"ASSESSMENT OF THE INTEGRATED DEVELOPMENT AND MANAGEMENT OF WATER RESOURCES FOR PRODUCTIVE AND EQUITABLE USE IN THE NYABUGOGO WETLAND"

By

Reg. N°. 102000814

Under guidance of

Dr.Christian SEKOMO BIRAME

And

Dr.Omar MUNYANEZA

Submitted to the Department of Civil Engineering in the School of Engineering

In partial fulfillment of requirement

For the award of the degree of

Master of Science in

Water Resources and Environmental Management

UNIVERSITY OF RWANDA

COLLEGE OF SCIENCE AND TECHNOLOGY

SCHOOL OF ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING

HUYE CAMPUS

SEPTEMBER, 2013

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September, 2013

BONAFIDE CERTIFICATE

Certified that this research report entitled "**ASSESSMENT OF THE INTEGRATED DEVELOPMENT AND MANAGEMENT OF WATER RESOURCES FOR PRODUCTIVE AND EQUITABLE USE IN THE NYABUGOGO WETLAND**" is the bonafide work of **Mr. Joseph KAGABO** who carried out the research under my supervision. Certified further, that to the best of my knowledge the work reported herein does not form part of any other research report or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

Signature of the Supervisor

Dr. Christian BIRAME SEKOMO.

Submission of the Corrected Version of the Thesis, at University of Rwanda, Huye campus, university Avenue, Rwanda

DEDICATIONS

To my late father and Mother who died without seeing this great achievement,

To My spouse, son, aunts, uncles, brothers and cousins who helped me in one way or the other for the accomplishment of this work.

To the Almighty God

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ABSTRACT

Rwanda is rapidly developing after the 1994 genocide. This development is highly concentrated in the Nyabugogo catchment where Kigali City is located. Water resources planning and management is an important component of development processes and therefore its integrated management is required to assure effective long term development as regards to social and economic development; however there is limited knowledge in assessment of the Integrated Development and Management of Water Resources for Productive and Equitable Use in the Nyabugogo wetland.

The main objective of this study was to assess the alternative means for increasing productivity of water, through better management of multiple water uses in the Nyabugogo catchment. Precipitation, evaporation data were obtained from Meteorological office in Kigali, Flow/ discharge used were computed and were obtained from integrated water resources management department of Rwanda natural resources authority and run –off data estimates were computed and used and a delineated map using ArcGIS was used to calculate the wetland area.The percentage of land use in the catchment is distributed as follows: agriculture 88.65%, forest 3.99%, urban area 1.93%, wetland 3.39%, and Lake 2.04%and this is almost the same in the wetland area of the studya digitized land use map and hydrological soil group classification of the catchment were used to estimate the runoff coefficient of nyabugogo wetland.

Storage capacities, increased water losses from increased evaporation, increased surface run-off were found to be the dominant features of the wetland.

Key words, integrated development, equitable and productive use, land use, wetland .ArcGIS

1.0. INTRODUCTION

1.1. BACKGROUND

The wetlands in Rwanda cover a total area of 165,000 hectares, which is about 7 percent of the total surface area (26,338 Km2). They provide an important function of water treatment and purification and serve as sources of water for the lakes and connecting rivers in the country. Many rivers flow throughout the year because wetlands, just like the rain forests, gradually release their stored water. Wetlands are, therefore, important in maintaining perennial rivers and streams. They also enable the movement of large volumes of water into the underground aquifers, thereby recharging the water table.

The Nyabugogo natural wetland is located in Kigali, the capital of Rwanda, It has a surface area of 60.09haaccording to CGIS (Centre of Geographic Information Systems),Butare, Rwanda) (Sekomo et al.; 2011).Water resources are one of the greatest gifts of nature and it is our fundamental responsibility to properly utilize and manage them.as the population increases and urbanization spreads, the prime objective of water resource management has to be to maximize the use of available water resources, from various sources, while at the same time taking due care of the environmental, ecological and socio-economic aspects, and their interrelationshipsin a holistic manner.

Development of our water resources is causing an adverse irreversible impact on conservation of river systems and is a major cause for concern with regard to the sustainability of projects. Until now, water resource projects were targeted at meeting the water requirements of existing agricultural production centers. Our contemporary scenario, coupled with future needs, mark an important departure from the current need-based planning, to growth-based planning. Sustainability of the entire river basinfrom its origin to the deltawill be of prime importance in any developmental project.

However, the management of the extensive water resources is currently undertaken by individual states,following political rather than geographical boundaries.Individual river basins, by their very nature, fall withinthe jurisdiction of several state authorities, leading, inevitably, to conflicts in all aspects of water management including storage, distribution, equitable supply, multipurpose use, pollution, ecological aspects, planning forfuture needs.

The water resources of Rwanda face growing challenges arising from pressures of rapidly changing demographic patterns, the demands of intensified socio-economic development, degradation resulting from unsustainable and inappropriate land use practicesand the uncertainties created by climate change, among others. At the same time, the water resources are relied upon to meet many conflicting demands and play its full role in facilitating the achievement of the country's 2020 vision goal. Meeting the above challenges requires a sound policy and legal framework supported by robust institutions that are adequately resourced and staffed by technically competent personnel andthereforeequal to the task of managing a water resources sub-sector.

The daily management of national and regional water resources requires aclear understanding water allocation and sharing principles. Water resources are limited but, water users are ever growing and mostly with conflicting interests. There is a need of an Integrated Management of water resources based on an Integrated and comprehensive planningthat has taken into consideration the present and future possible water users.

Generally water resources have a direct influence on the quality of life of the people, their health and their overall productivity. Thuswater is essential, not only to human life but for animals, agriculture, industrial development,hydropower generation, transport, socio-economic development and poverty eradication (REMA, 2009).However, water has always been a rare commodity in Africa, whose rapidly growing population is now closing on the 800 million mark. At least five African countries namelyKenya, Morocco, Rwanda, Somalia and South Africa are expected to face water scarcity within the next 10 years, (U.N. Population Fund, 2009).

The rapid population growth is increasing the water demand for domestic, agricultural, and industrial uses and is causing water scarcity in Rwanda. There is also an increasing pressure on all natural resources including water (Munyaneza, 2008). Rwanda is struggling to attain Vision 2020 prospects, and water is an essential asset towards achieving this goal especially in ecotourism and agricultural sustainability.

1.1. PROBLEM STATEMENT

The problem of wetland managements has become increasingly important in many parts of theworld and Rwanda is not an exception. Among many anthropogenic activities, agricultural activities have been reported to contribute to degradation of water quality within the wetland. (Daniel et al.;2000).Rwanda as a country is facing a number of serious challenges related to water resources management. These challenges are concentrated in the Nyabugogo catchment where Kigali city is located. This catchment includes also some other districts like Gatsibo, Kayonza and Rwamagana in the Eastern Province; Gicumbi and Rulindo in the Northern Province. The catchment is subdivided into two zones, the urban and rural areas where the Nyabugogo wetland is located.

A number of these challenges are as a result of factors both within and outside the water sector. Climate variability and increasing demand for water as a result of development and population pressure are factors that the sector may not be able to control but can initiate mitigation measures to ensure sustainable water resource development.

At present the country is facing some socio-economic hardships. Water legislation has been recently approved, promulgated based upon policy principles as reflected in a Rwanda Water policy document.

In Nyabugogo catchment, there is serious water competition between and within the major water using sectors such as agriculture, urbanization, industrial and mining (UIM) and rural domestic and drinking water. Due to discharges of domestic, agricultural and industrial wastes into the river, problems have arisen with regard to the water quality conditions. Governmental institutions in charge of water resources management have limited capacity and funds to properly coordinate and manage the catchment.

The development of the Country in different sectors and the construction of new power generation plants, along with the population growth, the consideration of environmental flows, the revitalization of small scale irrigation schemes in Nyabugogo catchment and the improvement of the accessibility to water in new villages under construction are going to increase the water demands in this catchment. On the top of this, the variable hydrology and the effect of climate change make it difficult to quantify the available water resources to satisfy these increasing demands.

1.2. RESEARCH OBJECTIVES,

In the context of increasing scarcity and competition for water uses across the sectors, themain objective of the study is to assess alternative means for increasing productivity ofwater, through better management of multiple water uses in the Nyabugogo catchment “a case study of Nyabugogo wetland”

1.3.2. SPECIFIC OBJECTIVES

1. To identify the key stakeholders operating within the wetland and possible impacts on present water resources;
2. To assess the existing water use and water balance of Nyabugogo wetland; and
3. To develop best management practice strategies for implementing IWRM&Development within the wetland.

1.3. RESEARCH QUESTION

1.Who are the existing water users?

2.What are the formal and informal arrangements for managing water for different uses in the wetland?

3.What is the current state of water balance in the wetland?

4.What are the possible mitigation measures to implement IWRM in the wetland?

1.4. SCOPE OF THE RESEARCH

The present study is limited both in time and space. According to the main objective of this research which is the main objective of the study is to assess alternative means for increasing productivity of water, through better management of multiple water uses in the Nyabugogowetland.

1.5. CONTRIBUTION OF THE RESEARCH

The Contribution of this research is to develop strategies for IWRM in the Nyabugogo wetland and setting and emphasizing on the management of the Nyabugogo wetland as it is facing serious flooding problem and providing good management practices involving many stakeholders.

1.6. THESIS STRUCTURE

This study is made up of five chapters:

The first chapter establishes the importance of the problem selected and gives a clear statement of the problem. Additionally, the background, objectives, scope of research, contributions of the research and the research outline are given in this chapter.

The second chapter reviews the integrated management and development of water resources for productive and equitable use within the catchment and more precisely in Nyabugogo wetland.

The third chapter gives a brief description of the study area and the methodology used to determine the management practices of the water resources in the wetland.

The fourth chapter presents the obtained results, their analysis and discussion.

Finally, the fifth chapter provides the conclusion and recommendations.

2.0. LITURATURE REVIEW

2.1. WHAT ARE WETLANDS?

Wetlands are areas where water is the primary factor controlling the environment and the associated plant and animal life. They occur where the water table is at or near the surface of the land, or where the land is covered by water.Under the International Convention on Wetlands (better known as the1971 Ramsar Convention) wetland are defined under articles 1.1 and 2.1.Article 1.1Wetlands are areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters.In addition, Article 2.1 of the Convention provides that wetlandsmay incorporate riparian and coastal zones adjacent to the wetlands, and islands orbodies of marine water deeper than six meters at low tide lying within the wetlandsaccording to (Cowardin, 1979) wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface.

2.2. RWANDA‘S WETLANDS

Rwanda’s wetlands inventory consists of marshlands, lakes and rivers. The country is home to 860 marshlands that covera total area of 278 536 ha. These account for 10.6 percent of the national territory. Natural vegetation covers 41 per centof the marshes while 53 per cent is covered by fields and 6 percent lies fallow. The marshlands are complemented by 101 lakes which collectively covers anarea of 149,487ha and 861 rivers with a combined length of 6462 km (REMA 2009).Thebest known of Rwanda’s wetlands is the Rugezi-Burera-Ruhondo wetland complex which was designated by Ramsar as awetland of international importance in December 2005. The location of this and other wetlands in the country is depictedin Photo 1. Legal Protection of Wetlands

Figure 2.5: Rwanda's wetland protection levels. Source: Adapted from Republic of Rwanda/REMA 2008

Figure 1.1 : Rwanda’s wetlands

The country’s wetlands are protected by Organic Law N° 04/2005 determining the modalities of protection, conservationand promotion of the environment. Its stipulations are consistent with those of the Convention onWetlands ofInternational Importance especially as Waterfowl Habitat (Ramsar Convention). Rwanda ratified the RamsarConvention in 2003 and it came into force in the country in April 2006. The Organic Law prohibits a range of activities in the

country's wetlands including construction of buildings, sewage plants, dumping of untreated waste water and hazardous waste and creates a 20 meter construction-free buffer zone around all swamps. It also stipulates that the use of wetlands shall be preceded by environmental impact assessments (EIAs).To give effect to the Organic Law, a Ministerial Order N° 008/16.01 dated October 13, 2010 established the list of Rwanda's swamps, their geographic limits and regulates their management and use. In addition, a detailed map that contains Rwanda's wetlands inventory has been developed and is reproduced inphoto1 above.This wetland protection levels map assigns different utilization categories of either unconditional exploitation (which is the most permissive and covers 6 per cent of the total wetland area), conditional exploitation (which represents 74 per cent of the total wetland area)or total protection (which is the most stringent utilization category and accounts for 20 percent of the entire country's wetland area).

2.3.NYABUGOGO WETLAND

Nyabugogo Wetland is still facing some challengesto fallow fields,afforestation, pisciculture(Fish farming), human settlement, agriculture and many other, this has resulted to the increased degradation, sedimentation, erosion and pronounced flooding in the area despite the strict legal regime imposed on the protection of wetland by the government

Figure 2.1 : View of the Nyabugogo River valley which falls under The conditional exploitation category based on national Wetland management criteria(REMA,2006)

Figure 2.2 : Abandoned warehouse in the Nyabugogo wetland(REMA,2006)

2.4. THE IMPORTANCE OF WETLAND ECOSYSTEMS

The Wetlands play an important role in water quantity and quality management; they contribute to water resources regulation to downstream water courses and water resources retention. Much of the water we use originates from natural wetlands and each natural wetland is a functioning ecosystem supporting its own assemblage of aquatic plants and animals; wetlands are Rwanda's richest ecosystems(Hategekimana et al,2007)

InNamibia's wetland policy, (2004) reported that the wetland provided major benefits in natural aquatic ecosystems conservation are underestimated. They include; Water provision, Contribution to climatic stability, Sediment and erosion control ,Flood control, maintenance of water quality and abatement of pollution, contributions to grazing and agriculture, maintenance of surface and underground water supply, provision of habitat for wildlife, especially, water fowl and floodplain grazers, contributions to fisheries as well as contributions to the multimillion dollar ecotourism industry.

2.5. MAJOR CAUSES OF WETLANDDEGRADATION WORLDWIDE.

Previous studies on other wetland have identified the following as a major cause for wetland degradation.

2.5.1. Over exploitationof resources.

Over exploitation of wetland resources is mainly due to population pressure, poverty, limited ecological and biological knowledge, and "open access" toresources (lack of tenure) (Turpie*et al.*,2004).

2.5.2. Over abstraction of surface and groundwater.

This poses a threat to wetlands as thiscan lead to the loss of springs and other surface waters, underground aquifers and riparianvegetation. This has begun to affect the riparian trees and the water securityof people living downstream (Amakali, 2002). An example of over abstraction from the Okavango River inNamibia could have severe Trans-boundary impacts on the unique ecosystems that make up theOkavango Delta in Botswana (Shaw *et al.*,2004).

2.5.3.Lack of adequate ecological protection.

Most of wetlands worldwide are under protected(Barnard *et al.* 1998) and the majority is not incorporated within the country's protected areasnetwork. Implementing protected area regulations adequately is difficult because many wetlands arepart of larger systemsusually with significant components in unprotected areas or in othercountries (Curtis, *et al.*,1998).

2.5.4. Declining water quality.

Global trends regarding declining water quality are linked directly tochemical and nutrient pollutionassociated mainly with domestic and industrial effluent and run-offwater (containing agrochemicals) from irrigation fields. Many pesticides that are commonly used tocontrol agricultural pests and water-borne diseases like malaria are classified as Persistent OrganicPollutants (POPs), which accumulate in wetlands and exhibit high levels of toxicity (Tarr& NWAC, 2002).

2.5.5.Altered hydrology.

Changes in water flow regimes caused by the construction of weirs, dams andcanals for water storage and supply, for hydropower plants, large irrigation schemes, aquacultureventures and the development of residential areas can reduce and alter the timing, extent andfrequency of flows that sustain wetlands (Amakali*et al.*,2002).

2.5.6.Introduction of invasive species.

Water weeds (including the water hyacinth), can alter normalhydrological flows by clogging waterways and threatening the survival of native species, whilst the introduction of invasive animals can cause pest problems, habitat destruction and in the case of non-indigenousspecies, genetic pollution of closely related native animals (Bethune & Roberts 2002,Bethune *et al.*,2004).

2.5.7. Aquaculture.

Aquaculture developments can have devastating impacts on wetlands both fromdirect destruction of habitat and indirect effects on water quality and native biota (resulting fromconcentrated fish excreta, food and medicine residues).(Bethune, 2004).

2.5.8.Climate Change.

Global warming and changes to the world's climates will have majorImplications for wetlands in the decades to come (Hulme*et al.*,1996). More extreme flood events during years of good rain are also likely. As aconsequence, current constraints that threaten the freshwater fisheries sector and wetland integrity ingeneral will be dramatically altered (Tarr, 1998).

Traditional and commercial agricultural development, in the absence of well planned, integrated land-use management procedures, farming activities can cause substantial losses towetland functions and values.The irrigation sector, as the largest water user, needs to seriouslyconsider the implementation of water demand management (Van der Merwe*et al., 1999.)*However in Rwandan wetlands mostly Nyabugogo wetland the degradation is caused by different aspects and these are:

Land use practices

Nyabugogo wetland is mainly affected by reclamation and degradation, due to it being locatedoutside national parks also human activities threatening the wetland include settlements like those in Nyabugogo tax park and houses near the bridge on the Kigali-Katuna road (Mirimo House),Kiruhura side of the wetland where the houses are as near as less than 10m from the wetland and the river side. road construction, drainage, unplanned conversion to agriculture, industrial pollution mostly from Utexrwa , Gikondo industrial area, sludges from kimisagara water treatment plant and so many others of that kind mostly contribute to the pollution of the wetland, trampling or sprawling of stocks into the wetland mostly by the people living near by the wetland, human disturbances, burning of vegetation, soil excavation processes have devastated the vegetation cover to such an extent that the soil surface of areas has become susceptible to a pronounced and critical erosions mostly during heavy rainfall,

Increased housing developments associated with urbanization, directly affects the soilsphysical characteristics thus lowering water infiltration and increasing runoff and soil erosion with increased potential for floods in the Nyabugogo have been remarkably seen in Kigali city and to a lesser extent in other provincial towns across the country mostly in Rubavu, Nyabihu,and Musanze towns.

Roofing of housing complexes and paving of roads and other access routes has reduced the surface area available for soil infiltration. During the rainy season much of the run-off flows to the valleys below with minimal infiltration which is one of the main ground water recharge pathways.

In cases of the existence of open sewers and exposed drainage canals, the rain water carries along with it the domestic waste directly into the marshlands below as is the case for the Gikondo and Nyabugogo wetlands for Kigali.

The direct impact of reduced soil infiltration is increased run-off, soil erosion on bare soils and siltation of water ways in the lower slopes or marshlands is also highly pronounced in the wetland areas.

Also associated with urbanization is wetland destruction and increasing incidences of dumping of untreated effluent in rivers and marshlands (MINIFRA 2003). In urban areas wetlands are most likely to be used as dumping sites for wastes or wetlands may be converted to other forms of land use, such as residential and industrial development, road construction,

or aquaculture. The Gikondo industrial area located in Gikondo-Nyabugogo wetland greatly affects the ability of the wetland to clean wastewater and control siltation of streams (REMA 2006). This can be shown by the photos recently taken from the wetland in the annex of this thesis.Together with the above, Pollution in the wetland and agriculture intensification have been the most severe cause ofdegradation of the wetland.

2.6.THE CONSEQUENCES OF WETLAND DEGRADATION AND CHALLENGES TO RWANDANWETLANDS.

Water remains inaccessible for 1.1 billion of people in the world and 400 children below five years old die every hour because of biological contamination of drinking water. Moreover half of the population in developing countries is suffering from one or more diseases associated with water supply and sanitation (Ashok,1998).In this context of Rwanda, the wetlands management wetland has been facing the serious degradation due to population pressure. The tangibleexample is Rugezi wetland, in their study (Hategekimana et al.,2007) highlighted the problem within RugeziMarsh as they face an environmental crisis related to marsh agricultural reclamation and drainage. These activities are the major cause of lowering the water table water quality and the decline of water level in the Lakes Bureraand Ruhondo.

2.7. WATER USE:

Water is a strategic natural resource for any country's economic, social and cultural development. It is an important geo-political tool especially when waters are shared or are available so abundantly as to make a country powerful through production of food, energy, transport and other needed services.It is an indispensable resource for sustaining human, animal and plant life.For Rwanda, water is probably the most important natural endowment, a basis on which nearly almost all economic and social activities are anchored.

Rwanda's water comes naturally and is almost entirely used naturally. Over the last 3 decades, however, the water resources have been severely degraded, as evidenced by heavy sediments in rivers; pollution from agricultural chemicals and fertilizers, industrial effluents and municipal waste; reduced water levels and flow volumes, resulting in shortages. The water resources management (WRM) regime did not reflect the important position of water in sustaining lives,livelihoods and economy of Rwanda(WRM Sub-sector strategic plan for 2011-2015).

Rwanda has a total of 860 wetlands covering a total area of 165,000Ha that is to say 7% of the total surface area(REMA,2010).Wetlands are amongthe most productive aquatic ecosystems in Rwanda. Performing valuable ecological, social and economic functionsin Nyabugogowetland, water is used by different users including but limited to; Agriculture, livestock development, industries, domestic and municipal use and water for infrastructure development.Understanding the multiple uses of water is of paramount importance for exampleall water uses can be categorized as:

2.7.1.Water for Basic human needs and poverty reduction.

Water is of fundamental importance to food production, for drinking, for sanitation and hygiene. Adequate quality water underpins health and basic quality of life.

2.7.2.Water for social and economic development:

Demand for water in social development includes education and health care. Without clean water and sanitation, schooling is curtailed as hygiene deteriorates. In economic development, water is central to energy generation and industrial development. Emerging non-food crops like bio-fuels will increase the demand for water

2.7.3.Water for ecosystems sustenance:

Natural ecosystems are fundamental to human well-being and development. Water is central to habitats' sustainability. Increasing water crises contributes immensely to biodiversity loss;

2.7.4.Water Security:

Floods, droughts, pollution spills onto water systems, etc., are of growing concern as agricultural, industrial, settlement and infrastructural development activities intensify. In many areas, increase in frequency and intensity of floods, droughts and accidents related to water. More people are living in zones prone to water-related disasters, such as wetlands, steep hills and congested slums. Resource scarcity is already fuelling human conflicts.(UN Water: Status Report on Integrated Water Resources Management and Water Efficiency Plans. 2008).

2.8.0. WATER BALANCE WITH IN THE WETLANDS.

2.8.1. WHAT IS A WATER BALANCE

The scientific base of hydrology is the continuity equation or water balance equation, which can be written as $$I - O = \frac{\Delta S}{\Delta t} (1)$$

Where *I* is the inflow in [m^3/t], *O* is the outflow in [m^3/t], and (**Δ***S*/**Δ***t)* is the rate of change in Storage over a finite time step in [m^3/t] of the considered control volume in the system. The equation holds for a specific period of time and may be applied to any given system provided that the boundaries are well defined. Other names for this equation are Storage Equation and Law of Conservation of Mass. The water balance equation can be applied to many different systems, such as:

- The (terrestrial and oceanic part of the) earth;
- An entire river basin where the wetlands belong
- The root zone, interception reservoir, lake, etc.
- A local area like a city, a forest, or a polder**(Ward,and Robinson, 1990.)**

2.8.2. WHY ITS ESTIMATION IS CARRIED OUT

In the natural environment, especially in wetlands water is almost constantly in motion and is able to change state from liquid to a solid or a vapour under appropriate conditions. Conservation of mass requires that, within a specific area over a specific period of time, water inflows are equal to water outflows, plus or minus any change of storage within the area of interest. Put more simply, the water entering an area has to leave the area or be stored within the area. The simplest form of water balance equation is as follows:

$$P = Q + E \pm \Delta S, (2)$$

Where, P is precipitation, Q is runoff, E is evaporation and ΔS is the storage in the soil, aquifers or reservoirs. In water balance analysis, it is often useful to divide water flows into 'green' and 'blue' water. Bluewater is the surface and groundwater that is available for irrigation, urban and industrial use and environmental flows. Greenwater is water that has

been stored in the soil and that evaporates into the atmosphere. The source of greenwater is rainfall or bluewater has been used for irrigation.(Water balance estimation in Anthemountas river basin and correlation with underground water level by development agency of eastern Thessaloniki Anatolikis.a.K. Rafailidi 3, Thermi, 57001, Greece)

Water entering the wetland is directly/indirectly obtained from different processes which are as follows;

- Rainfall/precipitation
- Surface water runoff from inter sub catchments
- Surface water runoff and ground water discharges either from Seeps or aquifers and discharges to the wetland

The Magnitude of the above mentioned sources changes seasonally and annually and also water discharges from the wetland of Nyabugogo through,

- Water discharges from the wetland through surface depressions and drainage ditches ,
- Ground water flow through the aquifers,
- Water also discharges from the wetlands as ET, like the magnitude of the sources, the magnitude of discharges through different pathways changes seasonally and annually.

Basing on the above parameters, a wetland water budget can be assessed but of course considering other factors such as run off coefficients as well as rainfall intensities.

2.8.3. WATER BALANCE USE

Water balance estimation is an important tool to assess the current status and trends in water resource availability in an area over a specific period of time.

Furthermore, water balance estimates strengthen water management decision-making, by assessing and improving the validity of visions, scenarios and strategies.

Water balance techniques, one of the main subjects in hydrology, are a means of solution of important theoretical and practical hydrological problems. On the basis of the water balance approach, it is possible to make a quantitative evaluation of water resources and their change under the influence of peoples activities. The study of the water balance structure of lakes, river basins, and ground-water basins forms a basis for the hydrological substantiation of

projects for the rational use, control and redistribution of water resources in time and space (Sokolov& Chapman 1974).

2.9. INTEGRATED WATER RESOURCES MANAGEMENT (IWRM)

Integrated water resources management is a process which promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (GWP,2000).The message of the developing worldgrappling with poverty, growing population, increasing urbanization and industrializationis clear. Freshwater supply will be a critical issue in the years to come. Information, assessment and monitoring of global water resources will be crucial (Klaus Toepfer, Executive Director of the United Nations Environment Programme(UNEP).

IWRM is necessary to combat increasing water scarcity and pollution. Methods include water conservation and reuse, water harvesting, and waste management. An appropriate mix of legislation, pricing policies and enforcement measures is essential to optimize water conservation and protection (UNDP1991).

3.0. MATERIAL AND METHODS

3.1. DESCRIPTION OF THE STUDY AREA.

Geographically, Nyabugogowetlandis located at 1,354m to2,278m above the mean sea level, between1°94'S and 30.°04'E. Thewetland drains a total area of 1647 km^2.Nyabugogo is located within the Nyabugogo catchment and it covers both rural and urban areas as it covers the Rwanda capital city, Kigali.The wetland is composed of two districts of Nyarugenge and Gasabo with an estimated population of 825,767 inhabitants (2012, population housing census report)unlike Nyabugogocatchment which is comprising of some districts of Eastern Province like Kayonza, Rwamagana, and Gatsibo, and districts of Northern Province like Gicumbi and Rulindo and other districts of Kigali city such Kicukiro, Nyarugenge, and Gasabo districts where the study area wetland is located.Its estimated population is about1,135,428 inhabitants (2012,Population housing census report) people.

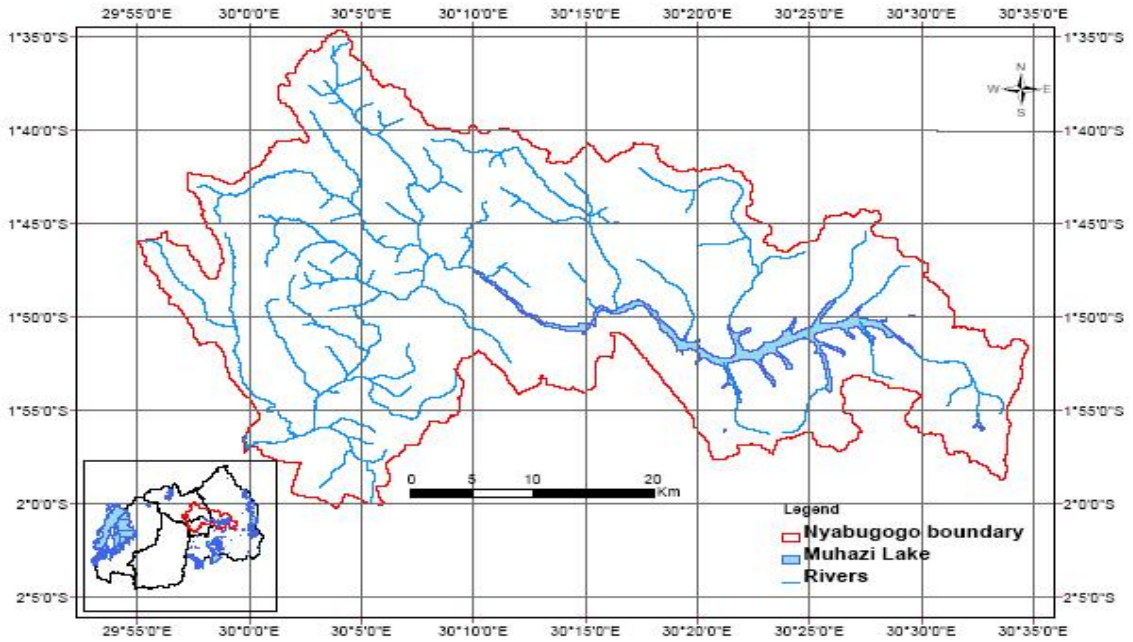


Figure 3.1 : Nyabugogo catchment from the administrative map of Rwanda

This study was carried out in Nyabugogo wetlandlocated in the flat bottoms of Kigali, Figure 2 shows wetland extracted fromNyabugogo catchment with a total area of 60.09ha (CGIS).

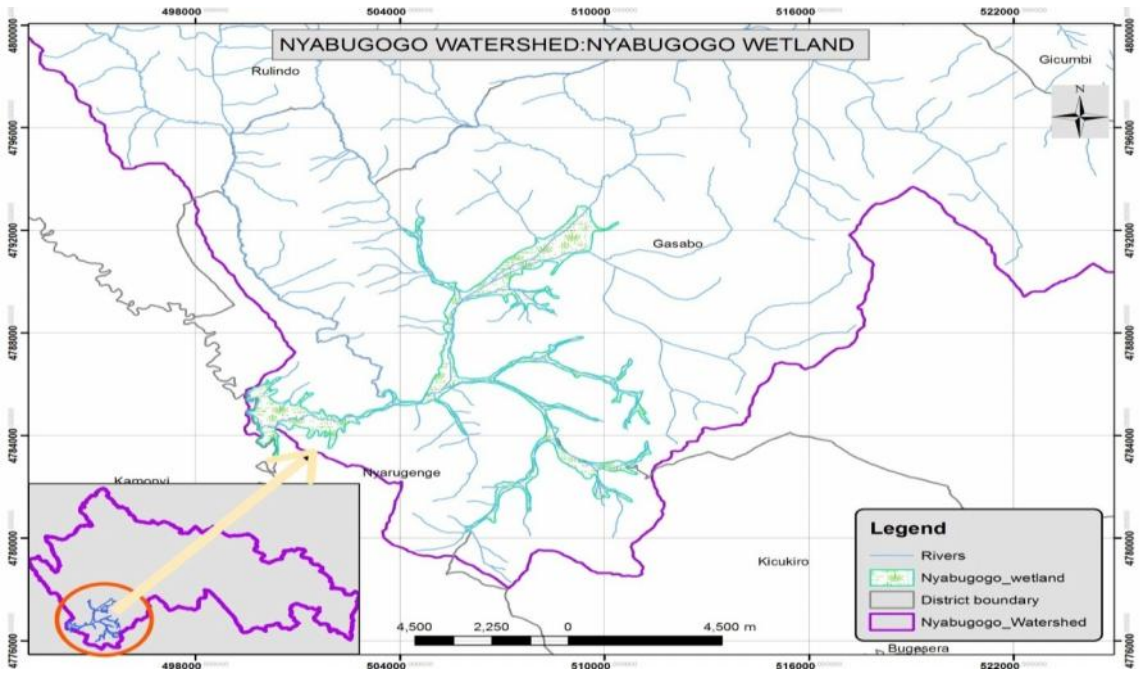


Figure 3.2 : Location of the study area (wetland) in the Nyabugogo catchment

3.1.1. METEOROLOGICAL DATA COLLECTION

In this study, we considered only onemeteorological stationof Kigali international airport which gave us the rainfall and evaporation data records for 20 year (1993-2012) and were analyzed and computedthe mean atmospheric temperature varies with time but normally between 19°C and 21°C.There are 15 rainfall stations in and around the Nyabugogo catchment. However, since after the genocide of 1994, meteorological data have not been observed in almost all stations except at Kigali airport station this therefore triggered me to use the data available.

3.1.2. AVERAGE ANNUAL RAINFALL

Considering the period from1993 to 2012 atKigali airport meteorological station, the minimum and maximum average annual rainfall at that station are 98.65mm and 173.14 mm Note that Kigali airport meteorological station is located around the Nyabugogo catchment in southern part at $01^{o}\,58^{\text{‟}}$ latitude and $30^{o}11^{\text{‟}}$longitude with 1490 m of altitude.

3.2.IDENTIFY THE KEY STAKEHOLDERS

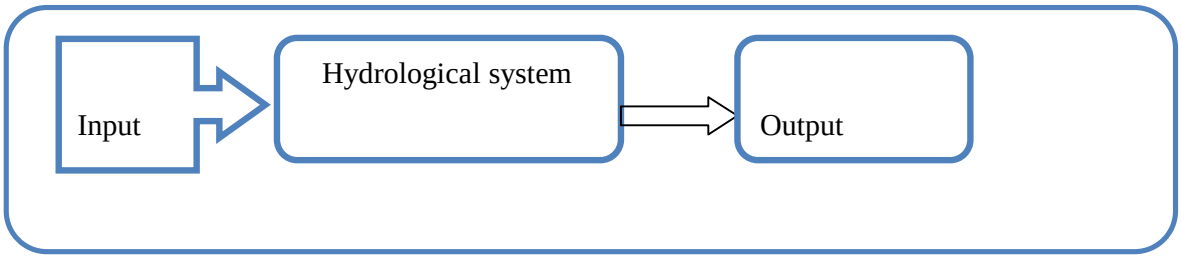
To achievethe study aim, the following methodology was applied:

1. Identification of the main problems to be addressed and key stakeholders Involved within the wetland using interview.
2. Identification the structure of stakeholders involved and propose a strategy to implement IWRM with in the wetland.
3. Assessment of values associated with these objectives for current practices;
4. Identification of possible solutions and the stakeholders that control them
5. Assessment of values associated with expected impacts of solutions;
6. Implementation, monitoring and evaluation by stakeholders.

3.3. WATER USE AND WATER BALANCE IN NYABUGOGO WETLAND.

Rainfall is most frequently input in water balance calculation,flow (run-off) sub-surface lateral flow, stream/river flow and groundwater inflow can represent significant inputs of water in many locations and should not be neglected from consideration in hydrological point of view.Significant water outputs from a catchment are generally considered to be stream/river flow, surface evaporation, vegetation water use (transpiration), surface run-off, sub-surface flow and groundwater movement. Knowledge of the water balance of Nyabugogo wetland is important for agriculture and irrigation management, for runoff and peak discharge forecasts in regions. In its simplest form, the water balance of a catchment is described by the Water Balance equation which is described as below.

From the catchmentapproach, we can deducewater budget of Nyabugogo wetland as below



$$I - O = \Delta S \quad (3)$$

Where I = input of water to the wetland; O = output from the wetland; and ΔS = change in storage within the wetland

Rational Method:

For this study a Rational Method analysis, rainfall intensity in mm per hour must be determined from an event with a duration equivalent to the time of concentration.

The Rational Method is based on the Rational Formula:

$$Q = CIA \quad (4)$$

In which:

Q = the maximum rate of runoff cubic meter per second

C = runoff coefficient representing the fraction of rainfall that becomes runoff

I = rainfall intensity for a duration equal to the time of concentration

A = drainage area

The general procedure for Rational Method calculations for a single wetland is as follows:

1. Delineate the wetland boundary and calculate its area.
2. Calculate time of concentration.
3. Determine the average precipitation of the preferred period.
4. Determine the average evaporation of the preferred period.
5. Calculate the discharge/ Flow.
6. Determine the runoff coefficient, *C*

As one objective of the research is to assess the existing of water use and water balance in Nyabugogo wetland. Rational Method analysis was used considering the average daily rainfall (in mm)and evaporation data from 1993 to 2012 obtained from meteorological office in Kigali.

3.4. BEST PRACTICE STRATEGIES TO IMPLEMENT IWRM WITHIN THE WETLAND

Different strategies for implementing IWRM withinNyabugogoWetland will be discussed such as the wise use of wetland and other related best practices to its implementation will be elucidated for example we will be focusing on the institutional context,adoptive capacity to cope with pressures from upstream development, climate and variability, urbanisation and many others and how we shall overcome these challenges to its integration wetland observation was taken into consideration and the data obtained from Meteo offices were analysed and discussed.

CHAPTER .IV. RESUTS AND DISCUSSION

4.0. STAKEHOLDERS EXISTING IN THE WETLAND

Several stakeholders operate within and across whole area of Nyabugogowetland; we assess the different stakeholders by interviewing them.

First of all we identify the garages in Gatsata operating in close proximity of Nyabugogo river. They are continuously polluting the surrounding wetlands. Just after the Nyabugogo bridge, on the Gatsata-Karuruma-Gatuna road is a stretch of land of about 300 meters occupied by garages. The strip is located between the main road and the Nyabugogoriver,which is the main drain of the entire Nyabugogo wetland. The question is who should take care of this issue The organic law No.04/2005 of 08/04/2005, determining the modalities of protection, conservation and promotion of the environment in Rwanda, provides an answer to that. Article 60 of this law stipulates that in general, local administrative entities are charged with implementing the laws, policies, strategies and programs of protection, conservation and promotion of the environment in Rwanda. Article 61, paragraph 4 further specifies that local administrative entities are particularly charged with the proper management of wetlands. By local administrative entities it means provinces, districts, sectors and cells even at village level.

Agriculture activities have been reported to be intense in Nyabugogo wetland and these include rice and sugarcaneplantationscooperatives,vegetables growing, banana plantations, cattlerearing,mining and quarry activities,and many other activities in area are practiced especially on the upstream of the Nyabugogo River. Many industries are located inside and around the Nyabugogo wetland these including Kabuye Sugar Factory, Mining processing factory(PHOENIX METAL), Gikondo industries,Kimisagara water treatment plant,Jabana

power station,UTEXRWA Textile Factory, Nyacyonga Flowers Farm which carried out their activities in Nybugogowetland.The above mentioned activities together with many others have diverse /direct impact on the water use in the wetland.

4.1.0. IMPACTS ON THE PRESENT WATER RESOURCES

Nyabugogo wetland is experiencing severe water related challenges due to high population pressure and over-reliance on water for livelihood. These challenges are reflected within the catchments. Population Growth, Drought conditions, Lack of data, Floods and Poverty. Issues at river basin level are water quality deterioration which is brought by the volume of the sewage effluent has increased and led to discharges effluents into tributary, serious deterioration of river quality leading to anoxic conditions, possibility of a number of nonpoint sources affect the quality agriculture, mines. Inthe wetland, the common challenge comprise of:

4.1.1. Water pollution

Water pollution from Household, Pollution of water from point sources industries (abattoirs, toilets, market centres etc.), inappropriate solid waste disposal in market centers, encroachment on and drainage of wetlands/inappropriate use of agro-chemicals,Soil erosion on the farms, where by farming is practiced in the upstream of the river Nyabugogo which drains into the wetland. From the studies done on the Nyabarongo watershed/catchment showed that the water in the Nyabugogo River system is polluted as far as physical parameters are concerned and the chemical parameters monitored showed consistently high levels of pollution, warranting urgent attention to arrest further deterioration of water quality in the Nyabugogo River (Uwonkunda, 2010, and Karulanga, 2013)

4.1.2. Population Growth

Encroachment of natural resources for example theriver banks, wetlands and many others for settlement and agricultural needsstressed Social services for examples schools, hospitals, water supply and sanitation, housing facilities to mention but a few has made us worry about this increasing demand that is caused by the increased population and demography of the country for instance in the third general census and population of Rwanda ,august ,2002, the population was **8,128,553**, with male being **3,879,448** and female **4,249,105**representing**47.7% and 52.27%** respectively.

In 2009, the population was projected to be 10.1 million, 53% ofwhom were female (PRB, 2009; NISR, 2009; GoR, 2009[2]). With an average population growth being 2.6%per annum,

and although this represents a decline from 3% in 2006, fertility rates are still high(averaging 5.5 children per woman). With an average population density of 534 people per sq Km,

Rwanda being the most densely populated country in Africa. The population is generally young with about 67% of the populationunder 25 years. In terms of socio-economic wellbeing, 83% of Rwandans are rural, with only 17% of the people categorized as urban. But the urban population is increasing fast, and it is estimated that by 2020, it will be 30%. Women make up 70% of the rural and 65% of the illiterate population (MINAGRI, 2009).

In the last year'spopulation and Housing Census of Rwanda it was observed that the population had increased to 10,537,222 people as of August 15th 2012, "census night". When comparing to the enumerated population in 2002 Census of 8,128,553, an increase of 2,408,669 people and an average annual growth rate of 2.6% have been observed.Deducing the above statistical data from the National institute of statistics ,we can see that there is an increase of population of about 22.7% in almost 10 years and if this population growth persists , in 2022 the population will increase to almost 45% meaning that it will directly trigger huge demand for waterfor drinking and hygiene, sanitation and other domestic uses and indirectly through demand for food, industrial products, infrastructure development ,urbanization ecosystem maintenance, recreation and other amenities. Population growth has in past increased pressure on land and forests for agriculture and settlements, resulting in land degradation, siltation of water bodies and reduced water quality and has been pronounced in the wetland for decades.

4.1.3. Drought Conditions

Reduced water table levels, accelerated rate of poverty Impact on the economy, livestock, ecology and health. Lack of water resource information (water quantity, quality, rainfall, water use, and sediment yield)Contributions and impacts of different strategies unable to be tracked inadequate work force and reliable facilities, affects future planning and developments, difficult to quantify and qualify decisions

4.1.4. Floods

Recently flood have been affecting Nyabugogo wetland through Loss of properties, Loss of human and animal life and disruption of social economic activities , disruption of the business in the area and other issues related to transport facilitation are at times at standstill due to flooding in the wetland during the rainy season.

Figure 4.1 : A man lifting a lady to cross the flooded area in Nyabugogo,and a car devastated by floodsof February 23rd 2013

4.1.5. Poverty

Economically powerful groups dominate within the wetland boundaries, Poor standards of living for example,health and hygienically facilities as well as destruction of natural resources for example Forests, wetlands are highly pronounced within the wetland.

4.2. WATER USE WITHIN THE WETLAND

4.2.1. Domestic water use

Nyabugogowetlands are vital ecosystems that provide livelihoods for the people who live around them. The domestic use are intense such as drinking water for humans and/or livestock, food for humans, food for livestock,medicinalproducts,recreational and fishing, can bewater for sports,tourism, educational values and importance for research, The spiritual and religious values can applied even thecultural heritage.

4.2.2.Agriculture water use

Nyabugogo wetlands have been drained to convert them into agricultural land for rice and sugarcane. Intensive agricultural use within the wetlands has definitely carried out in all wetland and may probably alter their ecological character. However, high-intensity agriculture takes place in wetlands, involving a regime of extensive use of fertilizers or pesticides; this may be highly affecting the diversity of the wetland landscape. With this fertilizer and pesticide may affect the surface and groundwater water quality and destroyed their status. The relationship between wetlands and agricultureneed a deep research by agronomists and environmental scientists to optimize such solutions.

4.2.3. Industrial water use.

Nyabugogowetland is located in Kigali city region where the urbanization has resulted in direct loss of wetland biodiversity as well as degradation of wetlands. This degradation is due to changes in water quality, quantity, and flow rates; increases in pollutant inputs. The major pollutants associated with urbanization may be the sediment, nutrients, oxygen-demanding substances, factory salts, heavy metals, hydrocarbons, bacteria, and viruses. These pollutants may enter wetlands from point sources or from nonpoint sources. Construction activities are a major source of suspended sediments that enter wetlands through urban runoff. Wastewater treatment plant effluent and urban stormwater are a source of pollutants that continue to degrade wetlands. Heavy metals may bio-accumulate in wetlands, causing the cancers, and death of aquatic animals and their terrestrial predators. Urban and industrial storm water, sludge, and wastewater from treatment plant effluent, rich in nitrogen and phosphorus, can lead to algal blooms in wetland. Algal blooms deplete dissolved oxygen, leading to mortality of benthic organisms.

A table summarizing the above is estimated as

Land use	**Area (Km2)**	Area[%]
agriculture	1473	88.7
Forests	66.36	4
Urban	32.11	1.9
Wetland	56.38	3.4
Lake	33.83	2.0

Table 4.1 : Agriculture land is the biggest land use class and the smallest is the urban land use classand follows the sequence that land use in the catchment is distributed as follows: Agriculture 88.65%, forest 3.99%, urban area 1.93%, wetland 3.39%, and Lake 2.04 within the catchment which was estimated to be the same in the wetland (Musoni,2009)

4.3. WATER BALANCE

4.3.1. Sitedescription

The Nyabugogo wetland is in form of a network spread across four sub watershed of the Nyabugogo catchment. These are known as Rwampara, Nyagisenyi, Nyacyonga and Karuruma but the area of interest is estimated to be 60 ha.The following table provides a brief description of the concerned sub watershed.

ID	Name	Area (Km^2)	Runoff coefficient
1	Karuruma	43,78	0,23
2	Rwampara	81,88	0,36
3	Nyagisenyi	76,19	0,25
4	Nyacyonga	59,51	0,18

Table4. 2 : Description of concerned sub catchments (Musoni, 2009)

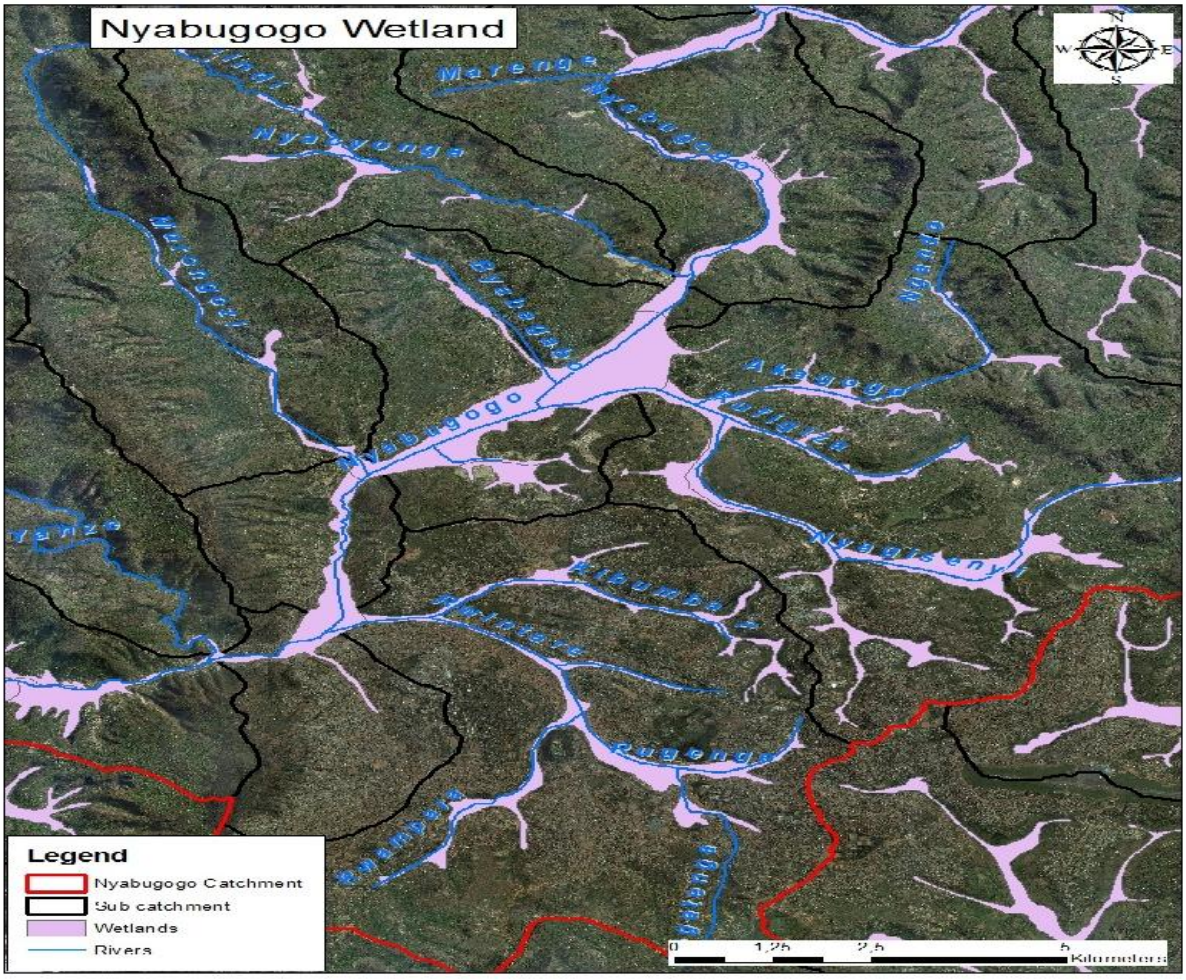


Figure 4.1 : Nyabugogo wetland map

4.3.2. Water Balance Principle

The formula adopted for this exercise is as follows:

$$I - E - S = O \quad (5)$$

Where **I** represent the inflow of water from the rainfall, **E** is the loss of water from evaporation; **S** is the water storage incorporating the infiltration and storage variation and **O** which is the outflow of water in this particular case the surface runoff.

The idea behind this exercise was to estimate the water balance using available data. It was then estimated that the inflow and evaporation and precipitation using existing data from MeteoRwanda, then the outflow was calculated using available data and runoff coefficient of the concerned area as calculated by (Musoni,2009), and at the end the storage capacity of the wetland was deduced.

4.3.3. Water Inflow (Precipitation)

The water inflow was estimated using the existing rainfall data for the last 20 years (from 1993 up to 2012) and only the inflow from precipitation was used due to the fact there is no records related to other sources of inflowand the following graph was obtained.

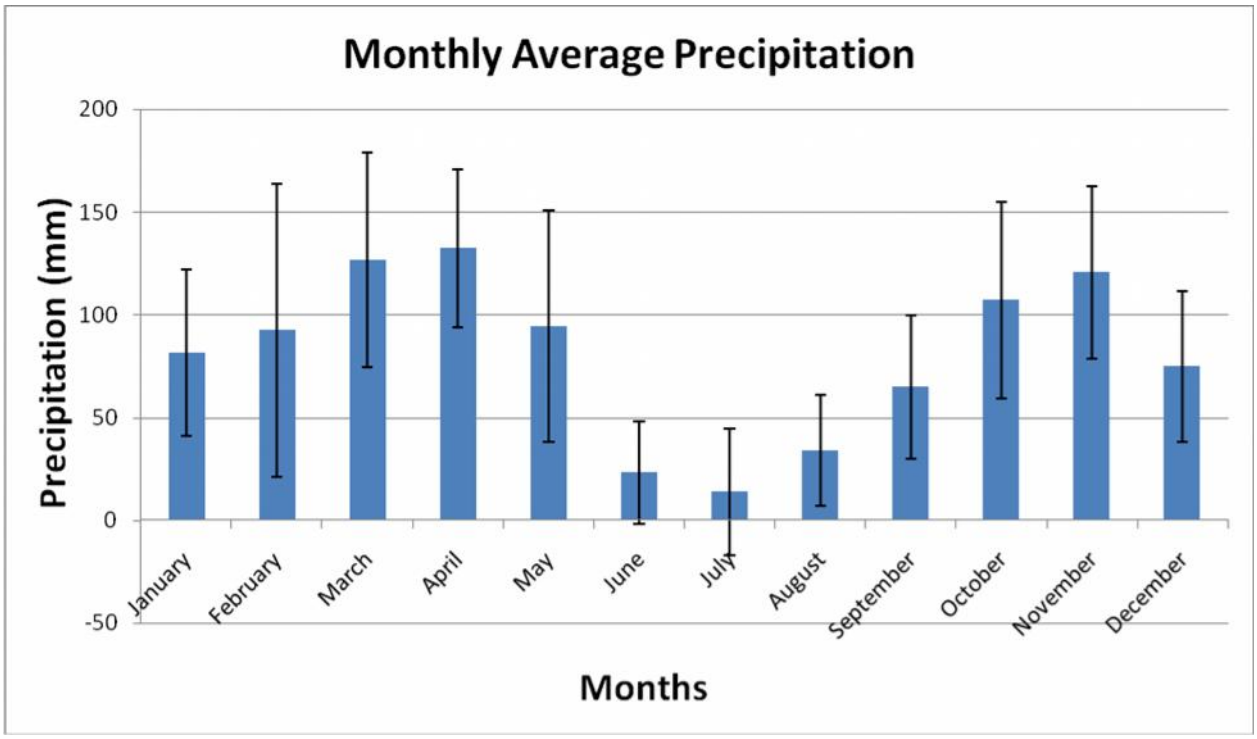


Figure 4.2 : Average Precipitation of 20 years from 1993 to 2012

4.3.4.Waterloss (Total evaporation)

The evaporation was considered the only loss for this research since the storage incorporate change in storage, infiltration, and so on .The following is the resulting graph of the average evaporation for the last 20 years (from 1993 to 2012).

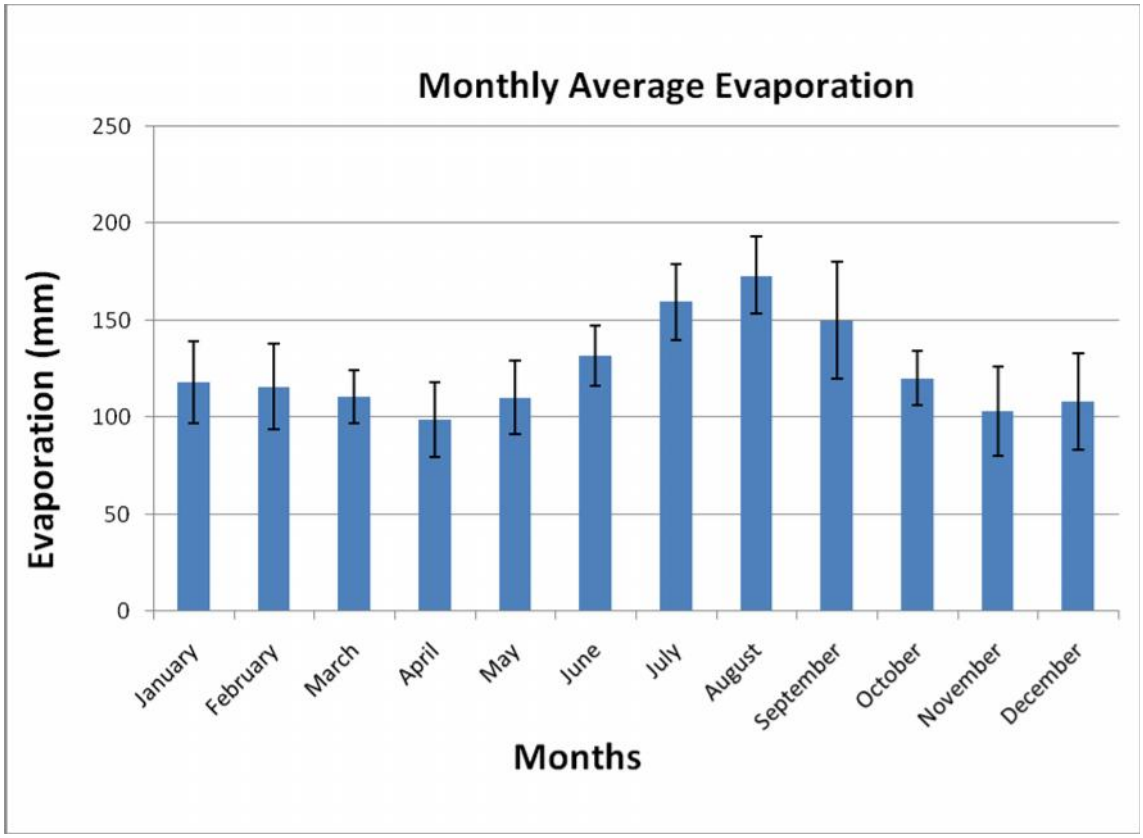


Figure 4.3 : Monthly Average Evaporation of 20 years from 1993 to 2012

4.3.5.Water outflow

The following was estimated using the average runoff coefficient of the concerned watershed where the wetland is located and its area.

Average runoff coefficient

This was calculated so as to be able to determine the run-off in the wetland of different run-off coefficients as it is in equation 4.

$$C = \sum(Ci * Ai) / A(6)$$

Area

The concerned area where water is flowing in the Nyabugogo wetland is equal to 261.36 Km^2which is 26136 ha but only a portion of 60 ha was delineated and used.

Monthly average runoff estimates

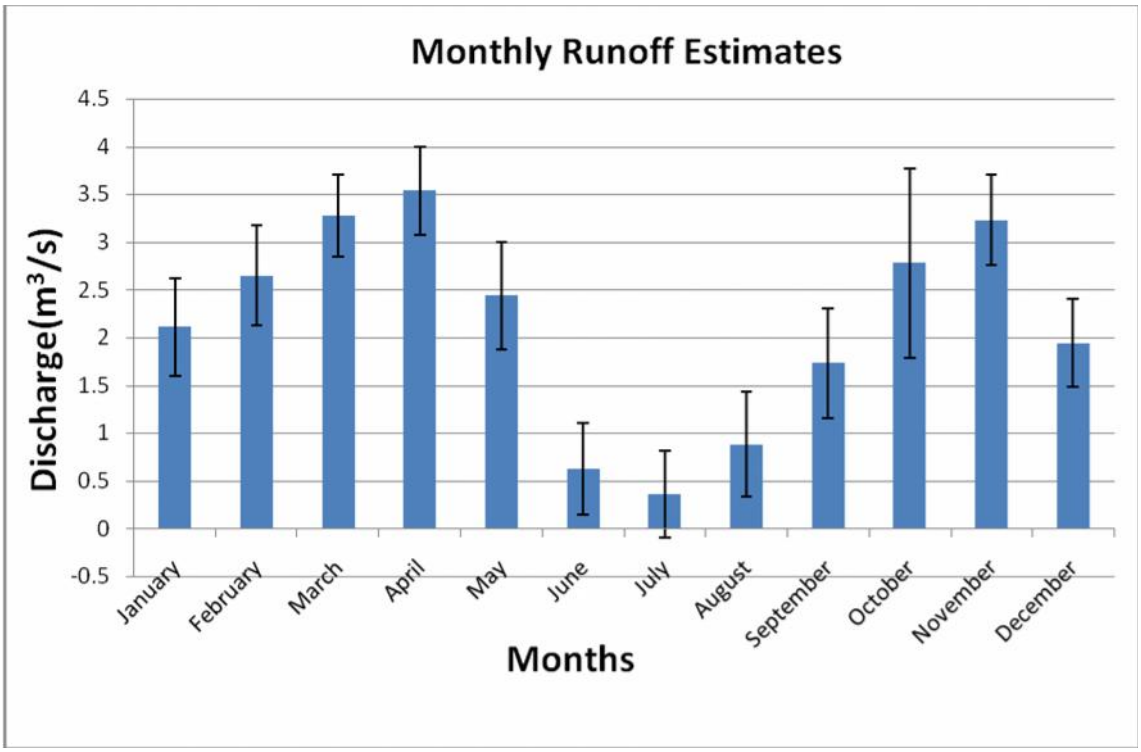


Figure 4.4 : Runoff estimates obtained from the rational method

RESULTS FOR NYABUGOGO WETLAND WATER BALANCE ESTIMATION

Months	Rainfall (mm)	Standard deviation rainfall	Evaporation (mm)	Standard deviation evaporation	Rainfall (m3/s)	Evaporation (m3/s)	Surface Runoff (m3/s)	Standard Deviation Runoff	Storage (m3/s)
January	81.68	40.47	117.98	21.02	7.97	11.51	2.11	0.51	-5.65
February	92.4	71.18	115.81	22.05	9.98	12.51	2.65	0.52	-5.17
March	126.91	52.22	110.49	13.51	12.38	10.78	3.28	0.43	-1.68
April	132.56	38.42	98.65	19.11	13.37	9.95	3.54	0.46	-0.12
May	94.36	56.28	110.34	18.95	9.21	10.77	2.44	0.56	-4
June	23.42	24.99	131.64	15.78	2.36	13.27	0.63	0.48	-11.54
July	13.77	30.67	159.52	19.52	1.34	15.57	0.36	0.45	-14.58
August	33.99	27.2	173.14	19.82	3.32	16.89	0.88	0.55	-14.46
September	64.81	34.71	149.89	30.04	6.53	15.11	1.73	0.57	-10.31
October	107.36	47.89	120.08	14.13	10.48	11.72	2.78	0.99	-4.02
November	120.79	41.91	103.31	22.98	12.18	10.42	3.23	0.47	-1.46
December	74.88	36.52	108.16	24.8	7.31	10.55	1.94	0.46	-5.18

Table 4.3 : Water balance table of the concerned catchment (same as that of the wetland)

4.3.6. Summary of result interpretation.

Monthly average rainfall.

The results interpret the four seasons of Rwanda which are two rain seasons and two dry seasons, the main rain season is followed by the main dry season meaning that the water storage in the catchment is minimal within the wetland.

Standard deviation for rainfall data.

The Rainfall partners of the catchment are unpredictable, and this is indicated by the high values of the monthly standard deviation.

Monthly average evaporation.

The evaporation of the catchment is higher in dry seasons than in rain seasons, meaning that the natural wetland storage is less. Due to the high permeability of the wetland and high water table,this catchment is therefore vulnerable to water pollution transmission to both surface and ground water including the downstream catchment

Surface run-off

The surface run-off is high in rainy seasons and mainly this due to natural catchment configurations and climatic conditions (Higher in rainy seasons and lower in dry seasons) and such a catchment requires adequate watershed management planning.

Storage

To develop any type of storage in the catchment for any purpose, hydro power, water supply, irrigation, agriculture etc requires external; addition of water in the upstream sub-catchments and ground abstraction is impossible, the results are in line with the findings of the National Water Resources Master Plan.

4.5. INSTITUTIONAL FRAMEWORK FOR THE IMPLEMENTATION OF IWRM

The National policy for water resources management (MINIRENA, 2011)definesIWRM as follows: 'IWRM is a water resources management approach that addresses the interdependence of the different uses and users of water resources'

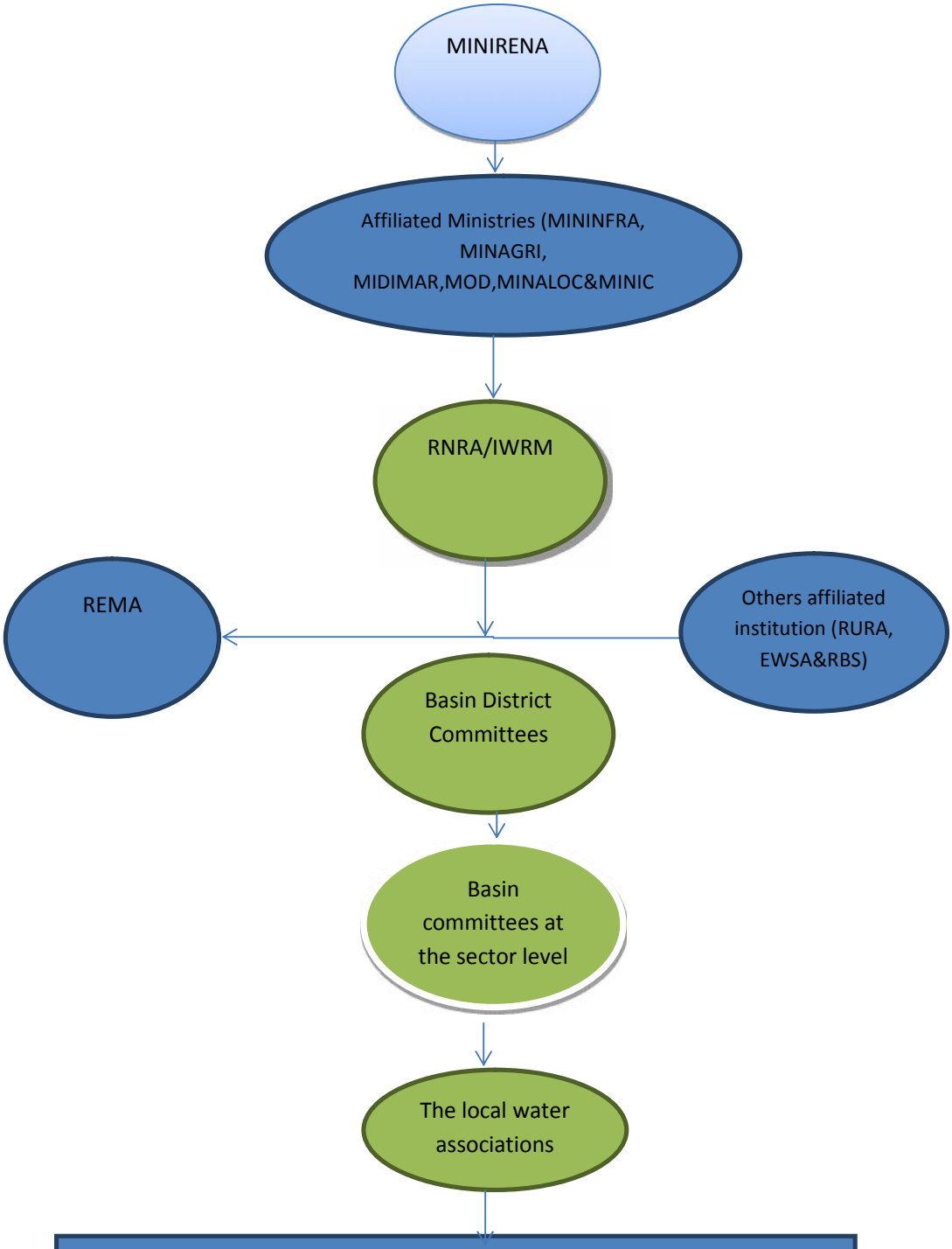
The establishment of a reliable framework for the protection of Nyabugogo Wetland will preventfurther deterioration and protects and enhances the status of aquatic ecosystem and, with regard to their water needs. This will be achieving with relevant policies on wetland with internationalagreements such as Ramsar Convention and the Convention on Biological diversity, both of which include obligations to wetland ecosystems.In Rwanda, the Ministry of Mineral and Natural Resources (MINIRENA) is the Institution responsible for the formulation of the Water resource Management policy and the legal and regulatory framework required for its implementation. After formulation of the policy and affiliated structure it needs to handle their adoption by appropriate Institutions for instance the Cabinet paper for Policies, adoption by Parliament for laws, checking of compliance of laws with Constitution by Supreme Court then promulgation of laws by the President of the Republic.

As per the 2008 water law, the Ministry has to consult the Inter-ministerial committee prior to the submission of any strategic tool to the appropriate institutions.

This Inter - ministerial committee is composed of all Ministerial department representatives concerned with water resources and use in their domain. It shall be consulted on all legislative draft Bills regarding planning in the water domain elaborated at the national level, as well as on matters of national, regional or international level.

The institutional actors at the national level and their roles are schematically depicted in the organization chart below.

Proposed structure for the proper implementation of IWRM in Nyabugogo wetland



The level of knowledge on wetland management is quite limited, the above framework will be the major tools to implementing the IWRMwithin the wetland even at catchments level. The Ministry of Natural resources through Rwanda Natural Resources Authority in its integrated water resources management department should be actively involved in implementing and enforcing the existing laws. Policies as well as guidelines meant for the use of the existing water resources in a productive , equitable way , this can be achieved by always involving at any level of water use all the policy institutions ,regulatory, financing, management/services institutions, local communities, private sector, as well as non-governmental organization before any water use.The proposed framework for IWRM does not however replace the existing one but it has proposed the direct involvement of district, sector basin committees, and local communities before direct use of water resources is done.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS.

This chapter describes the conclusion of this research. It concludes on the results and discussions and states the main contribution of this research by relating the findings to the research objectives. Finally the recommendations and further research are given based on the discussion and findings of this research.

5.1. CONCLUSION:

Despite huge amount of water all over the year there is no groundwater storage in the wetland, this is shown by the negative values in the table of results

The topography of the catchments is steep within very urbanized areas, the whole leading to flash floods during heavy rains.

The high total water evaporation are known to be a characteristic of Nyabugogo catchment but also this is a catchment that is prone to flash floods with water disappearing in few hours after lots of damages specifically near urban areas after and during intense rainfall.

It is advised to develop agricultural scheme of water loving crops like rice for example, in order to benefit from the wetland natural conditions. In this case, the wetland is protected but also an economic development is made out of it and this is suggested and it is helpful after a detailed study on water requirement for rice growers in the catchment is done.

5.2. RECOMMENDATIONS.

Involve key actors who will maintain a local presence and develop long-term relationships with farmers.It is crucial to recognize farmer's positive contributions to the environment, but without forgetting that farmers are also businesses oriented people.

Provide comprehensive support to farmers, including access to information and technical advice, andalso competitive financial compensation.

Implement a system that supports the development of large-scale projects with a water basin approach.This way, different stakeholders can be involved by considering the multi-functionality of wetlands (e.g.flood prevention). Payments for ecosystem services may be a promising way forward to generate a platformfor a broader stakeholder approach.

Wetlands initiatives should promote multiple benefits, not focus less narrowly on nutrient retention. Ingeneral, the agriculture sector (and society as a whole) should focus more on reuse and recycling ofnutrients, and efficient on-field (both management and technical) measures to prevent nutrient leakage.Wetlands, meanwhile, should be recognized more for their long-term functions and benefits, e.g. as anatural buffer and sink, and for the full range of environmental services they provide.

The flood prone areas should be left alone with no activities in it for security and disaster management.

Economic activities like garages, industries, etc. should be appropriately relocated to protect the wetland water quality. In fact, its flow dynamic may lead to indicate possibility of storage in a neighboring catchment, this resulting in groundwater pollution downstream.

The household sanitation is a consequent (biological) none point source polluter. In fact pit latrines and septic tanks are the common method of black water treatment used in urban areas in Rwanda, the fact that these households are located in a wetland with a high water table; it automatically result in the pollution of the ground flow which will be stored in a downstream catchment.

A solution will be to relocate appropriately those households for their security in case of disasters and also for the water quality protection of the wetland.

A wetland policy should be elaborated for the future wetland use and management

Proposed national water resources master plan should be put in place, and different stakeholder's ideas or views be considered before its ratification,this will reduce the mismanagement of water resources by different stakeholders.

The Gikondo industrial area relocation should be done quickly as proposed different stakeholders. Houses near the Nyabugogo wetland should be relocated in a shortest possible time.

The Ministry of Natural resources through Rwanda Natural resources Authority in its integrated water resources management department should immediately put in place a water abstraction guideline document for all stakeholders to follow and use it together with that a license should be drafted to every water user before anything is done.Solid waste management plan to mitigate sources of materials obstructing channels is a must.

There should be mapping up of households in high risk zones and their relocation outside the wetland as it was reported by restoration of the damaged portions of the Mpazi channel; this can reduced by designing a flood water retention ponds in the Nyabugogo flood plainand widening the water storage canal towards the Mpazi-Nyabugogo confluence which seem to discharge huge amount of water in the wetland in question but without any discharge/ flow measurement instrument placed at the outlet

Hydrological measures are proposed in and around the wetland or more so in the whole catchment and these can either be short term or long term that can even last for years, for example reduction of rainwater flows by increasing infiltration through terracing, afforestation and rooftops rainwater harvesting, Reduce runoff produced per area in the mpazibasin and in other urban basins, Reduce the speed of flow in the Canal by increasing itsroughness.

Further research should be conducted on the multiple functions of wetlands. For example, it would be Useful to investigate how well wetlands retain nutrients and prevent other kinds of damage during floods.

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ANNEXES OF FIGURES, TABLES

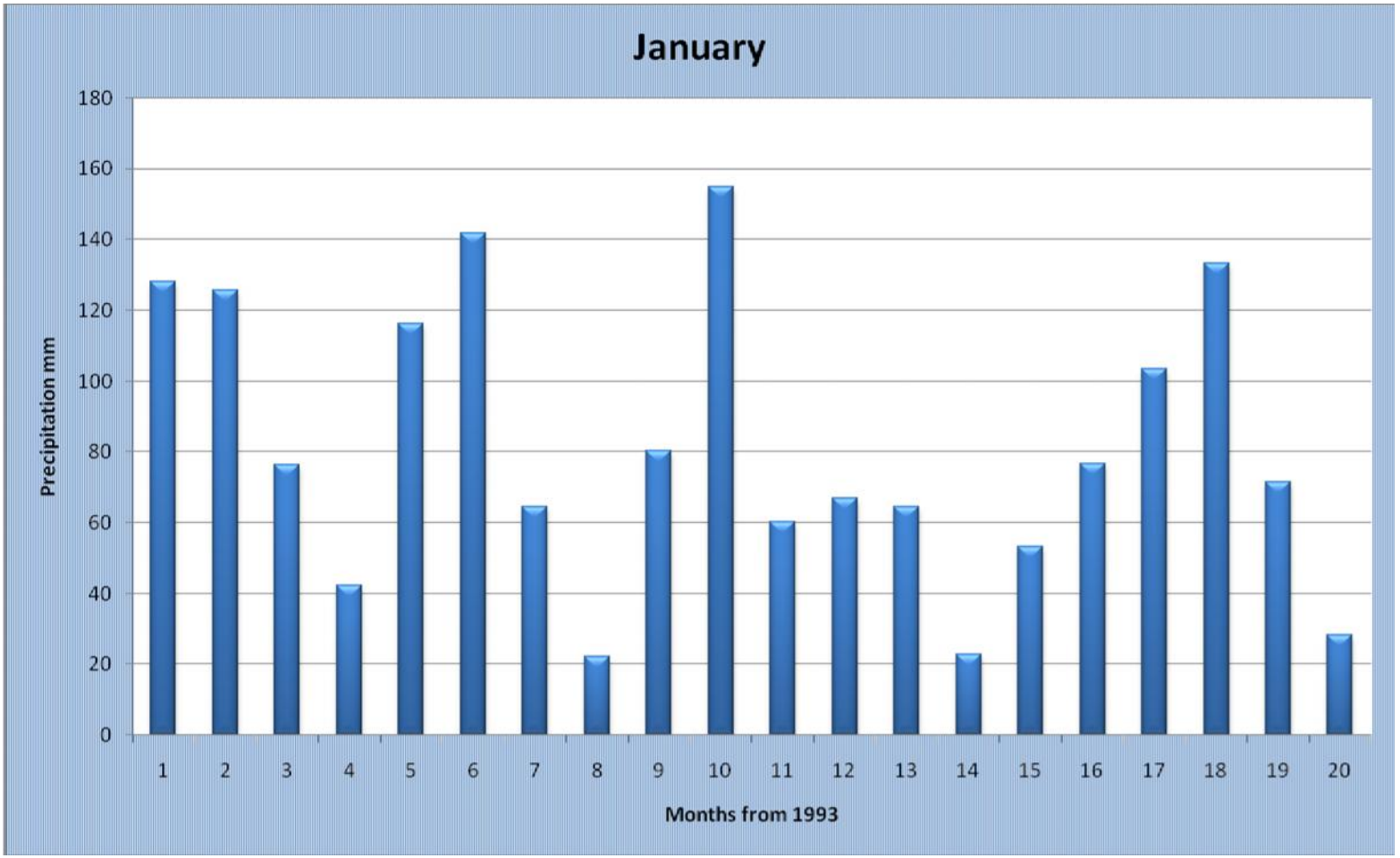

Figure 1. Showing average rainfall variation for the months of January for a period of 20 years

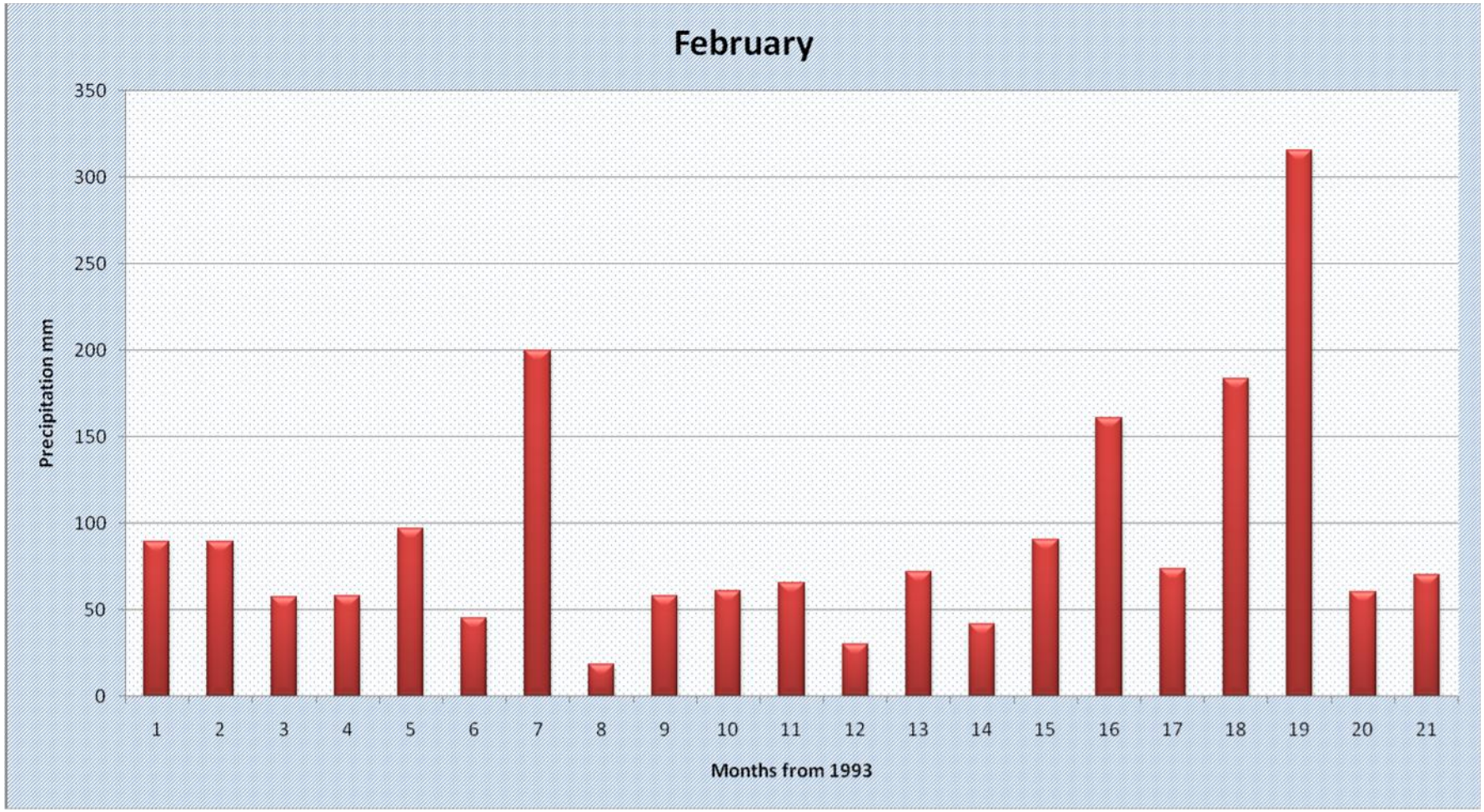

Figure 2. Showing the average evaporation for the Months of February for a period of 20 years

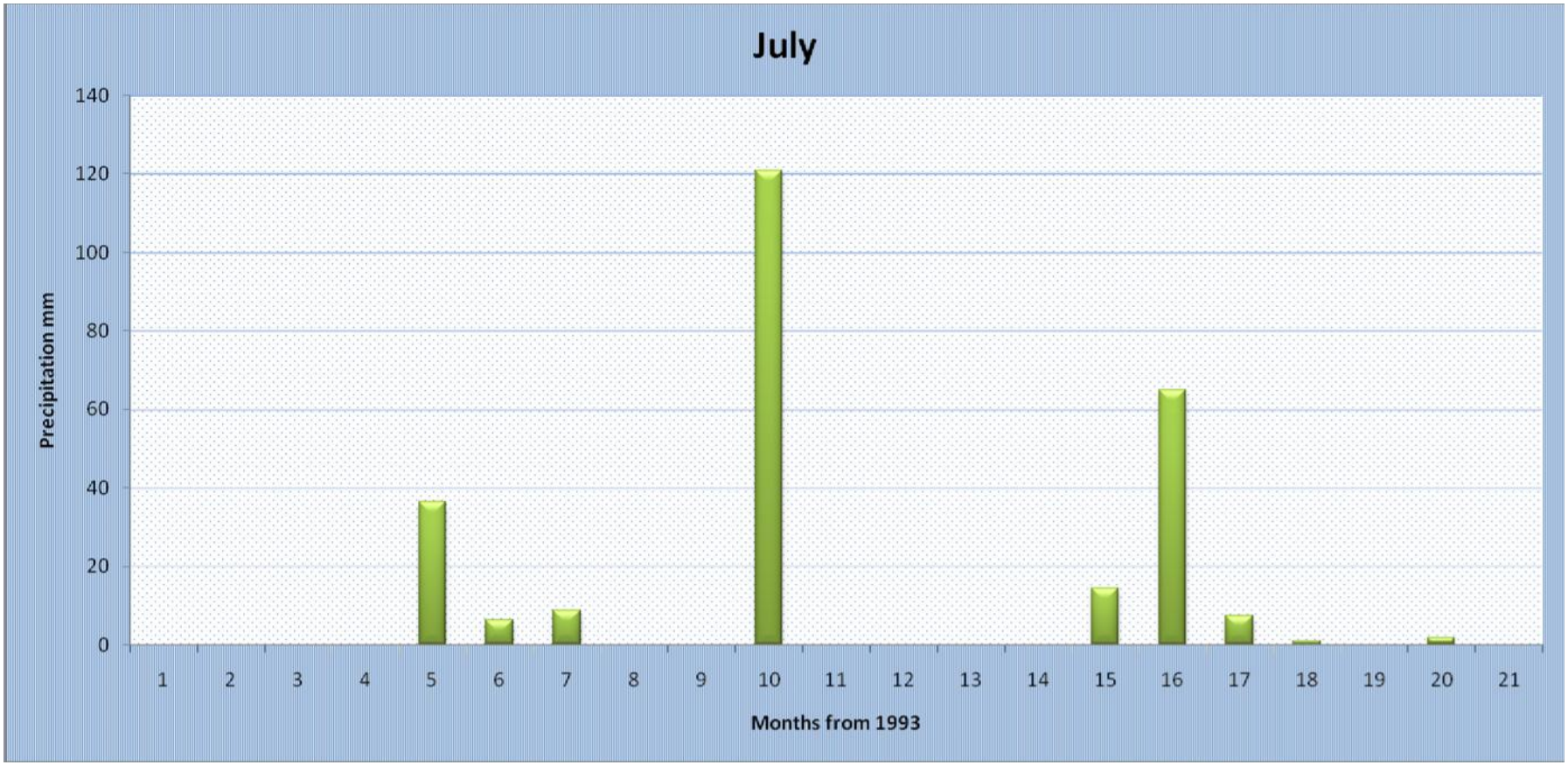

Figure 3.Showing average rainfall for the months of July for aperiod of 20 years

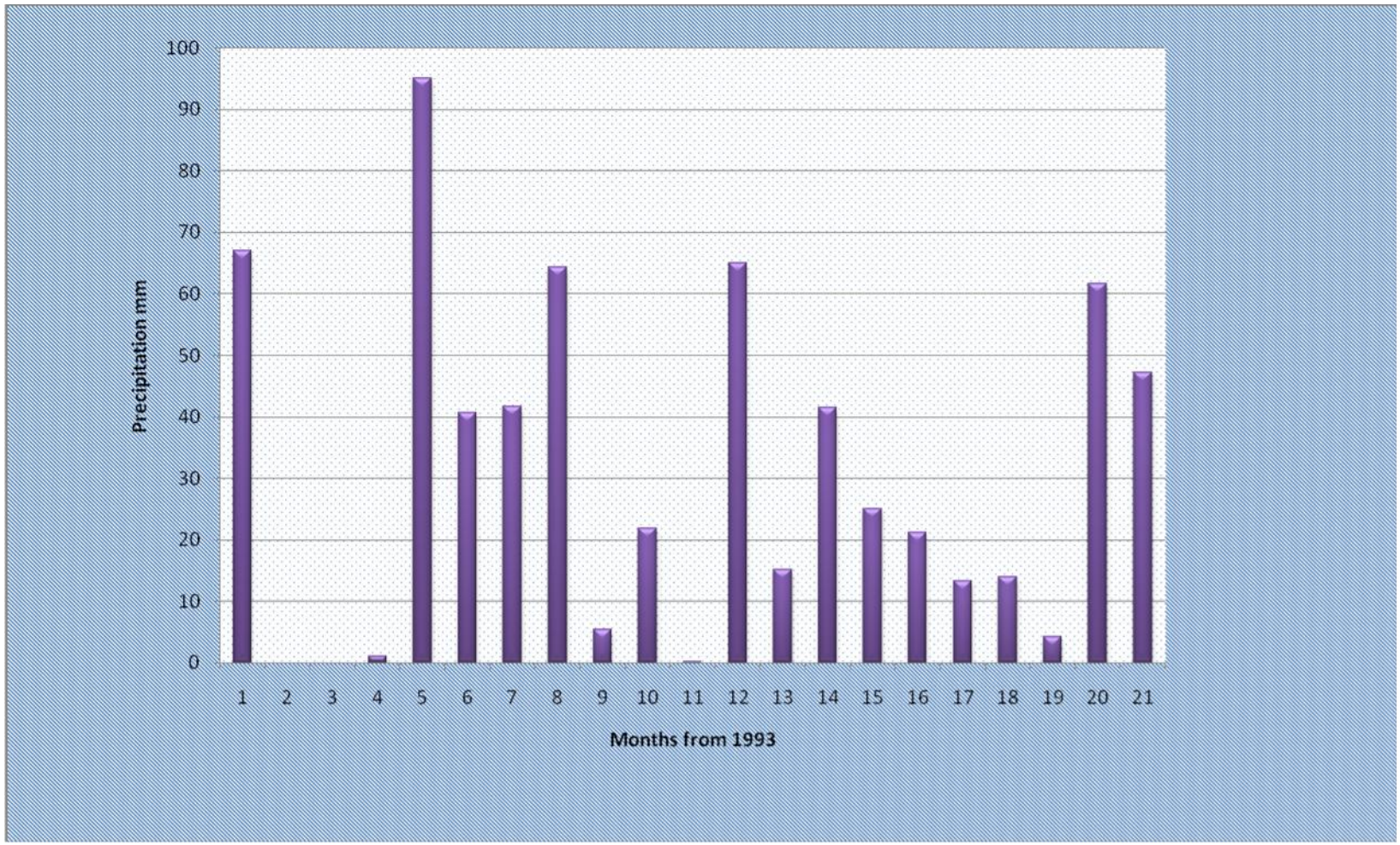

Figure .4.Average evaporation for the Months of August for a period of 20 years

Precipitation data Used												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1993	128	89.2	65.5	88.6	119.9	8.7	0	67.1	22.7	34.4	121.3	28.8
1994	125.8	57.4	206.9	129.2						65.1	157.7	118.2
1995	76.4	57.7	119.8	155.2	114	63.9	0	1.1	74.7	131.1	139.7	46
1996	42.2	97.1	136.4	124.9	42.4	45.6	36.5	95	80.3	52	67.6	28.3
1997	116.3	45.4	98.8	171.1	59.8	67.3	6.2	40.6	11.7	166.8	147	134.1
1998	141.9	200	161.3	93.3	222.7	35.8	8.7	41.7	85.1	107.1	122.1	54.6
1999	64.4	18.3	218.2	121.8	43.9	0	0	64.4	77.8	48.9	106	104.3
2000	22.1	58.2	100.7	84.1	51.3	0	0	5.4	32.6	129.2	144.2	76.3
2001	80.3	60.8	257.3	84.3	61.4	0.2	120.8	21.8	86.1	225.9	185	98.9
2002	155	65.7	98.9	156	145.6	0	0	0.2	34.6	99.7	116.5	131.7
2003	60.3	29.8	74.6	121.7	49.9	0	0	65.1	147.5	106.7	101.1	49.5
2004	67	71.8	114.3	201.4	23.1	4	0	15.1	74.6	70.7	75.8	82.8
2005	64.6	41.8	134.3	91.6	88	10.3	0	41.6	112.4	128.2	55.3	30
2006	22.7	90.6	112.2	218	117.8	5.3	14.5	25.1	35.4	57.4	210.2	141.4
2007	53.1	161	40.6	134.7	124.5	39.5	65	21.2	68	163.9	125.3	50.9
2008	76.7	73.5	154.8	115	63	58.9	7.4	13.3	34.5	64.8	55.5	39
2009	103.6	183.5	97.4	116.9	99.4	0	0.8	14	21.1	132.1	122.7	69.1
2010	133.3	315.7	120.6	135.1	88.6	40.8	0	4.3	87	128.1	79.6	87.7
2011	71.5	60.4	115.8	123.8	55.3	50.7	1.8	61.7	83.9	137.1	112.6	51.6
2012	28.3	70	109.7	184.4	222.3	13.9	0	47.2	61.3	97.9	170.6	74.3
	81.675	92.395	126.905	132.555	94.36316	23.41579	13.77368	33.99474	64.80526	107.355	120.79	74.875
	2.112023	2.645219	3.28162	3.54198	2.440125	0.625689	0.356172	0.879066	1.731651	2.776079	3.227609	1.936183

Table 1. Precipitation data for 20 years

	EVAPORATION DATA USED											
ear	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1993	100.8	103	132	156	122.5	115	167	184.7	213.5	117.6	144.4	115.
1994		109.8								89.3	56	75.
1995	94.3	92.9	123.9	96.8	101.8	121.3	159.2	198.1	181.1	120.1	120.3	107.
1996	122.7	110.1	126.6	122.1	112.8	120.2	130.9	173.4	148	128.5	95.4	134.
1997	123.9	120.7	110.1	75.8	104.2	125.1	124.7	182.1	199.4	110.2	69.5	67.
1998	111.8	84.4	112.7	102.2	98	133.8	151.2	172.7	145.2	123.6	121.9	120.
1999	114.2	160.6	87.2	76.1	116.2	137.3	169.9		120.6	136.9	79.1	61.
2000	146.7	126.8	98	99	119							
2001		94.6	95	100.7	103.6	126.3	129.4	142.8	131.1	107.2	118.6	117.
2002	79.4	109.8	95.7	76.8	131.5	156.6	180.4	188.5	171.3	123.6	94.2	78.
2003	151.3	156.1	133.1	101.9	100.7	129.2	183.4	170.9	118	127.9	118.9	140.
2004	121.8	127.3	107.9	93.1	146.6	154.7	190.5	193.5	174.2	142.9	101.1	120.
2005	143.1	130.5	104.5	114.7	111.2	123.6	170.8	168.3	150.6	138.3	105.3	144.
2006	149.4	130.4	119	90	117	154.2	165.2	178.2	161.2	137.9	67.3	85.
2007	107.3	97.9	115	109.1	96.4	100.9	134.2	131.7	109.3	103.3	101.5	109.
2008	99.9	104.5	88.1	87.3	123.5	121.6	150.2	159.4	132.8	116.5	118.7	127.
2009	106.6	79.7	110.9	91.4	112.7	158.3	180	183.1	165.8	124.9	111.1	112.
2010	130.2	111.3	107.6	99.2	116	134.6	159.5	205.6	141.8	121.6	121.4	123.
2011	128.1	120.2	117.2	105.7	112.2	135.1	159.8	147.5	113.4	101.8		
2012	92.1	145.5	114.9	76.4	50.5	121.8	165	162.8	120.7	109.4	114.8	104.
	117.9778	115.805	110.4947	98.64737	110.3368	131.6444	159.5167	172.1353	149.8889	120.0789	102.3056	108.161

Table 2.Evaporation data for 20 years