hydrological response of the catchment area following a rainy event is then very rapid, resulting in a high risk of flash floods and a potential risk that the low-water level will be lower. The overall balance sheet, however, undergoes very little change even if there is an impact on actual evapotranspiration.

In order to quantify erosion and hence soil loss within the study area, the Revised Universal Soil Erosion Equation (RUSLE) model was used. This equation is the product of 5 factors as shown in the equation below :

$$A = R * K * LS * C * P$$

where

A = annual soil loss (t /ha/year);

R = rain erosion factor (MJ.mm/ha/h/year);

K = soil erodibility factor (t.ha-h/ha/MJ/mm);

LS = slope length factor and slope factor (without unit);

C = crop and canopy index factor (without units);

P = factor from practices to soil conservation (without unit).

As the collection of these extensive measures is not integrated in this project, secondary data available in GIS were used. Data on climate, soils, topography and land cover are derived from existing secondary data sources. Also, the P factor was not taken into account in order to obtain the actual potential erosion at the scale of the catchment area.

The erosive factor of the rains was taken from a SHER study conducted in 2014 in Burundi[59]. The K-factor was calculated from the FAO soil classification and its associated K-factor[60]. The LS factor was obtained from the DTM of the study area. The C factor was obtained from ESA CCI data from 2016.

The use of this model therefore makes it possible to highlight the correlation between the expansion of cultivated land on steep slopes and the extreme risk of soil erosion by water. It also makes it possible to identify erosion hotspots that require management efforts.

[59] Integrated Analysis of Vulnerability in Burundi - Volume I: "Introduction and Integrated Analysis of Vulnerability to Climate Change at National Level" (SHER - GIZ - MEEATU & MINAGRE) - 2014

[60] Agro-ecological land resources assessment for agricultural development planning. A case study of Kenya. Resources Data Base and Land Productivity - World Soil Resources Reports - Land and Water Development Division Food and Agriculture Organization of the United Nations and International Institute for Applied Systems Analysis - Rome, 1992

VI. Description of the CROM model

Description of the CROM model

In order to reduce erosion in the watershed, the Catchment Restoration Opportunity Mapping (CROM) tool was used. This tool makes it possible to determine the most appropriate erosion restoration measures according to different factors, such as soil depth, slope and geology. The data for this model were also obtained from secondary GIS data.

The land cover data were obtained from ESA CCI from 2016. Slope data were obtained from the DTM with a resolution of 30m over the 3 countries. Finally for soil depth, data was available for Rwanda and Burundi with a resolution of 30m, but no data is available for DRC. An extrapolation of the data was therefore made, based on the FAO soil classification (SOTERCAF) available for the entire study area.

Table 28 below summarises the various erosion control measures [61]

Table 28: CROM matrix of slope/depth classes and alternative land-use options

Ground depth→ Land slope↓	> 0.5 m	< 0.5 m
1 : (0-6%)	**Class I** ▪ Agroforestry + contour ploughing + strip cropping in pathways	**Class VI** ▪ Agroforestry + contour ploughing + strip cropping in pathways ▪ Forests where the soil depth is too limited and not suitable for crops. ▪ Perennial crops, coffee, tea, bananas, fruit trees
2 : (6 - 16%)	**Class II** ▪ Progressive terraces (reinforced with agroforestry hedges and strips of grass) ▪ Perennial crops, coffee, tea, bananas, fruit trees	**Class VII-a** ▪ Progressive terraces (reinforced with agroforestry hedges and strips of grass) ▪ Perennial crops, coffee, tea, bananas, fruit trees ▪ Forests where the soil depth is too limited and not suitable for crops
3 : (16 - 40%)	**Class III** ▪ Bench terraces (option only in case of suitable and stable parent material / geology; avoid introducing landslide risks) ▪ Progressive terraces (reinforced with agroforestry hedges and strips of grass) ▪ Perennial crops, coffee, tea, bananas, fruit trees	**Class VII-b** ▪ Progressive terraces (reinforced with agroforestry hedges and strips of grass) ▪ Forests where the soil depth is too limited and not suitable for crops ▪ Perennial crops, coffee, tea, bananas, fruit trees
4 : (40- 60%)	**Class IV** ▪ Narrow terraces (option only if parent material / stable and suitable geology; avoid introducing landslide risks) ▪ Progressive terraces (reinforced with agroforestry hedges and strips of grass) ▪ Forests (Biological measures) ▪ Perennial crops, coffee, tea, bananas, fruit trees	**Class VIII-a** ▪ Forests (biological measures) + trenches / ditches
5 : (> 60%)	**Class V** ▪ Forests (biological measures) + trenches / ditches ▪ Perennial crops, coffee, tea, bananas, fruit trees	**Class VIII-b** ▪ Natural vegetation

[61] IWRM Programme Rwanda - Catchment restoration supporting sustainable and efficient investments in hydropower generation in the most degraded areas of Upper Nyabarongo, June 2018

The techniques used to control erosion are based on the erosion factors outlined above, the logic being to try to reduce each of them to a minimum. Unfortunately, the climatic index and soil erodability are not controllable, as climate is the main erosion factor. Erosion control techniques are therefore oriented towards minimising the LS indices of slopes and C of crops and land use by combined biological and physical measures.

The first factor, the depth of the soil, is limiting in terms of the measures to be put in place. A soil depth of less than 0.5m, for example, does not allow the installation of radical terraces.

For the LS slope index, the approach will be to combine physical and biological measures to reduce (i) the length of the slope by establishing contour trenches and quickset hedges (Leucaena, Calliandra, Pennisetum, Setaria, Gliricidia, etc.), and (ii) the slope by building terraces.

The cultivation index is also certainly a very important factor to be taken into account in the fight against erosion. The associated measures involve limited investments and ensure an improvement in fertility. Each crop and each associated farming system has a specific efficiency in protecting the soil against erosion, as shown in the Table 28 above. Biological erosion control measures associated with the crop index use different types of crops or farming systems, agroforestry and afforestation/reforestation. The success of agroforestry depends on the use of appropriate species that are well accepted by farmers because of their multiple potential uses (i.e. fodder for livestock, nitrogen fixation fertilization, firewood and wood for furniture and construction).

Terracing in cultivated areas with steep slopes is one of the solutions, as in the Sebeya basin where a project is currently underway. The installation of progressive or radical terracing makes it possible to reduce soil loss by reducing the speed of the water, lowering the LS factor and directly increasing its infiltration. Other conservation practices are recommended, such as agroforestry, reforestation, river bank stabilisation, increasing the canopy and understorey vegetation, control of human activities, etc.

VII. Description of the WEAP model

1. WEAP software description

The WEAP (Water Resources Assessment and Planning System) software is a powerful and user-friendly tool, developed by the Stockholm Environment Institute (SEI), which takes an integrated approach to water resources management and planning.

The challenges of water management are increasingly critical. The allocation of scarce water resources between agriculture, water supply, livestock and environmental functions now requires an integration of supply, demand, water quality and ecological issues. The Water Evaluation and Planning Assessment and Assessment System (WEAP), aims to integrate these elements into a practical and robust tool for water resources planning.

WEAP is a computer-based tool for integrated water resources planning that attempts to assist rather than replace the planner. It provides a comprehensive, flexible and user-friendly framework for planning and policy analysis.

Indeed, over the last decade, an integrated approach to water development has emerged (the IWRM approach), which places supply projects in the context of the management of the demand, the water quality and the preservation and protection of ecosystems. WEAP integrates these elements into a practical tool for water resources planning and policy analysis. WEAP integrates issues of demand for different uses, water use scenarios, equipment efficiencies, reuse strategies, costs and water allocation schemes on an equal basis with water supply elements such as river flow, groundwater resources, reservoirs, and water transfers. WEAP is also differentiated for its integrated approach capable of simulating not only the natural components (e.g., evapotranspiration demands, runoff, base flow) but also the engineering components (such as reservoirs, groundwater pumping) of water systems, allowing the planner to obtain a comprehensive view of the wide range of factors that need to be considered in managing water resources for present and future use. The result is an operational tool for examining water development and management options.

WEAP operates based on the following architecture:

- Water balance database: WEAP provides a system for updating information on supply and demand.
- Scenario production tool: WEAP simulates demand, supply, runoff, flows, storage, and water quality.
- The Policy Analysis Tool: WEAP assesses a full range of water development and management options and takes into account the multiple competing uses of water systems.

WEAP operates on the basic principle of a water balance and can be applied to water supply and agricultural systems, ranging from simple water sources to complex transboundary watershed systems. In addition, WEAP can simulate a wide range of natural and engineering components of these systems, including rainwater runoff, baseflow, groundwater recharge from rainfall, sectoral demand analyses, water conservation, water rights and priority allocation, reservoir operations, hydropower generation, pollution and water quality monitoring, vulnerability assessment, and ecosystem conditions. The financial analysis module also allows the user to explore cost-benefit comparisons of projects.

WEAP applications involve several steps:

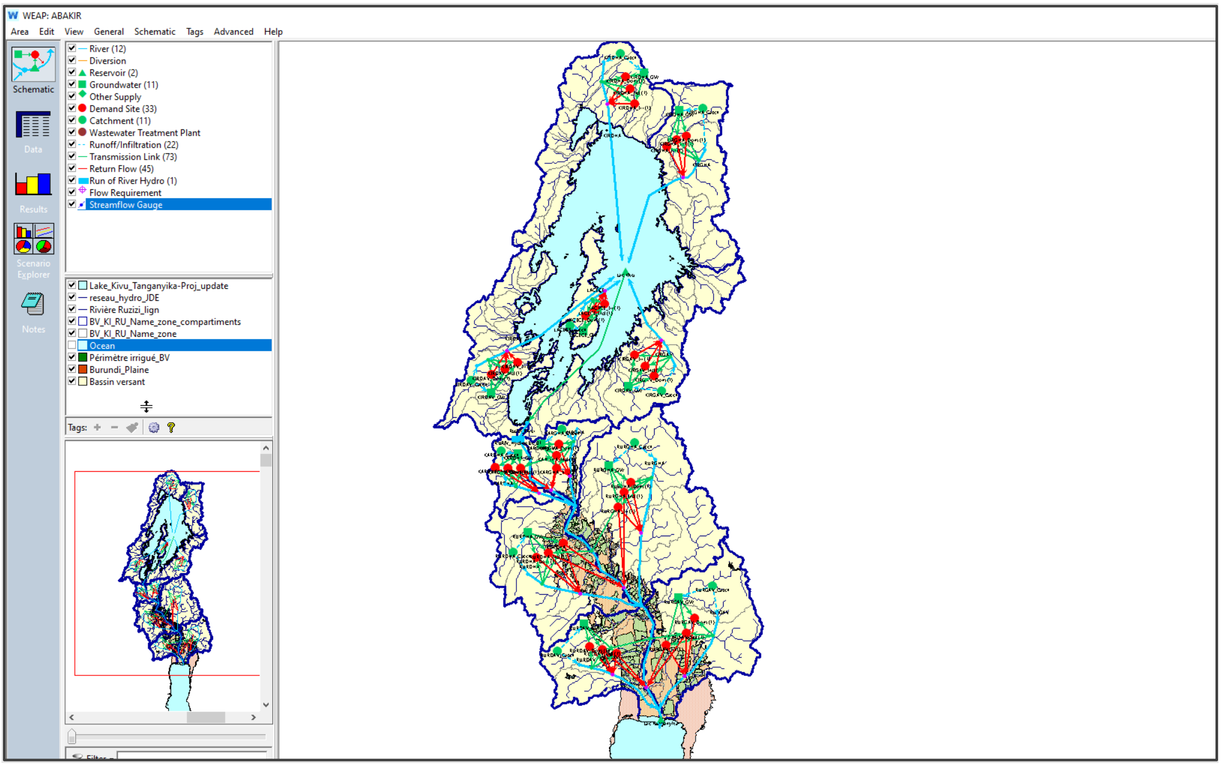
- ***Definition of the study***: the timing, spatial boundaries, system components and problem configuration are established.

- ***Current values***: an overview of the current water demand, pollution loads, resources and supplies for the system are developed. This can be seen as a calibration step in the development of the application.
- ***Scenarios***: a number of alternative assumptions on future impacts of policy, costs and climate, e.g. on water demand, supply, hydrology and pollution can be explored.
- ***Evaluation:*** Scenarios are evaluated in terms of water availability, costs and benefits, compatibility with environmental objectives and sensitivity to uncertainty of key variables.

2. WEAP model carried out as part of the study

2.1. Modelled area

As part of the study, WEAP modelling of the entire area of intervention was carried out. It is shown in the figure below for illustrative purposes.



The modelled area was divided into 11 sub-compartments, corresponding to a grouping of the 128 sub-watersheds. It is at this scale that the model is parameterised, both for the calculation of the water resources that can be mobilised and for the integration of the different water uses.

The 11 sub-compartments are as follows :

- Lake Kivu Basin – West - Upstream
- Lake Kivu Basin – West - Downstream
  Lake Kivu Basin – East - Upstream
- Lake Kivu Basin – East - Downstream
- Lake Kivu Islands
- Rusizi Basin to Kamanyola - West
- Rusizi Basin to Kamanyola - East
- Rusizi Basin from Kamanyola to Tankanyika Lake – West - Upstream
- Rusizi Basin from Kamanyola to Tankanyika Lake – West – Downstream

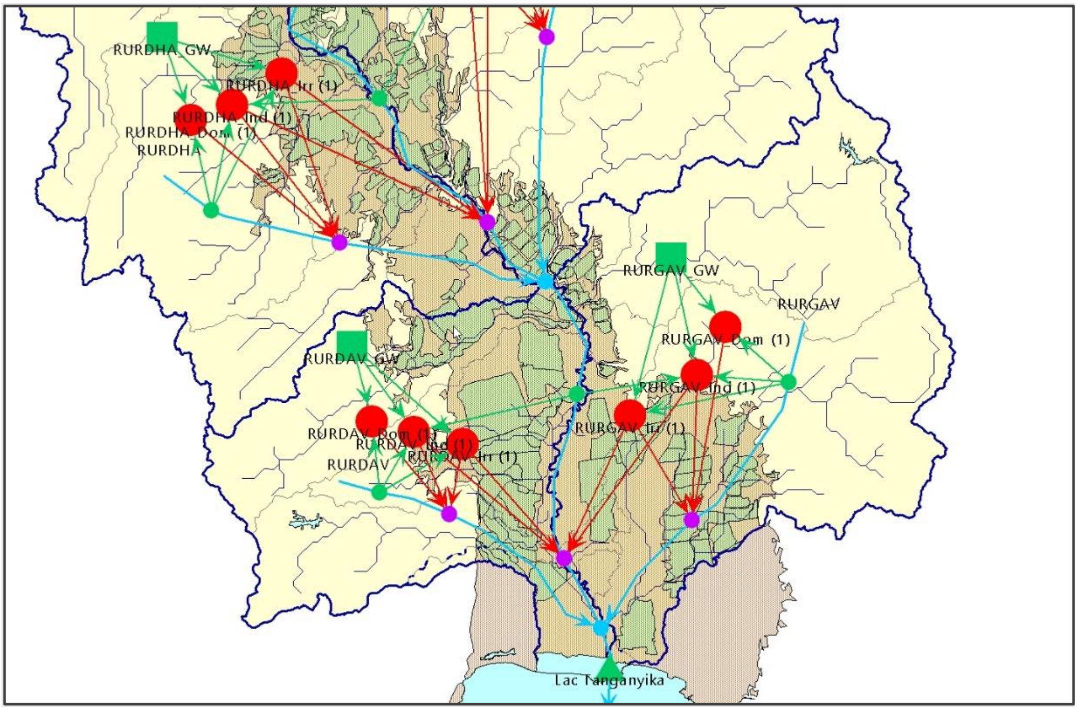
- Rusizi Basin from Kamanyola to Tankanyika Lake – East - Upstream
- Rusizi Basin from Kamanyola to Tankanyika Lake – East - Downstream

For each of these sub-compartments, the model defines a 'river' element, an 'aquifer' element, a 'catchment' element, as well as an element per water use (domestic use in rural areas, domestic use in urban areas, industrial use, agricultural use).

The model also explicitly includes an element representing Lake Kivu, and an element representing the Ruzizi River.

Transmission and return links are defined between all these elements, and simulation results are produced for all the corresponding nodes.

The figure below shows, as an illustration for the southern part of the model, the different elements relating to water resources and uses, the nodes, and the transmission and return links between these elements.



2.2. Defined scenarios

The scenarios defined in the study, and used in the WEAP model, are as follows:

1. Reference situation (year 2020, and average climatic conditions).
2. Increase in drinking water needs by 2050: using the annual population growth rates defined for the three countries (BUR, DRC, RWA) in rural and urban areas;
3. Improving the rate of access to drinking water by 2050: definition of a function for increasing annual per capita demand for drinking water, in rural and urban areas;
4. Increase of irrigated agriculture in the Ruzizi plain: increase of irrigated areas from the reference situation (operational boundaries currently in activity) to a situation of cultivation of all current and projected boundaries;
5. Climate change: consideration of the reference climate situation (P50), and a climatic evolution towards a drought situation corresponding to the P80 level defined in the water balance.

2.3. Parameterisation

The model parameterisation is carried out on the scale of the 11 sub-compartments defined above, at monthly time steps. It concerns the rain-flow relations and the corresponding flow volumes at the level of each sub-compartment, as well as the water demands for the different uses. The parameterisation is carried out for a reference situation (2020), as well as for the different scenarios defined.

The main parameterisation elements are listed below.

The rain-flow relationships and the corresponding discharge volumes are shown below for each sub-compartment in the reference climate situation (P50) and in the drought climate scenario (P80).

P50		Month											
Compartment	Unit	1	2	3	4	5	6	7	8	9	10	11	12
KI-RG-AV	million m³/month	106.9	66.3	76.0	76.1	66.3	31.2	20.8	66.8	69.3	75.6	71.1	79.5
	m³/s	39.9	27.4	28.4	29.3	24.8	12.0	7.8	24.9	26.7	28.2	27.4	29.7
KI-RG-HA	million m³/month	65.7	49.1	57.1	58.8	53.9	35.9	26.2	60.8	52.6	54.4	60.7	54.2
	m³/s	24.5	20.3	21.3	22.7	20.1	13.9	9.8	22.7	20.3	20.3	23.4	20.3
KI-RD-AV	million m³/month	95.5	55.0	59.5	57.0	53.9	33.2	24.1	54.4	59.7	69.9	67.5	72.8
	m³/s	35.6	22.8	22.2	22.0	20.1	12.8	9.0	20.3	23.0	26.1	26.0	27.2
KIRDHA	million m³/month	74.9	51.9	60.7	61.5	58.9	42.6	38.4	81.9	67.7	63.7	73.6	66.1
	m³/s	28.0	21.4	22.7	23.7	22.0	16.4	14.3	30.6	26.1	23.8	28.4	24.7
LACECE	million m³/month	19.4	13.1	14.8	16.2	15.4	9.7	7.2	15.1	14.7	18.4	17.1	15.5
	m³/s	7.2	5.4	5.5	6.3	5.8	3.8	2.7	5.6	5.7	6.9	6.6	5.8
KARDHA	million m³/month	20.6	17.4	22.4	20.2	21.3	8.1	4.5	12.3	14.6	12.3	16.8	18.8
	m³/s	7.7	7.2	8.4	7.8	8.0	3.1	1.7	4.6	5.6	4.6	6.5	7.0
KARGHA	million m³/month	30.2	25.8	34.4	34.7	36.4	12.3	4.9	18.7	22.0	20.8	25.0	27.3
	m³/s	11.3	10.7	12.9	13.4	13.6	4.7	1.8	7.0	8.5	7.8	9.6	10.2
RURGHA	million m³/month	152.9	140.7	173.3	205.5	208.2	42.7	14.7	82.2	98.8	112.1	129.8	138.1
	m³/s	57.1	58.2	64.7	79.3	77.7	16.5	5.5	30.7	38.1	41.8	50.1	51.6
RURDHA	million m³/month	86.3	71.2	85.3	97.1	98.2	30.4	10.1	32.0	46.0	42.1	62.7	74.5
	m³/s	32.2	29.4	31.9	37.4	36.7	11.7	3.8	11.9	17.8	15.7	24.2	27.8
RURGAV	million m³/month	55.7	56.1	64.2	68.6	64.8	13.9	5.1	27.4	33.1	35.9	44.4	49.9
	m³/s	20.8	23.2	24.0	26.5	24.2	5.4	1.9	10.2	12.8	13.4	17.1	18.6
RURDAV	million m³/month	55.5	48.8	56.5	61.7	55.3	12.6	4.5	13.5	23.1	25.4	39.5	48.0
	m³/s	20.7	20.2	21.1	23.8	20.7	5.2	1.7	5.2	8.6	9.8	14.7	17.9
Ruzizi sortie lac Kivu	m³/s	82.0	80.0	83.0	89.0	94.0	85.0	71.0	67.0	66.0	68.0	75.0	78.0

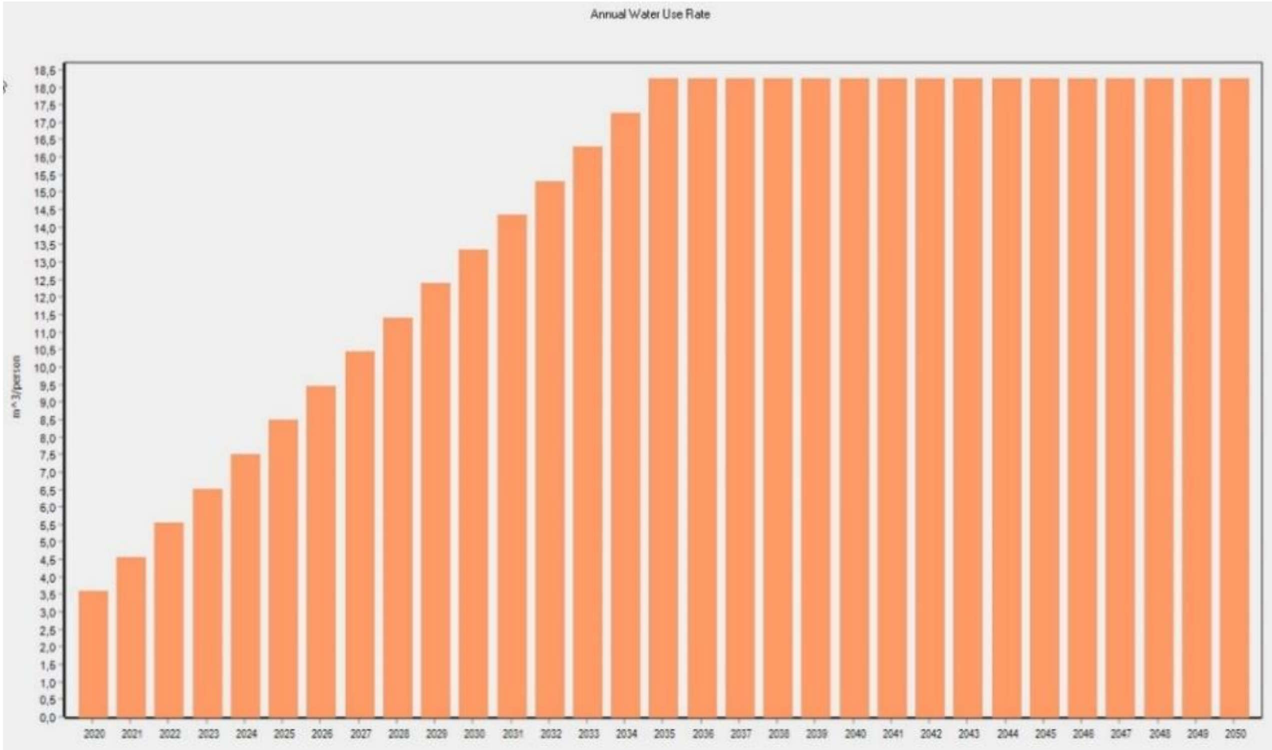
P80		Month											
Compartment	Unit	1	2	3	4	5	6	7	8	9	10	11	12
KI-RG-AV	million m³/month	113.3	88.5	72.3	73.6	60.4	20.8	16.3	55.6	64.7	70.1	73.0	69.1
	m³/s	42.3	36.6	27.0	28.4	22.5	8.0	6.1	20.7	25.0	26.2	28.1	25.8
KI-RG-HA	million m³/month	69.4	61.1	56.6	59.5	50.9	31.8	17.2	59.7	51.7	52.2	62.8	48.5
	m³/s	25.9	25.3	21.1	23.0	19.0	12.3	6.4	22.3	19.9	19.5	24.2	18.1
KI-RD-AV	million m³/month	105.0	71.7	57.2	58.9	48.5	23.1	18.9	52.2	59.3	61.7	68.9	68.5
	m³/s	39.2	29.6	21.4	22.7	18.1	8.9	7.1	19.5	22.9	23.0	26.6	25.6
KIRDHA	million m³/month	78.8	63.4	58.2	61.5	57.3	37.1	28.4	87.5	66.8	60.3	77.2	61.7
	m³/s	29.4	26.2	21.7	23.7	21.4	14.3	10.6	32.7	25.8	22.5	29.8	23.0
LACECE	million m³/month	21.5	17.3	14.3	15.6	14.3	7.1	5.5	15.0	14.8	16.6	17.4	13.5
	m³/s	8.0	7.1	5.3	6.0	5.3	2.7	2.1	5.6	5.7	6.2	6.7	5.0
KARDHA	million m³/month	17.3	15.6	18.9	18.4	16.1	5.5	3.2	8.6	10.8	9.9	13.7	16.7
	m³/s	6.4	6.4	7.1	7.1	6.0	2.1	1.2	3.2	4.2	3.7	5.3	6.2
KARGHA	million m³/month	23.9	22.5	28.8	30.3	28.1	7.3	3.8	11.4	15.8	16.7	20.5	23.8
	m³/s	8.9	9.3	10.8	11.7	10.5	2.8	1.4	4.3	6.1	6.2	7.9	8.9
RURGHA	million m³/month	124.8	114.8	134.9	171.7	164.6	25.1	7.7	46.2	77.8	92.7	112.1	117.9
	m³/s	46.6	47.5	50.4	66.2	61.5	9.7	2.9	17.3	30.0	34.6	43.3	44.0
RURDHA	million m³/month	74.6	61.9	71.8	86.4	76.6	19.6	6.0	22.6	32.2	35.3	50.3	65.5
	m³/s	27.9	25.6	26.8	33.3	28.6	7.6	2.2	8.4	12.4	13.2	19.4	24.5
RURGAV	million m³/month	42.4	41.0	51.0	52.6	47.4	6.8	1.2	17.7	25.4	27.4	34.3	38.9
	m³/s	15.8	16.9	19.1	20.3	17.7	2.6	0.5	6.6	9.8	10.2	13.2	14.5
RURDAV	million m³/month	47.0	42.6	47.6	52.3	40.4	8.8	2.8	10.2	16.8	21.6	31.3	41.0
	m³/s	17.5	17.6	17.8	20.2	15.1	3.6	1.0	3.9	6.3	8.3	11.7	15.3
Ruzizi sortie lac Kivu	m³/s	45.0	45.0	47.0	53.0	55.0	47.0	34.0	30.0	30.0	34.0	42.0	44.0

The distribution of the basin's population, as well as annual growth rates and per capita water needs, are given below.

Geographical entities		Population 2020				Water needs in L/pers/day	
PROVINCES	LOCALITY	Urban	Rural	Total	Annual growth rate	Urban	rural
NORTH KIVU	GOMA	1 065 261	0	1 065 261	1.033	50	20
	MASISI	0	864 007	864 007	1.033	50	20
	NYIRAGONGO	0	195 902	195 902	1.033	50	20
SOUTH KIVU	KALEHE	0	914 306	914 306	1.033	50	20
	KABARE	0	926 267	926 267	1.033	50	20
	BUKAVU	1 033 474	0	1 033 474	1.033	50	20

Geographical entities		Population 2020				Water needs in L/pers/day	
PROVINCES	LOCALITY	Urban	Rural	Total	Annual growth rate	Urban	rural
	WALUNGU/KAMANYOLA	0	558 933	558 933	1.033	50	20
	UVIRA	0	928 673	928 673	1.033	50	20
	IDJWI	0	362 379	362 379	1.033	50	20
WEST	RUBAVU	180 383	307 615	487 997	1.024	80	20
	KARONGI	27 510	373 621	401 131	1.024	80	20
	RUTSIRO	8 504	383 979	392 483	1.024	80	20
	NYAMASHEKE	7 419	455 766	463 185	1.024	80	20
	RUSIZI	76 474	408 133	484 608	1.024	80	20
	NYABIHU	17 299	105 997	123 296	1.024	80	20
	NGORORERO	0	34 149	34 149	1.024	80	20
	NYAMAGABE	0	19 780	19 780	1.024	80	20
	MUSANZE	2 894	24 561	27 455	1.024	80	20
	NYARUGURU	0	86 753	86 753	1.024	80	20
CIBITOKE	BUGANDA	0	99 595	99 595	1.031	40	20
	BUKINYANA	0	109 266	109 266	1.031	40	20
	MABAYI	0	95 732	95 732	1.031	40	20
	MUGINA	0	127 589	127 589	1.031	40	20
	MURWI	0	118 621	118 621	1.031	40	20
	RUGOMBO	34 453	78 905	113 359	1.031	40	20
BUBANZA	BUBANZA	28 894	91 808	120 702	1.031	40	20
	GIHANGA	0	79 832	79 832	1.031	40	20
	MPANDA	0	84 980	84 980	1.031	40	20
	MUSIGATI	0	118 580	118 580	1.031	40	20
	RUGAZI	0	83 491	83 491	1.031	40	20
RURAL BUJUMBURA	MUTIMBUZI	16 877	83 410	100 287	1.031	40	20
KAYANZA	MATONGO	0	99 902	99 902	1.031	40	20
	MURUTA	0	83 286	83 286	1.031	40	20
	KABARORE	0	89 610	89 610	1.031	40	20
MURAMVYA	BUKEYE	1 203	93 692	94 895	1.031	40	20

The function included in the scenario for increasing access to drinking water by 2050 corresponds to a linear increase from 2020 to 2035, in order to reach the water demand objective defined at the level of each country in rural and urban areas by that date. It is given below, by way of illustration, for the demand for domestic water in urban areas in DRC (expressed in m³/capita/year).



The water requirements for irrigation are given below, for the operational boundaries in activity (reference situation) as well as for the projected / planned boundaries.

Water needs - irrigation (million m³/year - P50)					Month											
Compartment	Category	Country	Surf.	Basin	1	2	3	4	5	6	7	8	9	10	11	12
KA-RG-HA	PI Planes Priority 1	Rwanda	295	Rubyiro	0.24	0.14	0.18	0.20	0.14	0.13	0.15	0.19	0.31	0.30	0.21	0.26
KA-RG-HA	PI Planes Priority 1	Rwanda	150	Rubyiro	0.12	0.07	0.09	0.10	0.07	0.07	0.07	0.10	0.16	0.15	0.11	0.13
KA-RG-HA	PI Planes Priority 1	Rwanda	652	Rubyiro	0.53	0.31	0.39	0.45	0.31	0.29	0.33	0.42	0.70	0.67	0.47	0.58
KA-RG-HA	PI Planes Priority 1	Rwanda	244	Rubyiro	0.20	0.12	0.15	0.17	0.12	0.11	0.12	0.16	0.26	0.25	0.18	0.22
KA-RG-HA	PI Planes Priority 1	Rwanda	241	Rubyiro	0.19	0.12	0.15	0.17	0.12	0.11	0.12	0.15	0.26	0.25	0.17	0.22
KA-RG-HA	PI Planes Priority 1	Rwanda	33	Rubyiro	0.03	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.04	0.03	0.02	0.03
KA-RG-HA	PI Planes Priority 1	Rwanda	645	Rubyiro	0.52	0.31	0.38	0.44	0.31	0.29	0.32	0.41	0.68	0.66	0.46	0.57
KA-RG-HA	PI Planes Priority 1	Rwanda	10	Rubyiro	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
KA-RG-HA TOT					1.83	1.09	1.36	1.56	1.09	1.01	1.13	1.44	2.41	2.34	1.63	2.02
UK-RD-AV	PI Planes Priority 2	DRC	341	Sange	0.27	0.16	0.20	0.23	0.16	0.15	0.17	0.21	0.36	0.35	0.24	0.30
UK-RD-AV	PI Planes Priority 2	DRC	91	Sange	0.07	0.04	0.05	0.06	0.04	0.04	0.04	0.06	0.10	0.09	0.07	0.08
UK-RD-AV	PI Planes Priority 2	DRC	71	Sange	0.06	0.03	0.04	0.05	0.03	0.03	0.04	0.04	0.08	0.07	0.05	0.06
UK-RD-AV	PI Planes Priority 1	DRC	260	Sange	0.21	0.12	0.16	0.18	0.12	0.12	0.13	0.16	0.28	0.27	0.19	0.23
UK-RD-AV	PI Planes Priority 1	DRC	1661	Sange	1.33	0.79	0.99	1.13	0.79	0.73	0.82	1.04	1.75	1.69	1.19	1.47
UK-RD-AV	PI Planes Priority 2	DRC	616	Sange	0.49	0.29	0.36	0.41	0.29	0.27	0.30	0.38	0.64	0.62	0.43	0.54
UK-RD-AV	PI Planes Priority 2	DRC	337	Sange	0.27	0.16	0.20	0.23	0.16	0.15	0.16	0.21	0.35	0.34	0.24	0.29
UK-RD-AV	PI Planes Priority 2	DRC	342	Sange	0.27	0.16	0.20	0.23	0.16	0.15	0.17	0.21	0.35	0.34	0.24	0.30
UK-RD-AV	PI Planes Priority 1	DRC	1448	Kiliba	1.14	0.68	0.85	0.97	0.68	0.63	0.70	0.90	1.50	1.46	1.02	1.26
UK-RD-AV	PI Planes Priority 1	DRC	881	Kiliba	0.69	0.41	0.52	0.59	0.41	0.38	0.43	0.55	0.92	0.89	0.62	0.77
UK-RD-AV	PI Planes Priority 2	DRC	708	Kiliba	0.56	0.33	0.41	0.47	0.33	0.31	0.34	0.44	0.73	0.71	0.50	0.62
UK-RD-AV	PI Planes Priority 2	DRC	178	Kiliba	0.14	0.08	0.10	0.12	0.08	0.08	0.09	0.11	0.19	0.18	0.13	0.16
UK-RD-AV	PI Planes Priority 1	DRC	1060	Kiliba	0.84	0.50	0.63	0.72	0.50	0.47	0.52	0.66	1.11	1.07	0.75	0.93
UK-RD-AV	PI Planes Priority 2	DRC	584	Kiliba	0.46	0.28	0.35	0.40	0.28	0.26	0.29	0.37	0.61	0.59	0.41	0.51
UK-RD-AV	PI Planes Priority 1	DRC	1327	Kiliba	1.05	0.63	0.78	0.89	0.63	0.58	0.65	0.83	1.39	1.34	0.94	1.16
UK-RD-AV	PI Planes Priority 2	DRC	57	Kiliba	0.05	0.03	0.03	0.04	0.03	0.02	0.03	0.04	0.06	0.06	0.04	0.05
UK-RD-AV	PI Planes Priority 2	DRC	122	Kiliba	0.10	0.06	0.07	0.08	0.06	0.05	0.06	0.08	0.13	0.12	0.09	0.11
UK-RD-AV	PI Planes Priority 2	DRC	563	Sange	0.45	0.27	0.34	0.39	0.27	0.25	0.28	0.36	0.60	0.58	0.41	0.50
UK-RD-AV	IP projects	DRC	680	Sange	0.55	0.33	0.41	0.47	0.33	0.30	0.34	0.43	0.72	0.70	0.49	0.60
UK-RD-AV	PI Planes Priority 2	DRC	185	Kiliba	0.15	0.09	0.11	0.12	0.09	0.08	0.09	0.12	0.19	0.19	0.13	0.16
UK-RD-AV	PI des Usines Sucrières	DRC	966	Kiliba	0.76	0.45	0.57	0.65	0.45	0.42	0.47	0.60	1.01	0.97	0.68	0.84

Water needs - irrigation (million m^3/year - P50)					Month											
Compartment	Category	Country	Surf.	Basin	1	2	3	4	5	6	7	8	9	10	11	12
UK-RD-AV	PI des Usines Sucrières	DRC	535	Kiliba	0.42	0.25	0.32	0.36	0.25	0.23	0.26	0.33	0.56	0.54	0.38	0.47
UK-RD-AV	PI des Usines Sucrières	DRC	812	Kiliba	0.64	0.38	0.48	0.55	0.38	0.36	0.40	0.51	0.85	0.82	0.57	0.71
UK-RD-AV	PI des Usines Sucrières	DRC	616	Kiliba	0.49	0.29	0.36	0.42	0.29	0.27	0.30	0.38	0.64	0.62	0.44	0.54
UK-RD-AV	PI des Usines Sucrières	DRC	919	Kiliba	0.72	0.43	0.54	0.62	0.43	0.40	0.45	0.57	0.95	0.92	0.65	0.80
UK-RD-AV	PI des Usines Sucrières	DRC	288	Kiliba	0.23	0.14	0.17	0.19	0.14	0.13	0.14	0.18	0.30	0.29	0.20	0.25
UK-RD-AV	PI des Usines Sucrières	DRC	142	Kiliba	0.11	0.07	0.08	0.10	0.07	0.06	0.07	0.09	0.15	0.14	0.10	0.12
UK-RD-AV	PI des Usines Sucrières	DRC	93	Kiliba	0.07	0.04	0.06	0.06	0.04	0.04	0.05	0.06	0.10	0.09	0.07	0.08
UK-RD-AV	PI des Usines Sucrières	Burundi	12	Kiliba	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
UK-RD-AV	IAP zone	DRC	3040	Kiliba	2.42	1.44	1.80	2.06	1.44	1.34	1.49	1.90	3.19	3.08	2.16	2.67
RU-RD-AV TOT					15.02	8.95	11.18	12.78	8.95	8.31	9.27	11.82	19.81	19.17	13.42	16.62
UK-RD-HA	PI Planes Priority 1	DRC	1092	Luvimvi	0.88	0.53	0.66	0.75	0.53	0.49	0.54	0.69	1.16	1.13	0.79	0.98
UK-RD-HA	PI Planes Priority 2	DRC	264	Luvubu	0.21	0.13	0.16	0.18	0.13	0.12	0.13	0.17	0.28	0.27	0.19	0.24
UK-RD-HA	PI Planes Priority 2	DRC	459	Luvubu	0.37	0.22	0.28	0.32	0.22	0.21	0.23	0.29	0.49	0.47	0.33	0.41
UK-RD-HA	PI Planes Priority 2	DRC	627	Luvubu	0.51	0.30	0.38	0.43	0.30	0.28	0.31	0.40	0.67	0.65	0.45	0.56
UK-RD-HA	PI Planes Priority 2	DRC	329	Luvubu	0.27	0.16	0.20	0.23	0.16	0.15	0.16	0.21	0.35	0.34	0.24	0.30
UK-RD-HA	PI Planes Priority 2	DRC	335	Luvubu	0.27	0.16	0.20	0.23	0.16	0.15	0.17	0.21	0.36	0.35	0.24	0.30
UK-RD-HA	PI Planes Priority 2	DRC	1717	Luvubu	1.39	0.83	1.03	1.18	0.83	0.77	0.86	1.09	1.83	1.77	1.24	1.53
UK-RD-HA	IP projects	DRC	40	Luberizi	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.03	0.04	0.04	0.03	0.04
UK-RD-HA	IP projects	DRC	274	Luberizi	0.22	0.13	0.16	0.19	0.13	0.12	0.14	0.17	0.29	0.28	0.20	0.24
UK-RD-HA	IP projects	DRC	168	Luberizi	0.14	0.08	0.10	0.12	0.08	0.08	0.08	0.11	0.18	0.17	0.12	0.15
UK-RD-HA	PI Planes Priority 2	DRC	182	Luberizi	0.15	0.09	0.11	0.13	0.09	0.08	0.09	0.12	0.19	0.19	0.13	0.16
UK-RD-HA	PI Planes Priority 2	DRC	215	Luberizi	0.17	0.10	0.13	0.15	0.10	0.10	0.11	0.14	0.23	0.22	0.16	0.19
UK-RD-HA	PI Planes Priority 2	DRC	158	Luberizi	0.13	0.08	0.09	0.11	0.08	0.07	0.08	0.10	0.17	0.16	0.11	0.14
UK-RD-HA	PI Planes Priority 2	DRC	79	Luberizi	0.06	0.04	0.05	0.05	0.04	0.04	0.04	0.05	0.08	0.08	0.06	0.07
UK-RD-HA	PI Planes Priority 2	DRC	287	Luberizi	0.23	0.14	0.17	0.20	0.14	0.13	0.14	0.18	0.31	0.30	0.21	0.26
UK-RD-HA	PI Planes Priority 2	DRC	200	Luberizi	0.16	0.10	0.12	0.14	0.10	0.09	0.10	0.13	0.21	0.21	0.14	0.18
UK-RD-HA	PI Planes Priority 2	DRC	136	Luvubu	0.11	0.07	0.08	0.09	0.07	0.06	0.07	0.09	0.15	0.14	0.10	0.12
UK-RD-HA	PI Planes Priority 2	DRC	141	Luvubu	0.11	0.07	0.08	0.10	0.07	0.06	0.07	0.09	0.15	0.15	0.10	0.13
UK-RD-HA	IP projects	DRC	661	Luvubu	0.53	0.32	0.40	0.45	0.32	0.30	0.33	0.42	0.70	0.68	0.48	0.59
UK-RD-HA	PI Planes Priority 2	DRC	512	Luvimvi	0.41	0.25	0.31	0.35	0.25	0.23	0.26	0.33	0.55	0.53	0.37	0.46
UK-RD-HA	IP projects	DRC	136	Luvubu	0.11	0.07	0.08	0.09	0.07	0.06	0.07	0.09	0.15	0.14	0.10	0.12
UK-RD-HA	PI Planes Priority 2	DRC	151	Luvubu	0.12	0.07	0.09	0.10	0.07	0.07	0.08	0.10	0.16	0.16	0.11	0.13
UK-RD-HA	PI Planes Priority 2	DRC	702	Luvubu	0.57	0.34	0.42	0.48	0.34	0.31	0.35	0.45	0.75	0.72	0.51	0.63
UK-RD-HA	PI Planes Priority 2	DRC	308	Luvubu	0.25	0.15	0.19	0.21	0.15	0.14	0.15	0.20	0.33	0.32	0.22	0.28
UK-RD-HA	PI Planes Priority 2	DRC	274	Luvubu	0.22	0.13	0.16	0.19	0.13	0.12	0.14	0.17	0.29	0.28	0.20	0.25
UK-RD-HA	PI Planes Priority 2	DRC	114	Luvubu	0.09	0.05	0.07	0.08	0.05	0.05	0.06	0.07	0.12	0.12	0.08	0.10
UK-RD-HA	PI Planes Priority 2	DRC	164	Luvubu	0.13	0.08	0.10	0.11	0.08	0.07	0.08	0.10	0.17	0.17	0.12	0.15
UK-RD-HA	PI Planes Priority 2	DRC	413	Luvubu	0.33	0.20	0.25	0.28	0.20	0.18	0.21	0.26	0.44	0.43	0.30	0.37
UK-RD-HA	PI Planes Priority 2	DRC	509	Luvubu	0.41	0.24	0.31	0.35	0.24	0.23	0.25	0.32	0.54	0.52	0.37	0.45
UK-RD-HA	PI Planes Priority 2	DRC	160	Luvubu	0.13	0.08	0.10	0.11	0.08	0.07	0.08	0.10	0.17	0.17	0.12	0.14
UK-RD-HA	IP projects	DRC	424	Luberizi	0.34	0.20	0.25	0.29	0.20	0.19	0.21	0.27	0.45	0.44	0.31	0.38
UK-RD-HA	PI Planes Priority 1	DRC	415	Luvubu	0.34	0.20	0.25	0.29	0.20	0.19	0.21	0.26	0.44	0.43	0.30	0.37
UK-RD-HA	PI Planes Priority 1	DRC	498	Luvubu	0.40	0.24	0.30	0.34	0.24	0.22	0.25	0.32	0.53	0.51	0.36	0.45
RU-RD-HA TOT					9.81	5.85	7.31	8.35	5.85	5.43	6.05	7.72	12.94	12.53	8.77	10.86
RU-RG-AV	IP projects	Burundi	258	Kagunuzi	0.20	0.12	0.15	0.17	0.12	0.11	0.12	0.16	0.27	0.26	0.18	0.22
RU-RG-AV	PI Planes Priority 2	Burundi	314	Kagunuzi	0.25	0.15	0.18	0.21	0.15	0.14	0.15	0.19	0.32	0.31	0.22	0.27
RU-RG-AV	PI Planes Priority 2	Burundi	293	Kagunuzi	0.23	0.14	0.17	0.20	0.14	0.13	0.14	0.18	0.30	0.29	0.21	0.25
RU-RG-AV	PI Planes Priority 1	Burundi	111	Kagunuzi	0.09	0.05	0.06	0.07	0.05	0.05	0.05	0.07	0.11	0.11	0.08	0.10
RU-RG-AV	PI Planes Priority 1	Burundi	347	Kagunuzi	0.27	0.16	0.20	0.23	0.16	0.15	0.17	0.21	0.36	0.35	0.24	0.30
RU-RG-AV	PI Planes Priority 1	Burundi	92	Kagunuzi	0.07	0.04	0.05	0.06	0.04	0.04	0.04	0.06	0.09	0.09	0.06	0.08
RU-RG-AV	PI Planes Priority 1	Burundi	163	Kagunuzi	0.13	0.08	0.09	0.11	0.08	0.07	0.08	0.10	0.17	0.16	0.11	0.14
RU-RG-AV	PI Planes Priority 1	Burundi	125	Kagunuzi	0.10	0.06	0.07	0.08	0.06	0.05	0.06	0.08	0.13	0.12	0.09	0.11
RU-RG-AV	PI Planes Priority 2	Burundi	200	Mpanda	0.15	0.09	0.11	0.13	0.09	0.09	0.10	0.12	0.20	0.20	0.14	0.17
RU-RG-AV	PI Planes Priority 2	Burundi	249	Mpanda	0.19	0.11	0.14	0.16	0.11	0.11	0.12	0.15	0.25	0.25	0.17	0.21
RU-RG-AV	PI Planes Priority 1	Burundi	211	Mpanda	0.16	0.10	0.12	0.14	0.10	0.09	0.10	0.13	0.21	0.21	0.14	0.18
RU-RG-AV	PI Planes Priority 1	Burundi	203	Mpanda	0.16	0.09	0.12	0.13	0.09	0.09	0.10	0.12	0.20	0.20	0.14	0.17
RU-RG-AV	PI Planes Priority 1	Burundi	154	Mpanda	0.12	0.07	0.09	0.10	0.07	0.07	0.07	0.09	0.16	0.15	0.11	0.13

Water needs - irrigation (million m³/year - P50)					Month											
Compartment	Category	Country	Surf.	Basin	1	2	3	4	5	6	7	8	9	10	11	12
RU-RG-AV	PI Planes Priority 1	Burundi	221	Mpanda	0.17	0.10	0.13	0.14	0.10	0.09	0.10	0.13	0.22	0.22	0.15	0.19
RU-RG-AV	PI Planes Priority 2	Burundi	102	Mpanda	0.08	0.05	0.06	0.07	0.05	0.04	0.05	0.06	0.10	0.10	0.07	0.09
RU-RG-AV	PI Planes Priority 2	Burundi	317	Mpanda	0.24	0.14	0.18	0.21	0.14	0.13	0.15	0.19	0.32	0.31	0.22	0.27
RU-RG-AV	PI Planes Priority 2	Burundi	66	Mpanda	0.05	0.03	0.04	0.04	0.03	0.03	0.03	0.04	0.07	0.06	0.05	0.06
RU-RG-AV	PI Planes Priority 2	Burundi	275	Mpanda	0.21	0.13	0.16	0.18	0.13	0.12	0.13	0.17	0.28	0.27	0.19	0.23
RU-RG-AV	PI Planes Priority 2	Burundi	105	Mpanda	0.08	0.05	0.06	0.07	0.05	0.04	0.05	0.06	0.11	0.10	0.07	0.09
RU-RG-AV	PI Planes Priority 1	Burundi	410	Mpanda	0.32	0.19	0.24	0.27	0.19	0.17	0.19	0.25	0.42	0.40	0.28	0.35
RU-RG-AV	PI Planes Priority 1	Burundi	741	Mpanda	0.57	0.34	0.43	0.49	0.34	0.32	0.35	0.45	0.75	0.73	0.51	0.63
RU-RG-AV	PI Planes Priority 1	Burundi	62	Mpanda	0.05	0.03	0.04	0.04	0.03	0.03	0.03	0.04	0.06	0.06	0.04	0.05
RU-RG-AV	PI Planes Priority 1	Burundi	191	Mpanda	0.15	0.09	0.11	0.13	0.09	0.08	0.09	0.12	0.19	0.19	0.13	0.16
RU-RG-AV	PI Planes Priority 1	Burundi	648	Mpanda	0.50	0.30	0.37	0.42	0.30	0.27	0.31	0.39	0.65	0.63	0.44	0.55
RU-RG-AV	PI Planes Priority 1	Burundi	501	Mpanda	0.38	0.23	0.29	0.33	0.23	0.21	0.24	0.30	0.51	0.49	0.34	0.43
RU-RG-AV	PI Planes Priority 1	Burundi	66	Mpanda	0.05	0.03	0.04	0.04	0.03	0.03	0.03	0.04	0.07	0.06	0.05	0.06
RU-RG-AV	PI Planes Priority 2	Burundi	130	Kagunuzi	0.10	0.06	0.08	0.09	0.06	0.06	0.06	0.08	0.13	0.13	0.09	0.11
RU-RG-AV	PI fonctionnels	Burundi	1400	Mpanda	1.09	0.65	0.81	0.93	0.65	0.60	0.67	0.86	1.43	1.39	0.97	1.20
RU-RG-AV	IP projects	Burundi	351	Mpanda	0.27	0.16	0.20	0.23	0.16	0.15	0.17	0.21	0.36	0.35	0.24	0.30
RU-RG-AV	IP projects	Burundi	389	Mpanda	0.30	0.18	0.22	0.26	0.18	0.17	0.19	0.24	0.40	0.38	0.27	0.33
RU-RG-AV	IP projects	Burundi	399	Mpanda	0.31	0.18	0.23	0.26	0.18	0.17	0.19	0.24	0.41	0.39	0.28	0.34
RU-RG-AV	IP projects	Burundi	376	Mpanda	0.29	0.17	0.22	0.25	0.17	0.16	0.18	0.23	0.38	0.37	0.26	0.32
RU-RG-AV	IP projects	Burundi	328	Mpanda	0.25	0.15	0.19	0.22	0.15	0.14	0.16	0.20	0.33	0.32	0.23	0.28
RU-RG-AV	IP projects	Burundi	104	Mpanda	0.08	0.05	0.06	0.07	0.05	0.04	0.05	0.06	0.11	0.10	0.07	0.09
RU-RG-AV	IP projects	Burundi	289	Mpanda	0.22	0.13	0.17	0.19	0.13	0.12	0.14	0.18	0.29	0.28	0.20	0.25
RU-RG-AV	IP projects	Burundi	122	Mpanda	0.09	0.06	0.07	0.08	0.06	0.05	0.06	0.07	0.12	0.12	0.08	0.10
RU-RG-AV	IP projects	Burundi	377	Mpanda	0.29	0.17	0.22	0.25	0.17	0.16	0.18	0.23	0.38	0.37	0.26	0.32
RU-RG-AV	IP projects	Burundi	598	Mpanda	0.47	0.28	0.35	0.40	0.28	0.26	0.29	0.37	0.62	0.60	0.42	0.52
RU-RG-AV	IP projects	Burundi	560	Mpanda	0.44	0.26	0.33	0.37	0.26	0.24	0.27	0.34	0.58	0.56	0.39	0.48
RU-RG-AV	IP projects	Burundi	459	Mpanda	0.36	0.21	0.27	0.30	0.21	0.20	0.22	0.28	0.47	0.46	0.32	0.39
RU-RG-AV	IP projects	Burundi	201	Mpanda	0.16	0.09	0.12	0.13	0.09	0.09	0.10	0.12	0.21	0.20	0.14	0.17
RU-RG-AV	IP projects	Burundi	539	Mpanda	0.42	0.25	0.31	0.36	0.25	0.23	0.26	0.33	0.55	0.53	0.37	0.46
RU-RG-AV	IP projects	Burundi	576	Mpanda	0.45	0.27	0.33	0.38	0.27	0.25	0.28	0.35	0.59	0.57	0.40	0.49
RU-RG-AV	IP projects	Burundi	159	Kagunuzi	0.13	0.08	0.10	0.11	0.08	0.07	0.08	0.10	0.17	0.16	0.11	0.14
RU-RG-AV	PI des Usines Sucrières	Burundi	2319	Mpanda	1.81	1.08	1.35	1.54	1.08	1.00	1.12	1.43	2.39	2.31	1.62	2.00
RU-RG-AV	PI Planes Priority 2	Burundi	191	Mpanda	0.15	0.09	0.11	0.12	0.09	0.08	0.09	0.11	0.19	0.19	0.13	0.16
RU-RG-AV	PI Planes Priority 2	Burundi	220	Mpanda	0.17	0.10	0.13	0.14	0.10	0.09	0.10	0.13	0.22	0.21	0.15	0.19
RU-RG-AV	PI Planes Priority 2	Burundi	31	Mpanda	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.03	0.03	0.02	0.03
RU-RG-AV TOT					12.82	7.64	9.55	10.91	7.64	7.09	7.91	10.09	16.91	16.36	11.45	14.18
RU-RG-HA	PI Planes Priority 1	Burundi	1776	Nyakagunda	1.43	0.85	1.07	1.22	0.85	0.79	0.88	1.13	1.89	1.83	1.28	1.59
RU-RG-HA	IP projects	Burundi	291	Muhira	0.23	0.14	0.17	0.20	0.14	0.13	0.14	0.18	0.31	0.30	0.21	0.26
RU-RG-HA	IP projects	Burundi	124	Kaburantwa	0.10	0.06	0.07	0.08	0.06	0.05	0.06	0.08	0.13	0.13	0.09	0.11
RU-RG-HA	IP projects	Burundi	183	Kaburantwa	0.14	0.09	0.11	0.12	0.09	0.08	0.09	0.11	0.19	0.18	0.13	0.16
RU-RG-HA	IP projects	Burundi	120	Kaburantwa	0.09	0.06	0.07	0.08	0.06	0.05	0.06	0.07	0.12	0.12	0.08	0.10
RU-RG-HA	IP projects	Burundi	112	Kaburantwa	0.09	0.05	0.07	0.08	0.05	0.05	0.05	0.07	0.12	0.11	0.08	0.10
RU-RG-HA	IP projects	Burundi	134	Kaburantwa	0.11	0.06	0.08	0.09	0.06	0.06	0.07	0.08	0.14	0.13	0.09	0.12
RU-RG-HA	IP projects	Burundi	175	Kaburantwa	0.14	0.08	0.10	0.12	0.08	0.08	0.09	0.11	0.18	0.18	0.12	0.15
RU-RG-HA	IP projects	Burundi	230	Kaburantwa	0.18	0.11	0.14	0.16	0.11	0.10	0.11	0.14	0.24	0.23	0.16	0.20
RU-RG-HA	IP projects	Burundi	173	Kaburantwa	0.14	0.08	0.10	0.12	0.08	0.08	0.08	0.11	0.18	0.17	0.12	0.15
RU-RG-HA	IP projects	Burundi	320	Kaburantwa	0.25	0.15	0.19	0.21	0.15	0.14	0.16	0.20	0.33	0.32	0.23	0.28
RU-RG-HA	IP projects	Burundi	169	Kaburantwa	0.13	0.08	0.10	0.11	0.08	0.07	0.08	0.10	0.18	0.17	0.12	0.15
RU-RG-HA	IP projects	Burundi	193	Kaburantwa	0.15	0.09	0.11	0.13	0.09	0.08	0.09	0.12	0.20	0.19	0.14	0.17
RU-RG-HA	PI fonctionnels	Burundi	386	Muhira	0.31	0.18	0.23	0.26	0.18	0.17	0.19	0.24	0.41	0.39	0.28	0.34
RU-RG-HA	PI fonctionnels	Burundi	93	Nyamagana	0.07	0.04	0.06	0.06	0.04	0.04	0.05	0.06	0.10	0.10	0.07	0.08
RU-RG-HA	PI fonctionnels	Burundi	162	Nyamagana	0.13	0.08	0.10	0.11	0.08	0.07	0.08	0.10	0.17	0.17	0.12	0.14
RU-RG-HA	PI fonctionnels	Burundi	77	Nyamagana	0.06	0.04	0.05	0.05	0.04	0.03	0.04	0.05	0.08	0.08	0.06	0.07
RU-RG-HA	PI fonctionnels	Burundi	88	Nyamagana	0.07	0.04	0.05	0.06	0.04	0.04	0.04	0.06	0.09	0.09	0.06	0.08
RU-RG-HA	PI fonctionnels	Burundi	669	Nyamagana	0.54	0.32	0.40	0.46	0.32	0.30	0.33	0.42	0.71	0.69	0.48	0.60
RU-RG-HA	PI fonctionnels	Burundi	53	Nyamagana	0.04	0.03	0.03	0.04	0.03	0.02	0.03	0.03	0.06	0.05	0.04	0.05
RU-RG-HA	PI fonctionnels	Burundi	1825	Nyamagana	1.47	0.88	1.10	1.25	0.88	0.81	0.91	1.16	1.94	1.88	1.31	1.63

Water needs - irrigation (million m³/year - P50)					Month											
Compartment	Category	Country	Surf.	Basin	1	2	3	4	5	6	7	8	9	10	11	12
RU-RG-HA	PI fonctionnels	Burundi	852	Nyamagana	0.69	0.41	0.51	0.59	0.41	0.38	0.42	0.54	0.91	0.88	0.61	0.76
RU-RG-HA	PI fonctionnels	Burundi	121	Nyamagana	0.10	0.06	0.07	0.08	0.06	0.05	0.06	0.08	0.13	0.12	0.09	0.11
RU-RG-HA	IP projects	Burundi	146	Kaburantwa	0.12	0.07	0.09	0.10	0.07	0.06	0.07	0.09	0.15	0.15	0.10	0.13
RU-RG-HA	IP projects	Burundi	162	Kaburantwa	0.13	0.08	0.10	0.11	0.08	0.07	0.08	0.10	0.17	0.16	0.11	0.14
RU-RG-HA	IP projects	Burundi	120	Kaburantwa	0.10	0.06	0.07	0.08	0.06	0.05	0.06	0.07	0.13	0.12	0.09	0.11
RU-RG-HA	IP projects	Burundi	641	Kaburantwa	0.50	0.30	0.38	0.43	0.30	0.28	0.31	0.40	0.67	0.64	0.45	0.56
RU-RG-HA TOT					7.52	4.48	5.60	6.40	4.48	4.16	4.64	5.92	9.92	9.60	6.72	8.32

2.4. Main results

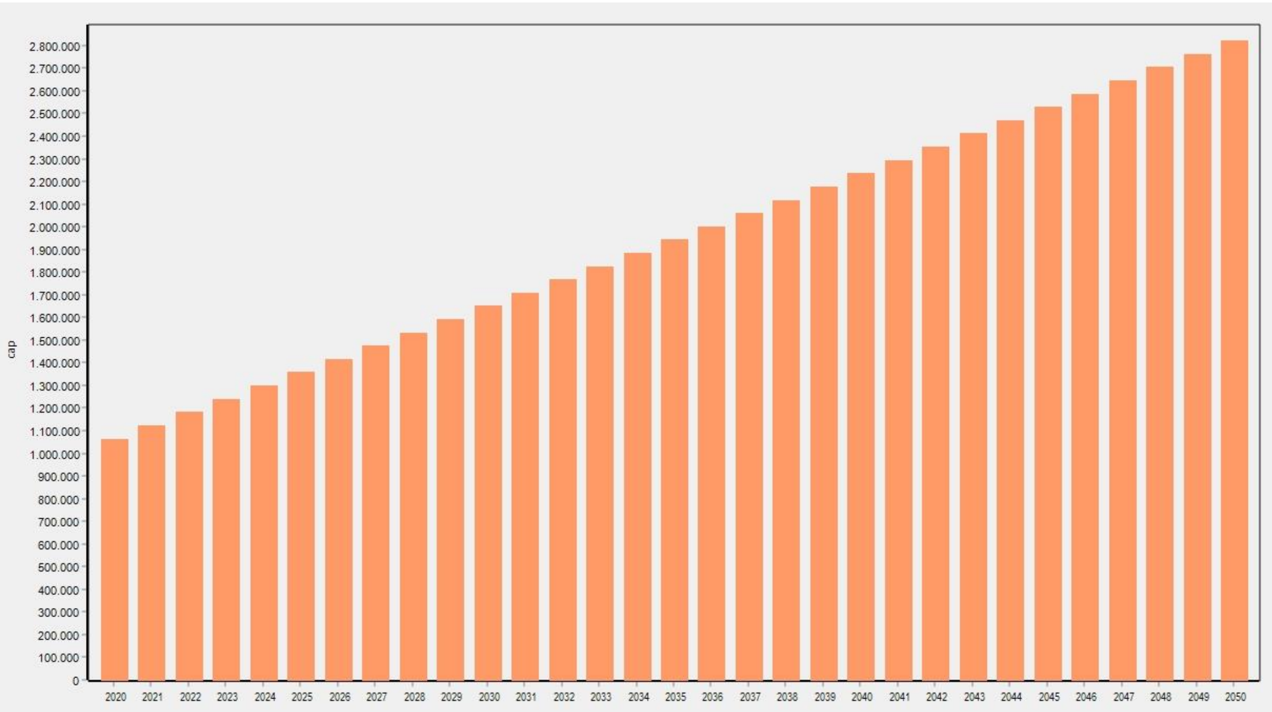
The simulations carried out enable the calculation of monthly flows and discharge volumes for each compartment (grouping of sub-basins) and for each model node on rivers, as well as the monthly water demand for each compartment and for each use, for each of the 5 defined scenarios. The simulations make it possible to compare the differences between the scenarios, to quantify the impact of changes in each scenario, and to quantify possible unmet water demands. Given the very high number of results, it is not possible to include them exhaustively in this annex. They are nevertheless available in the WEAP files made available. As an illustration, some representative results for the basin are given below.

2.4.1. Domestic water demand (drinking water in urban and rural areas)

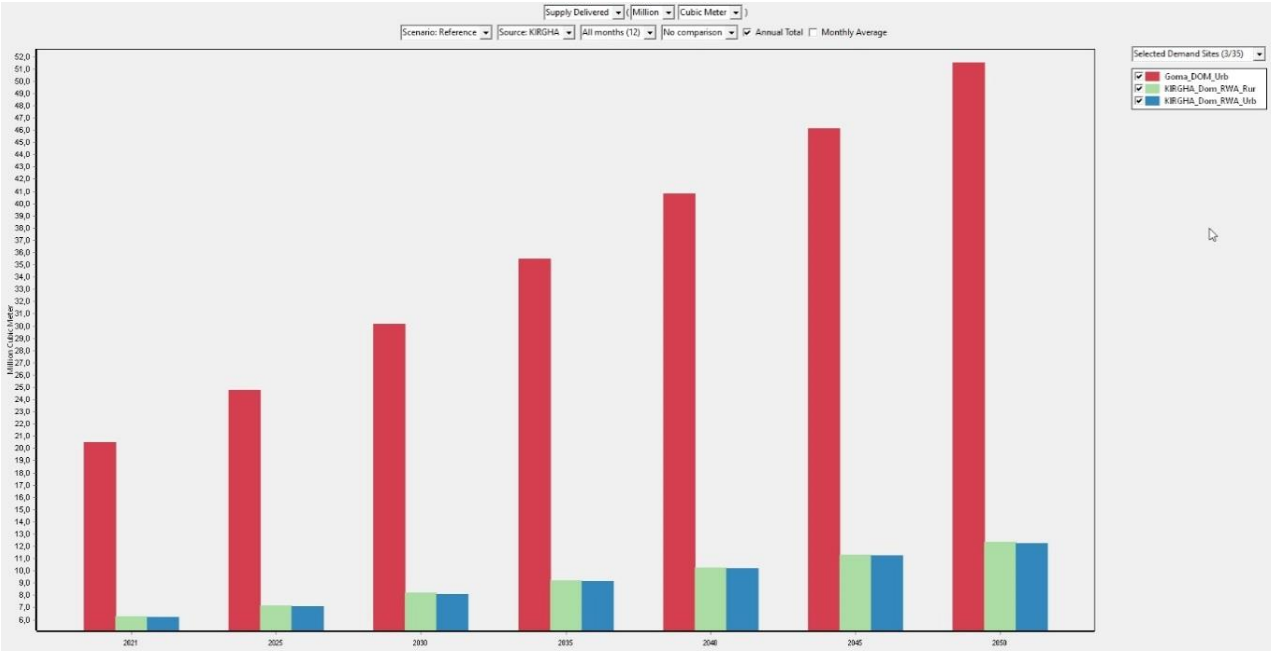
<u>Drinking water demand of the 'Lake Kivu Basin - East - Upstream' compartment (including the city of Goma)</u>

By way of illustration, the situation of the 'Lake Kivu Basin - East - Upstream' compartment is presented. The graph shows the water resources that can be mobilised for the cities of Goma and Gisenyi, and consequently a very high demand for drinking water supply.

Evolution of the compartment's population by 2050

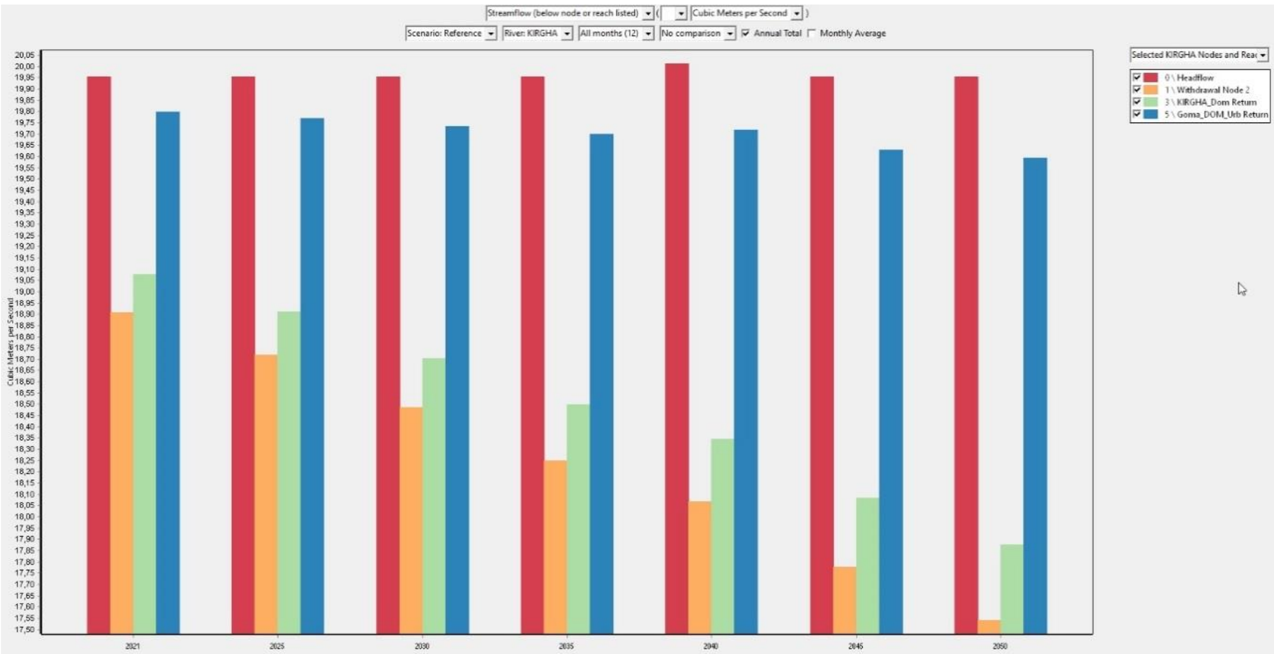


Evolution of water demand (million m³/year) of the compartment by 2050 (urban, rural) and of the city of Goma.



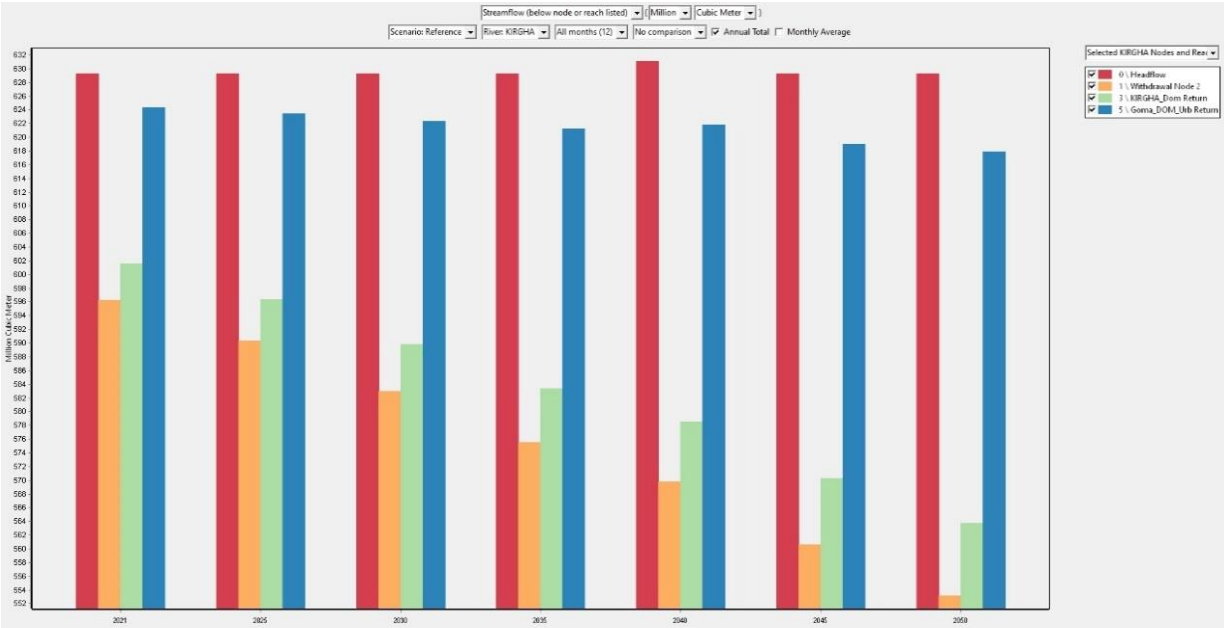
	2021	2025	2030	2035	2040	2045	2050
Goma_DOM_Urb	20,51	24,78	30,12	35,47	40,81	46,15	51,49
KIRGHA_Dom_RWA_Rur	6,28	7,12	8,17	9,22	10,27	11,32	12,37
KIRGHA_Dom_RWA_Urb	6,23	7,06	8,10	9,14	10,18	11,22	12,26
Sum	33,02	38,96	46,40	53,83	61,26	68,69	76,12

Evolution of flow rates (m³/s) by 2050, upstream of domestic abstraction, downstream of domestic abstraction, and downstream of the return of domestic abstraction (hypothesis of return of domestic water = 85%).



	2021	2025	2030	2035	2040	2045	2050
0 \ Headflow	19,96	19,96	19,96	19,96	20,01	19,96	19,96
1 \ Withdrawal Node 2	18,91	18,72	18,48	18,25	18,07	17,78	17,54
3 \ KIRGHA_Dom Return	19,08	18,91	18,70	18,50	18,35	18,08	17,87
5 \ Goma_DOM_Urb Return	19,80	19,77	19,73	19,70	19,72	19,63	19,59

Evolution of the volumes discharged (million m³/year) by 2050, upstream of domestic abstraction, downstream of domestic abstraction, and downstream of the restitution of domestic abstraction (hypothesis of restitution of domestic water = 85%).



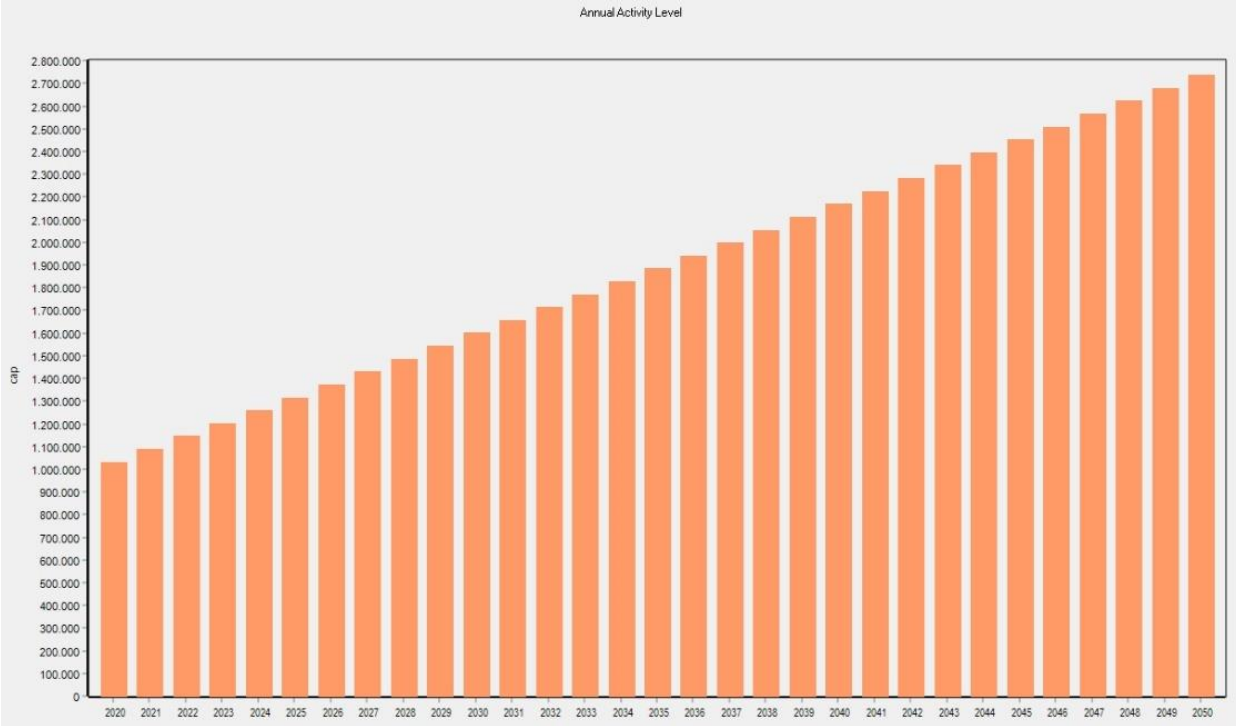
	2021	2025	2030	2035	2040	2045	2050
0 \ Headflow	629,31	629,31	629,31	629,31	631,06	629,31	629,31
1 \ Withdrawal Node 2	596,29	590,34	582,91	575,48	569,80	560,62	553,18
3 \ KIRGHA_Dom Return	601,63	596,40	589,86	583,32	578,53	570,24	563,70
5 \ Goma_DOM_Urb Return	624,35	623,46	622,35	621,23	621,87	619,00	617,89

It can be seen that the demand for domestic water (drinking water in urban and rural areas) will continue to be met by 2050 from the surface water of the compartment, including the drinking water supply of the cities of Goma and Gisenyi.

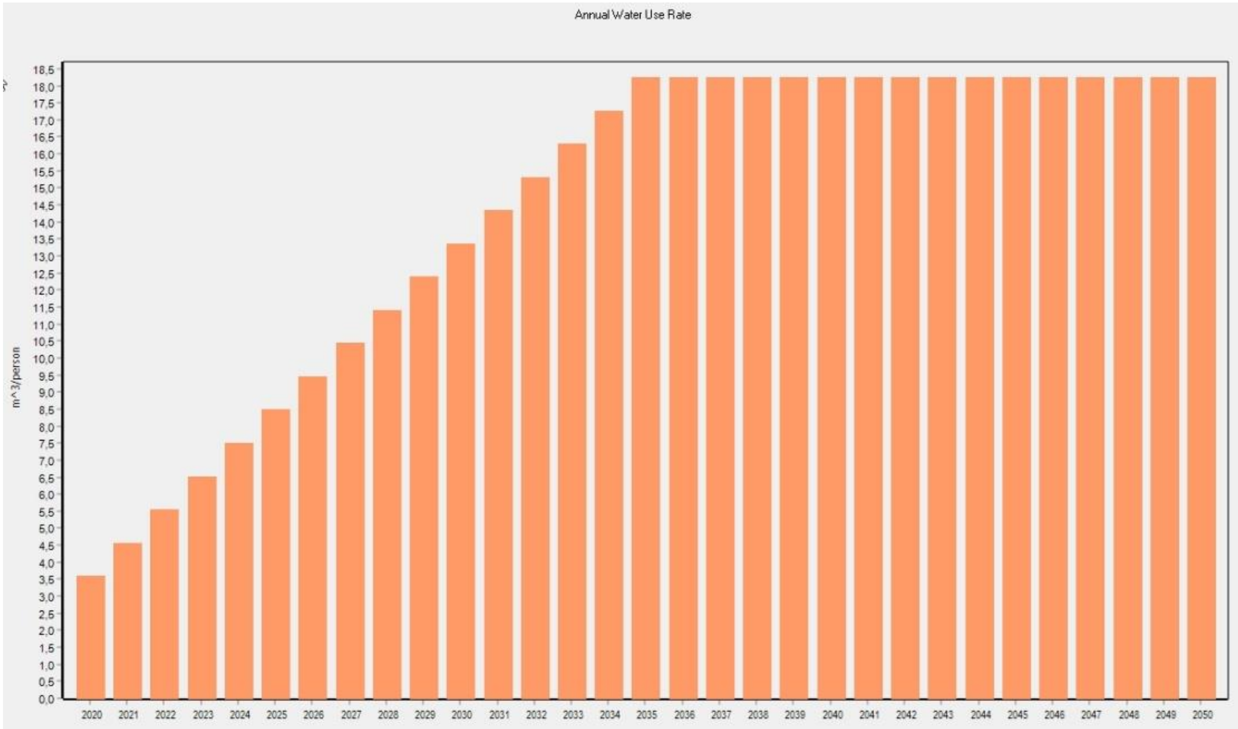
Drinking water demand of the city of Bukavu

Given its current and projected population, the city of Bukavu, like Goma, also has a very high demand for drinking water in the basin. The situation is therefore presented below by way of illustration.

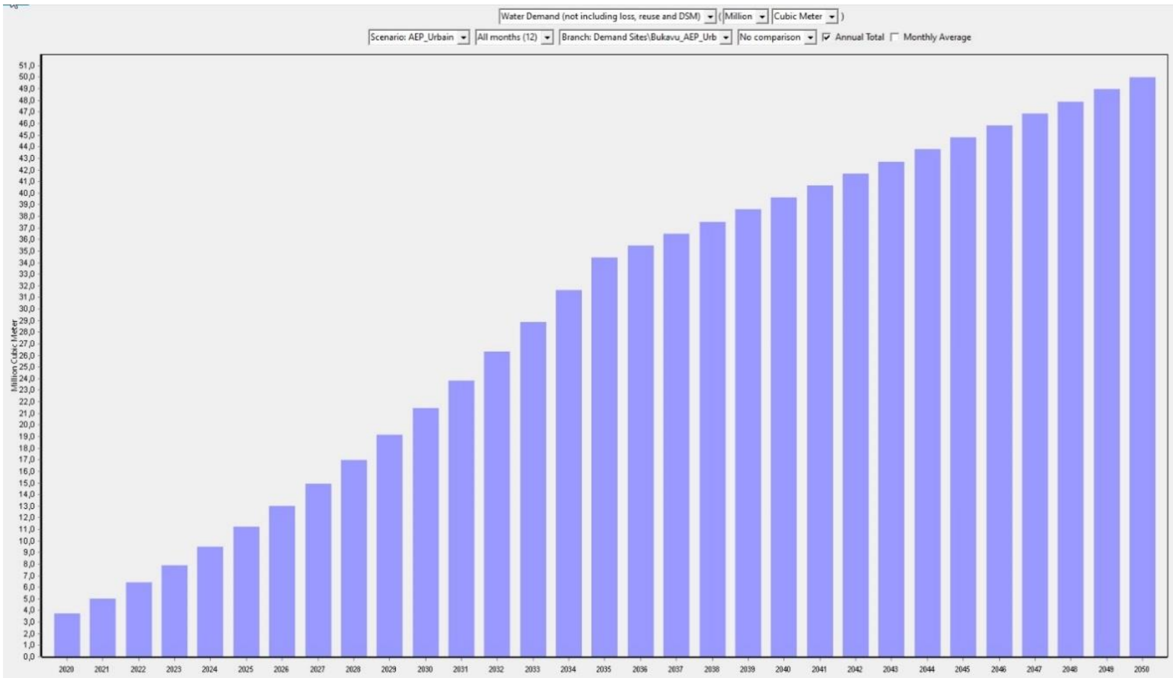
Evolution of the population of Bukavu by 2050



Increase in per capita water demand: hypothesis of reaching the objective of 50 L/capita/year by 2035



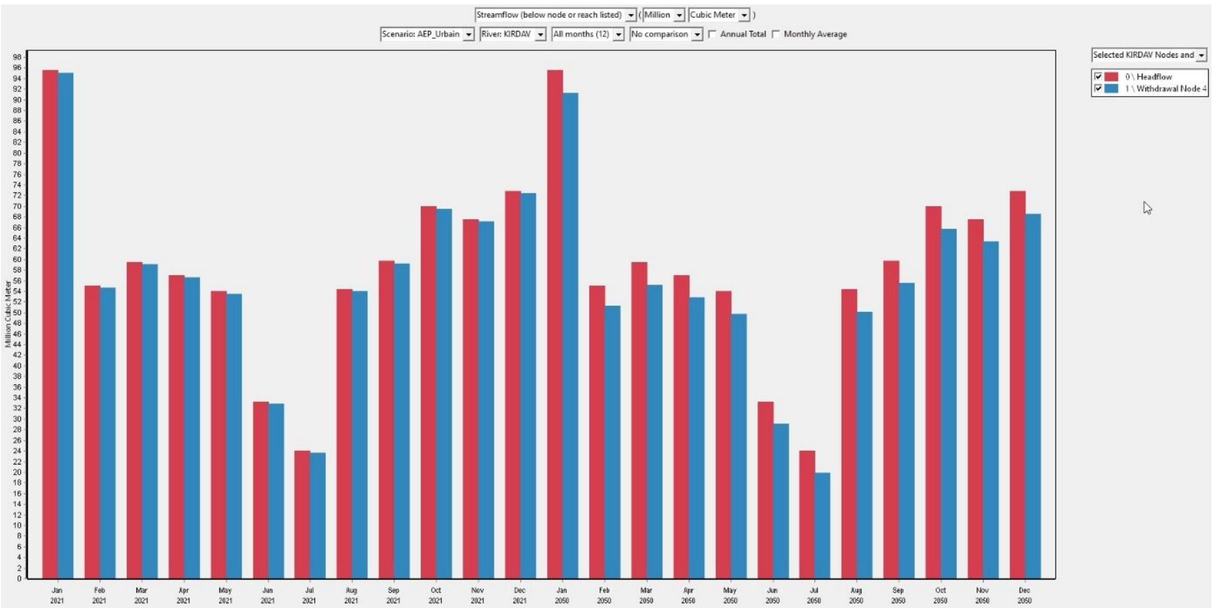
Evolution of the total water demand of the city of Bukavu up to 2050 (million m³/year)



	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Bukavu_AEP_Urb	3,72	4,99	6,37	7,86	9,46	11,17	13,00	14,93	16,98	19,13	21,40	23,78	26,27	28,87	31,58	34,40

	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Bukavu_AEP_Urb	35,44	36,47	37,51	38,55	39,58	40,62	41,66	42,69	43,73	44,77	45,80	46,84	47,88	48,91	49,95

Monthly volumes discharged (million m³) in the Bukavu city compartment (West Kivu Downstream), upstream of domestic abstraction and downstream of domestic abstraction, in 2021 and 2050.



	Jan 2021	Feb 2021	Mar 2021	Apr 2021	May 2021	Jun 2021	Jul 2021	Aug 2021	Sep 2021	Oct 2021	Nov 2021	Dec 2021
0 \ Headflow	95,48	55,06	59,46	56,97	53,94	33,20	24,05	54,37	59,67	69,91	67,50	72,83
1 \ Withdrawal Node 4	95,06	54,68	59,04	56,56	53,52	32,79	23,63	53,95	59,26	69,48	67,09	72,40

	Jan 2050	Feb 2050	Mar 2050	Apr 2050	May 2050	Jun 2050	Jul 2050	Aug 2050	Sep 2050	Oct 2050	Nov 2050	Dec 2050
0 \ Headflow	95,48	55,06	59,46	56,97	53,94	33,20	24,05	54,37	59,67	69,91	67,50	72,83
1 \ Withdrawal Node 4	91,24	51,23	55,22	52,87	49,70	29,10	19,81	50,13	55,56	65,66	63,39	68,58

It can be seen that the demand for domestic water in the city of Bukavu will continue to be met by 2050 from the surface water of the compartment. The same is true if the total drinking water demand of the compartment is considered, i.e. adding the domestic demand in rural areas.

General conclusions on the demand for drinking water in the basin

The simulations carried out according to the different scenarios (population increase, increase in daily needs per inhabitant, climate change) indicate that the demand for drinking water will continue to be met by 2050 from rivers, in both urban and rural areas, for all compartments of the study area.

2.4.2. Water demand for irrigated agriculture

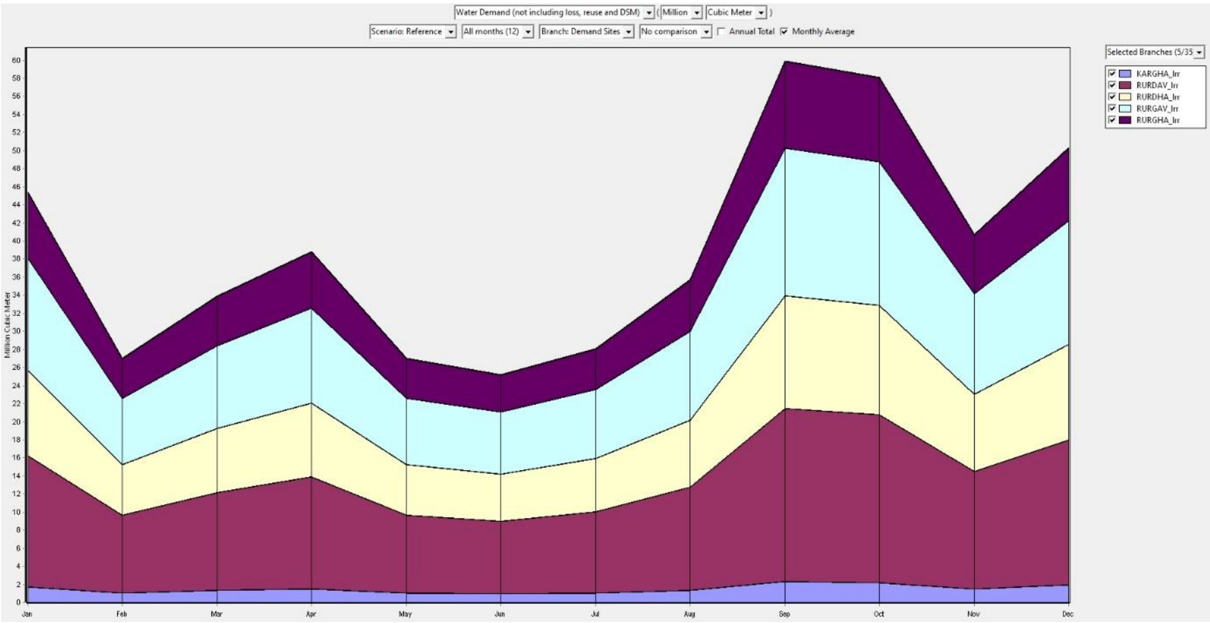
Irrigation in the Ruzizi plain

The vast majority of irrigated agriculture in the study area, both current and projected, is concentrated in the Ruzizi plain. The analysis of this area is therefore illustrated below.

The scenario illustrated corresponds to the cultivation of all existing, planned and projected boundaries. It is simulated for an average climatic year (P50) and a dry year (P80).

Total water demand:

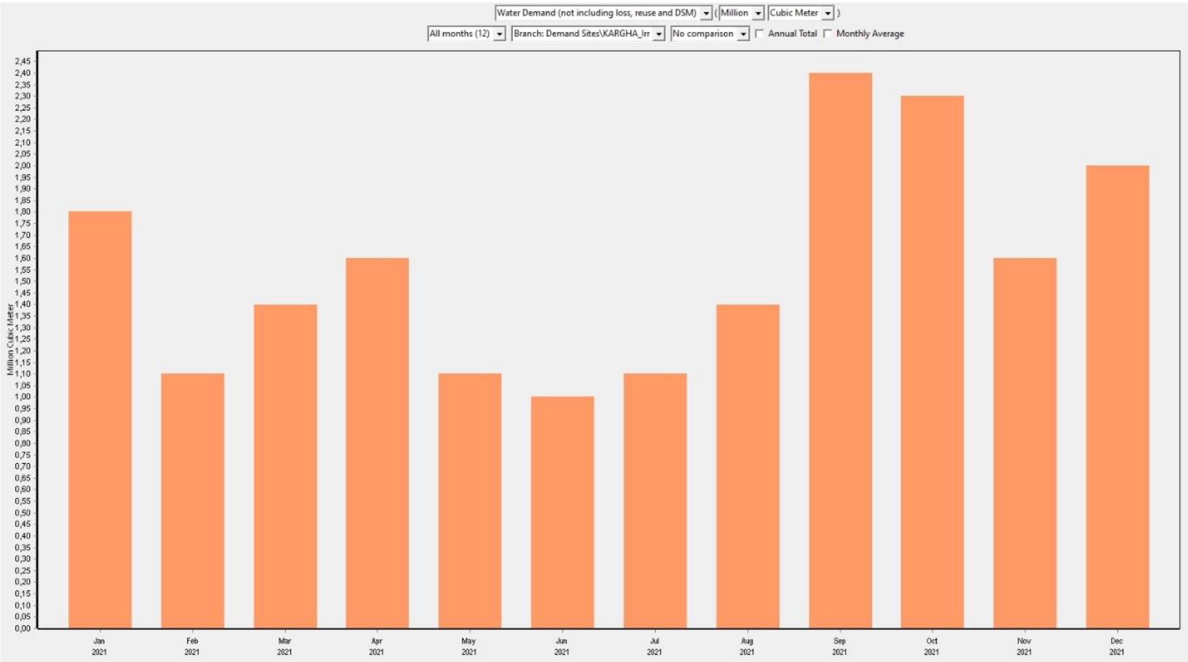
Total monthly water demand (million m³) for irrigation in the Ruzizi plain (5 compartments), according to the scenario for the cultivation of all existing, planned and projected boundaries.



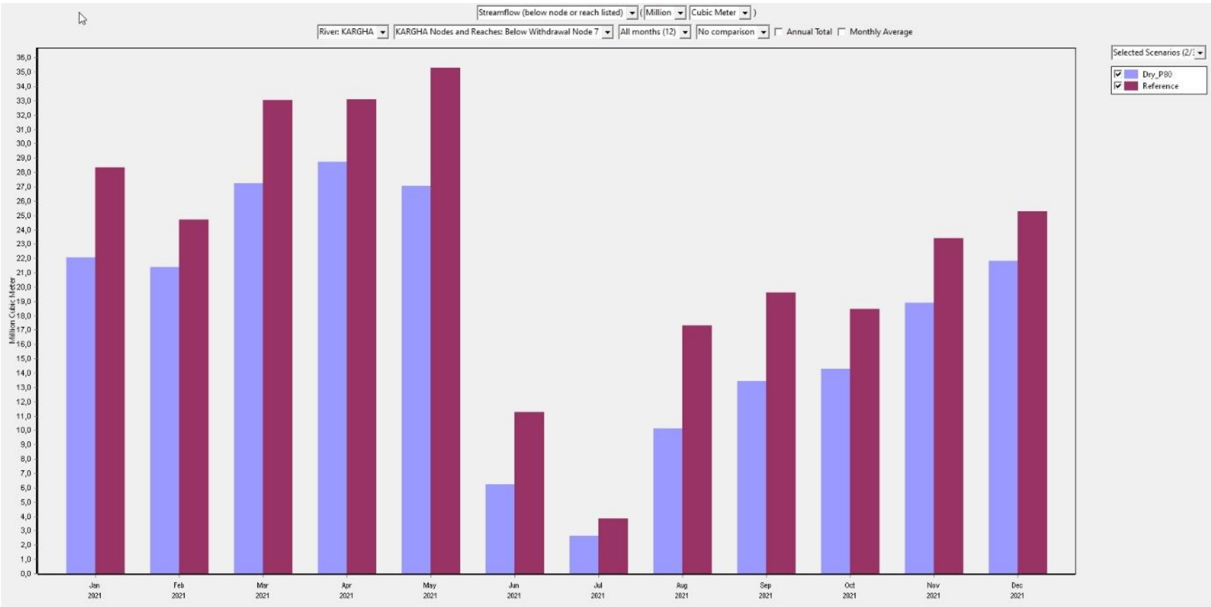
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
KARGHA_Irr	1,74	1,06	1,35	1,55	1,06	0,97	1,06	1,35	2,32	2,23	1,55	1,94	18,19
RURDAV_Irr	14,52	8,61	10,84	12,39	8,61	8,03	9,00	11,42	19,16	18,58	12,97	16,06	150,19
RURDHA_Irr	9,48	5,61	7,06	8,13	5,61	5,23	5,90	7,45	12,48	12,10	8,52	10,55	98,13
RURGAV_Irr	12,39	7,35	9,19	10,55	7,35	6,87	7,65	9,77	16,35	15,87	11,13	13,74	128,23
RURGHA_Irr	7,26	4,35	5,42	6,19	4,35	4,06	4,45	5,71	9,58	9,29	6,48	8,03	75,19
Sum	45,39	27,00	33,87	38,81	27,00	25,16	28,06	35,71	59,90	58,06	40,65	50,32	469,94

Left bank Compartment Kamanyiola:

Monthly water demand (million m³) for irrigation in the Kamanyiola compartment on the left bank, according to the cultivation scenario of all existing, planned and projected boundaries.



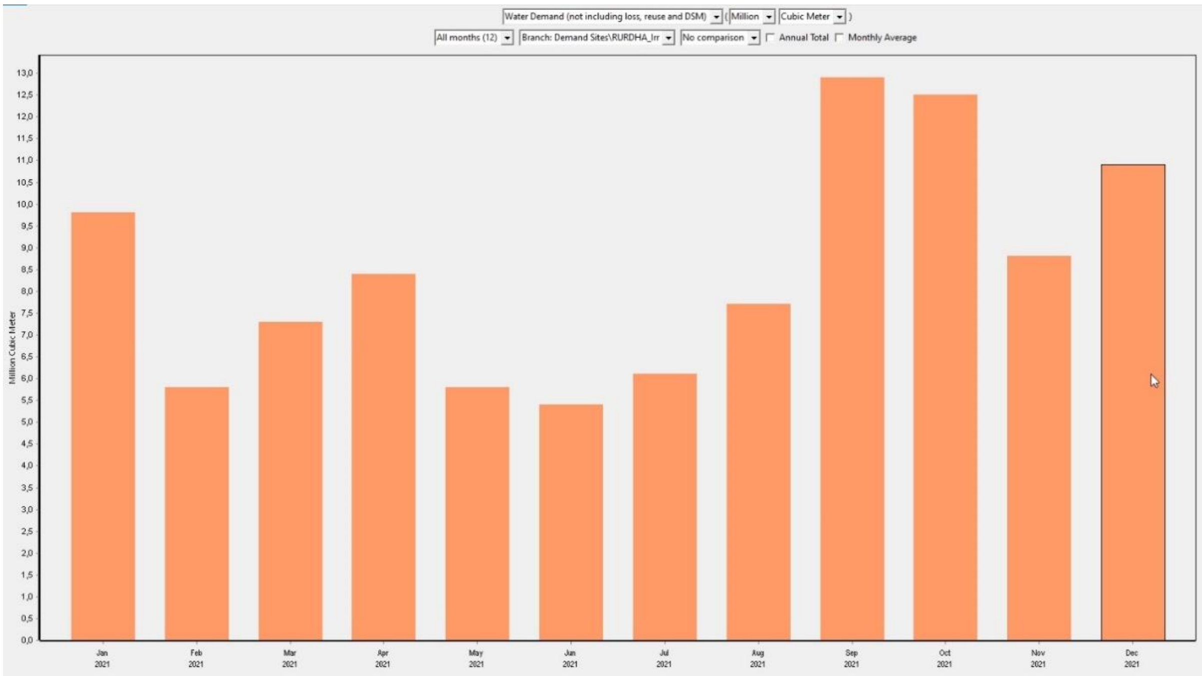
Monthly discharge volumes (millions m³) in the Kamanyola compartment on the left bank, after irrigation withdrawals according to the scenario for the cultivation of all the existing, planned and projected boundaries, in average year (P50) and dry year (P80)



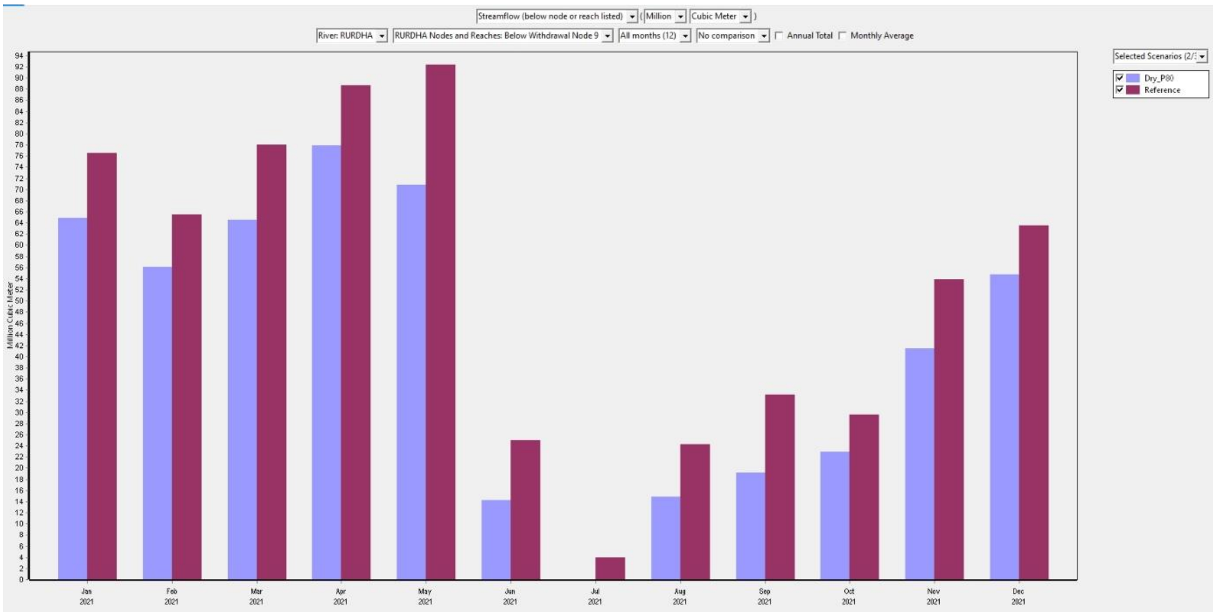
It can be seen that the demand for water for irrigation in this compartment is met every month of the year, both in an average climatic year and in a dry year.

Upstream right bank Compartment Ruzizi:

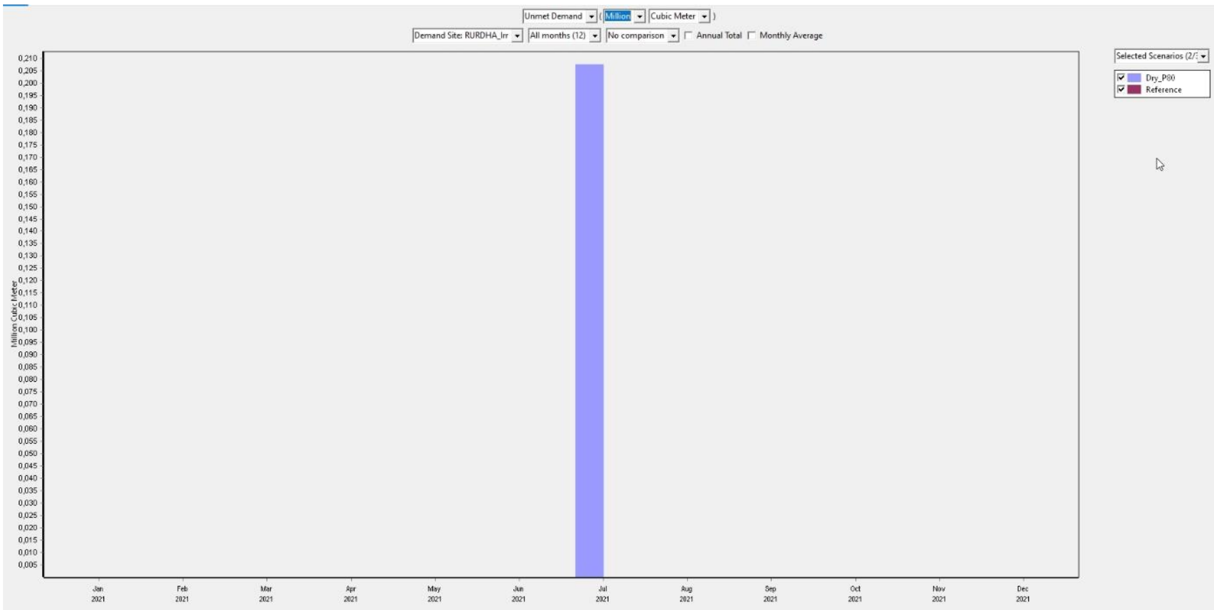
Monthly water demand (million m³) for irrigation in the Ruzizi compartment upstream right bank, according to the scenario of cultivation of all the existing, planned and projected boundaries.



Monthly flow volumes (millions m³) in the Ruzizi compartment upstream right bank, after irrigation withdrawals according to the scenario of cultivation of all the existing, planned and projected perimeters, in an average year (P50) and in a dry year (P80)



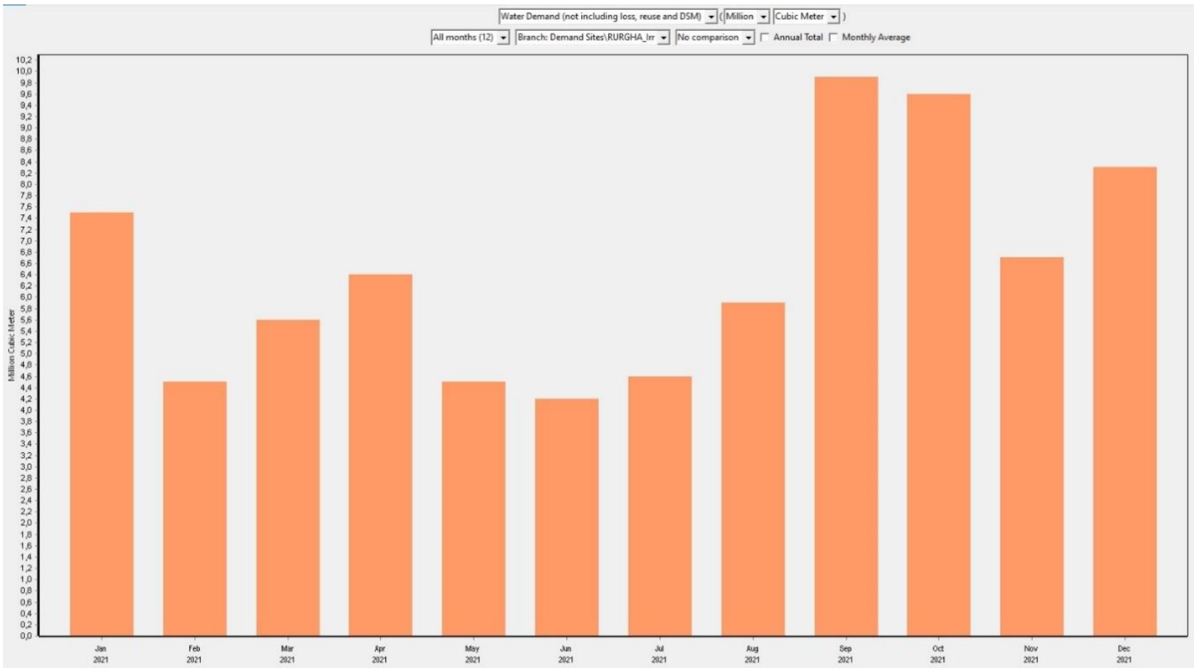
Monthly demand not met (millions m³) in the Ruzizi compartment upstream right bank, for irrigation according to the scenario of cultivation of all the existing, planned and projected perimeters, in an average year (P50) and in a dry year (P80)



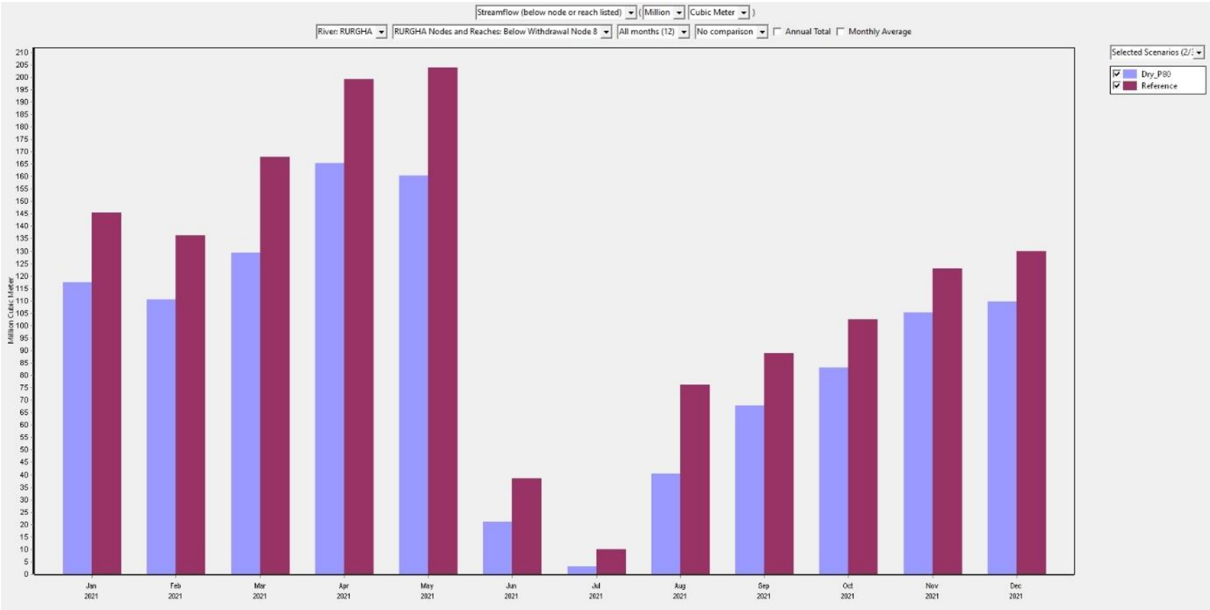
It can be seen that the demand for water from this compartment for irrigation is not fully met in July for the dry year scenario.

Upstream left bank Compartment Ruzizi:

Monthly water demand (million m³) for irrigation in the Ruzizi compartment upstream left bank, according to the scenario of cultivation of all the existing, planned and projected boundaries.



Monthly flow volumes (millions m³) in the Ruzizi compartment upstream left bank, after irrigation withdrawals according to the scenario of cultivation of all the existing, planned and projected boundaries, in an average year (P50) and in a dry year (P80).

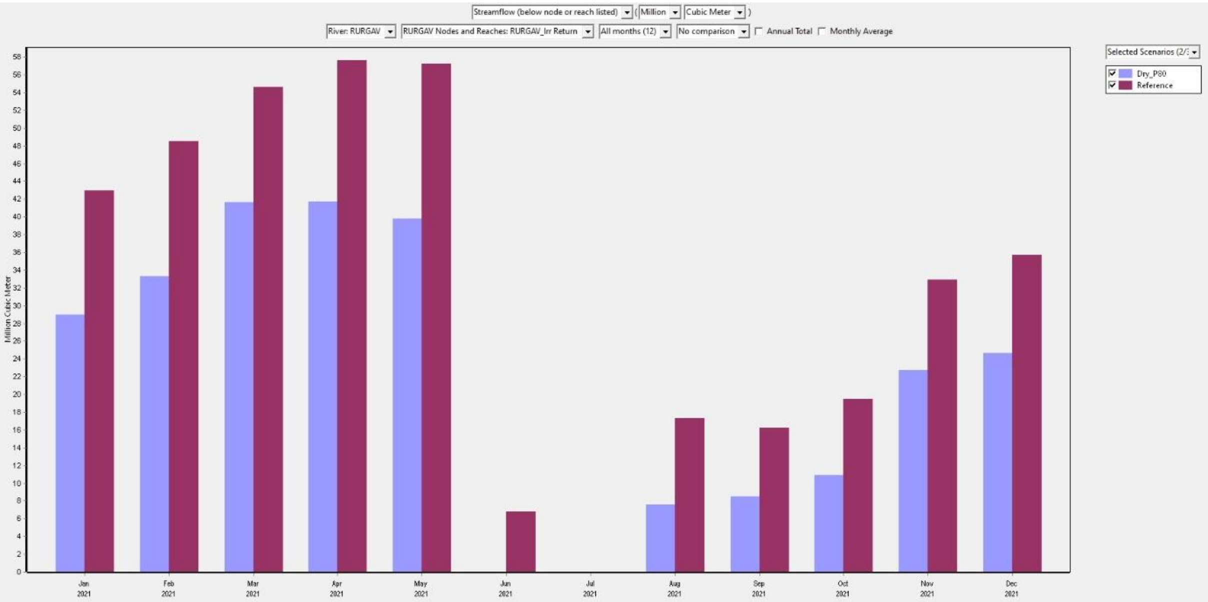


It can be seen that the demand for water for irrigation in this compartment is met every month of the year, both in an average climatic year and in a dry year.

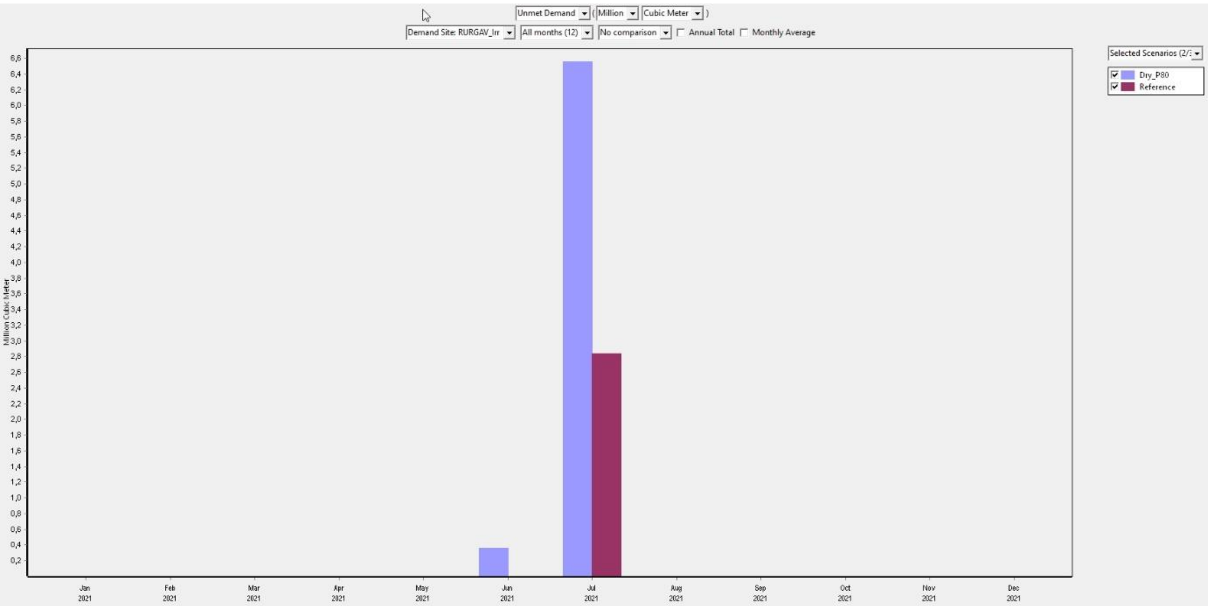
Downstream left bank Compartment Ruzizi:

Monthly water demand (million m³) for irrigation in the Ruzizi compartment downstream left bank, according to the cultivation scenario of all existing, planned and projected boundaries.

Monthly discharge volumes (millions m³) in the Ruzizi compartment downstream left bank, after withdrawals for irrigation according to the scenario for the cultivation of all the existing, planned and projected boundaries, in an average year (P50) and in a dry year (P80).



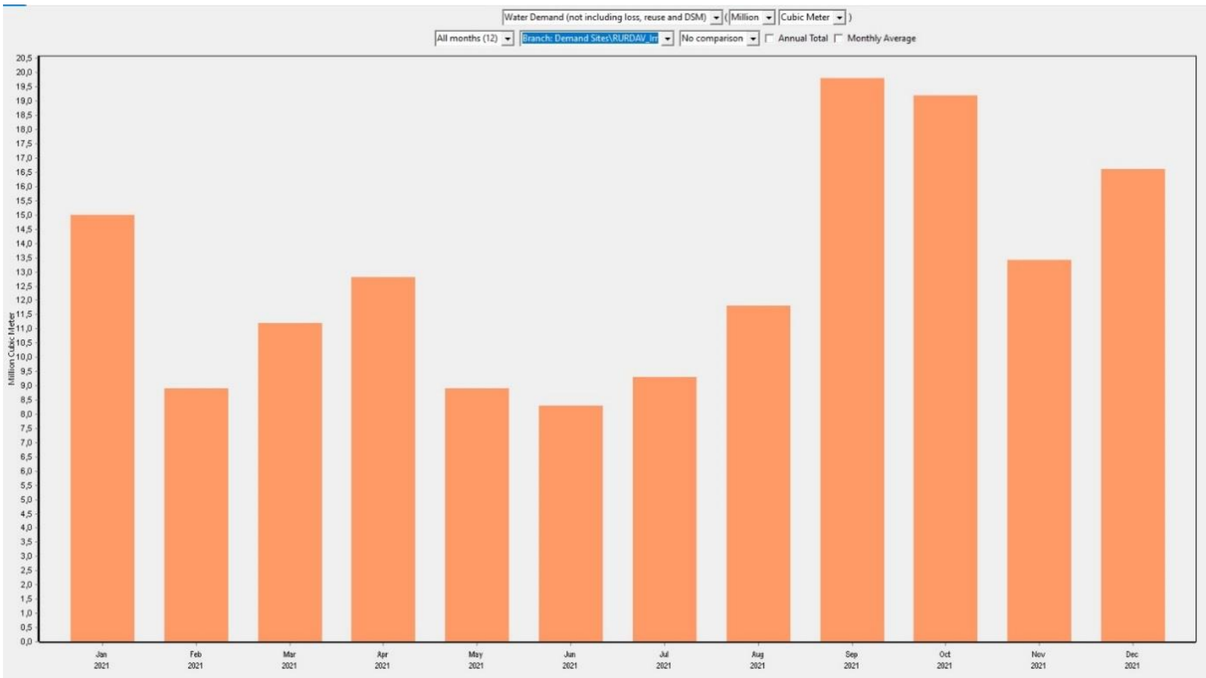
Monthly demand not met (millions m³) in the Ruzizi compartment downstream left bank, for irrigation according to the scenario of cultivation of all the existing, planned and projected boundaries, in an average year (P50) and in a dry year (P80)



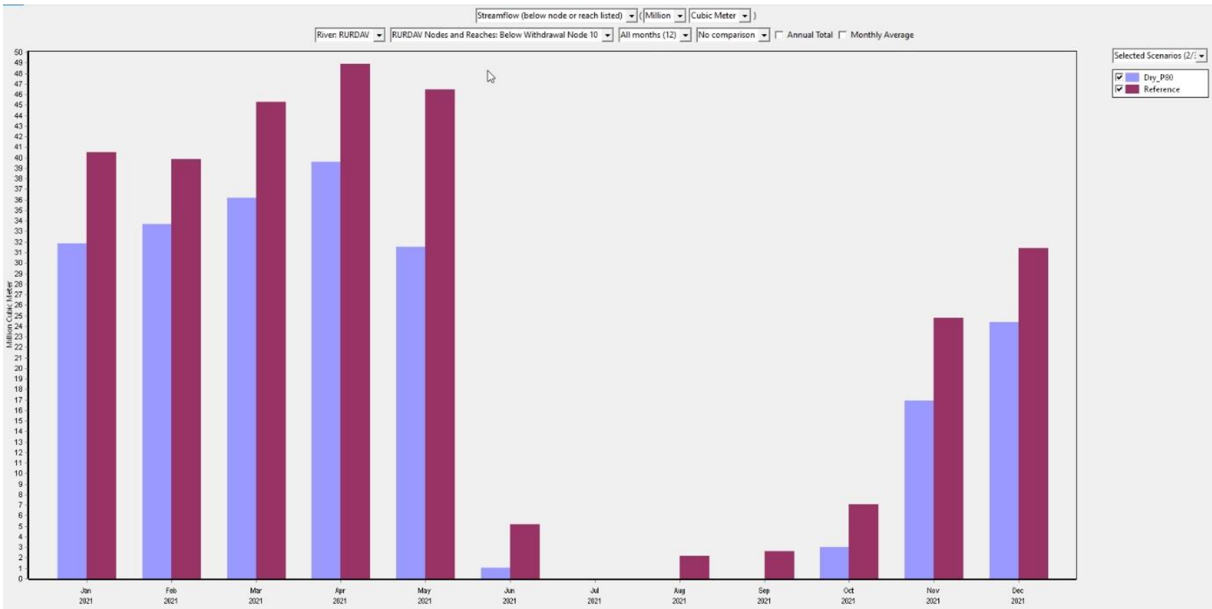
It can be seen that the water demand of this compartment for irrigation is not fully met in July for the average year scenario, and in June-July for the dry year scenario.

Downstream right bank Compartment Ruzizi:

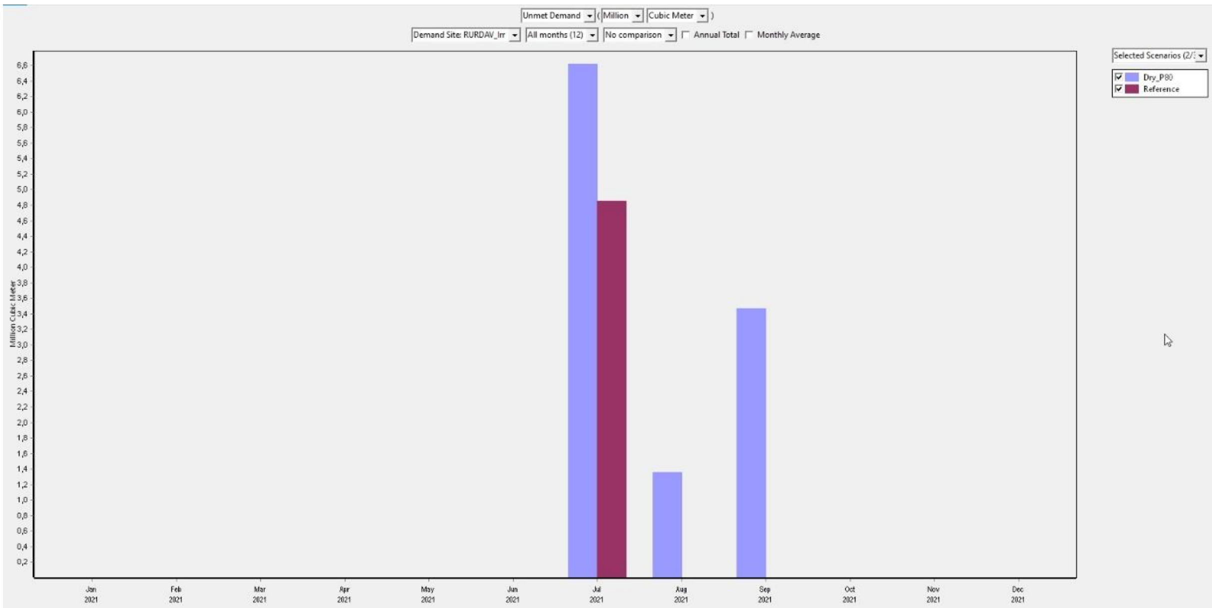
Monthly water demand (million m³) for irrigation in the Ruzizi compartment downstream right bank, according to the cultivation scenario of all existing, planned and projected boundaries.



Monthly discharge volumes (millions m³) in the Ruzizi compartment downstream right bank, after withdrawals for irrigation according to the scenario of cultivation of all the existing, planned and projected boundaries, in an average year (P50) and in a dry year (P80)



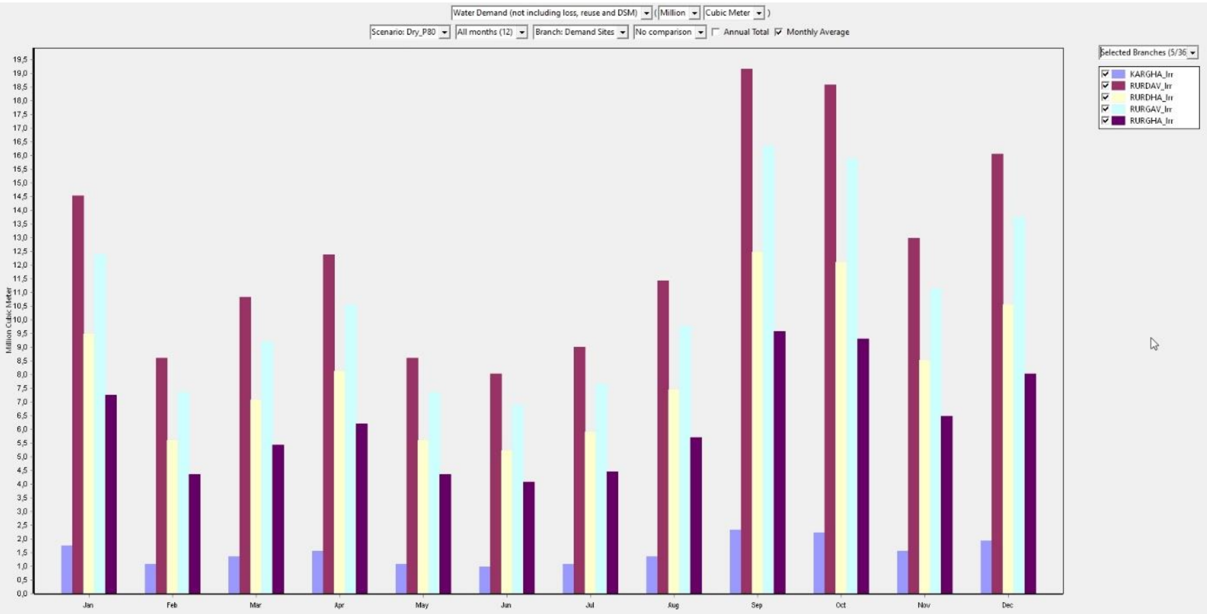
Monthly demand not met (millions m³) in the Ruzizi compartment downstream right bank, for irrigation according to the scenario of cultivation of all the existing, planned and projected boundaries, in an average year (P50) and in a dry year (P80)



It can be seen that the water demand of this compartment for irrigation is not fully met in July for the average year scenario, and in June-August-September for the dry year scenario.

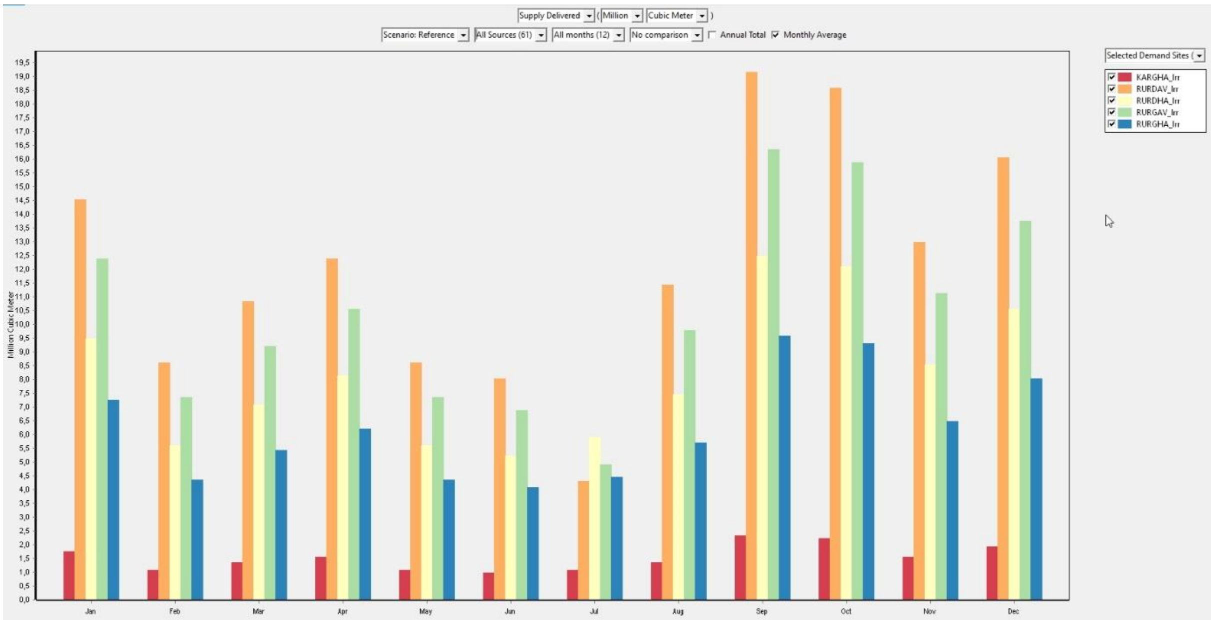
Synthesis for irrigation in the Ruzizi plain

Monthly water demand (million m³) for the 5 compartments



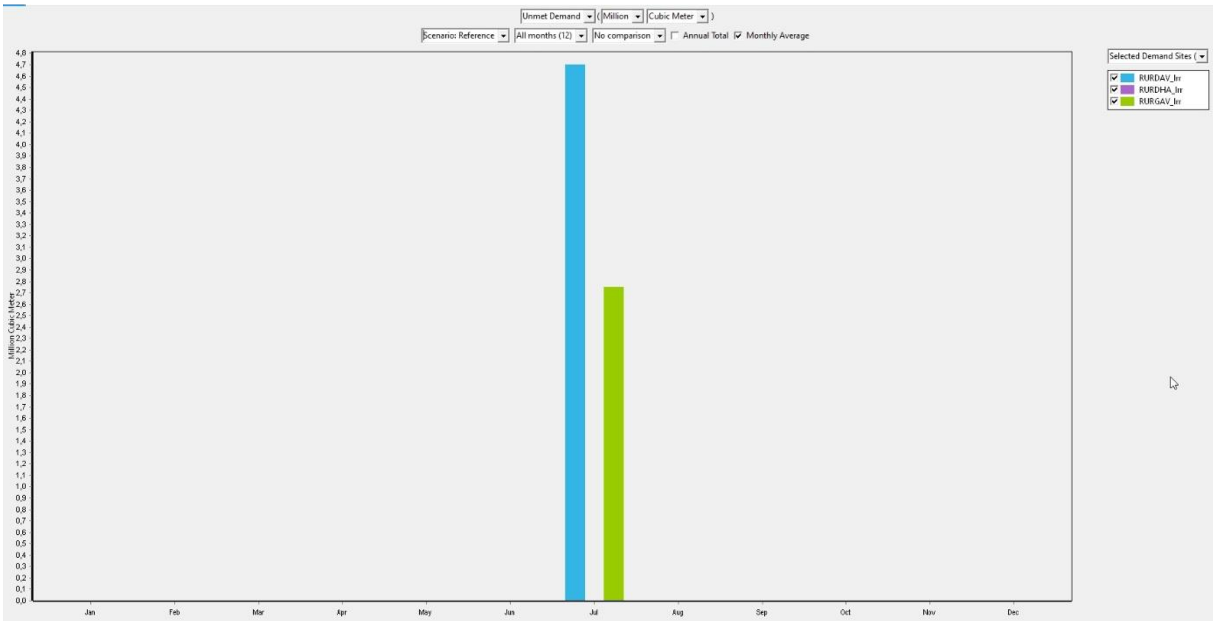
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
KARGHA_Irr	1,74	1,06	1,35	1,55	1,06	0,97	1,06	1,35	2,32	2,23	1,55	1,94	18,19
RURDAV_Irr	14,52	8,61	10,84	12,39	8,61	8,03	9,00	11,42	19,16	18,58	12,97	16,06	150,19
RURDHA_Irr	9,48	5,61	7,06	8,13	5,61	5,23	5,90	7,45	12,48	12,10	8,52	10,55	98,13
RURGAV_Irr	12,39	7,35	9,19	10,55	7,35	6,87	7,65	9,77	16,35	15,87	11,13	13,74	128,23
RURGHA_Irr	7,26	4,35	5,42	6,19	4,35	4,06	4,45	5,71	9,58	9,29	6,48	8,03	75,19
Sum	45,39	27,00	33,87	38,81	27,00	25,16	28,06	35,71	59,90	58,06	40,65	50,32	469,94

Monthly water demand met (million m³) for the 5 compartments, in an average climatic year (P50)



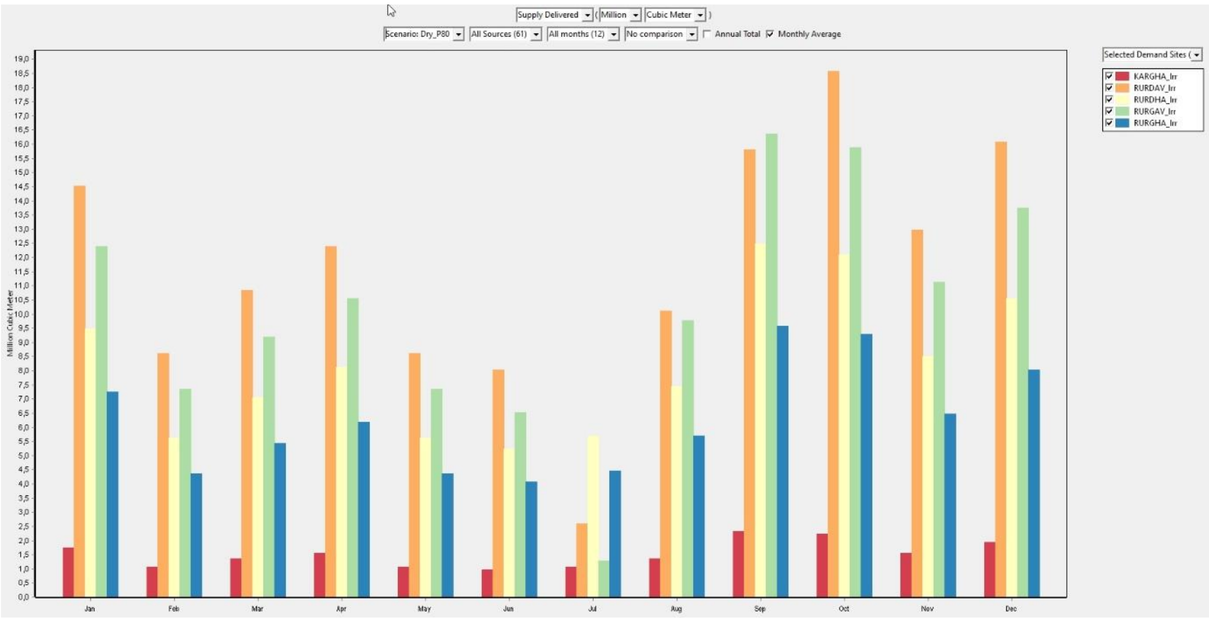
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
KARGHA_Irr	1,74	1,06	1,35	1,55	1,06	0,97	1,06	1,35	2,32	2,23	1,55	1,94	18,19
RURDAV_Irr	14,52	8,61	10,84	12,39	8,61	8,03	4,30	11,42	19,16	18,58	12,97	16,06	145,50
RURDHA_Irr	9,48	5,61	7,06	8,13	5,61	5,23	5,90	7,45	12,48	12,10	8,52	10,55	98,13
RURGAV_Irr	12,39	7,35	9,19	10,55	7,35	6,87	4,90	9,77	16,35	15,87	11,13	13,74	125,48
RURGHA_Irr	7,26	4,35	5,42	6,19	4,35	4,06	4,45	5,71	9,58	9,29	6,48	8,03	75,19
Sum	45,39	27,00	33,87	38,81	27,00	25,16	20,62	35,71	59,90	58,06	40,65	50,32	462,49

Monthly water demand not met (million m³) for the 5 compartments, in an average climatic year (P50)



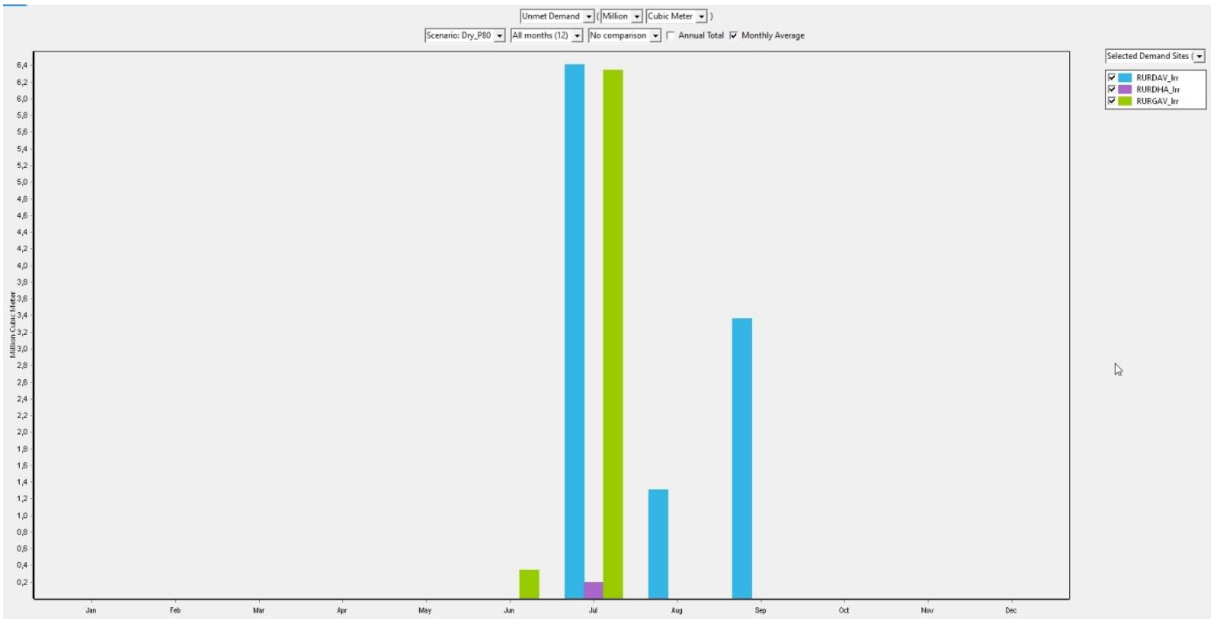
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
RURDAV_Irr	0,00	0,00	0,00	0,00	0,00	0,00	4,70	0,00	0,00	0,00	0,00	0,00	4,70
RURDHA_Irr	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
RURGAV_Irr	0,00	0,00	0,00	0,00	0,00	0,00	2,75	0,00	0,00	0,00	0,00	0,00	2,75
Sum	0,00	0,00	0,00	0,00	0,00	0,00	7,44	0,00	0,00	0,00	0,00	0,00	7,44

Monthly water demand met (million m³) for the 5 compartments, in a dry climatic year (P80)



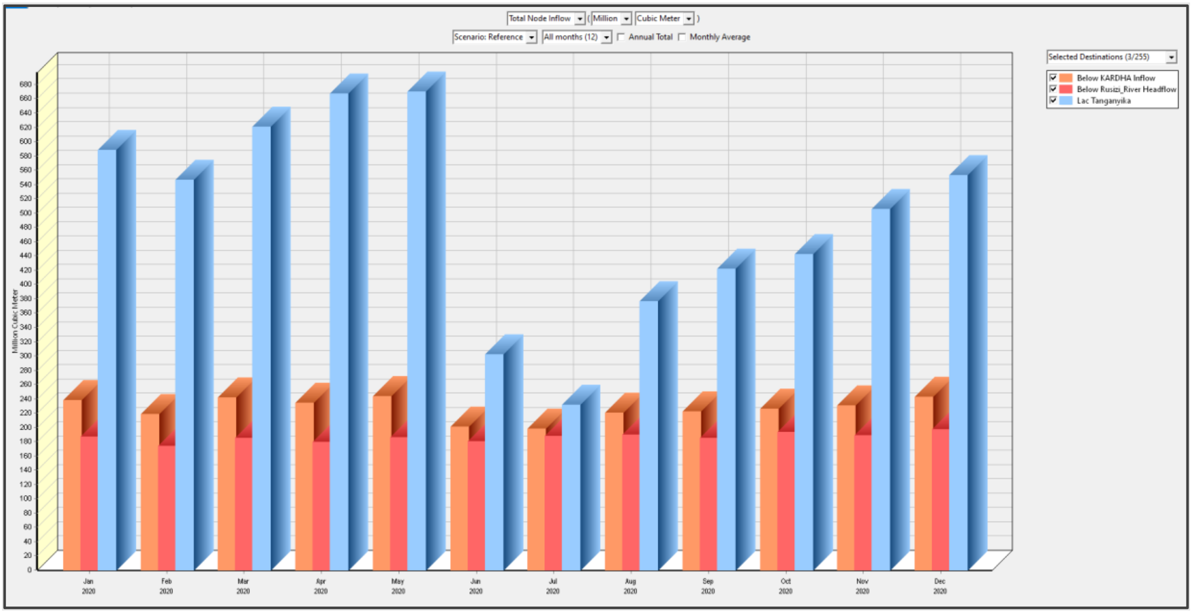
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
KARGHA_Irr	1,74	1,06	1,35	1,55	1,06	0,97	1,06	1,35	2,32	2,23	1,55	1,94	18,19
RURDAV_Irr	14,52	8,61	10,84	12,39	8,61	8,03	2,59	10,11	15,80	18,58	12,97	16,06	139,12
RURDHA_Irr	9,48	5,61	7,06	8,13	5,61	5,23	5,70	7,45	12,48	12,10	8,52	10,55	97,93
RURGAV_Irr	12,39	7,35	9,19	10,55	7,35	6,52	1,30	9,77	16,35	15,87	11,13	13,74	121,53
RURGHA_Irr	7,26	4,35	5,42	6,19	4,35	4,06	4,45	5,71	9,58	9,29	6,48	8,03	75,19
Sum	45,39	27,00	33,87	38,81	27,00	24,81	15,11	34,40	56,54	58,06	40,65	50,32	451,96

Monthly water demand not met (million m³) for the 5 compartments, in a dry climate year (P80)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
RURDAV_Irr	0,00	0,00	0,00	0,00	0,00	0,00	6,41	1,31	3,36	0,00	0,00	0,00	11,08
RURDHA_Irr	0,00	0,00	0,00	0,00	0,00	0,00	0,20	0,00	0,00	0,00	0,00	0,00	0,20
RURGAV_Irr	0,00	0,00	0,00	0,00	0,00	0,35	6,35	0,00	0,00	0,00	0,00	0,00	6,70
Sum	0,00	0,00	0,00	0,00	0,00	0,35	12,96	1,31	3,36	0,00	0,00	0,00	17,98

Monthly volumes discharged (millions m³) in an average climatic year (P50) in the Ruzizi River at the outlet of Lake Kivu (in red), at the entrance of the Ruzizi plain (in orange), and at the entrance of Lake Tanganyika (in blue) according to the scenario for the cultivation of all existing, planned and projected boundaries.

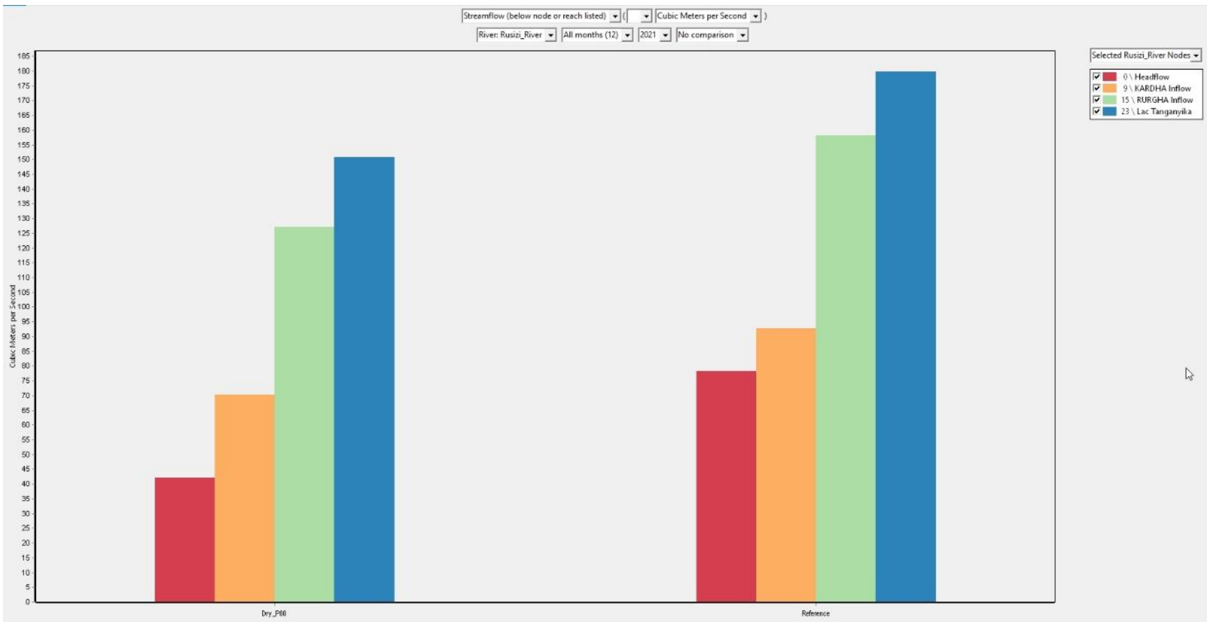


2.4.3. Climate Changes

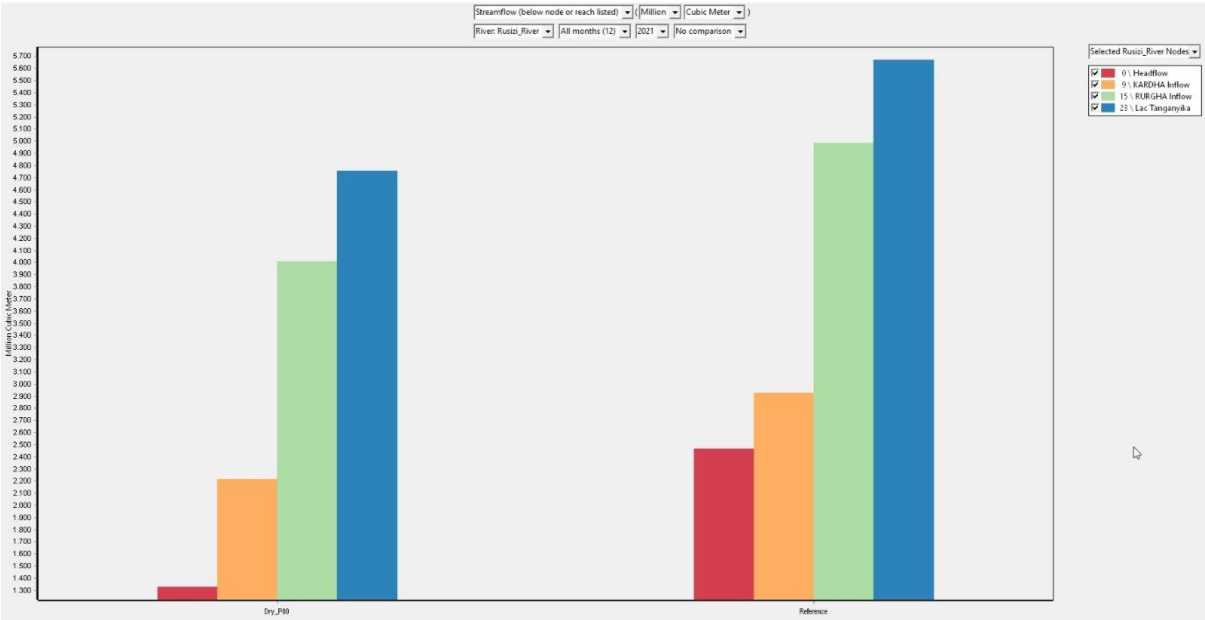
The scenarios simulating the impact of climate change compare a reference situation (average climate context P50) with a dry year situation (climate context P80).

The impact on the annual and monthly flows of the Ruzizi, and on the annual and monthly volumes discharged, is shown for illustration purposes in the figures below.

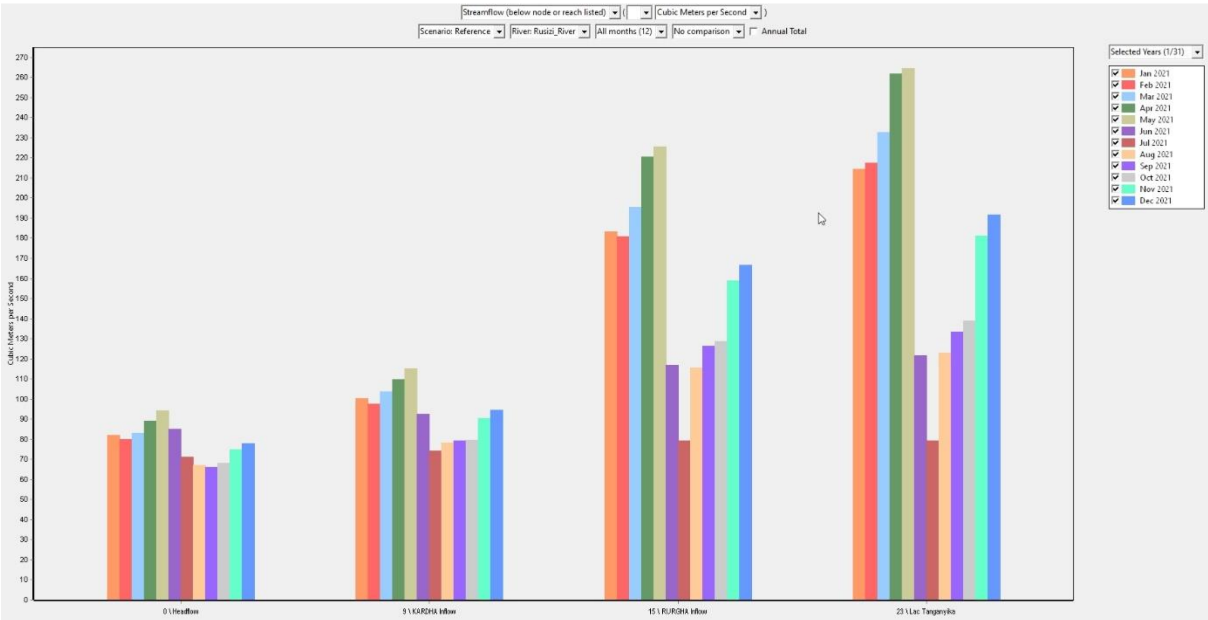
Mean annual flow (m³/s) in an average climatic year (P50) and a dry year (P80) of the Ruzizi at the outlet of Lake Kivu, at the outlet of the Kamanyola compartments left bank and right bank, at the outlet of the Ruzizi compartments upstream left bank and right bank, and at the outlet of the Ruzizi at the level of Lake Tanganyika.



Average annual discharge volumes (million m³) in an average climatic year (P50) and a dry year (P80) from the Ruzizi at the outlet of Lake Kivu, at the outlet of the Kamanyola compartments left bank and right bank, at the outlet of the Ruzizi compartments upstream left bank and right bank, and at the outlet of the Ruzizi at the level of Lake Tanganyika.

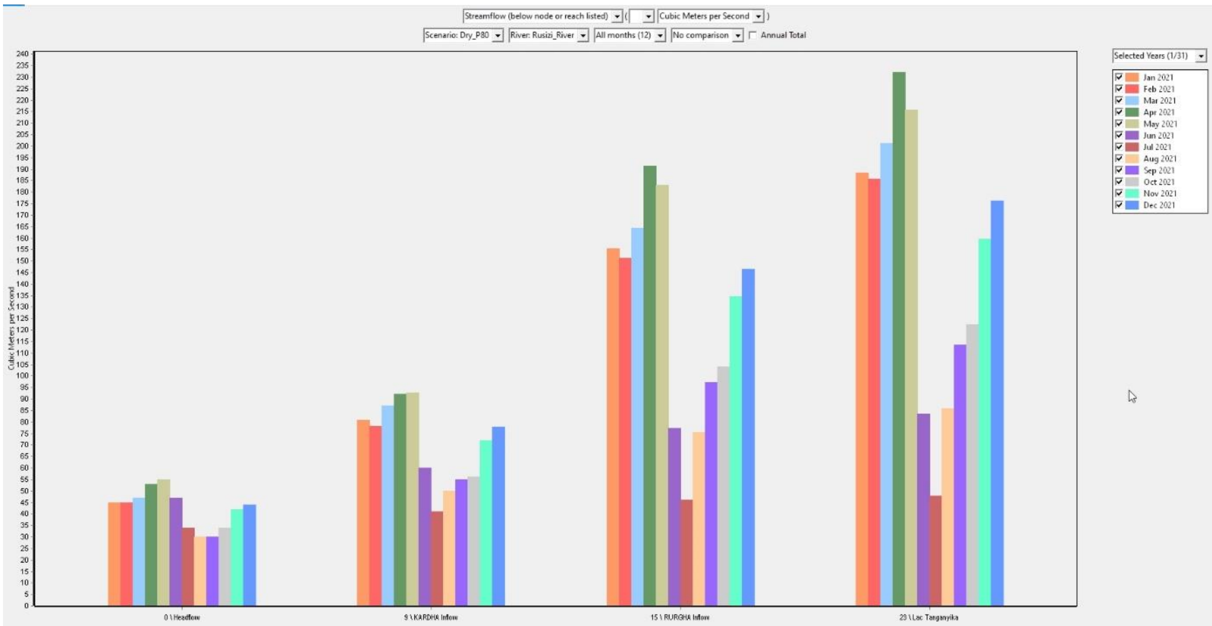


Average monthly mean flows (m³/s) in an average climatic year (P50) of the Ruzizi at the outlet of Lake Kivu, at the outlet of the Kamanyola compartments left bank and right bank, at the outlet of the Ruzizi compartments upstream left bank and right bank, and at the outlet of the Ruzizi at the level of Lake Tanganyika.



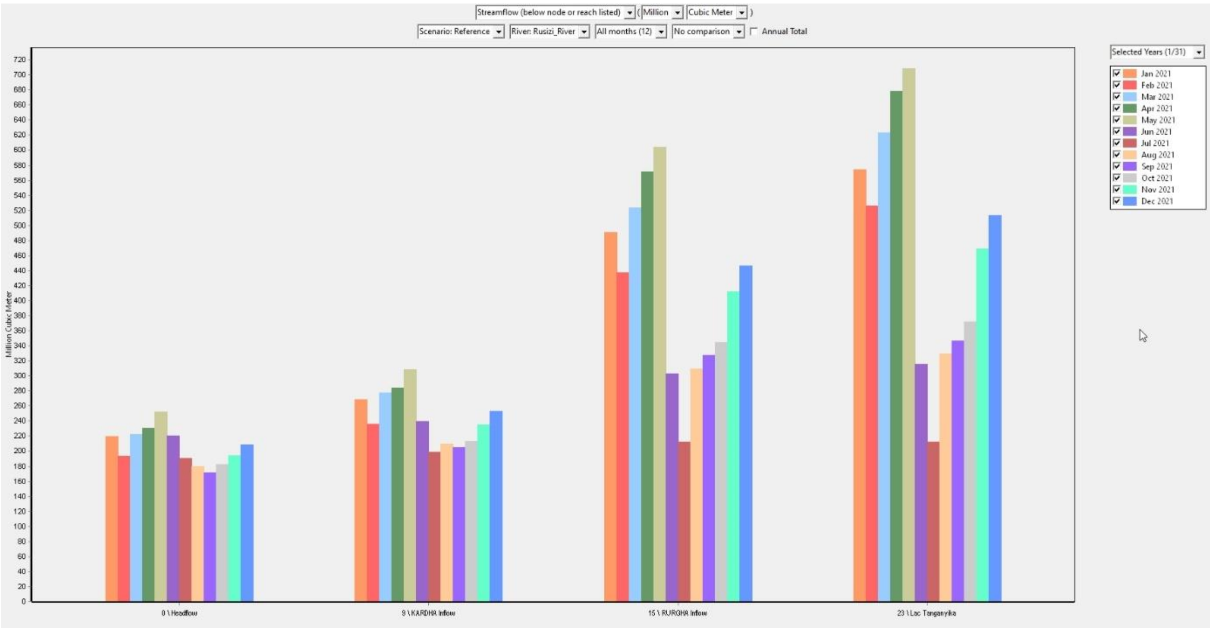
	0 \ Headflow	9 \ KARDHA Inflow	15 \ RURGHA Inflow	23 \ Lac Tanganyika
Jan 2021	82,00	100,28	183,14	214,30
Feb 2021	80,00	97,42	180,79	217,32
Mar 2021	83,00	103,71	195,46	232,77
Apr 2021	89,00	109,56	220,60	261,72
May 2021	94,00	115,14	225,69	264,39
Jun 2021	85,00	92,49	116,99	121,62
Jul 2021	71,00	74,10	79,35	79,35
Aug 2021	67,00	78,06	115,58	122,85
Sep 2021	66,00	79,20	126,29	133,54
Oct 2021	68,00	79,48	128,79	138,71
Nov 2021	75,00	90,50	158,77	181,05
Dec 2021	78,00	94,45	166,63	191,67

Average monthly flows (m³/s) in a dry year (P80) of the Ruzizi at the outlet of Lake Kivu, at the outlet of the Kamanyola compartments left bank and right bank, at the outlet of the Ruzizi compartments upstream left bank and right bank, and at the outlet of the Ruzizi at the level of Lake Tanganyika.



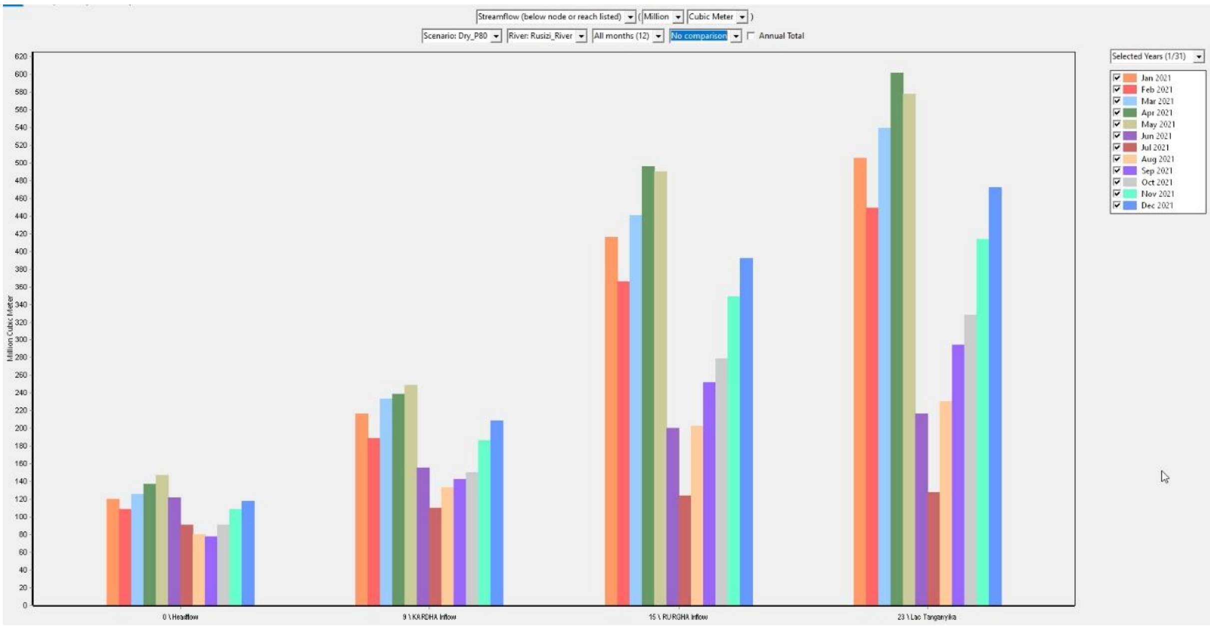
	0 \ Headflow	9 \ KARDHA Inflow	15 \ RURGHA Inflow	23 \ Lac Tanganyika
Jan 2021	45,00	80,90	155,40	188,50
Feb 2021	45,00	78,10	151,20	185,70
Mar 2021	47,00	87,20	164,40	201,20
Apr 2021	53,00	92,00	191,50	232,00
May 2021	55,00	92,80	182,90	215,70
Jun 2021	47,00	60,00	77,30	83,50
Jul 2021	34,00	41,10	46,20	47,70
Aug 2021	30,00	49,80	75,50	86,00
Sep 2021	30,00	54,90	97,30	113,40
Oct 2021	34,00	56,20	104,00	122,50
Nov 2021	42,00	72,00	134,60	159,50
Dec 2021	44,00	77,90	146,40	176,20

Average monthly discharge volumes (million m³) in an average climatic year (P50) from the Ruzizi at the outlet of Lake Kivu, at the outlet of the Kamanyola compartments left bank and right bank, at the outlet of the Ruzizi compartments upstream left bank and right bank, and at the outlet of the Ruzizi at the level of Lake Tanganyika.



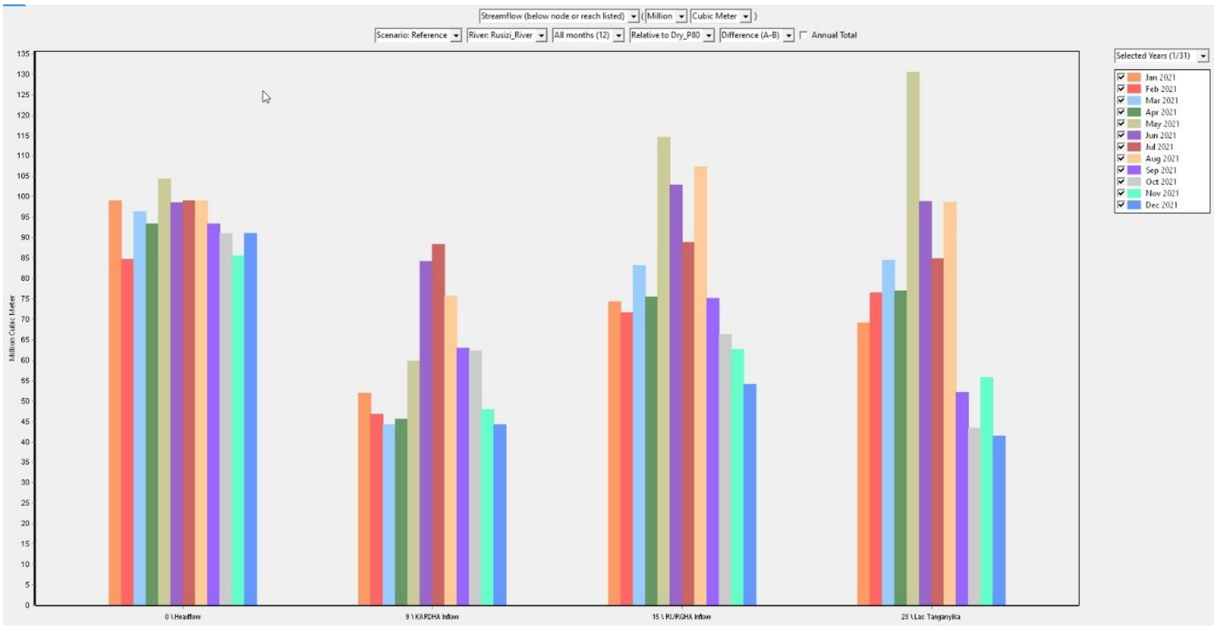
	0 \ Headflow	9 \ KARDHA Inflow	15 \ RURGHA Inflow	23 \ Lac Tanganyika
Jan 2021	219,63	268,58	490,52	573,98
Feb 2021	193,54	235,67	437,36	525,73
Mar 2021	222,31	277,77	523,52	623,46
Apr 2021	230,69	283,99	571,80	678,38
May 2021	251,77	308,39	604,50	708,15
Jun 2021	220,32	239,74	303,24	315,24
Jul 2021	190,17	198,47	212,54	212,54
Aug 2021	179,45	209,07	309,57	329,05
Sep 2021	171,07	205,30	327,34	346,13
Oct 2021	182,13	212,88	344,95	371,52
Nov 2021	194,40	234,58	411,54	469,27
Dec 2021	208,92	252,98	446,31	513,36
Sum	2.464,38	2.927,42	4.983,19	5.666,80

Average monthly discharge volumes (million m³) in a dry year (P80) from the Ruzizi at the outlet of Lake Kivu, at the outlet of the Kamanyola compartments left bank and right bank, at the outlet of the Ruzizi compartments upstream left bank and right bank, and at the outlet of the Ruzizi at the level of Lake Tanganyika.



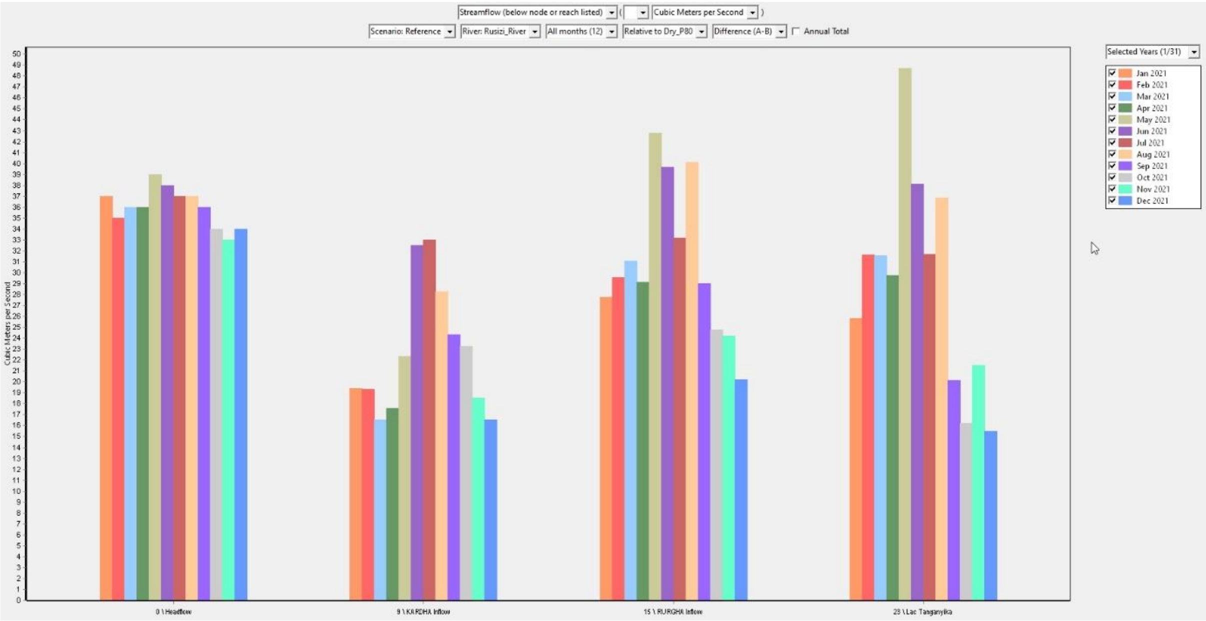
	0 \ Headflow	9 \ KARDHA Inflow	15 \ RURGHA Inflow	23 \ Lac Tanganyika
Jan 2021	120,53	216,68	416,22	504,88
Feb 2021	108,86	188,94	365,78	449,24
Mar 2021	125,88	233,56	440,33	538,89
Apr 2021	137,38	238,46	496,37	601,34
May 2021	147,31	248,56	489,88	577,73
Jun 2021	121,82	155,52	200,36	216,43
Jul 2021	91,07	110,08	123,74	127,76
Aug 2021	80,35	133,38	202,22	230,34
Sep 2021	77,76	142,30	252,20	293,93
Oct 2021	91,07	150,53	278,55	328,10
Nov 2021	108,86	186,62	348,88	413,42
Dec 2021	117,85	208,65	392,12	471,93
Sum	1.328,74	2.213,28	4.006,66	4.754,01

Difference in average monthly flow volumes (million m³) between an average climatic year (P50) and a dry year (P80) of the Ruzizi at the outlet of Lake Kivu, at the outlet of the Kamanyola compartments left bank and right bank, at the outlet of the Ruzizi compartments upstream left bank and right bank, and at the outlet of the Ruzizi at the level of Lake Tanganyika.



	0 \ Headflow	9 \ KARDHA Inflow	15 \ RURGHA Inflow	23 \ Lac Tanganyika
Jan 2021	-99,10	-51,90	-74,29	-69,10
Feb 2021	-84,67	-46,73	-71,58	-76,49
Mar 2021	-96,42	-44,21	-83,19	-84,56
Apr 2021	-93,31	-45,52	-75,43	-77,03
May 2021	-104,46	-59,83	-114,62	-130,42
Jun 2021	-98,50	-84,22	-102,88	-98,80
Jul 2021	-99,10	-88,39	-88,80	-84,78
Aug 2021	-99,10	-75,68	-107,35	-98,71
Sep 2021	-93,31	-63,00	-75,14	-52,20
Oct 2021	-91,07	-62,36	-66,40	-43,41
Nov 2021	-85,54	-47,96	-62,66	-55,85
Dec 2021	-91,07	-44,34	-54,20	-41,42
Sum	-1.135,64	-714,14	-976,54	-912,78

Difference in mean monthly flows (m³/s) between an average climatic year (P50) and a dry year (P80) of the Ruzizi at the outlet of Lake Kivu, at the outlet of the Kamanyola compartments left bank and right bank, at the outlet of the Ruzizi compartments upstream left bank and right bank, and at the outlet of the Ruzizi at the level of Lake Tanganyika.



	0 \ Headflow	9 \ KARDHA Inflow	15 \ RURGHA Inflow	23 \ Lac Tanganyika
Jan 2021	-37,00	-19,38	-27,74	-25,80
Feb 2021	-35,00	-19,32	-29,59	-31,62
Mar 2021	-36,00	-16,51	-31,06	-31,57
Apr 2021	-36,00	-17,56	-29,10	-29,72
May 2021	-39,00	-22,34	-42,79	-48,69
Jun 2021	-38,00	-32,49	-39,69	-38,12
Jul 2021	-37,00	-33,00	-33,15	-31,65
Aug 2021	-37,00	-28,26	-40,08	-36,85
Sep 2021	-36,00	-24,30	-28,99	-20,14
Oct 2021	-34,00	-23,28	-24,79	-16,21
Nov 2021	-33,00	-18,50	-24,17	-21,55
Dec 2021	-34,00	-16,55	-20,24	-15,47