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Thesis for the Degree of Master of Engineering

Water Resources Assessment in Communes Surrounding Kibira National Park in Burundi under Changing Climate System

by

MelchiadeBankuwiha

Department of Ecological Engineering

The Graduate School

Pukyong National University

February 2015

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Advisor: Prof. Sung Kijune

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Engineering

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Approved by:

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(Member) Prof. Daeseok Kang

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February 2015

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Table of Contents

Collection @ pknu

Collection @ pknu

List of Tables

Collection @ pknu

List of Figures

Collection @ pknu

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Water Resources Assessment in Communes Surrounding Kibira National Park in Burundi under Changing Climate System

Melchiade BANKUWIHA

Department of Ecological Engineering

Abstract

Water plays the fundamental role in sustaining the living system. It is impossible to think of a living without water. It is worth noting that the problem of water scarcity and water deprivation is mostly experienced dramatically by human living in poverty, most of them living in rural areas and often in the poorest countries. Burundi has been identified as one of those countries.

This study aimed to analyze and estimate the current and future water supply and demand in the seven communes surrounding Kibira National Park in Burundi. In conducting this study, we estimated the total current water supply under changing climate system by considering scenarios such as changing in Precipitation, Evapotranspiration, and River flow rates.

In terms of current and future water demand, we considered sectors such as households, livestock, agricultural and industrial production as the key water users in the study area. To attain the purpose of this study, we used the qualitative and quantitative method and some mathematical skills, with excel serving as a tool, to estimate and compare the current and future water demand in seven communes surrounding Kibira National Park. We, therefore, projected the future water demand from 2005 to 2020 and up to 2050.

The results showed an alarming scarcity in current and future water supply and as well as an alarming increase in current and future water demand in the horizons 2050 under scenario A & B. Among the sectors, the agriculture was recorded as the highest water demanding sector with an estimation of 306,018,349 m3/year in 2050. Among the communes, Musigati was shown as the most water demanding commune with an estimation of 138,413,304 m3/year in 2050. The results showed clearly that the condition of water in the seven communes is displayed as either water stress or water scarcity.

Key word: Water Supply; Water Demand, Water Conditions, Kibira National Park, Burundi

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기후변화에 따른 Kibira 국립공원 주변 지역의 수자원 평가

Melchiade Bankuwiha

부 경 대 학 교 대 학 원 생 태 공 학 과

물은 지구생태계를 유지하는데 필수적인 역할을 담당한다. 물이 없이는 생물이 살수는 없다. 그런데 세계 여러 나라에서 특히 대부분의 사람들이 시골에서 살고 있는 가난한 나라들에서의 물 부족 상황은 매우 심각한 문제가 된다. 부룬디는 이런 위험에 노출 될 수 있는 나라 중 하나이다.

본 연구에서는 부룬디의 키비라 국립공원 주변의 일곱 지역에 있어서 현재와 미래의 물 공급량과 수요량을 예측하였다. 모두 2005 자료를 기본으로 하여 2020년과 2050년의 상황을 예측하였는데, 물 공급량은 현재 문제가 제기되고 있는 기후변화를 고려하여 변화 가능한 강수량, 증발산량, 하천유출량 등을 이용하였으며, 물 수요량 예측을 위해서는 가정, 축산, 농업, 산업 부분으로 나누어 각 부문에서 필요로 하는 수요량 분석을 수행하였다.

두 개의 기후변화 시나리오를 이용한 분석결과 앞으로 대상 지역들에 있어서 효율적인 물 관리가 필요한 것으로 나타났다. 2050년에는 농업부문에서 306,018,349 m3/year 로 가장 많은 수자원을 필요로 하는 부문으로, 또한 7 곳의 대상지역 중 Musigati 에서 138,413,304 m3/year 로 가장 많은 물을 사용할 것으로 예측되었다. 본 연구 결과 2050년 대상 지역 모두 수자원 부족 및 스트레스 상황에 도달할 수 있음 도 보여주었다. 현명하고 지속적인 물관리 정책이 필요할 것으로 판단되었다.

Key word: 물 공급, 물 수요, 물 부족, 키비라 국립공원, 부룬디.

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I. Introduction

1.1. Background Information

Water is the most important natural resource, without which life cannot exist. The water resources play the fundamental role in sustaining the living system. Households use water for drinking, cooking, sanitation, irrigating their crops and watering their livestock. Water is also used for industrial production, hydroelectric power, etc. (Ratnayaka, 2009). Water affects both the environmental quality and food production. In this respect, the United Nations has declared that water is the very basic need and right for all human beings (USDA, 2006). It is estimated that currently one third of the world's population lives in countries that experience medium to high water stress. This ratio is expected to grow to two thirds by 2025 (Thivet et al., 2000). Water use has been increasing at more than double the rate of population growth in the past 100 years (UN-Water, 2010). In addition to an overall increase in water demand, the world today faces a wider variety of competing demands, including agricultural, livestock, and industrial, environmental, and other water sectors. These challenges are amplified by the shortcomings in water resources management (UN-Water, 2010).

In sub-Saharan African countries, the demand for water resources today is increasing and this rise in water demand is mostly caused by climate change effect and some socio-economic growth rates (UNDP, 2012). Since water supplies have not kept pace with water demand, water resources have been over-utilized and this leading to water scarcity. It is worth noting that the problem of water scarcity and water deprivation is mostly experienced dramatically by human living in poverty, most of them living in rural areas and often in the poorest countries. Burundi has been identified as one of those countries. The fundamental role that water plays in sustaining social, economic and environmental development makes water scarcity and competition for this resource a crucial problem (Kashaigili, 2009).

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Water resources in Burundi is a limiting factor for the growth and livelihood of Burundian population as its 90% get all their incomes from the agricultural production. Although Burundi is endowed with abundant water resources, its distribution is uneven and the country is experiencing increasing pressure on water resources (FAO, 2010). According to studies conducted by NAPA (2011) on Kibira national Park in Burundi, the rise of temperature is expected to cause an increase in evaporation and evapotranspiration inside and in the surrounding communes. The increase in precipitations is expected to cause erosion on the hills and floods in low lands, thus a room to the destruction of the socio-economic infrastructures like the roads, the bridges and other public infrastructures. On the agricultural level, rainy erosion might cause arable land losses due to floods, especially for the period of long rainy seasons (NAPA, 2011).

Burundi is known for its numerous rivers and water sources. It is thus often wrongly assumed that the country enjoys a limitless supply of water. However, according to a government survey (2006), Burundi's water production capacity has almost halved since 1993, owing to the war and other crises that have plagued the country. Public statistics indicate that the demand for drinking water in towns and cities has tripled in the last 20 years (REGIDESO, 2010). In rural areas, meanwhile, the water demand has jumped from 170 million m3 in 1990 to over 400 million in 2010. Despite the efforts of parastatal agencies, such as REGIDESO in cities and DAUGHTER in the rural areas, to produce and distribute water, the quantities produced remain inadequate. The same government survey (2006) points out that in order to find water, residents of certain towns, usually women and children, must walk long distances, sometimes several times a day, sacrificing time which should be dedicated to income-generating activities or to education. Those without access to drinking water have no option but to take water from rivers and marshes, which

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is often not fit for consumption. Burundian water supply system is obviously subjected to adverse effects of climate change. Notably, rainfall deficits have resulted in severe droughts, the significant reduction of the principal wetlands and the drying up of several rivers and lakes (Kigeme, et al., 2011).

Regarding the Burundian hydrological system, the Nile and the Congo basins have their source on the crest where Kibira National Park is situated. However, it has been observed that water scarcity during the last 20 years may be due partially to climate change in many regions of Burundi including the regions surrounding Kibira National Park (USAID, 2009). Until now, there has been no study to determine the water conditions, by estimating the current and future water supply and demand within different climate scenarios, carried out on water resources in Burundi in general or around Kibira National Park in particular.

Kibira National Park (KNP) is the most important natural forest ecosystem in Burundi. While sheltering the chimpanzees and other primate species, KNP holds the potential to attract the attention of the world from both scientific and touristic sectors. In spite of its remarkable richness in terms of biodiversity, KNP is confronted by threats that mainly have impacts on the overall water resources demanded by surrounding sectors such as households, agriculture, livestock and industry (Barakiza, 2008).

Kibira National Park and its surrounding municipalities have attracted the attention of this study due to its long history and its importance on socio-economic development of different sectors surrounding its boundary and especially its magnitude in regulating water-flow system. Studies have found that more than three-quarters of the water in the country’s largest dam, providing more than 50 percent of the hydroelectric energy consumed, comes from this historic forest (UNFCC, 2010). Therefore, this park, situated on

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the Congo-Nile basin, plays a fundamental role in regulating the hydrological system and protecting against soil erosion.

The status of water supply and demand in relations to water resources and climate change in and around KNP is still unknown though it is a critical issue for the local socio-economic development. This is one of the reasons this research has been undertaken to provide information and knowledge about the water supply and demand status on Kibira National Park and its seven surrounding communes. This research attempts to assess the water resources in seven communes surrounding Kibira National Park in Burundi under the changing climate.

The main objective of this research is to estimate and determine the water resources condition in relation to water supply and demand in Kibira National Park and its surrounding communes. This general objective is fulfilled through the specific objectives mentioned below:

a) Analyze and estimate the currently available water supply in and around Kibira National Park.

b) Analyze and estimate the future water supply under climate scenarios in and around Kibira National Park.

c) Evaluate and estimate the current water demand by different water users in seven communes surrounding Kibira National Park.

d) Evaluate and estimate the future water demand by different water users in seven communes surrounding Kibira National Park.

e) Assess and determine the water resources condition in and around Kibira National Park.

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1.2. Hypothesis

a) Higher population density is more likely to increase the risk of domestic water resources conflict than the probability of water cooperation in seven communes surrounding KNP.

b) Higher agricultural productivity is more likely to increase the risk of water resources scarcity in seven communes surrounding KNP.

c) Higher economic development including livestock and industry is more likely to increase the risk of water resources scarcity in seven communes surrounding KNP.

Factors such as population density, agricultural productivity, and economic development in livestock and industry increase pressure on water resources and the competition for these resources can create tensions between different water users. In turn, these tensions create pressure on water-managing institutions to find solutions for new sustainable ways of water exploitation (Rowland, 2005).

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The Fig.1 is an overview which summarizes the whole picture of this study.

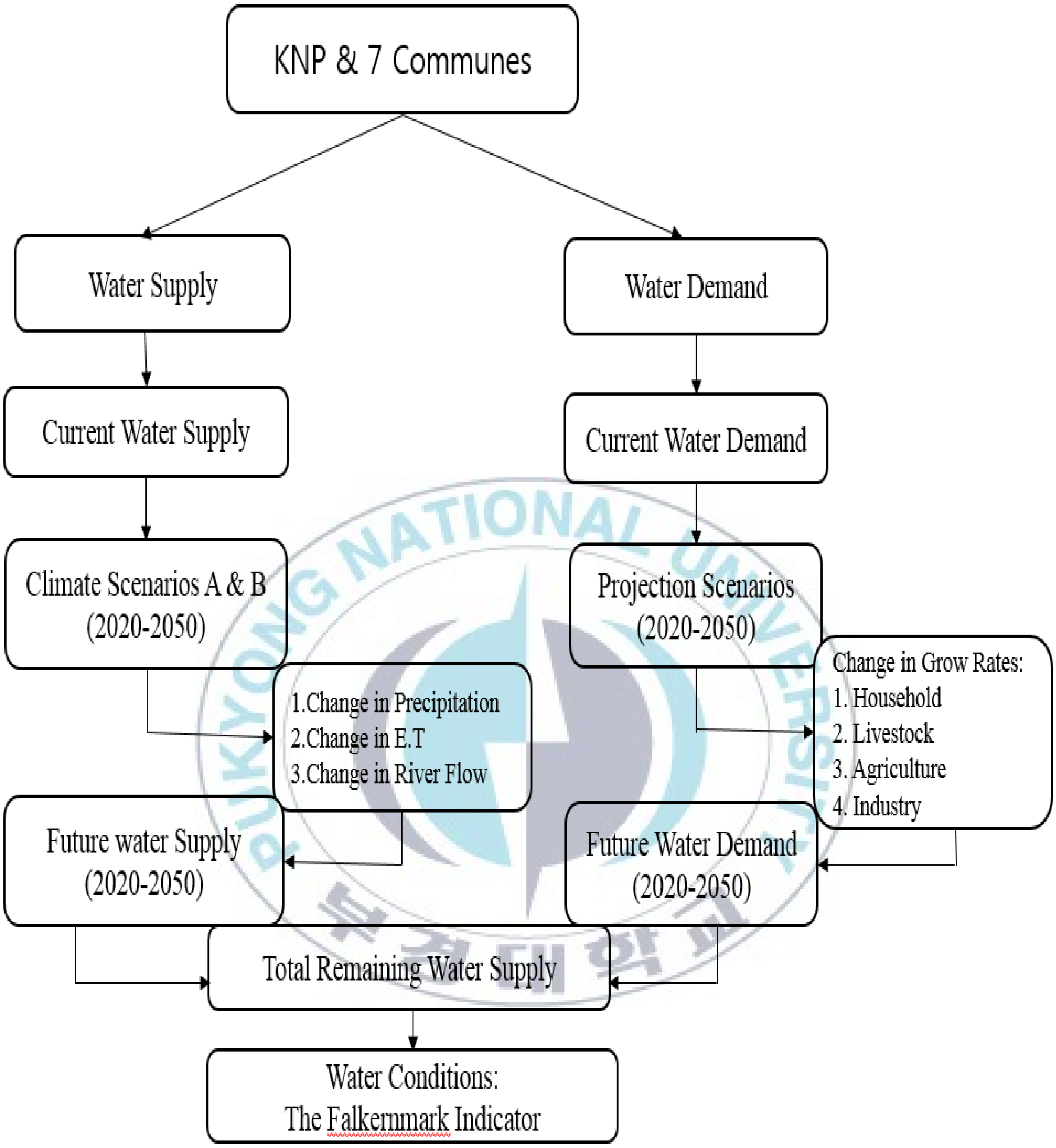

Fig. 1 The Study Flowchart

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1.3. Literature Review

Water resources is one of the most indispensable of all natural resources; it is essential for human beings, economic development and biological diversity. However, many countries have to face the challenge of rapidly growing water demands, driven by an increased population and socio-economic growth rates (King, 2004).

Water resources will play a key role as crops and livestock need a lot of water to grow (WWAP, 2012). Climate change will be mainly experienced through the water regime (FAO, 2008) and the availability of water resources will be affected by changes in rainfall distribution, soil moisture, glacier and ice/snow melt, and river and groundwater flow. Thus, it is likely that such climate change-induced hydrological changes will affect both the extent and the intensity of rain-fed as well as irrigated agriculture according to FAO (2008).

An increasing water demand might consequently contribute to an increased competition for scarce water resources. Floerke et al. (2012) analyzed future water demand and availability in the Black Sea region and they concluded that depending on their different scenarios, water withdrawal may either increase by 58% between 2005 and 2050 or it may decrease by 59% during the same period. Above all, ecosystem water requirements should not be forgotten in the competition for freshwater resources between the different water sectors. Whereas sectors such as agriculture or industry can usually define their water requirements quite well and defend their interests, it is much more difficult to define an ecosystem's water demand. As a result, water is often consumed at the expense of ecological systems' health. The environment is in danger of being compromised, notably, by a prioritization of the other water sectors such as households, livestock, agriculture and industry. Floerke, et al. (2012) concluded that agricultural sector would be one of the most heavily affected sectors by climate induced

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water shortages due to its high water demand; and at the same time it risks to be one of the principal factors aggravating water shortages due to its high water consumption rate.

Booker and Young (1994) developed a river optimization model for the Colorado River to identify optimal inter-regional allocations and prices. They find increasing benefits, which are generated by water use, of up to 50% through market transfers.

Rosegrant et al. (2000) developed an integrated economic hydrologic model for the Maipo River Basin in Chile that not only considers water allocation but also takes into account interactions of water allocation and agricultural productivity, non-agricultural water demand and environmental degradation. Consequently the model estimates economic as well as social gains from efficiency improvements of water use. Water Sources and inflows and water demands are modeled including agricultural, municipal and industrial water demand. With the objective of maximizing benefits from water use, water demand and supply are integrated into a system to determine efficient water allocations. Model results show that reallocations to higher water values yield higher benefits from water use.

Louw (2002) developed a methodology aiming to estimate the true value of water in the Berg River water management area in South Africa and assessed the potential impacts of a water market on the efficient utilization of water. With a positive mathematical programming model, the author developed a spatial equilibrium model to predict the impact of a potential water market. Besides irrigation he also includes water for urban uses like households and industries. The true value of water in irrigation was found to vary significantly between areas in the basin, with the marginal value of water ranging between zero and 20 Rand/m^3 (Rand: money unit in South Africa). These differences indicate that there are significant gains from allocative mechanisms possible in these areas.

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Mahan et al. (2002) determined efficient allocation of surface water resources in Southern Alberta, Canada by employing a standard welfare maximizing objective function. They find that intra-regional transfer from low value uses to high value uses yield substantial benefit increases of around 6% compared to the status quo situation. They conclude that efficiency improvements through market pricing are likely to be relatively important.

Rodgers and Zaafrano (2003) developed an integrated economic-hydrologic water resources simulation-optimization model for the Brantas Basin in East Java, Indonesia. They estimate municipal water demands using data from a household survey. However, for the estimation of industrial water demands they use average water values and literature-based water demand elasticity and the agricultural water demand function is based on different studies of rice yields and FAO yield coefficients. The model is able to simulate new infrastructure allowing the analysis of benefits associated with the construction of two new dams. Hence the model does not only emphasize water demands management but also considers supply management side.

Kirsten et al. (2004) developed a large-scale economic-engineering optimization model of California's water supply system. Results suggest significant improvements to system operation and water transfer and exchange within different water sectors. The authors show that there is great potential to improve the flexibility and economic performance of the water system and that both water scarcity and its cost can be considerably reduced.

Cai et al. (2006) and Cai (2008), building on the research by Rosegrant et al. (2000), developed a holistic model integrating water resources and economic components into a mathematical programming model for the Maipo River Basin in Chile. The model optimizes water allocation by maximizing economic profits from water uses in various sectors and

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confirmed previous results where welfare gains could be reached through reallocations to high value uses.

Kashaigili et al. (2009) discusses in his paper, the major constraints and potential for achieving efficient systems of allocating water resources to different uses and users in Tanzania. The discussion is supported by evidence drawn from international examples. The result shows that there is great potential for improving water management through allocation systems in Tanzania.

Niyongabo, (2008) developed a methodology in order to conduct the study regarding identification and documentation of best practices in water harvesting and irrigation in Burundi. The main objective of the study was to promote the efficient water use especially in Burundian agricultural sector.

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II. Materials and Methods

2.1. Study Area and Geography

Kibira National Park (KNP) is situated in the northwest part of Burundi. Overlapping four provinces (Muramvya, Kayanza, Cibitoke and Bubanza) and covering 4000 hectors, Kibira National Park lies atop the mountains of the Congo-Nile Divide. KNP is mainly characterized by mountainous forests and forms the watershed of the Congo-Nile Basin. The park extends to Bukeye (Bugarama zone) in the southern part and stretches up to Mabayi in the north, near the border with Rwanda. KNP, as shown in Fig. 2, is surrounded by seven administrative communes such as Bukeye, Matongo, Muruta, Kabarore, Musigati, Bukinanyana and Mabayi (Michel, 2000).

Fig. 2 Kibira National Park boundary, 7 Communes and 8 Rivers

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The quantity of rainfall in the area is very important and can be as much as 2,000mm per year in Mabayi and 1,800mm in the rest of the park. In the rest of the country, three-quarters of surface water flow has its origins in the Kibira Forest (Kigeme, 2005). Burundi has a tropical climate with two main seasons: dry and rainy seasons. However, KNP is described as a mountainous tropical climate that is nearly temperate. The relief is characterized by steep slopes around Teza Mountain, in Bukeye commune, on both sides of the crest.

All water flow in Burundi has its sources in the mountains within this national park. Many rivers, such as Ruvubu, Mpanda ,Kagunuzi, Kaburantwa, Muhira, Nyamagana, Nyakagunda and Ruhwa flow from KNP into surrounding communes and throughout the country. The natural characteristics of the KNP primary forest is its high organic matter content that is important for all types of soils regardless of the original kinds of substratum. This means that cultivating these types of soils always leads to the reduction of organic matter content. Fragile soils are subject to irreversible drying when they are poorly cultivated and exposed to erosion (Ngowenubusa, 2009).

It is a rich zone in both animal and plant biodiversity: 644 plant species have been recorded in KNP, while Nyungwe National Park, the northern continuation of KNP, has 1,061 plant species (Plumptre, et al., 2007). The park contains several tree communities. The most impressive, among others, are: Entandrophragma excelsum and Parinari excelsa stands, Parinari excelsa varholstii and Polyscias fulva stands, Polyscias fulva, Macaranga kilimandscarica and Syzygium parvifolium stands, Hagenia abyssinica and Faurea saligna secondary forest stands, Erica benguelensis and Protea madiensis high-altitude stands on ridges, Sinarundinaria alpina (pure bamboo). About 98 species of mammals (primates, servals, African civets, etc.) have also been identified within KNP (Nzigidahera, 2009). Bird life is also rich and varied, with 43 families and more than 200 species identified, and the most remarkable are

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Lophaethus occipitalis, Corythaecola cristata and Bycanistes sbcylindricus. Ten species of insectivores are seen as endemic including Myosorex blarina, Crocidura Lason and Crocidura Niobe. Eight species of Chiroptera have been identified. Of ten species of primates the most frequently encountered is Cercopithecus mitis dogetti. There are also Pan Troglodytes. The reptiles of the park are poorly known, but ophidiens are most frequently observed, including Atheris nitchei and Bitis gabonica ((Nzigidahera, 2009).

2.2. Population, Social and economic impacts

The total population living around KNP is estimated at about 472,047 inhabitants with the total land area of about 2,084km² (Table 1). The region covers the population density of about 226 inhabitants per square kilometer. The rapid population growth within the municipalities surrounding KNP will have a negative impact on the overall economy.

Table 1 Commune, population and land area

Sectors	Population	Area(km²)
KNP	-	400
Bukeye	63,235	184
Muisigati	91,712	293.82
Muruta	51,234	147.08
Matongo	63,208	167.8
Kabarore	50,365	200.12
Mabayi	69,634	347.54
Bukinanyana	82,661	344.6
Total	472,049	2084.96

(MININTER, 2006)

The agricultural activities are practiced by farmers using traditional methods, and characterized by small sowing areas (± 35 Acres). Rudimentary tools, improved inputs deficiency and using a mainly family labor make the agricultural performance be much poorer. Therefore, the agricultural production generates little income to local population. Major food

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crops grown in those municipalities are mainly: Banana, bean, maze, sweet potato, potato, cassava, and rice. The cultural practice in the region is more traditional with the predominant culture in association. The livestock domesticated in the region is traditional type and consists of cattle, goats, sheep, pigs and poultry. The animals in seven municipalities around Kibira National Park are mostly local race "Ankole" for cattle. These animals rarely receive basic health care or dietary supplements. In terms industry, only three communes have factories processing of tea: a tea processing factory located Bukeye, a tea processing factory located in Muruta, and the one located in Mabayi (MININTER, 2006).

2.3. Data and Methodology

2.3.1. Water Supply

The set up for this study was developed within seven communes of four provinces surrounding Kibira National Park in Burundi. The latter is of critical importance due to its location at the summit of the Congo-Nile Divide and its impact on these watersheds. It stretches across northwestern Burundi, joining with the Nyungwe Forest Reserve across the border in Rwanda. All the waters used by different sectors within the seven communes of the study area flow out from Kibira National Park. Previous studies show that three-quarters of surface water flowing throughout Burundi, has its origin in the Kibira Forest (Kigeme, 2011).

This study section aims to assess the water resources supply in seven communes surrounding Kibira National Park in Burundi. The study focuses on estimating the total amount of current water resources and as well as the future water available in the study area.

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Below is the water supply flowchart (Fig.3) which provides an overview of how this study dealt with the water supply system in the study area.

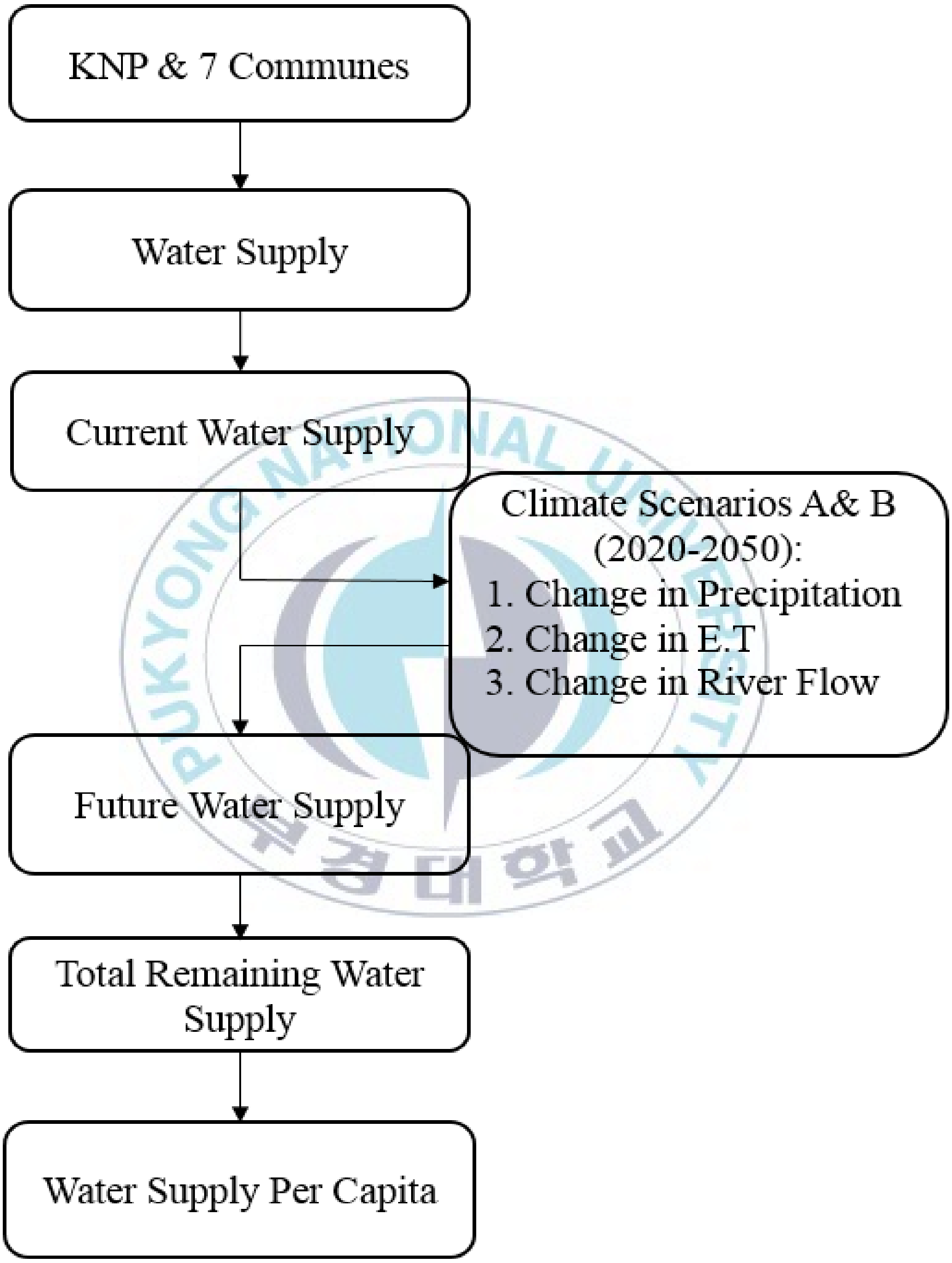

Fig. 3 Water Supply flowchart

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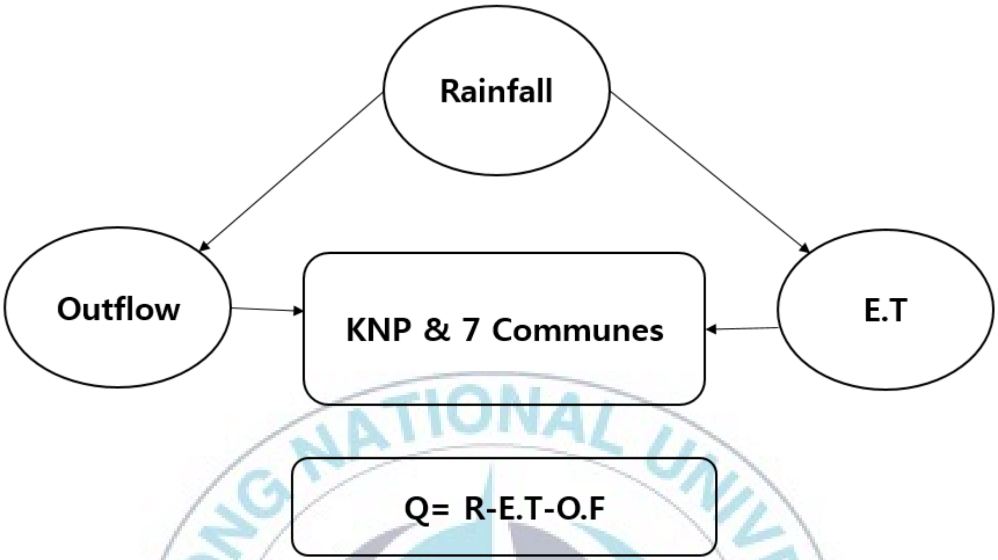
In order to achieve this objective, we analyzed and estimated the total available water resources in a year on KNP and surrounding communes, using the whole system as it appears below (Fig.4).



Q= Total water resources in a year; R=Rainfall; E.T= Evapotranspiration; O.F= Outflow

Fig. 4 Portraying the water assessment system in the study area

Total amount of rainfall in Kibira National Park and its surrounding seven communes were calculated using the land area of KNP and each commune and multiplied by the local precipitation rate. The Precipitation rate in KNP and surrounding communes ranges between 1,850 and 1,650mm/year (Kigeme, 2005).

The amounts of water which transpire in a year within the study area was estimated based on the land area of KNP and each commune and multiplied by the local evapotranspiration rate. To calculate the local evapotranspiration rate, the precipitation and evapotranspiration ratio by taking the national evapotranspiration rate times national precipitation rate times 100 (Table 2).

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Table 2 Precipitation and Evapotranspiration in Burundi

ET_N (mm/year)	PR_N[2] (mm/year)	ET_N/PR_N[3] %
872	1,274	68

[1] National Evapotranspiration Rate (mm/year), [2] National Precipitation Rate (mm/year)

[3] Precipitation and Evapotranspiration Ratio (%)

(World Bank, 2011)

Local evapotranspiration rate was estimated by taking the precipitation rate in KNP and each commune and multiplied by the national precipitation and evapotranspiration ratio (ET_N/PR_N) as mentioned in Table 2. Total amounts of evapotranspired water in a year were estimated using the local evapotranspiration rate times the land area of KNP and seven communes.

The total amounts of water outflowing in a year of 8 rivers flowing from KNP through the surrounding communes were estimated using the outflow rates provided by the previous studies in Table 3 (Geographic Institute of Burundi, 2012).

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Table 3 Precipitation, evapotranspiration, and river outflow in the study area

<table>
<tr><th>KNP & Communes</th><th>Precipitation (mm/year)</th><th>Evapotranspiration (mm/year)</th><th>River</th><th>Outflow (m^3/s)</th></tr>
<tr><td>KNP</td><td>1,850</td><td>1,266</td><td></td><td></td></tr>
<tr><td>Bukeye</td><td>1,650</td><td>1,129</td><td></td><td></td></tr>
<tr><td>Musigati</td><td>1,650</td><td>924</td><td>Mpanda</td><td>2.09</td></tr>
<tr><td>Muruta</td><td>1,350</td><td>1,129</td><td></td><td></td></tr>
<tr><td>Matongo</td><td>1,650</td><td>1,129</td><td>Ruvubu</td><td>1.06</td></tr>
<tr><td>Kabarore</td><td>1,650</td><td>1,129</td><td></td><td></td></tr>
<tr><td rowspan="3">Mabayi</td><td rowspan="3">1,350</td><td rowspan="3">924</td><td>Ruhwa</td><td>1.2;</td></tr>
<tr><td>Nyakabanda</td><td>2.16;</td></tr>
<tr><td>Nyamagana</td><td>1.03</td></tr>
<tr><td rowspan="3">Bukinanyana</td><td rowspan="3">1,650</td><td rowspan="3">1,129</td><td>Muhira</td><td>2.01</td></tr>
<tr><td>Kaburantwa</td><td>1.91</td></tr>
<tr><td>Kagunuzi</td><td>1.82</td></tr>
</table>

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Data about water resources availability were collected and projected changes in available water supply under climate scenarios up to 2050 were estimated using previous data set or suggested data in precipitation, evapotranspiration and river flow rates.

The scenarios (Table 4) we used for this study are from the climate projections for Burundi conducted during the first National communication on climate change (2001) using the MAGIC/SCENGEN model (2010-2050). Some data of scenario B were collected from the East African climate trends and projections (IPCC- Africa, 2007).

Table 4 Climate Change: IPCC Scenarios A&B.

Scenario A[a]	Scenario B[b]
1. Increase of 4.6% in Precipitation in 2020 Increase in 10.3% in Precipitation in 2050	1. Decrease of 50mm in Precipitation rate in 2020 Decrease of 100mm in Precipitation rate in 2050
2. Increase of 5% in E.T in 2020 Increase of 10.3% in E.T in 2050	2. Increase of 5% in ET in 2020 Increase of 10% in ET in 2050
3. Increase of 4.6% in Flow rate (2020) Increase of 10.3% in Flow rate (2050)	3. Decrease of 50mm in Flow rate in 2020 Decrease of 100mm in flow rate in 2050

[a] IPCC, 2007, [b] MLTE-NAPA, 2007

2.3.2. Water demand

The study also investigates the current and future water demand by different water users in the seven communes surrounding Kibira National Park. Therefore, the calculation and estimation of water supply per capita and water demand per capita, using the falkenmark indicator, will help us determine the water resources conditions in and around Kibira National Park.

We took households, livestock, agricultural production and industry as the key water users in the communes surrounding Kibira National Park. The study area is characterized by

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preponderantly rural population with a high population density. Households use big amount of water in their daily activities and there are several large scale of agricultural farmers who are mainly producing for the Burundi and regional market and who are using large amounts of water (FAO, 2007). Besides, livestock is a very important asset for the rural population, and it necessitates much of water for healthy livestock domestication in the region. In addition to that, there is a growing tea industry in the area with extending tea plantations which have increasing water needs.

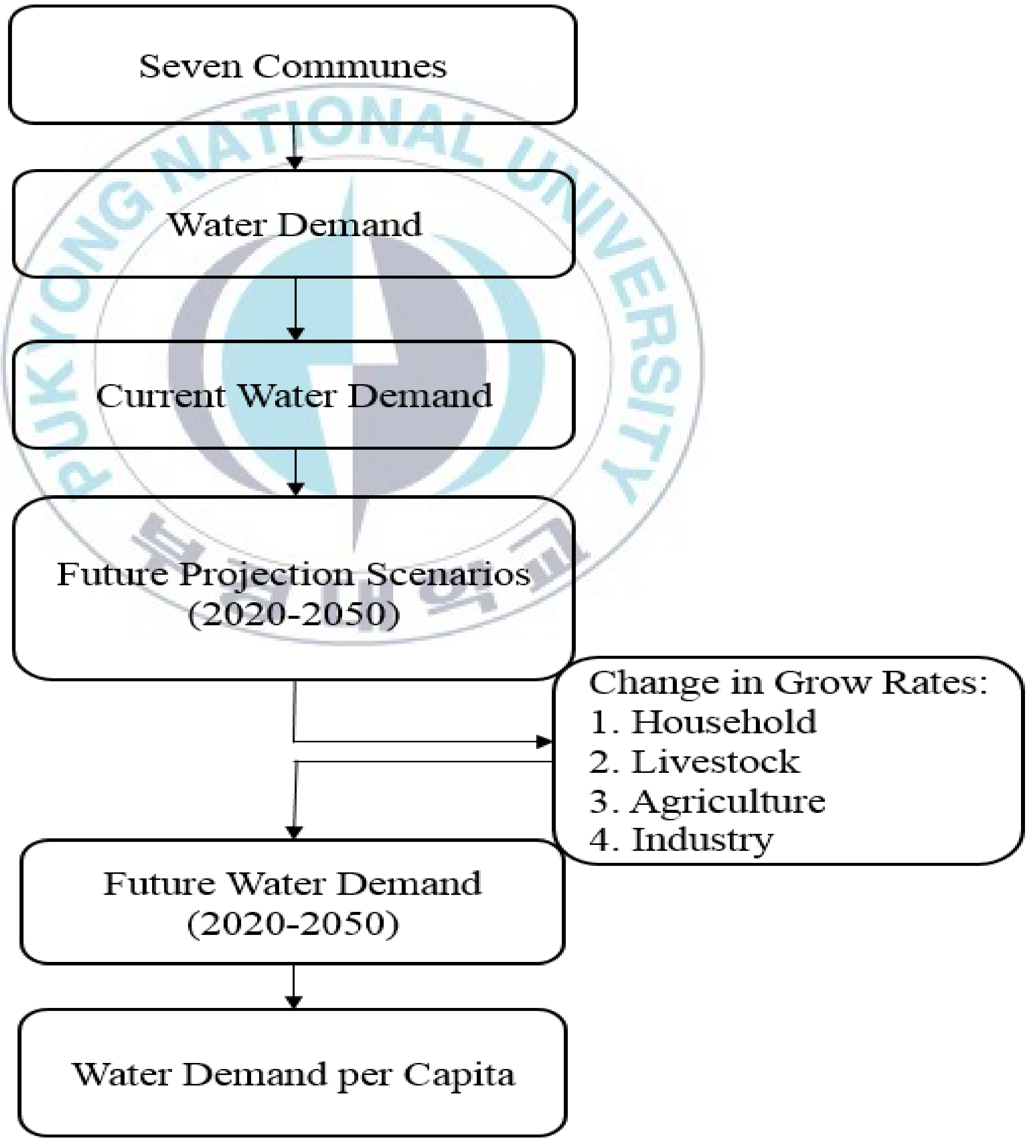

Fig. 5 Water demand flowchart

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This study section aims to analyze and assess the current and future water demand in seven communes surrounding Kibira National Park in Burundi. The study focuses on estimating the total amount of current and future water demanded by different water users in seven communes surrounding Kibira National Park. Fig.5 is an overview which summarizes the big picture of water demand section.

Data about water use sectors were collected and projected changes in population, livestock, agricultural and tea production were estimated using previous data set or suggested growth rates data provided (Table 5).

Table 5 Shows growth rates used in projection of water demand (2020-2050)

Communes	Population growth rate	Livestock growth rate	Agricultural growth rate	Tea Industry growth rate
Bukeye	1.31	2.9	0.198	0.9
Musigati	3.31	2.9	0.198	
Muruta	1.19	2.9	0.198	0.9
Matongo	1.19	2.9	0.198	
Kabarore	3.39	2.9	0.198	
Mabayi	3.96	2.9	0.198	0.9
Bukinanyana	3.96	2.9	0.198	

[MININTER, 2006; FA0, 2008 (FAO-East African Region); FAO, 2009 (FAO-Burundi)]

Water demand in 2020-2050 was projected based on data from projection of 2003-2010 conducted by the interior ministry (2006) in Burundi. We calculated the population growth rate in each commune based on the population projection of 2003-2010 (MININTER, 2006). Livestock growth rate in Burundi was suggested by FAO (2009). We calculated the growth rate of food crops grown in the study area based on the 2003-2010 agricultural projection and we projected the agricultural production to the horizons 2020-2050 using the same growth rate. We used 0.9% as black tea growth rate and this was suggested by FA0 (2008)

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for the East African Region. Based on the total amount of water supply per capita and the total amount of water demand per capita, we determined the water conditions in the study area by utilizing the Falkenmark indicator as we find it in the work of Marty (2011).

The Falkenmark Indicator is known as the most widely used measure of water stress. It is defined as the fraction of the total annual runoff available for human use. Based on the per capita usage, the water conditions in the study area has been categorized as: no stress, stress, scarcity, and absolute scarcity (Table 6). The index thresholds 1,700m3 and 1000m3 per capita per year are used as the thresholds between water stressed and scarce areas, respectively.

Table 6 Water barrier differentiation proposed by Falkenmark

Index (m3 per Capita)	Category/ Condition
> 1,700	No Stress
1000-1,700	Stress
500-1000	Scarcity
< 500	Absolute Scarcity

(Marty, 2011)

Individual usage is the basis for the Falkenmark water stress index and therefore provides a way of distinguishing between climate and human-induced water scarcity. Thus, we used this indicator to estimate the water condition in the 7 communes surrounding Kibira National Park. Microsoft Excel has, therefore, been used as the main tool for different calculations and estimations.

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III. Results and Discussion.

3. 1. Water Supply at KNP and surrounding Communes

3.1.1. Current Water Resources: Overall Water Resources available in 2005

The total amount of available water in the Kibira national Park and within its seven surrounding communes (Table 7) was estimated at about 645,577,965 m3/year. Kibira National Park accounts 36% of the whole amount of water resources present in the study and that is about 233,500,785 m3/year. The 7 communes account for 412,077,180 m3/year. Bukinanyana with minus -1,480,040 m3/year.

Table 7 Total Available Water Supply at KNP & the surrounding communes

Provinces	KNP & 7 communes	Total Available Water (m3/year)
-	KNP	233,500,785
Muramvya	Bukeye	95,864,000
Bubanza	Musigati	87,169,980
Kayanza	Muruta	62,656,080
Kayanza	Matongo	53,995,640
Kayanza	Kabarore	104,262,520
Cibitoke	Mabayi	9,609,000
Cibitoke	Bukinanyana	- 1,480,040
Total	KNP & 7 Communes	645,577,965

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The Fig. 6 shows the total water resources available at Kibira National Park and the seven surrounding communes with Bukinanyana showing minus (-1,480,040 m3/year).

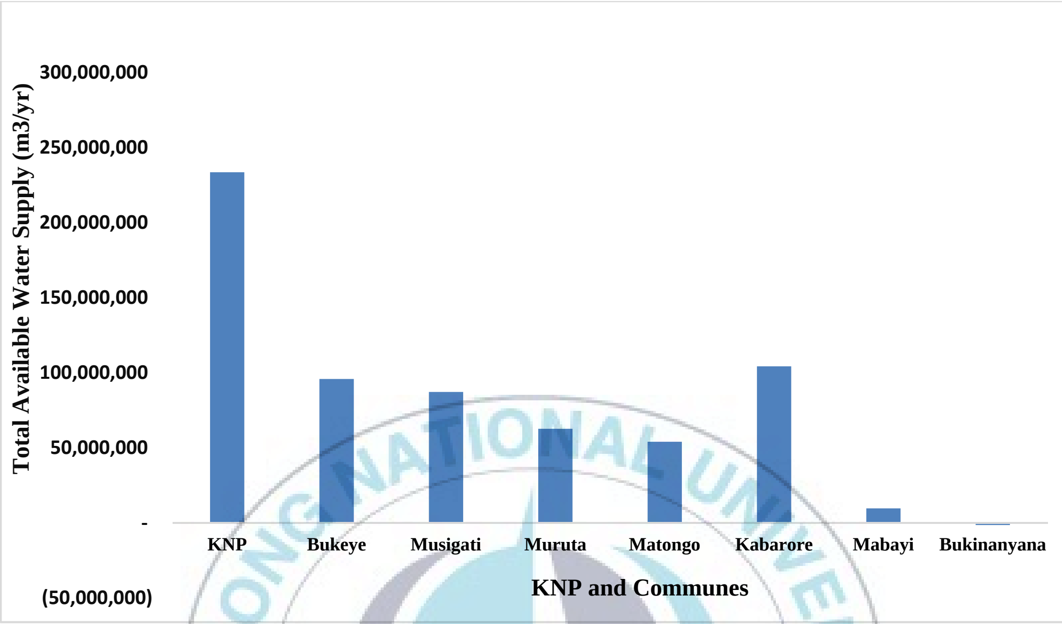

Fig. 6 Total Available Water Supply at KNP and surrounding Communes.

The Fig. 7 shows the availability of water resources within the system in terms of percentage. Kibira National Park on its own has 36% of the total water resources present in the study area. Bukeye Commune is endowed of 15%, Musigati has 13%, Muruta has 10%, Matongo 8%, Kabarore 16%, Mabayi 2% and Bukinanyana having minus and therefore about 0%. Kibira National Park is therefore the main water body to support and sustain the surrounding communes in times of er crisis.

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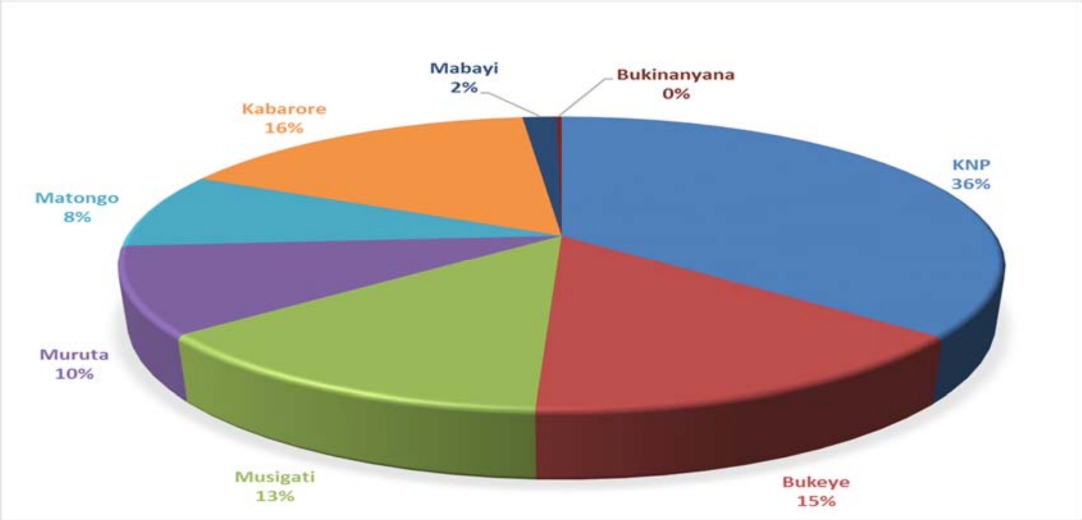

Fig. 7 Total Available Water Supply (%)

3.1.2. Overall future water resources under climate change (2020-2050)

The water resources at Kibira National Park and surrounding communes are fluctuating due to the effects of climate change. In 2050 under scenario B, the water was diminished to 38,974,522 m3/year comparing with the 2005 water available resources (645,577,965 m3/year) (Table 8; Fig.8).

Table 8 Water Supply under climate scenarios (2020-2050)

Year and Scenarios	Water Resources (m3/year)
2005	645,577,965
2020-Scenario A	674,830,436
2020-Scenario B	625,873,006
2050-Scenario A	711,594,339
2050-Scenario B	606,603,443

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The Fig. 8 shows clearly the water fluctuation going on in the future water resources availability due to different factors notably the changing climate system. In 2020 and 2050 under scenario A, water supply was relatively not affected by climate change, 2050 under scenario B, Water Supply was increased enough comparing with the water supply in 2005. The water problem was obvious in 2020 and 2050 under scenario B, where the results show a huge decrease in water supply due to climate change factors.

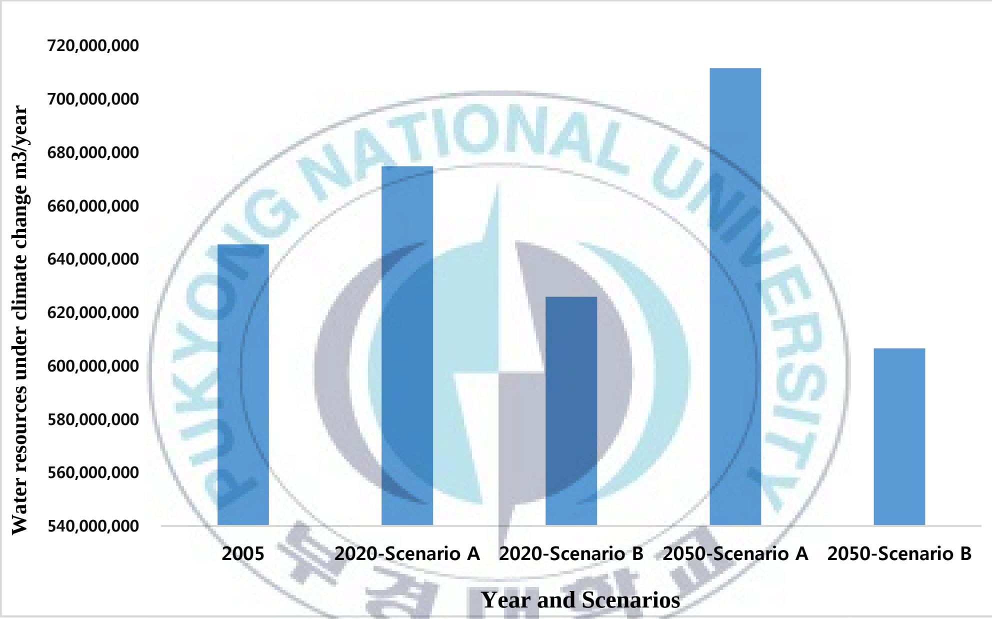

Fig. 8 Overall future water resources under climate scenarios

3. 1.3. Future water resources in each commune under climate scenarios (2020)

The total available water supply in 2020 under scenario A was estimated at 674,830,436 m3/year. The increase in water supply was shown comparing with 645,577,965 m3/Year in 2005 (Fig.9).

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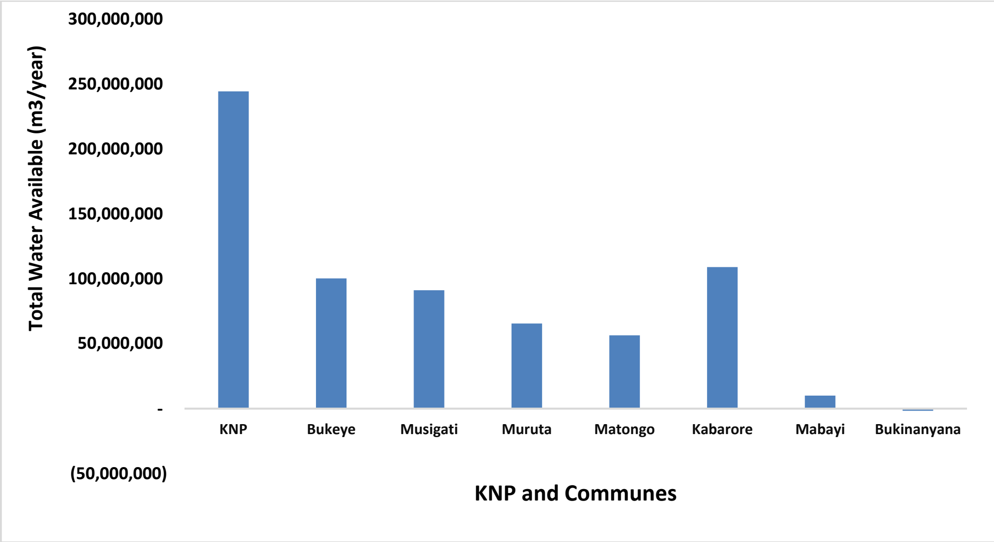

Fig. 9 Future Water Supply in each Commune in 2020 under scenarios A

The total available water supply was estimated in 2020 under scenario B at about 625,873,006 m3/year. The increase in water supply was shown comparing to available amount of water in 2005 (Fig.10).

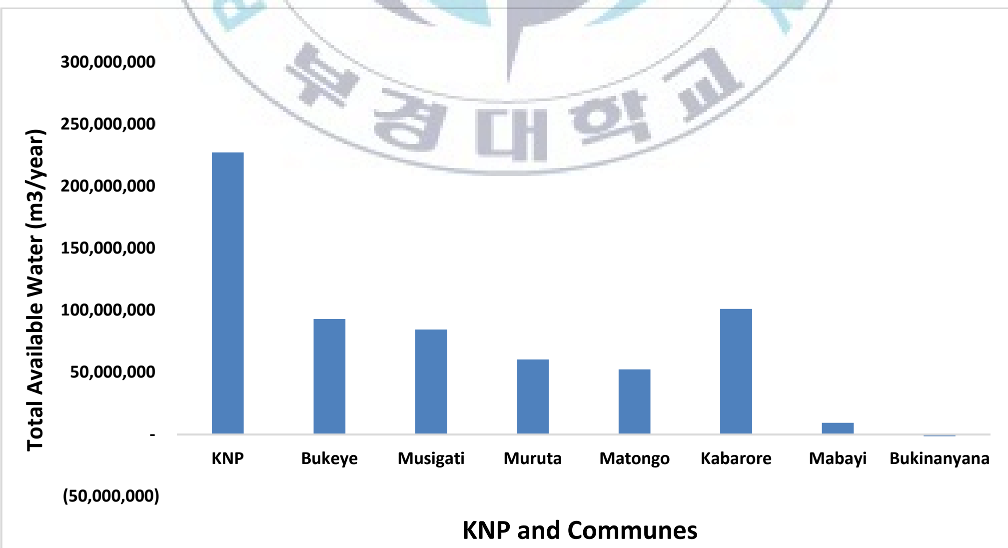

Fig. 10 Future water supply in 2050 under Scenario B

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3.1.4. Future water resources in each commune under climate scenario (2050)

The total available water supply was estimated in 2050 under scenario A at about 711,594,339 m3/year. A spectacular increase in water supply availability was shown in comparison with the amounts of water resources available in 2005 (Fig.11).

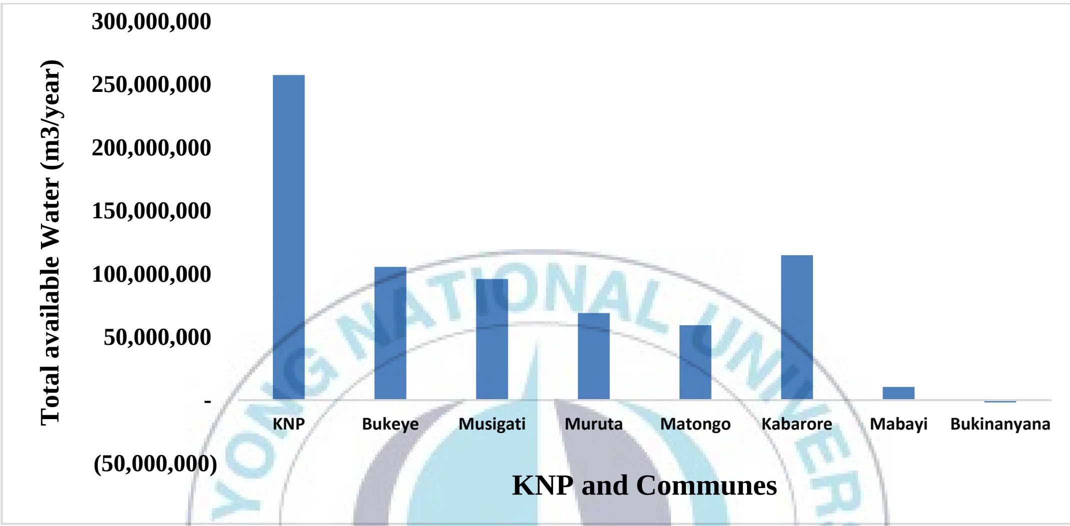

Fig. 11 Future water supply in 2050 under Scenario A.

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The total available water supply was estimated in 2050 under scenario B (Fig.12) at about 606,603,443 m3/year. The results show the huge decrease in water resources available in the study area. Fig.12 shows the great importance of Kibira National Park as the main water supplier to the surrounding communes in 2050 under scenario B. This shows that the seven communes surrounding Kibira National Park cannot survive alone without this protected area. KNP should therefore be taken care by both public administration and local people in order to preserve this water reserve and look forward to alleviating the changing climate factors.

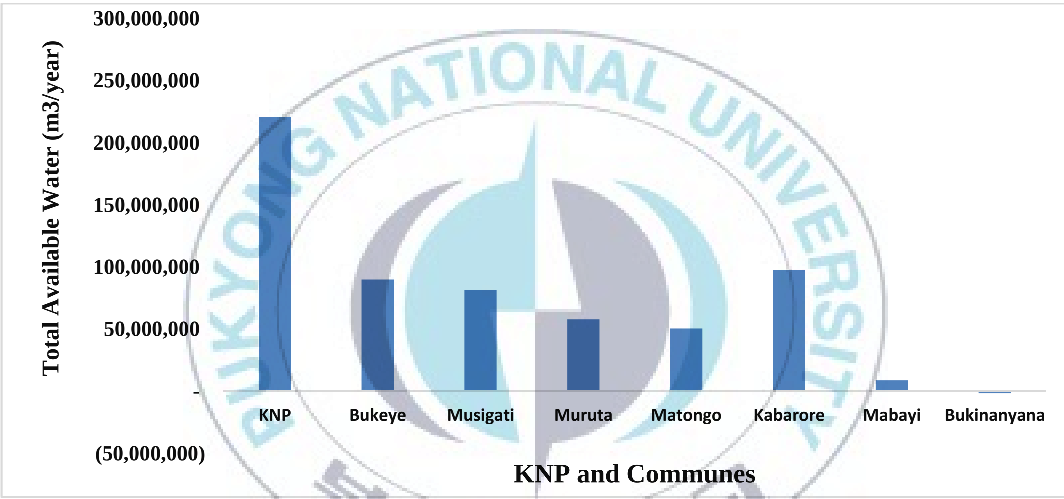

Fig. 12 Future water demand in 2050 under scenario B.

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3.2. Current Water Demand

3.2.1. Overall Current Water Demand in the study area in 2005

We considered Household, livestock, agriculture and industry as water users in the study area. Musigati is currently shown as the most water demanding commune. Agriculture is shown as the one demanding more water than any other sector. In Muruta, Industry demands the highest amount of water (Table 9).

Table 9 Overall current water demand (2005)

Communes	Households (m3/year)	Livestock (m3/year)	Agriculture (m3/year)	Industry (m3/year)
Bukeye	461,615.500	139,298.235	49,498,921.000	17,688,930.000
Musigati	669,497.600	125,236.245	123,745,253.000	-
Muruta	374,008.200	64,571.530	4,849,094.000	21,173,530.000
Matongo	461,418.400	194,570.076	7,977,494.000	
Kabarore	367,664.500	141,628.249	11,340,283.000	
Mabayi	508,328.200	115,534.290	36,722,553.000	7,262,640.000
Bukinanyana	603,425.300	69,127.569	46,402,354.000	
7 Communes	3,445,957.700	849,966.193	280,535,952.000	46,125,100.000

The results show (Fig.13) that Agriculture is overall demanding the highest amount of water at current state. Musigati commune is taking the lead in terms of water consumption in agricultural production, together with Bukeye and Bukinanyana communes. Matong and Kabarore are showns as less water demanding in agricultural production due to their small land areas.

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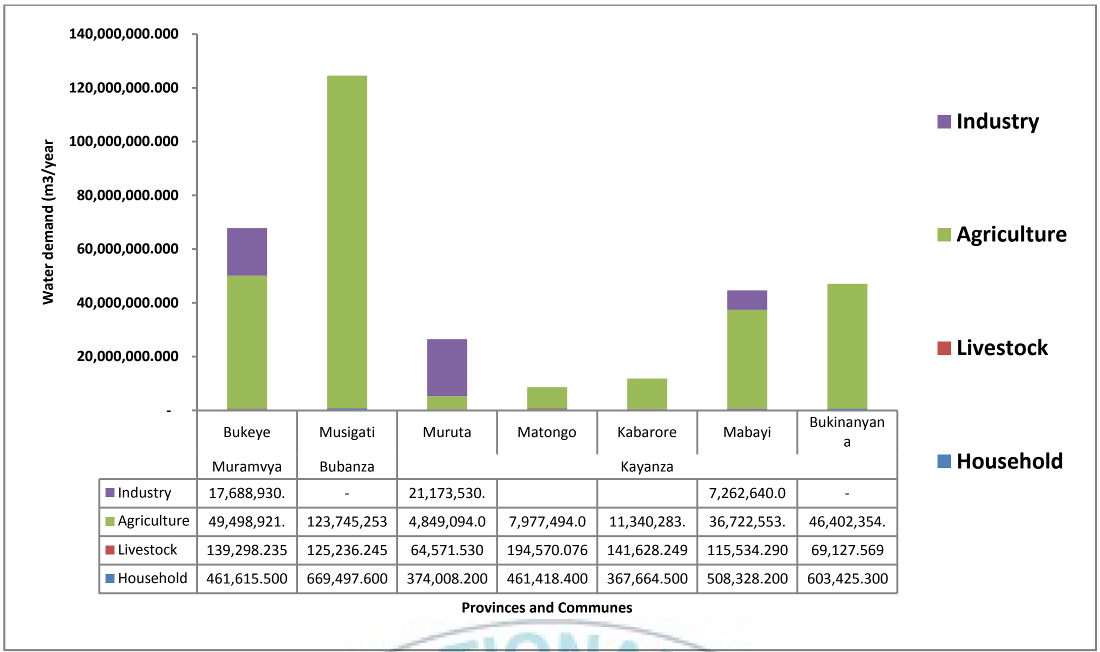

Fig. 13 Overall Current water demand in 2005

3.2.2. Current Water Demand by households in 7 communes (2005)

According to FAO (2007), water required for one person in Burundi is 20 liters per day. Total water demanded by household was estimated at about 3,445,958 m3/year. Musigati and Bukinanyana are shown (Table 10 and Fig. 14) as the most water demanding communes in the study area.

Table 10 Current Water Demand by households in 2005

Communes	Population	Total water (m3/year)
Bukeye	63,235	461,616
Musigati	91,712	669,498
Muruta	51,234	374,008
Matongo	63,208	461,418
Kabarore	50,365	367,665
Mabayi	69,634	508,328
Bukinanyana	82,661	603,425
Total	472,049	3,445,958

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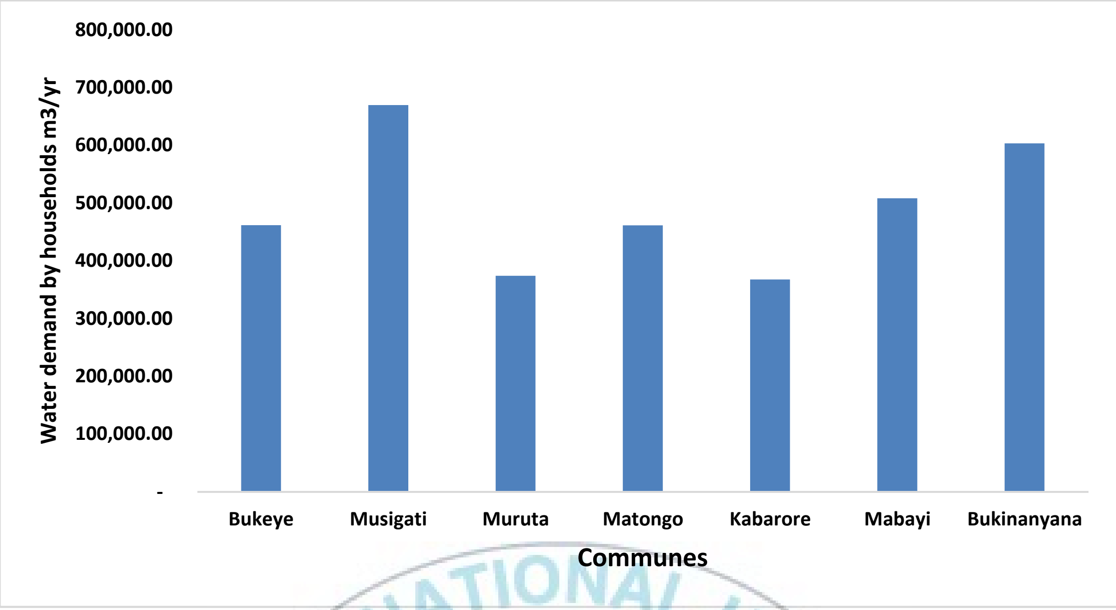

Fig. 14 Current Water Demand by household in 2005

The results show that the more the population increases, the more amount of water demand. Musigati with 91,712 as the size of the population observed 669,498 m3/year of water demand while Bukinanyana having 82,661 as the size of the population, has performed 603,425 m3/year of water demand.

In terms of water demand by household, the size of the population matters. Therefore, in order to control or to manage well water resources available in any given area, family planning system is to be implemented at first place and regularly controlled to be able to minimize the water use speed.

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3. 2. 3. Current Water demand by livestock (2005)

Goats are shown as the most water demanding livestock (80%). Poultry, the least water demanding livestock in the study area (0%). Matongo shown as the highest water demanding in terms of livestock. The results show that the goats are the most water demanding in the seven communes, accounting about 80% of the total water demanded by the livestock.

The Results show the water demand (2005) in terms of percentages of livestock such as Beef Catte (12%), Sheep (2%), Goats (80%), Pig (6%), and Poultry (0%).

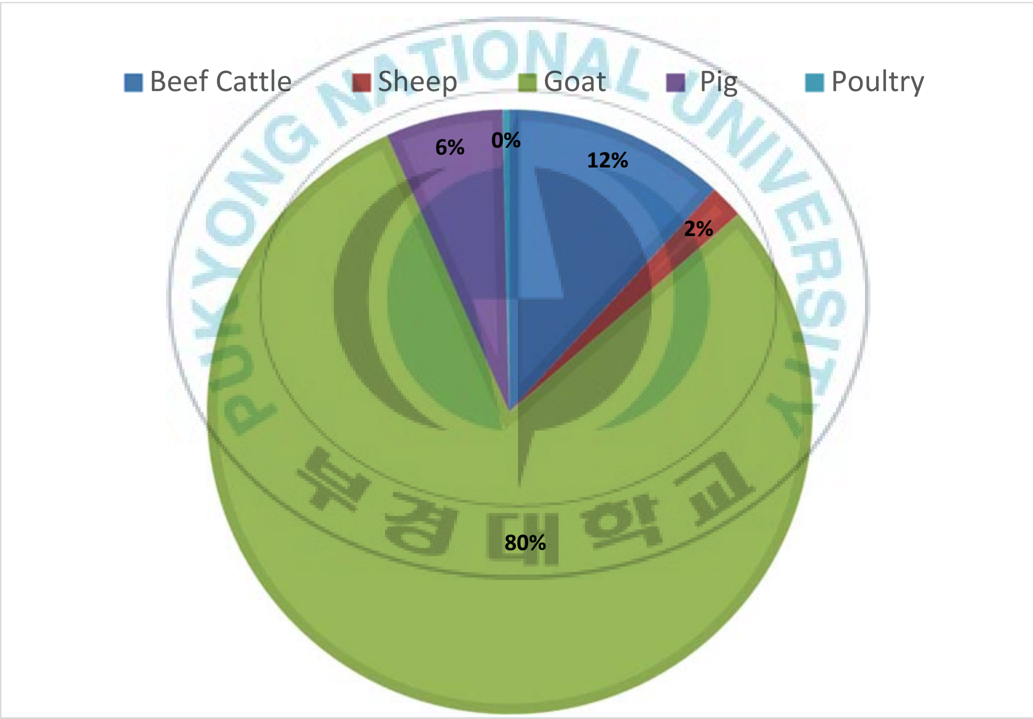

Fig. 15 Current Water demand by livestock in 2005

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3.2. 4. Current Water demand by agricultural production (2005)

The total amount of current water demanded by agriculture was estimated at about 284,951,383 m3/year. Musigati being the most water demanding commune with 123,745,253 m3/year.

The results show Banana as the most water demanding food crop in the study area accounting about 65% of the total water demanded by agricultural production. Bean being the second water demanding with 23%. Fig.16 shows the water demand in terms of percentages of different food crops grown in the study area such as Banana (65%), Bean (23%), Maze (2%), Sweet Potato (5%), Potato (5%), and Rice (0%).

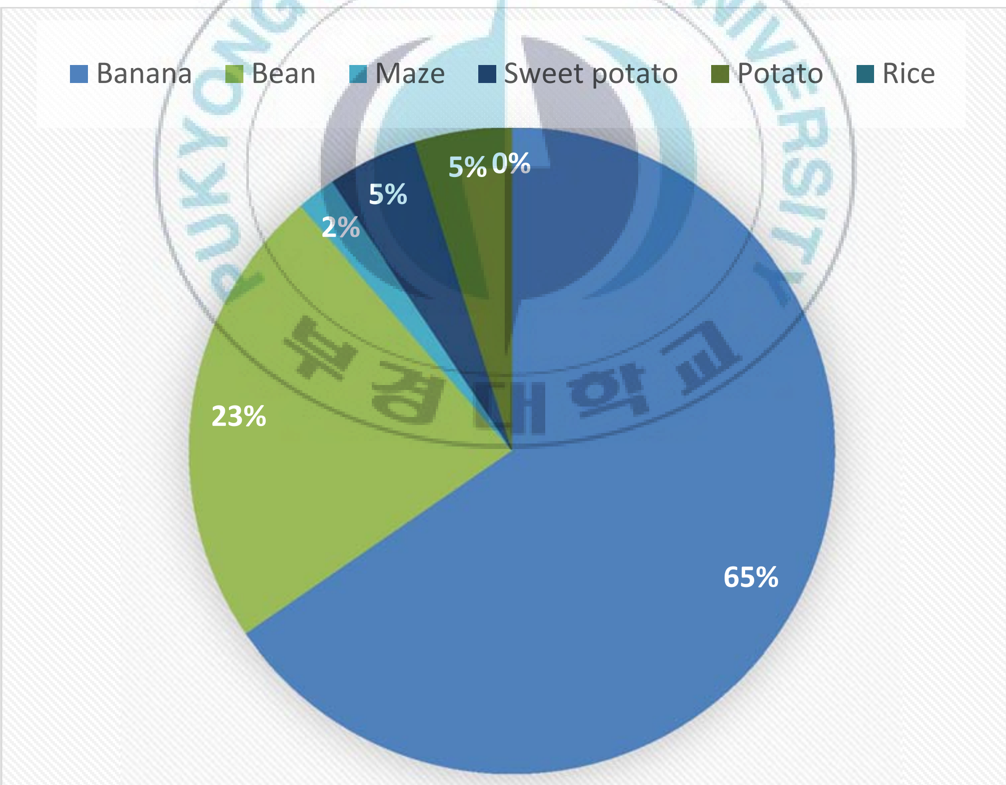

Fig. 16 Current water demand by agriculture in 2005 (%)

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3.2. 5. Current Water demand by industrial production (2005)

With 9170 m3 of water demanded by one hectare in a year (Chapagain, et al., 2007) and with the plantation areas within the three tea growing communes, the results show that the total amounts of water demand by the tea industry is about 46,125,100 m3/year.

The Table 11, Fig.17 and Fig. 18 show Muruta as the highest water demanding commune with 21,173,530 m3/year and which is about 46%. Bukeye appears to be the second water demanding commune with 17,688,930 m3/year and which has about 38%. Mabayi was shown as the least water demanding commune with only 7,262,640 m3/year and has only about 17% of the total water demand by tea industry in three tea growing communes.

Table 11 Current water demand by tea complex factories in the tea growing communes

Commune	Plantation Area (Ha)	Water Demand m3/ha)	Total Water Demand (m3/year)
Bukeye	1,929		17,688,930
Muruta	2,309	9170	21,173,530
Mabayi	792		7,262,640
Total	5,030		46,125,100

(Burundi Tea Board, 2006)

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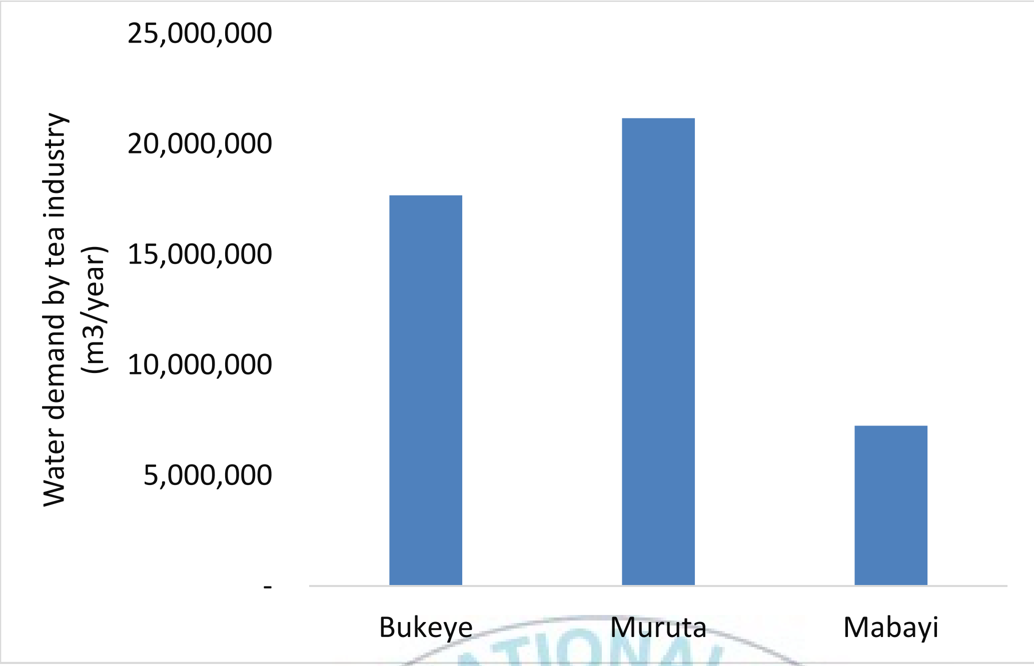

Fig. 17 Current Water demand by Industry (2005)

Among the total amount of water demanded by industry in the study, the results show that Muruta demanded 46%, Bukeye 38% and Mabayi 16%.

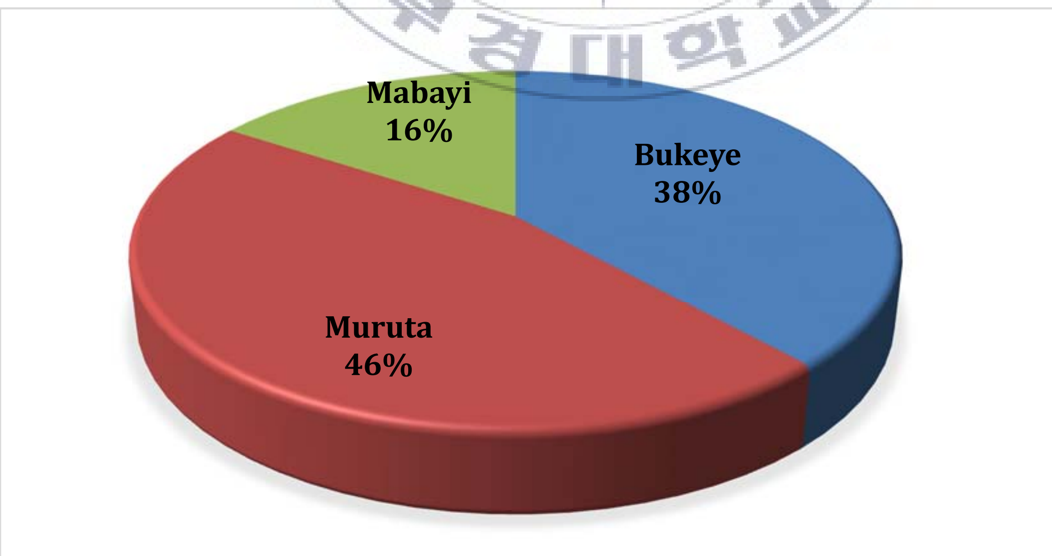

Fig. 18 Current Water demand by Industry in terms of % (2005)

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3.3. Future Water Demand

3.3.1. Future Water Demand in seven communes (2020)

The results show a spectacular increase in future water demand as increase the population, livestock, food and industrial production in 2020. The results show Musigati being the highest water demanding commune. Agriculture was shown as the most future water demanding with more than 80%. The livestock is depicted as demanding less future water amounts (Table 12, Fig.19).

Table 12 Future water demand in 2020

Communes	Total Water Demand (m3/year)
Bukeye	71817503.09
Musigati	128790387.7
Muruta	29532124.09
Matongo	8791680.176
Kabarore	12458258.47
Mabayi	47164455.14
Bukinanyana	48969362.67
Total	347,523,771

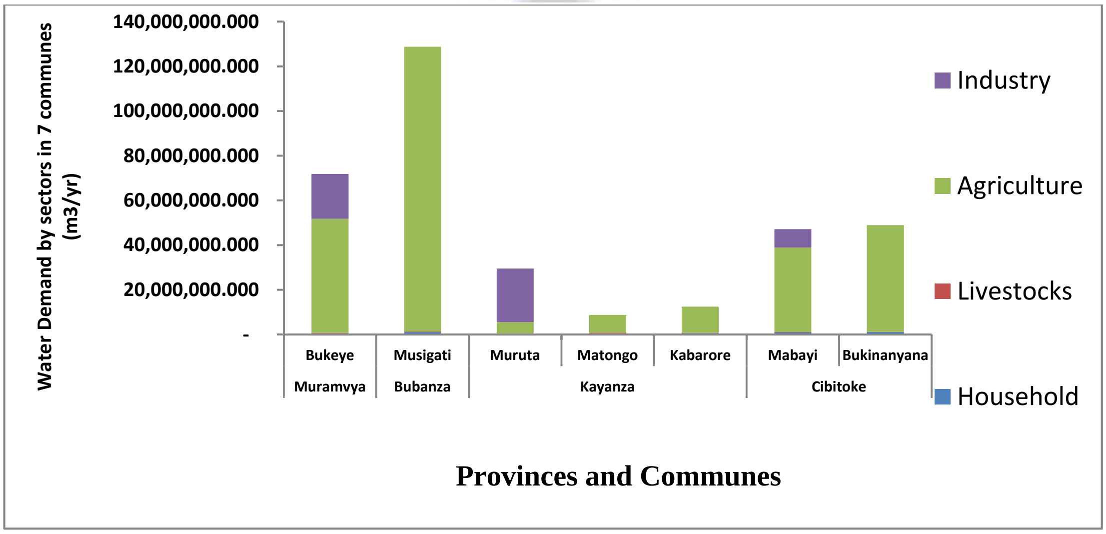

Fig. 19 Future Water Demand in seven communes (2020)

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Fig.20 shows the total water demand by different water sectors in seven communes around 2020 in terms of percentage, such as Household with 15%, Livestock with 0%, Agriculture with 83%, and Industry with 2%.

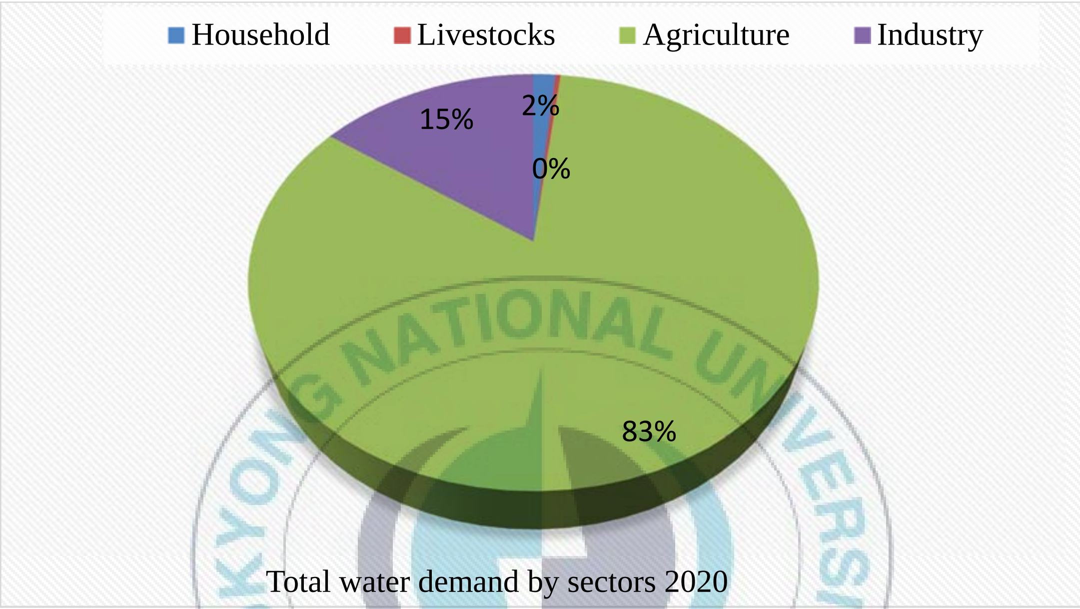

Fig. 20 Future water demand in seven communes (2020) in %

3.3.2. Future Water Demand in seven communes (2050)

The results show an overall increase in future water demand in all water sectors. Agricultural production keeps its pace in being the most future water demanding sector in 2050 accounting more than 80%. Musigati commune was shown as demanding the highest future amounts of water (Table 13, Fig.21 and Fig 22).

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Table 13 Future water demand in 2050

Communes	Total Water Demand (m3/year)
Bukeye	81359295.35
Musigati	138313499.4
Muruta	37413718.17
Matongo	9054400.998
Kabarore	14199790.96
Mabayi	53961592.81
Bukinanyana	54268550.2
7 communes	388570847.9

Fig. 21 Future Water Demand in 2050

Fig. 22 shows the future water demand in 2050 by seven communes in terms of percentage. The results show Bukeye (21%), Musigati (35%), Muruta (10%), Matongo (2%), Kabarore (4%), Mabayi (14%) and Bukinanyana (14%).

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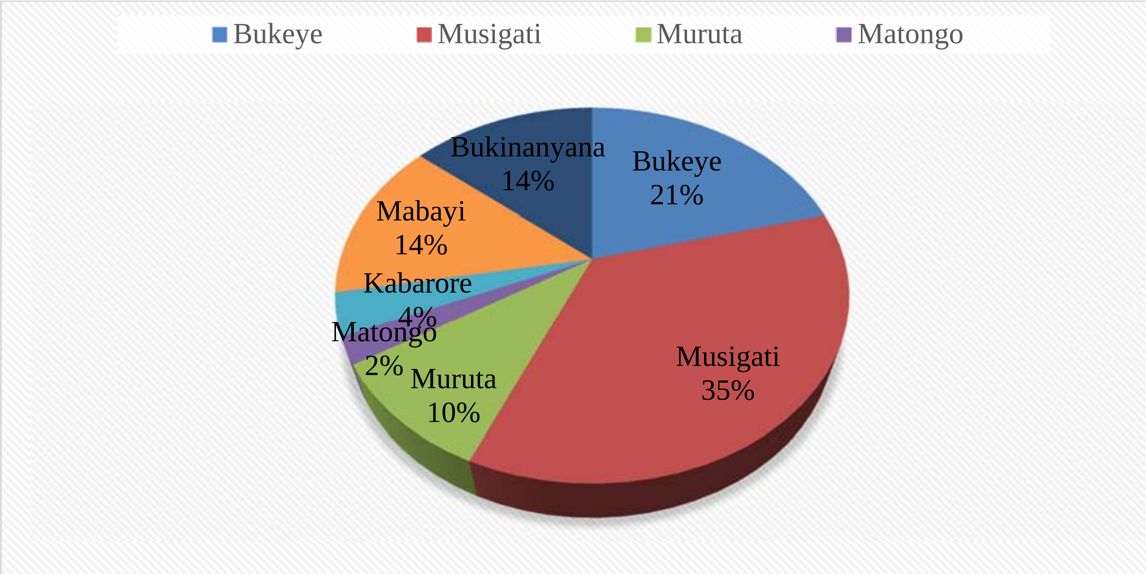

Fig. 22 Future Water Demand in 2050 (%)

3. 3. 3. Overall Future Water Demand in seven communes (2020-2050)

The overall future water demand shows that the agricultural sector will be demanding the major available amounts of water in the seven communes surrounding Kibira National Park. The future water demand is increasingly alarming as the population, livestock, food production and industry continue to grow at a runaway rate (Fig 23).

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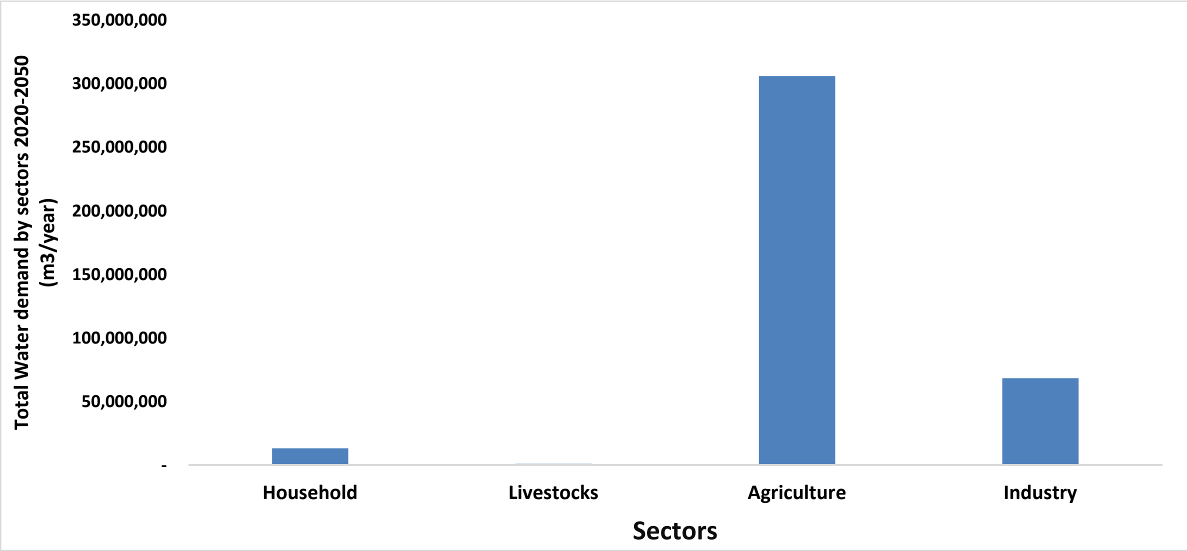

Fig. 23 Overall future water demand (2020-2050)

Fig. 24 shows an overall future water demand in 2020 and 2050 in terms of percentage such as household (3%), Livestock (0%), Agriculture (79%), and Industry 18%.

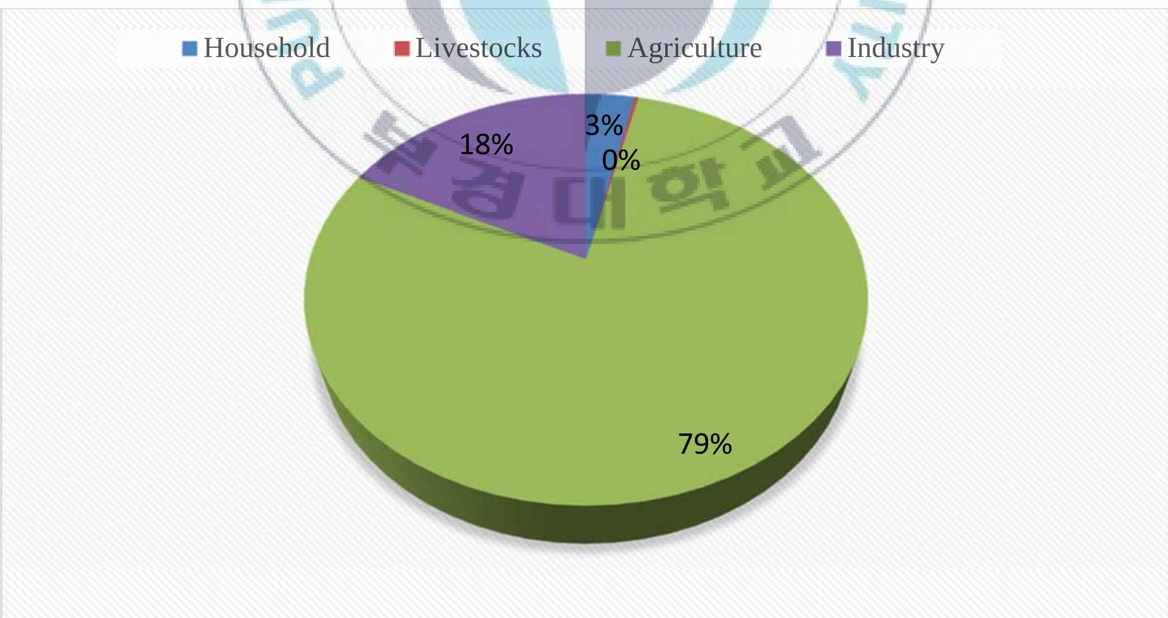

Fig. 24 Overall Future Water Demand (2020-2050) in terms of %

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3. 4. Water Conditions: The Falkenmark Indicator

3.4.1. Overall Water Supply and Water Demand per Capita

By applying the Falkenmark indictor to this study, the results show the overall conditions of water in the seven communes surrounding Kibira National Park. In 2005, the results demonstrate that water within seven communes will show an indication towards water stress.

In 2020 under scenario A, the results demonstrate that the water condition will show water scarcity in all seven communes. In 2020 under scenario B, the results display Water scarcity as water condition in all seven communes. In 2050 under scenario A, the results display water scarcity as water condition within seven communes. In 2050 under scenario B, the results also display Water scarcity as the water condition in the region (Table 14 and Fig.25).

Table 14 Water Supply and demand per capita under Water Scenarios (A&B)

Scenarios	Supply per Capita	Demand per capita
2005	1367	701
2020-Scenario A	938	483
2020-Scenario B	870	483
2050-Scenario A	394	215
2050-Scenario B	335	215

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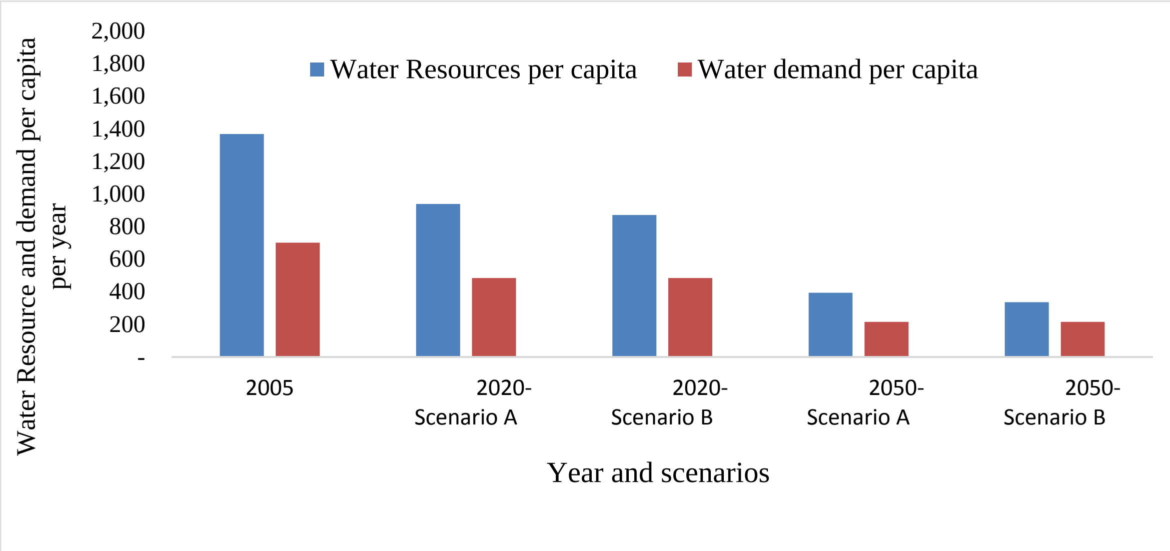

Fig. 25 Water Supply per Capita and Water Demand per capita under Water Scenarios (A& B)

Looking at the results of this study, the water resources appear to be the greatest challenges for the overall development of the communities surrounding Kibira National Park. The current water resources may not be enough and therefore may not be able to meet the needs of those seven communities around KNP. The future water demand is increasingly alarming as the population continue to grow at a runaway rate.

According to studies conducted on Kibira national Park, the rise of temperature is expected to cause an increase in evaporation and evapotranspiration. Increased in precipitations is expected to cause erosion on the hills and floods in low lands. On the agricultural level, rainy erosion might cause arable land losses due to floods, especially for the period of long rainy seasons. (NAPA, 2011).

The results showed clearly that water resources are the limiting and restricting factor for any kind of growth especially in the sectors that we have investigated in this study. The communities should have accurate information and knowledge to oversee the water changes and this study maybe of the great tool to face at any cost the current and future water challenges.

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IV. Conclusion

Households, livestock, agricultural production and industry are key factors in any human environment. These sectors cannot survive without demanding water resources. For the rural areas such as the seven communities living around Kibira National Park would need much more from food crops and livestock. Human health issues are always linked to water. Livestock are valued assets for the rural and poor communities and marketing of livestock products is a practical and effective pathway out of poverty (Lucas, 2010). The industry, especially specializing in agricultural manufacturing system is also a huge asset for the rural and low income people. However, some measures to select the priorities in the way towards efficiently managing the water resources should be put into place.

The study showed that the livestock sector is the one demanding very less amount of water for the domesticated animal species to produce healthy. Looking at the outcome, one would recommend the communities around Kibira National Park to improve and upgrade the domestication of animal species and livestock production in general. In the agricultural sector which obviously takes most of the current and future available water, as it keeps booming, most efficient practice may be to decrease irrigation of feeds grown in areas where rainfall is too low to avoid freshwater depletion, at least during certain periods of the year.

The results from this study may play as back up to help the seven communes surrounding Kibira National Park to know the water challenges ahead of them. I would love to recommend researchers to investigate more deeply this topic and especially conduct it on those remote and rural areas where the information and knowledge about current and future water demand status are still undefined.

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