RAINFALL VARIABILITY ANALYSIS FOR CROP PRODUCTION IN BURUNDI

By

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CERTIFICATION

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I Didace RWABITEGA, declare that this dissertation is my own original work and that it has not been presented and will not be presented by me to any other University for similar or any other degree award.

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Date……………………….

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DEDICATION

To

My wife and our children.

ABSTRACT

In Burundi, agriculture engages for approximatively 80% of the economically active population and it remains a very important economic sector. In this part of the world rainfed agriculture is largely dominant; food security and income of rural populations are vulnerable to rainfall variability. Therefore, rainfall being an important climatic factor in crop production, the main objective of this research was to analyze the spatial and temporal variability of rainfall in Burundi. For this purpose, 16 meteorological stations with 30 years of data record have been used. Investigation of monthly, seasonal and annual rainfall variability using different methods reveals that there is spatial variability of rainfall in Burundi. Spatial analysis shows that the entire country can be classified into four homogeneous zones depending upon their moisture availability index. The results indicated that distribution of annual rainfall didn't show significant change within the period considered. The seasonal variability analysis shows that the temporal distribution of the two main seasons is variable from year to year. From monthly rainfall variability analysis, the months of May, June, July, August, September and October are characterized by high variability in rainfall data series indicating low reliability of rainfall during these periods. The remaining months of the year showed less to moderate variability. Another observation is that rainfall variation increases as the time becomes shorter, i.e. the variability is higher when evaluated on monthly basis than on annual basis. Trend detection analysis conducted using Mann-Kendall non-parametric test on monthly rainfall series with high variability showed negative trend indicating the decrease in precipitation, but this trend was statistically significant for some months and stations. Because of variability of rainfall in space within the study area, the future research should increase the spatial coverage by including more number of stations. Moreover, it is also suggested to extend the analysis to other time scales such as daily or ten days period in order to see the effect of rainfall variability over short time intervals on crop production. Further studies are also recommended to predict the future monthly and seasonal distribution of rainfall.

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ABBREVIATIONS

AI	Aridity Index
BDI	Burundi
Ck	Coefficient of kurtosis
Cs	Coefficient of skewness
CV	Coefficient of variation
FAO	Food and Agriculture Organization of the United Nations
GI	Gaussian Index
IGEBU	Burundi Geographical Institute
INECN	National Institute for the Environment and Conservation of Nature
IPCC	International Panel on Climate Change
L-MRDs	L-Moments Ratio Diagrams
MAI	Moisture availability index
MINATTE	Ministry of Land Management, Tourism and Environment
MK	Mann-Kendall
MRDs	Moments Ratio Diagrams
NGOs	Non-governmental Organizations
NMSA	National Meteorological Service Agency (Ethiopia)
PDNE	National Water Master Plan
PET	Potential evapotranspiration
RWH	Rainwater Harvesting
SCDI	Simple Climate Departure Index
SOSUMO	Society Sugar Plant of Moso
SP/REFES	Economic and Social Reform Permanent Secretariat
SRDI	Society for the Development of Imbo Region
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
WFP	World Food Program
WMO	World Meteorological Organization of the United Nations

CHAPTER ONE

INTRODUCTION

1.1. General

Water is a precious natural resource vital for sustaining all life on the earth. However, this important resource is not uniformly distributed in time and space. Nowadays, water in Burundi is becoming a vulnerable resource, limited by various factors including especially the frequent unfavorable climate conditions in some areas and unequal space-time distribution of rainfall (MINATTE, 2001).

Burundi, a landlocked country in the middle of Central Africa covers an area of 27,834 km². Its relief forms a complex of five geomorphologic zones: Imbo plain, the Congo-Nile watershed, the Central Plateau and the depressions of Bugesera and Kumoso. The climate varies according to altitude and annual precipitations ranging from 800 mm in Imbo plain to 1600 mm in Congo-Nile crest (IGEBU, 2001). Compared to most African countries, during years with normal rainfall, Burundi experiences abundant precipitation except in its peripheral parts in the West, the East and the North-East. The country is divided into two large catchments areas: the Nile basin and the Congo River basin. Apart from these two sources of water (surface water and rainwater), Burundi has also groundwater resources estimated approximately at 6,600 liters of water per second (FAO/AQUASTAT, 1995). Water resources are used in various ways including direct consumption, agriculture, fisheries, hydropower, industrial production, recreation, navigation, environmental protection. For the present study, only the agriculture aspect is the sector to be taken into account depending upon our objectives. This sector of crucial importance in the economic life of the country is dependant on rainfall conditions; this is thus very vulnerable to rainfall variability and related risks. In Burundi, agriculture engages for about 80 % of the economically active population and it remains a very important social and economic sector.

Rainfed agriculture is a dominant practice in the country. Under such conditions, food security and income of rural populations are vulnerable to rainfall variability, and food production is often less than the requirements of a growing population. It means that among the three water resources (surface water, rainwater, and groundwater), rainwater plays a key role in crop production.

However during the last years, reports from FAO-BDI and non-governmental organizations indicated that Burundian farmers are facing food and poverty crises due to fluctuations in seasonal distribution of rainfall. There is generally enough rainfall to double and often even quadruple yields in rainfed farming systems, even in water constrained regions, but it is available at the wrong time, causing dry spells, and much of it is lost.

In general, in case of rainfall deficit, the effects will include dryness, famine, deficit of water for various uses, fall in livestock and agricultural production, loss of human lives and biodiversity, degradation of vegetable cover, migrations of the population and cattle, drying up or reduction of the level of dams and rivers, and reduced hydropower energy (MINATTE, 2001).

In Burundi, integrated planning of the use of water resources has been constrained due to lack of information on major elements such as hydrological variables. As information on water availability and water use is of key importance for sound water planning and water management (Leeden F.V., 1975), investigation concerning rainfall variability in Burundi is essential. Therefore, rainfall being an important climatic element in agricultural production in Burundi, characterization of its variation is very helpful in rainfed agriculture.

1.2. Problem Statement

In Burundi like in most developing countries, a larger proportion of the population is rural. Agriculture engages for more than 80 % of the economically active population and it remains a very important social and economic sector. However, agricultural production is practiced under rainfed system. Rainfed agriculture is by definition dependent on the rainfall regime and is practiced during rainy season. But uncertainty in production due to fluctuations in total rainfall and changes in its distribution, reduces crop productivity lands and affects the livelihoods of many farmers.

In fact, two distinguished seasons are normally observed in Burundi each year: a dry season from June to September whereas October to May being rainy season (IGEBU, 2001). However, the amount of total precipitations recorded varies from a region to another and season to season.

Nowadays, Burundian farmers are observing perturbations in length of seasons; rainy season is becoming too short and consequently dry season long. Hence, because of these irregularities in seasonal distribution of rainfall, rural society's livelihood is affected and population is sometimes obliged to receive donations from different NGOs, FAO, and WFP (FAO-BDI, 2000). According to the same source, a total of 1,366 MT of bean seeds and 1,226 kg of vegetable seeds had been distributed in 1999 to target vulnerable families by FAO in collaboration with its partners (national and international NGOs) and the provincial department of agriculture and livestock. Therefore, it is becoming increasingly necessary to understand spatial and temporal variability of rainfall so as to be able to optimally utilize the available rainwater resources for agriculture production.

1.3. Objectives of the study

The main objective of this research is to analyze spatial and temporal variability of rainfall in Burundi. The specific objectives under the above main objective are the following:

- To analyze the variability of rainfall on monthly, seasonal and annual basis.
- To identify the months and locations which are highly subjected to rainfall variability.
- To detect existence of trend in rainfall data series for the period of study.

1.4. Significance of the study

As it has been stated, integrated planning of the use of water resources for crop production in Burundi should be designed based on knowledge and understanding of rainfall variability. This work focuses on developing indices and statistical information to characterize annual, monthly, seasonal and spatial variability of rainfall in Burundi. The results will be useful as a guideline for design and action planners in the field of water resources management for crop production.

1.5. Organization of the thesis

This thesis has been organized into five chapters. Chapter one presents the general context of the problem; including the statement of the problem, objectives of the study, and significance of the study. Under chapter two we focused on reviewing literatures dealing with rainfall variability impacts, existing technologies for mitigation of effects of rainfall variability in general and the situation in Burundi, and different methods of rainfall variability and trend analysis. Chapter three deals with materials and methods of data analysis. Three parts are the main components of this section such as: brief presentation of the study area, source of data and the methods used for data analysis in this study. Chapter four presents the results and discussion of overall work. Finally the summary, conclusion and recommendations are presented as the chapter five.

CHAPTER TWO

LITERATURE REVIEW

2.1. Rainfall variability impacts

Water is a precious natural resource vital for sustaining all life on the earth. Water resources are used in various ways including direct consumption, agriculture, fisheries, hydropower, industrial production, recreation, navigation, environmental protection. Agriculture is the principal user of all water resources taken together, i.e. rainfall (called green water) and water in rivers, lakes and aquifers (called blue water). Rainwater is the most important resource used in developing countries for crop production. However, this important resource is not uniformly distributed in time and space.

It seems obvious that any significant change in climate on a global scale should impact local agriculture, and therefore affect the world's food supply (IPCC, 2001). There is wide consensus that climate change, through increased extremes, will worsen food security in Africa. The continent already experiences a major deficit in food production in many areas, and potential declines in soil moisture will be an added burden. Food-importing countries are at risk of adverse climate change, and impacts could have as much to do with changes in world markets as with changes in local and regional resources and national agricultural economy. Africa is one of the most vulnerable continents to rainfall variability, a situation aggravated by the interaction of 'multiple stresses' occurring at various levels, and low adaptive capacity (Eric S. et Al, 1998). Africa's vulnerability to climate variability and its inability to adapt to these changes may be devastating to the agriculture sector, the main source of livelihood to the majority of the population. As most of the agriculture activities in African countries hinges on rainfed, any adverse changes in the rainfall regime would likely have a devastating effect on the livelihood of the global economy. Agriculture is the backbone of the African economy and will continue to be so for the foreseeable future. The majority of the rural population depends on rainfed agriculture, and the wellbeing of these people is intrinsically linked to the high year-to-year variation in rainfall. In most African countries the demand in water resources remains important for agriculture production since it is still a sector of crucial importance in the economic life of many countries.

The formal and informal economies of most African countries are strongly based on natural resources: Agriculture, pastoralism, and mining are dominant. Climatic variations that alter the viability of these activities, for better or for worse, have very high leverage on the economy.

The area where this research was conducted is concerned by this general situation prevailing in most developing countries. Nowadays, unequal space-time distribution of rainfall in Burundi is at the origin of the perturbations of farming seasons and drying of crops (MINATTE, 2001).

2.2. Existing technologies for mitigation of the effects of rainfall variability

Agriculture of any kind is strongly influenced by the availability of water. The occurrence of moisture stress during flowering, pollination, and grain-filling is harmful to most crops. Vulnerability to rainfall variability varies from country to country depending upon the stage of development. The major challenge in African countries is maintaining food security without degrading the fragile natural resource base on which agriculture depends (IPCC, 2001). Reducing climatic uncertainty has the potential to contribute to intensification and increased uptake of improved technologies, which may in turn contribute substantially to increased productivity and farmer income, as well as reduced soil degradation.

Different technologies are available in different parts of the world which were found to be effective to overcome the adverse effects of rainfall risks and thus, contribute towards food security. Some of the technologies obtained from literatures and electronic media are presented below.

2.2.1. Rainwater harvesting

Rainwater harvesting has recently been suggested as one response to protect against rainfall variability and climate change (Critchlely et Al, 1991). Rainwater Harvesting is the process or system of collecting, directing and concentrating all possible water that falls on an area to increase rainfall/runoff (Oweis et Al, 2001). To overcome the problem of poor distribution of rainfall in time, it is necessary to collect rainwater where it rains and store it for use to meet the water needs in the preceding dry period. This view expands the meaning of rainwater harvesting.

In the broadest sense, RWH is defined as the process of concentrating, collecting and storing water for different uses at a later time in the same area where the rain falls, or in other area during the same or later time. Instead of runoff being left to cause erosion, it is harvested and utilized for productive purpose (Critchlely, 1991). There are three main components of water harvesting systems are: *Catchment's area*: the part of the land that contributes some or its entire share of rainwater to a target area outside its boundaries. Catchment's surfaces can be either natural or treated (runoff inducement); it is a runoff area.

Storage facility: the place where runoff water is held from the time that it is collected until it is used. Storage can be in surface reservoirs, subsurface reservoirs such as cisterns, in the soil profile as soil moisture, and in ground water aquifers.

Target area: where the harvested water is used. In crop production, the target is the plant or the animal, while in domestic use, it is human being or the enterprise and its needs.

The Planning of a rainwater harvesting system involves the knowledge of the following elements (FAO, 1994):

- Factors such as climate, hydrology, topography, socio-economy, soils and agronomy aspect.
- Identification of suitable areas based on the previous factors.
- Identification of suitable method based on the particular conditions of the area.

Rainwater harvesting methods are classified in several ways mostly based on the type of use or storage, but the most commonly used classification is based on the catchment's size (FAO, 1994):

Micro-catchment systems: also called On-Farm Systems are those in which surface runoff is collected from a small catchment area with mainly sheet flow over a short distance. Runoff water is usually applied to an adjacent agricultural area, where it is either directly stored in the root zone, or stored in a small reservoir for later use. The size of the catchment ranges from a few square meters to around 1000 m^2.

Macro-catchment and floodwater harvesting systems: are characterized by having runoff water collected from a relatively large catchment. Often the catchment is a natural rangeland, hill slope or a mountainous area.

2.2.2. Irrigation technology

Irrigation technology has been adopted in many countries to protect population against the negative effects of water scarcity for agricultural production. Irrigation may be defined as the process of supplying water to land by artificial means for the purpose of cultivation. As such, the basic objective is to supplement the natural supply of water to land so as to obtain an optimum yield from the crop grown on the land. The following irrigation methods are mainly used methods in different countries:

Surface irrigation: This method of irrigation has been practiced from long past and is still very much used. Water is applied directly to the soil surface from a channel located at the upper reach of the field. Surface irrigation can be subdivided into furrow, border strip and check basin irrigation. It is often called "flood irrigation" when the irrigation results in flooding or near flooding of the cultivated land. Historically, this has been the most common method of irrigating agricultural land.

Surface irrigation offers a number of important advantages at both the farm and project level (FAO, 1989). Because it is so widely utilized, local irrigators generally have at least minimal understanding of how to operate and maintain the system. In addition, surface systems are often more acceptable to agriculturalists who appreciate the effects of water shortage on crop yields since it appears easier to apply the depths required to refill the root zone. The second advantage of surface irrigation is that these systems can be developed at the farm level with minimal capital investment. The control and regulation structures are simple, durable and easily constructed with inexpensive and readily-available materials like wood, concrete, brick and mortar, etc. Further, the essential structural elements are located at the edges of the fields which facilitate operation and maintenance activities.

Sprinkler irrigation: In this irrigation method, water is sprayed into the air and allowed to fall on the ground surface somewhat resembling rainfall. The spray is developed by flow of water under pressure through small orifices or nozzles. The pressure is obtained by pumping or even by gravity if the source is at higher elevation.

Drip irrigation: is defined as the application of water through point or line sources (emitters) on or below the soil surface at a small operating pressure and at a low discharge rate, resulting in partial wetting of the soil surface. This type of system can be the most water-efficient method of irrigation, if managed properly, since evaporation and runoff are minimized. In modern agriculture, drip irrigation is often combined with plastic mulch, further reducing evaporation, and is also the means of delivery of fertilizer.

Adoption of a particular method is governed by (Dahigaonkar J.G., 1985): Availability of water, topography of the farm, availability of funds for investment, experience of the farmer, type of soil-surface, type of crops, and weather (temperature, rainfall,…).

2.2.3. Agronomic strategies

Further, a wide variety of adaptive actions may be also taken to lessen or overcome adverse effects of rainfall variability on agriculture such as: varietal choice, selection of appropriate planting date, optimizing rate and technics of fertilizer application, determination of optimum planting dekad.

At the level of farms, adjustments may include the introduction of later- maturing crop varieties or species, switching cropping sequences, sowing earlier, adjusting timing of field operations. Concerning crop species point of view, a major adaptive response will be resistant crop varieties by utilizing genetic resources that may be better adapted to new climatic and atmospheric conditions.

2.3. Crop production systems in Burundi

2.3.1. Importance of irrigated agriculture

Burundi's agricultural system is not significantly benefiting from the technologies of water management and irrigation that could improve productivity and reduce the vulnerability to rainfall variability. Agriculture is the mainstay of the economy, and it is high reliant on rainfall. The farmers grow their crops on upland during the rainy season; meaning that the yield is function of rainwater requirement.

During the dry season, some crops such as Potatoes, fruit trees and Vegetables are grown in wetlands (or marshes).

Irrigated agriculture using flooding irrigation system is practiced in Rusizi valley and Tanganyika valley especially for rice crop, where the "SRDI Society for the Development of Imbo Region" is the main supervisor. Irrigation technology is also practiced in Malagarazi valley for growing sugarcanes using furrow irrigation system under the supervision of "SOSUMO Society Sugar Plant of Moso". In addition, traditional irrigation schemes are constructed under self-help programs carried out by farmers on their own initiative for the production of vegetables in wetlands during dry season. The following Table indicates that irrigation technology is not developped in Burundi according to PNDE (1998) database.

Table 2.1. Irrigated lands in different sub-basins (Areas in Km^2).

	Year	
Sub-Basin name	**1990**	**2000**
Rusizi	84.6	164.6
Tanganyika	27.0	49.3
Malagarazi	82.5	82.5
Total	194.1	296.4

As it can be seen from Table 2.1 the development of irrigation over 10 years showed only about 35% increase in total area. In sub-basin such as Malagarazi there was no increase in irrigated area over the time observed.

2.3.2. Economy and agricultural production in Burundi

According to the census of year 1990, Burundi counts approximately 7.2 million inhabitants. The average demographic density is 280 inhabitants per km², with a demographic growth rate of approximately 2.96%. The Burundian economy goes through important structural rigidities, such as dominant food agriculture but with very low productivity, a limited exporting capacity and clear regression with regard to its principal foreign income generating product, i.e. coffee, or a secondary industry with very limited fabric and heavily handicapped by its isolation.

It is to be noted that food production is still less than the requirements of a growing population. In general, the farmers grow their crops on upland during the rainy season; meaning that the yield is function of rainwater requirement.

In introduction part, it has been said that two main seasons are normally observed in Burundi each year: a dry season from June to September whereas from October to May we have a rainy season (IGEBU, 2001). The farmers have kept in mind this seasonal distribution as reference in their agricultural activities, meaning that if there are fluctuations the yield of some crops will be affected. Experiences have shown that crops which are sown at the end or beginning of the wet season have been negatively affected by that phenomenon these last years (FAO-BDI, 2000). The problem is that, Burundian farmers consider the growing season referring on the temporal distribution of seasons as mentioned above. However, the late beginning of the rainy season and the early end of the same are the climate phenomena that are nowadays at the origin of disturbance of the farming seasons and the drying of crops. Early warning systems are not available to provide timely information so that the design and action planners involved in agriculture production can take the necessary measures to reduce the impact of rainfall variability. Therefore, because the farmers are confused with respect to the beginning or end of growing season, don't know how to adapt their agricultural calendar. Referring on the main crops cultivated in Burundi, Maize and Beans respectively sown at the beginning and end of rainy season may be much affected than other crops.

Table 2.2. Crop calendar as known by farmers.

	J	F	M	A	M	J	J	A	S	O	N	D
Distribution of Rainfall												
Season A	**M**	**H**							**L**	**S**	**M**	**M**
Season B		**LS**	**S**	**M**	**M**	**H**						
Season C						**LS**	**LS**	**M**	**H**			

Source: FAO-BDI, 2000.

The symbols in Table 2.2 are designated as: **L** is land preparation/cultivation, **S** is seed sowing, **M** stands for other agricultural practices (weed control, fertilizers application…), and **H** stands for harvest.

In “season A” corresponding to the beginning of rainy season, the crop to be grown is mainly Maize in all regions of the country. Similarly, the “season B” corresponds to the end of rainy season and Beans are mainly cultivated in the whole country. In addition to these two crops, other crops such as bananas, sweet potatoes, vegetables are grown during season A and B. The crops for the “season C” concern especially the wetlands (Potatoes, fruit trees, Vegetables).

Figure 2.1 shows the trend of yield for the main crops cultivated in Burundi (in 10^3 Tones).

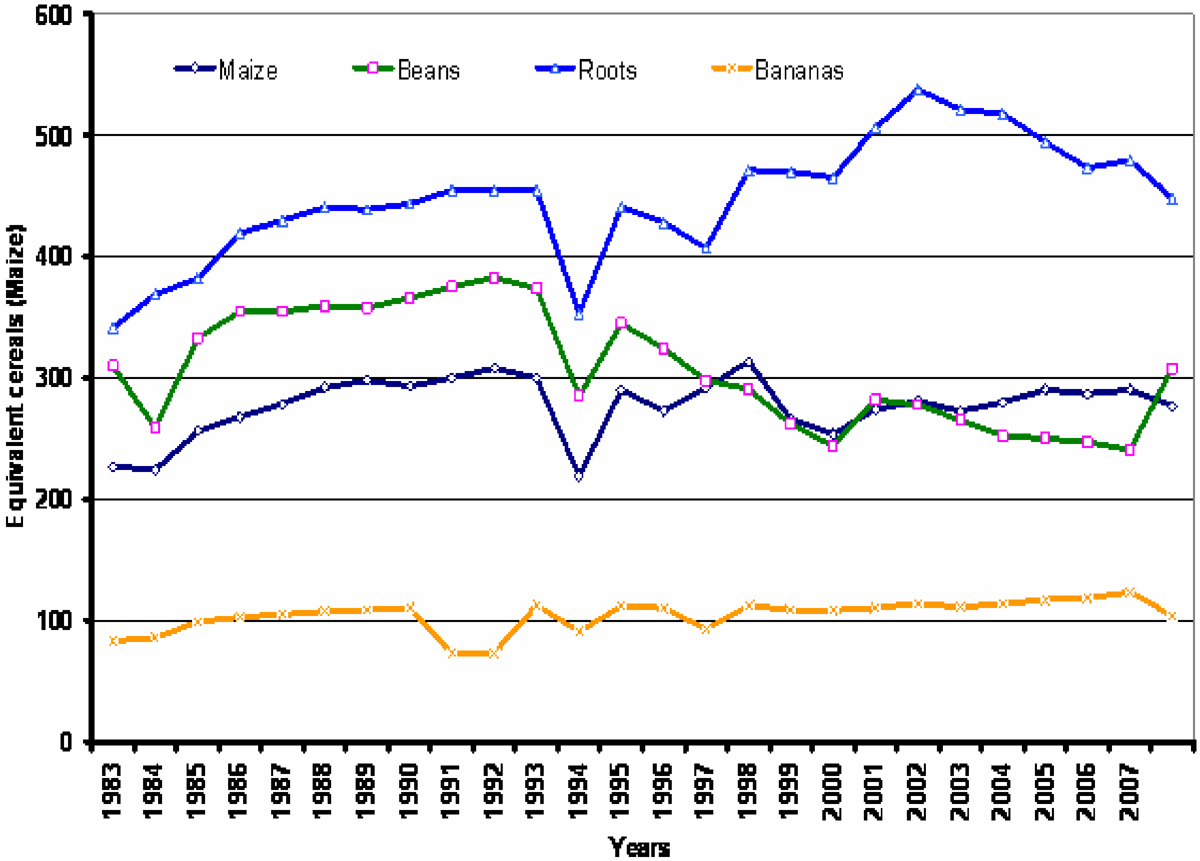

Figure 2.1: Production trend for main crops in Burundi (FAO-BDI, 2008).

Figure 2.1 shows that production of Bananas versus time doesn't change considerably. Concerning Beans, Maize and Roots crops, the observation from the same figure is that from year 1998 the graph starts to show some significant changes with time. With this regards, production in Beans and Maize shows almost a declining trend, whereas the Roots production increases. Reports from the same source (i.e. FAO-BDI) indicate that Burundian farmers are more interested in those crops production which are resistant to water stress due to rainfall fluctuations, even the Beans and Maize seeds obtained from different NGOs are sometimes used for direct consumption. Other sources from the Ministry of Agriculture and livestock attribute this decreasing trend to the variability of rainfall.

2.4. Rainfall variability and trend analysis methods

The variability or dispersion of any data series can be evaluated based on statistical analysis with the help of the following parameters (Suresh R., 2005): Mean deviation, Mode, standard deviation, coefficient of variation.

Analysis of rainfall variability can also be made using Rainfall variability indices methods such: Simple climate departure index, Cumulative Departure Index, Rainfall anomaly Index, Moisture availability index. There appears to be two definite advantages of the coefficient of variation as a measure of rainfall variability (Ketema, 2006). Firstly, it is considerably faster and easier to compute from original data; and secondly it is intimately related to a measure which characterizes the frequency distribution of any series of rainfall totals. It is a dimensionless measure of the variability computed as the ratio of standard deviation to the mean of a given data series. The INSTAT software is also another methodology used to assess the variability of rainfall.

Concerning trend detection analysis, both statistical and graphical methods are used to evaluate trend in a time series. The graphical method is used to analyze trend in rainfall data; it involves the plot of the time series on a graph and visually assessing the presence of a trend through the graph. It is the simplest and flexible method. There are many statistical approaches that can be used to detect trends and other forms of non-stationary in hydro-meteorological data. In deciding which approach to take, it is necessary to be aware of which test procedures are valid and most useful.

For this purpose, there are parametric and non-parametric tests for trends detection (Maidement, 1993). One type of parametric tests used for assessing the significance of trend is the statistical t-test. The KhronoStat software through Pettitt test was designed in the frameworking of a study on climatic variability in non-Sahelian West and Central Africa, and is thus focused on the analysis of hydrometeorological series (WMO, 1996). These tests require a tested series to be normally distributed. The advantage of non-parametric statistical tests over the parametric tests is that they are more suitable to non-normally distributed, outlier, and missing data, which are frequently encountered in hydrological time series (Yue et al., 2002 (2)).

CHAPTER THREE

MATERIALS AND METHODS

3.1. Overview of the study area

3.1.1. Geographical location

The present research was done using data collected from different climatic regions of Burundi. The study area is a landlocked country in the middle of Central Africa with a highly diversified environment. It is one of the smallest countries in Africa, covering an area of 27,834 km² and extends between the meridian lines 29°00 and 30°54' East and the Southern parallels 2°20' and 4°28' (IGEBU, 2001). It is bordered to the North by Rwanda, to the East and the South by United Republic of Tanzania and to the West by the Democratic Republic of Congo (Figure 3.1).

Figure 3.1: Geographical location of Burundi (UN-BDI, 2005).

3.1.2. Relief

The relief of Burundi forms a complex of five geo-morphological zones that are diversified enough, including the Imbo flood plain, the Congo-Nile watershed, the Central plateaus and the depressions of Bugesera and Kumoso (Figure 3.2). From West to East, these zones with an altitude range of 775 m to 2600 m are observed in the following manner (MINATTE, 2001).

- Western plain (Imbo plain) located between 775 and 1000 m of altitude,
- Western highlands forming the Congo-Nile watershed and located between 1000 and more than 2600 m of altitude,
- Central plateaus covering most of the country and located between 1400 and 2000 m of altitude,
- Eastern depression of Kumoso located between 1200 and 1400 m of altitude,
- Depression of Bugesera at the North-East of Burundi and located between 1200 and 1500 m of altitude.

3.1.3. Climate

The topography of Burundi is accompanied by the variation of climate according to altitude, which confers important geo-climate diversity to the country (IGEBU, 2001). Altitudes above 2000 m, materialized by the Congo-Nile watershed, are sprinkled with mean precipitations ranging between 1400 mm and 1600 mm and have annual mean temperatures oscillating around 15°C with minima temperature sometimes going as down as 0°C. The mean altitudes, grouped under the term of central plateaus and oscillating between 1500 and 2000 m, receive approximately 1200 mm of annual precipitations with 18-20°C of annual average temperatures. Altitudes below 1400 m represented by the plain of Imbo, and the depressions of Kumoso and Bugesera have annual average precipitations below 1200 mm and sometimes below 1000 mm like Imbo, with minima reaching 500 mm. Annual mean temperatures are above 20°C. The late beginning of the rainy season and the early end of the same are the climate phenomena that are nowadays at the origin of disturbance of the farming seasons and the drying of crops.

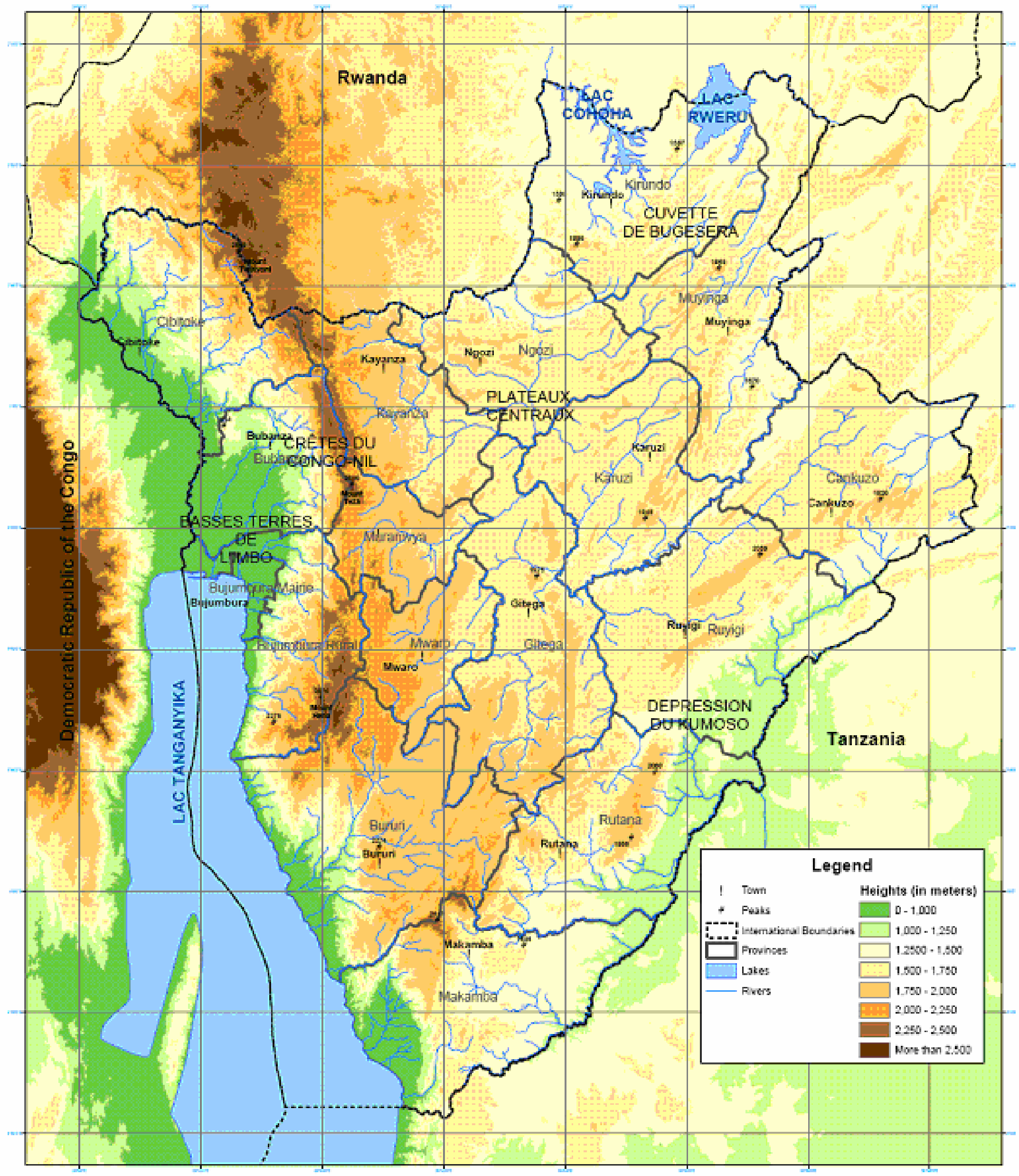

Figure 3.2: Geomorphologic zones defining the relief of Burundi (IGEBU, 2001).

3.1.4. Water resources distribution in Burundi

The water resources in Burundi are found in surface water (lakes, rivers, and streams), groundwater and rainwater resources. Burundi has groundwater resources estimated approximately at 6,600 liters of water per second (FAO/AQUASTAT, 1995), but there is no detailed information available on this resource. Rainwater resource which is very important for agricultural production in the country will be discussed later. Coming to surface water resources, the country is divided into two main catchments areas: the Nile basin and the Congo basin. Under these two catchments, there are six sub-basins based on the topography, with a very dense network of rivers and streams. The following table shows the coverage areas of these sub-basins.

Table 3.1. Coverage areas of sub-basins of Burundi and their water resources potential.

Sub-basins	Surface area (Km^2)	Mean Discharge (m^3/sec)
Rusizi	2,682	53
Tanganyika	3,871	78
Malagarazi	5,262	51
Ruvubu	10,063	108
Kanyaru	1,938	21
Kagera	1,217	8
Total	25,035	319

Source: PDNE, 1998.

During years with normal rainfall, abundant precipitations are observed except in its peripheral parts in the West, the East and the North-East of the country. The surface water resources, which include the whole of rivers and lakes, constitute the country internal resources available. According to FAO/AQUASTAT (1995), the internal renewable water resources amount is approximately 10.060 billion m^3 for the whole country, whereas the external water resources are estimated to reach a total of 2.476 billion m^3.

Concerning the ground water resources, Burundi has sources of approximately 6,600 liters of water per second. Imbo, Kumoso and Bugesera are the natural regions with the weakest sources. Conversely, the high altitude regions of Mugamba, Mumirwa and Bututsi are well provided with spring water with specific flows above 0.3 $l/s/km^2$ (MINATTE, 2001).

The Bugesera region located in the North-East of the country is most underprivileged with regard to the total water resources. Even though there are abundant rivers and groundwater, agriculture in the country mainly depends on the seasonal rainfall. Hence the failure of the seasonal rainfall has severe impact on the economy of the country.

3.2. Source of data and availability

This study was carried out using the following categories of data listed below:
Meteorological data: The basic data consists of monthly rainfall totals and monthly average temperature, derived from daily data for 16 stations in Burundi. Long-term monthly rainfall and temperature data from 1975 to 2004 (30 years) were provided by the IGEBU - National Meteorological Department of Burundi. The period of analysis is dictated by the rainfall data set and mean temperature which extends from 1975 through 2004. Note that 30-year period is a minimum recommended period made by WMO for climatic analysis. In addition to this criterion, the location of stations is important in such a way that they can represent approximately the whole study area. Therefore, the meteorological data described above are recorded from five main geomorphologic regions represented as follow by existing meteorological stations.

- Imbo Plain: Bujumbura, Mparambo
- Congo-Nile Crest: Gisozi, Rwegura, Tora.
- Central Plateau: Gitega, Karuzi, Ruvyironza, Muriza, Nyamuswaga
- Kumoso and Bugesera depressions: Cankuzo, Kinyinya, Musasa, Muyinga, Kirundo, Makamba.

Figure 3.2 displays the geomorphologic zones defining the relief of Burundi where different stations have been selected for the study.

After stations being selected, the next step was to check for consistency of data using *Double mass curve method* and missing data using *Arithmetic average method*. Another type of data is the losses of water by potential evapotranspiration (PET) derived from available meteorological data using Thornthwaite formula. The following information is also necessary for discussion of the results: Topography, land cover, crop production systems, socio-economics conditions, rainwater management systems available, hydrological data (surface water and rainwater resources), importance of irrigation technology in crop production.

3.2.1. Rainfall data

The data used to undertake this study were collected from different sources. In this case, rainfall data were provided from the National Meteorological Department of Burundi . In order to conduct this research, rainfall data of the past 30 years are used to study the basic statistical characteristics. The selection of the stations was restricted to sixteen stations due to unavailability of stations with complete data (Figure 3.3). The length of data record for all the stations was 30 years of climatic data needed to do accurate climatic analysis (Stewart, 1988). For many agro-meteorological purposes the WMO recommended that the length of 30 years will be quite adequate. This is especially the case for agricultural planning purposes where most of the decisions are made to the immediate, rather the most distant past (Todorov, 1985). In addition to this criterion, the location of stations is important in such a way that they can represent approximately the whole study area. Therefore, the meteorological data used in this study are recorded from five main geomorphologic regions defining the relief of Burundi. The latitude, longitude, and altitude of the selected meteorological stations are presented in Table 3.2.

Table 3.2. Geographical location of the meteorological stations.

Stations	Longitude East (degrees)	Latitude South (degrees)	Altitude (m)
Bujumbura	29.317	3.317	783
Makamba	29.817	4.133	1450
Mparambo	29.233	2.717	1509
Gisozi	29.683	3.567	2097
Mpota-Tora	29.570	3.730	2160
Rwegura	29.517	2.917	2302
Cankuzo	30.383	3.283	1652
Kinyinya	30.333	3.650	1308
Musasa	30.100	4.00	1260
Muriza	30.083	3.533	1616
Nyamuswaga	30.033	2.883	1720
Ruvyironza	29.767	3.817	1822
Karuzi	30.167	3.100	1600
Gitega	29.917	3.417	1645
Kirundo	30.117	2.583	1449
Muyinga	30.350	2.850	1756

3.2.2. Consistency of data

Consistency of data is determined for testing and adjusting the available rainfall data, especially when conditions relevant to the rain gauge station have gone significantly change and thus, causing the data inconsistency. Generally, the following reasons are responsible for making the rainfall data inconsistent (Suresh R., 2005): the change of location of the rain gauge station, construction of structures like buildings or growth of trees near rain gauge station and repetition of observational error from a certain period. The consistency of rainfall record is tested by double-mass curve method, which deals with the comparison between accumulated of monthly or annual rainfall of the station which data is expected to be inconsistent and the concurrent accumulated mean annual rainfall of the group of surrounding rain gauge stations known as *base stations*. The consistency of rainfall data have been checked using *double-mass curve method*.

The double-mass curve technique requires data sets from two weather stations, where X_i (i = 1, 2,..., n) is a chronologic data set for a given weather variable observed for a certain time length at a *reference or base station*, and which is considered to be homogeneous, and where Yi is a data set of the same variable, with the same time length, observed at another station and for which homogeneity needs to be analysed. In the double-mass analysis, starting with the first observed pair of values X_1 and Y_1, cumulative data sets are created by progressively summing values of X_i and Y_i to verify whether the long term trends in variation of X_i and Y_i are the same.

3.2.3. Missing data

Missing data is one of the main problems which are often encountered in hydrological analysis, may be due to the absence of observer. Another cause of missing data may be short interruptions in observations due to a large number of causes, the most frequent being the breakage or malfunction of instruments during a certain time period. When data are missing, it may be appropriate to complete these data sets from observations made in another nearby and reliable stations. So as much as possible was done the estimation of missing data for some stations with no complete rainfall data series.

There are various methods for estimation of missing data in hydrological data series; these are: Isohyetal method, Arithmetic average method, and Normal Ratio method. In this study, there were some missing data in monthly rainfall series for the stations: Makamba, Mparambo, Musasa, Muriza and Nyamuswaga. These missed data have been estimated from nearby stations using *arithmetic average method* as follows.

$$Px = \frac{1}{n}\left(P1 + P2 + ... + Pn\right) \qquad (3.1)$$

Where, Px = missing rainfall data at station x

Pn = rainfall data at the neighboring station i

n = number of neighboring rain gauge stations

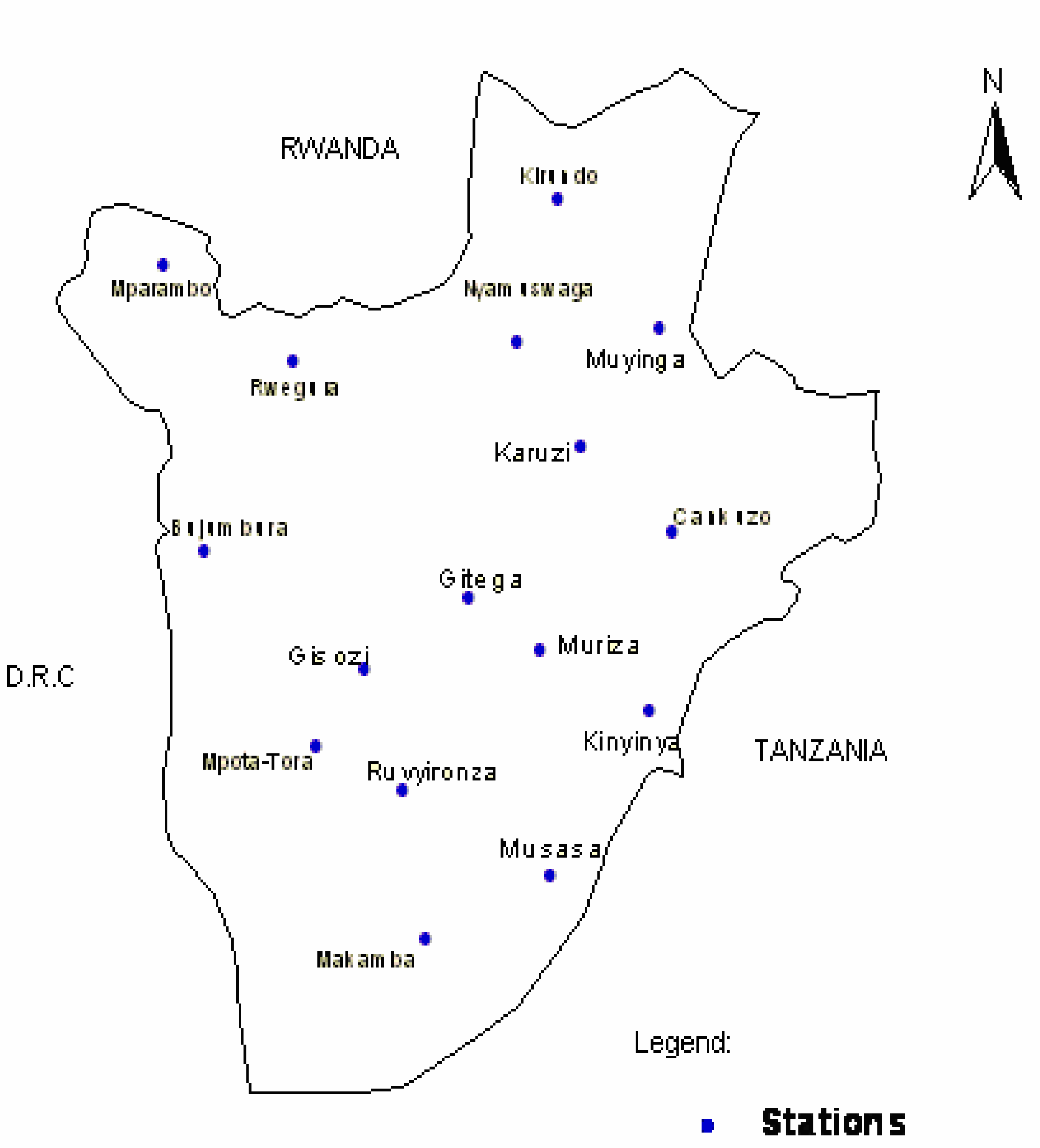

Figure 3.3: Location of the stations used for the study.

3.3. Rainfall variability analysis

3.3.1. Characterization of rainfall in Burundi

3.3.1.1. Agro-climatic zonation

In general, soil water management is faced with limited and unreliable rainfall and high evapotranspiration rate. Therefore, it is essential to understand the spatial and temporal variability of the amount of rainfall received in relation to evapotranspiration rate in order to develop effective management strategies (Stewart, 1988). In this study, the agro-climatic zonation of the meteorological stations has been determined using UNESCO *Aridity Index* (A.I) given as (Rodier, 1985):

$$AI = P/ETo \qquad \text{……………………………………………………. (3.2)}$$

Where P is the mean annual rainfall and ETo is the mean annual reference evapotranspiration.

An aridity index (A.I) is a numerical indicator of the degree of dryness of the climate at a given location. This indicator serves to identify, locate or delimit regions that suffer from a deficit of water, a condition that can severely affect the effective use of the land for such activities as agriculture. According to this index, the boundaries that define various degrees of aridity have been adopted by UNESCO classification as follows:

Table 3.3. Degrees of aridity by UNESCO classification.

Classification	Aridity Index
Hyper-arid	AI < 0.05
Arid	0.05 < AI < 0.20
Semi-arid	0.20 < AI < 0.50
Dry sub-humid	0.50 < AI < 0.65
Humid	> 0.65

Source: Rodier, 1985.

The mean annual rainfall is computed by taking the mean of the total rainfall amount of some consecutive years; usually 30 years rainfall data is considered for the purpose as recommended by WMO. Therefore, mean annual rainfall *P* was calculated from the rainfall data for each station. While rainfall can be directly measured, evapotranspiration is estimated from weather data.

Several empirical methods have been developed to estimate evaporative power of the atmosphere with different data requirements (Mekonen , Lecture notes 2008):

1. Blaney-Criddle method
2. Thornthwaite formula
3. Penman method
4. Christiansen method
5. Radiation method
6. Jensen-Haise method
7. Hargreave equation
8. Modified Penman formula and many others.

The FAO Penman Montheith method is recommended as the sole method for determining the reference evapotranspiration of the area. Required data are temperature, humidity, wind speed and sunshine duration (FAO, 1998). In most of the cases, these parameters required for the estimation of reference evapotranspiration using Penman method are not available at some selected meteorological stations. For those particular conditions, other empirical methods which require limited weather information can be used. Therefore, since no sufficient meteorological data could be obtained for all the stations selected for this study, *Thornthwaite formula* has been used to compute the potential evapotranspiration. He assumed that there is a good correlation between the mean temperature and variables such as moisture, wind velocity and solar radiation. The relationship is given as follows:

$$PET = 16.2 * Rf [10 * Tm / I]^{a} \quad \text{(in mm)} \quad \ldots\ldots\ldots\ldots(3.3)$$

Where, I is annual heat Index

Rf is the reduction factor

Tm is the mean monthly temperature in ◦C

"a" is a constant to be computed using I values:

$$I = \sum_{j=1}^{12} i \quad \text{Where, } i = [Tm_i / 5]^{1.514} \quad \ldots\ldots\ldots\ldots (3.4)$$

Therefore, the constant "a" is given by the following relation:

$$a = 0.4923 + 1.792*10^{-2} I - 7.71*10^{-5} I^{2} + 6.75*10^{-7} I^{3} \quad \ldots\ldots\ldots\ldots (3.5)$$

3.3.1.2. Range of annual rainfall

In a data series, a range is the simplest of measures of dispersion. It is defined as the difference between the largest and the smallest values of a given set of measurements.

$$Range = X\max - X\min \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.6)}$$

Where X_{max} is the largest value and X_{min} is the smallest value.

Apart from agriculture purpose, these extreme values are of prime interest in hydrology as inputs to estimate design floods, as a basis for designing drainage systems, culverts, and flood control structures or flood plain management and land use plans. Note that a range is a rather crude measure of dispersion because it doesn't indicate anything about the way the values are distributed within the range; other statistical parameters are necessary. The range of annual rainfall has been compared to the annual range of evapotranspiration in all the stations selected for the study and the results are presented in Chapter four.

3.3.1.3. Probability distributions of rainfall

Introduction

Rainfall is the most important environmental factor limiting agricultural activities and water resources projects. Although irrigation is believed to be an important strategy in alleviating the current food crisis, rain-fed agriculture is still the dominant practice in most developing countries. Soil water management faced with limited and unreliable rainfall and high variability in rainfall pattern. It is very hard for hydrologists to measure, collect and store hydrological data such as rainfall. It is generally assumed that a hydrological variable has a certain distribution type. For predictive purposes, it is often desirable to understand the shape of the underlying distribution of the population. To determine this underlying distribution, it is common to fit the observed distribution to a theoretical distribution. Fitting an appropriate probability distribution involves three steps namely: selection of a distribution, estimation of its parameters, and testing its goodness of fit to the observed data. Regarding the selection of proper distribution underlying the process, a wide variety of distribution functions should be considered (Jayarami, 1997): These are normal distribution, two and three parameter

Log-Normal distribution, exponential distribution, two parameter Gamma distribution, Pearson three distribution, log Pearson three distribution, generalized extreme value distribution, extreme value type one distribution, Weibul distribution, the four and five parameter Wakeby distribution, the generalized Pareto distribution, logistic distribution, generalized logistic distribution. Testing the goodness of fit to the observed rainfall data can be done using Moment Ratio Diagrams (MRDs) and L-Moment Ratio Diagrams (L-MRDs).

Moments Ratio Diagrams (MRDs)

For a given distribution, conventional moments can be expressed as functions of the parameters of distributions. The higher order moments are expressed as functions of lower order moments. Pairs of coefficients of skewness (Cs) and coefficient of kurtosis (Ck) are computed and plotted on the Cs-Ck diagram for each station. The location of the sample estimate with respect to the distributions gives an indication of the goodness of fit to the data. Approximations are used for constructing the Cs-Ck Moment Ratio Diagrams for some common distributions which are quite accurate for Ck<40 (Appendix 1). Applying these approximations, the Cs-Ck Moment Ratio Diagrams have been constructed as follows.

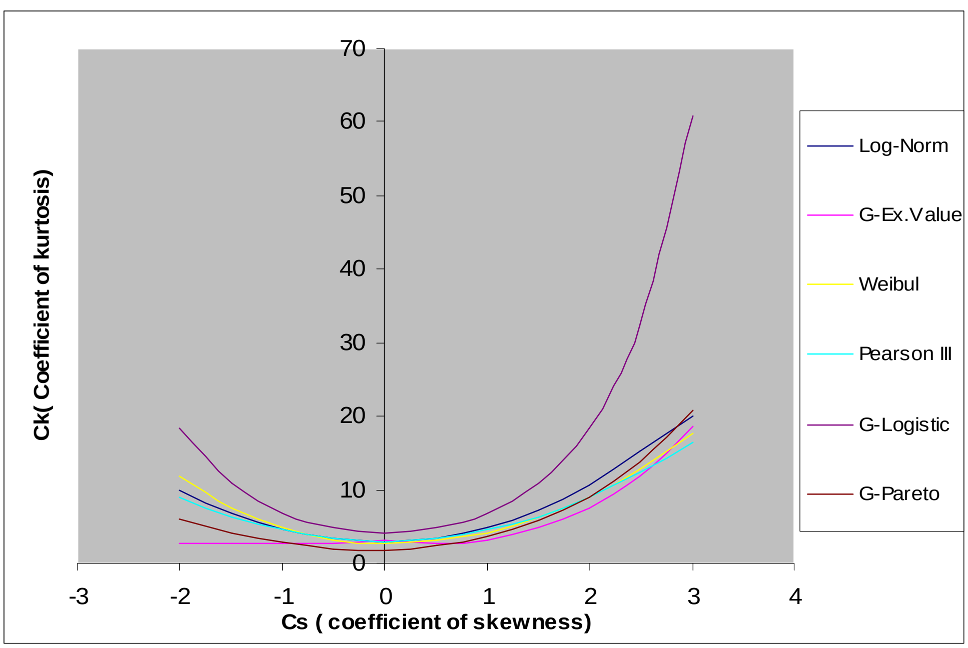

Figure 3.4: Graphs of Moments Ratio Diagrams (MRDs).

L-Moment Ratio Diagrams (L-MRDs)

The L-Moment Ratio Diagrams are based on relationships between the L-moments ratios, analogous to the conventional MRDs. A diagram based on L-Cs (t_3) versus L-Ck (t_4) is used similar to the conventional MRDs for identification of appropriate distributions that best fits the rainfall data. For each station, the sample L-moment ratios t_3 and t_4 are plotted on L-Moment Ratio Diagram. A suitable parent distribution is that which average value of (t_3, t_4) gets close to it. It was shown by Hosking (1990) that Cs and Ck values from several samples drawn from three different distributions lay close to a single line on the graph and overlaps each other offering little hope of identifying the population distribution (Figure 3.4). In contrast, the sample L-moment ratios plot as fairly well separated groups and permit better discrimination between the distributions (Figure 3.5). The identification of a parent distribution can be achieved much more easily by using L-MRDs than MRDs, especially for skewed distributions (Hosking, 1986b). Therefore, the L-Moment Ratio Diagrams have been used in this study for identification of an appropriate probability distribution. Some useful relationships for constructing the L-moment ratio diagrams for some common distributions are given by Hosking (1990). The following graphs have been plotted using these approximations described in Appendix 2.

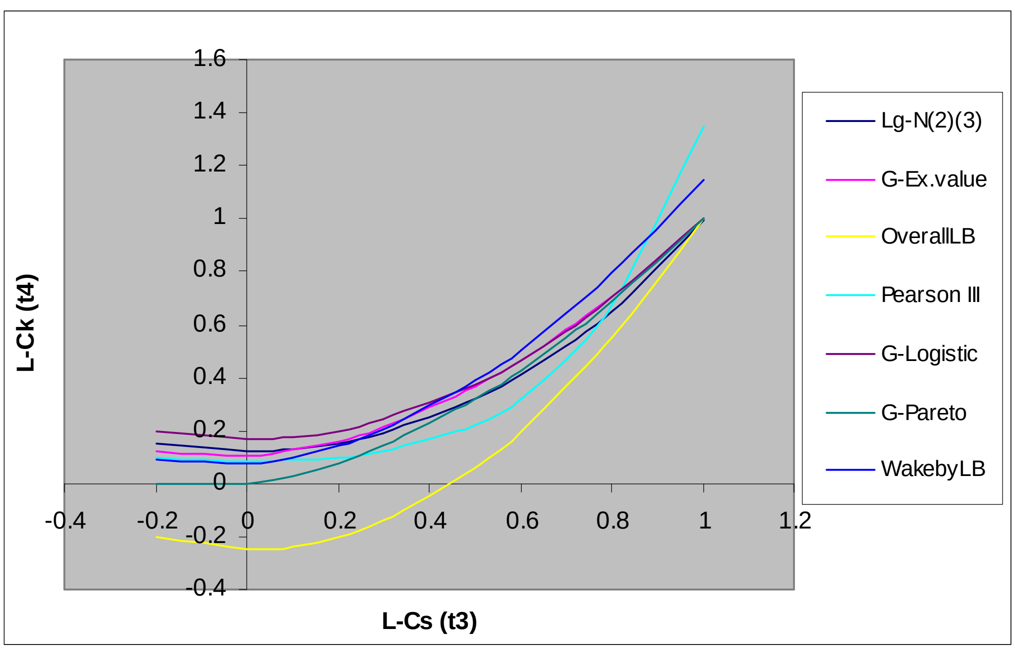

Figure 3.5: Graphs of L-Moments Ratio Diagrams (L-MRDs).

3.3.1.4. Probability of a wet day

The frequency of rainy days is an important determinant of annual rainfall (Hofmeyr and Gouws, 1964). It should however be noted that higher number of rainy days do not necessarily imply higher amount of rainfall in some areas. Knowledge of wet day probability is important in different phases of crop growth, soil and water conservation planning and to predict the incidence of crop diseases. In order to determine the probability of a wet day "P_{wet}", the number of days (n_i) that were wet was counted for each station and expressed as a fraction of the total number of days (N_s).

$$Pwet = ni / Ns \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.7)}$$

A day is considered to be wet when there is more than 1 mm of rainfall and dry when rainfall is 1 mm or less (Ketema, 2006). Rainy days over the period considered for all the sample stations, were counted on a monthly basis. The probability of a wet day is computed as a fraction of the number of days that are wet out of the total number of days in a month (eq. 3.7). Finally for each station, mean monthly of wet days is established and mean monthly probabilities of a wet day are determined in order to characterize the occurrence of rainy days in different regions of the study area. Estimation of the mean is required for understanding spatial and temporal characteristic of rainfall in term of wet day probability within the months during 30 years period (1975-2004) in this study.

3.3.1.5. Exceedance probability and return period of annual rainfall

The annual rainfall total are ranked in descending order by their magnitude, with m = 1 for the largest and m = 30 for the lowest value in our case, the data are arranged accordingly. The probability of occurrence P (%) for each of the ranked observations can be calculated from Weibull's formula:

$$P (\%) = (m / N+1) \times 100 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(3.8)}$$

Where: P = probability in % of the observation of the rank m

m = the rank of the observation

N = total number of observations

Annual 25%, 33%, 50%, 67%, 75% and 80% exceedance rainfall was calculated from the respective rainfall distribution of each station. A return period implies the frequency with which one would expect on average, a given total annual rainfall to occur. It can be calculated as:

$$T = 1/P \qquad (3.9)$$

Where T is the return period (years) and P is exceedance probability (i.e. the probability that a given annual rainfall is equaled or exceeded).

3.3.2. Methods of rainfall variability analysis

3.3.2.1. Monthly rainfall variability

The variability of any data series can be evaluated based on statistical parameters such as: Range, Standard deviation, Variance and Coefficient of variation (Ketema, 2006). Range is a simple measure of dispersion; it is not particularly sensitive to skewness because it doesn't depend on the shape of the distribution curve.

Standard deviation called also "variance of χ^2" has the same units as the mean value or of the variable itself. It is the positive square root of the variance and accordingly, variance is the square of standard deviation. It is a statistic which only measures the variability well when the observations are normally distributed. The standard deviation measures the dispersion about the arithmetic mean, and the units of measurements of the standard deviation are the same as that of arithmetic mean or of the variable itself. In such a situation the index of dispersion will be affected considerably by the units of measurement.

To enable the comparison of dispersion about the arithmetic mean we define the *coefficient of variation*. The variation amongst observations is determined using this statistical parameter, which is expressed in dimensionless units. For these reasons, coefficient of variation is used as the descriptor of variability to describe the spatial and temporal patterns of annual and monthly rainfall in Burundi.

The coefficient of variation (C.V) represents the ratio of the standard deviation to the mean, and it is a useful statistic for comparing the degree of variation from one data series to another.

Therefore, coefficient of variation is calculated as follows:

$$C.V = \sigma / \mu \qquad \text{……………………………………………} (3.10)$$

Where σ is the standard deviation and μ is the mean

$$\sigma = \{\Sigma (X - \mu)^2 / (N-1)\}^{½} \qquad \text{……………………………………………} (3.11)$$

Where μ is the mean of the data and N is the total number of observations. μ is the mean: a statistical parameter regarded as an estimate of the variable. It is a measure of the central tendency and expressed by the following equation:

$$\mu = (\sum X_i) / N \qquad \text{……………………………………………} (3.12)$$

Then, the computation of coefficient of variation involves the knowledge of the two components i.e. standard deviation and mean.

3.3.2.2. Variability of Annual rainfall

The variability of annual rainfall in Burundi is also examined through this study. For this purpose, the analysis consists of three methods: coefficient of variation, simple climate departure index (SCDI), and moisture availability index (MAI).

3.3.2.2.1. Coefficient of variation

The variation of annual rainfall can be characterized using statistical parameters i.e. *coefficient of variation* as defined in monthly rainfall variability analysis .

3.3.2.2.2. Simple climate departure index (SCDI)

In addition to the statistical parameter, the variability of annual rainfall can be analyzed using indices. These indices with rainfall as the only input perform comparatively well compared with more complicated indices in depicting periods and density dryness (Oladipo, 1985). One of the rainfall variability indices used is the *Simple climate departure index* (SCDI) or standard score; it is calculated as follows:

$$SCDI = (X - \mu) / \sigma \qquad \ldots\ldots (3.13)$$

Where, X is a given annual rainfall value

μ is the arithmetic mean of the distribution

σ is the standard deviation of the distribution

For a distribution of annual rainfall without significant change, approximately all SCDI values should be within the interval ±3 (Ketema, 2006).

3.3.2.2.3. Moisture availability index (MAI)

The dependable rainfall can be compared with the potential evapotranspiration to estimate moisture availability in different locations within the study area. These two basic parameters are helpful to classify a region into climatic zones based on the Hargreaves moisture availability index (Hargreaves, 1975). The *moisture availability index* (M.A.I) is the relative measure of the adequacy of precipitation in supply of moisture requirement.

$$M.A.I = (PD * 100) / PET \qquad \ldots\ldots (3.14)$$

Where M.A.I = Moisture availability index

PD = Dependable rainfall

PET = Potential evapotranspiration

Hargreaves (1975) proposed the following classes based on the ranges of Moisture availability index as follow.

Table 3.4. Hargreaves classification based on M.A.I values (Hargreaves, 1975).

Moisture availability index (%)	Classes	Zones
0 - 33	Very deficient	Zone I
34 - 67	Moderately deficient	Zone II
68 - 100	Some what deficient	Zone III
101 - 133	Adequate	Zone IV
> 134	Excessive	Zone V

3.3.2.3. Seasonal rainfall variability

For a country whose main national income is derived from agricultural production, seasonal variability of rainfall is an essential element in such a way agriculture is mainly practiced by rainfed system. This is important to evaluate the eventual fluctuations in length of seasons because it has negative effects since the success of crop production very much depends on seasonal distribution of rainfall. Therefore, these seasonal fluctuations were examined in this research for understanding the degree of variability in length of growing season (rainy season), which is the factor governing crop yield under rainfed. The *Gaussian Index* which takes into account the length of seasons was considered in this study. This method is based on combination of average monthly temperature and total rainfall (Gaussen and Vernet, 1940):

$$\textit{Gaussian Index (G.I)} = \frac{MonthlyRa\inf all}{MeanTemperature} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.15)$$

According to this method, different ranges of monthly Index values show the following situations: G.I ≤ 2: Dry month and G.I >2: Wet month.

It gives more precise climatic classification and its rationality allows also an easily climatic identification by determining separately the numbers of dry and wet months for a given year. The Gaussian common aridity index is defined in the way as the dry, or arid month, corresponds to the month having the ratio between precipitation (P) and temperature (T) less than two.

These two parameters can be plotted as an ombrothermic chart on the same graph doubling the values on the scale of precipitation. The months, in which the mean temperature curve is higher than the precipitation one, are considered as dry.

3.3.3. Rainfall trend analysis

The trend is the long term behavior of a given parameter with time; it shows increasing or decreasing trend against time. If a parameter is neither increasing nor decreasing then the parameter has no trend. Therefore, in order to identify the existence of increasing (positive) or decreasing (negative) trend, trend detection analysis was conducted.

Both statistical and graphical methods could be used to examine the trend in a time series. In this study statistical method has been utilized. There are many statistical approaches that can be used to detect trends and other forms of non-stationary in hydro-meteorological data. In deciding which approach to take, it is necessary to be aware of which test procedures are valid and most useful.

There are parametric and non-parametric tests for trends detection (Maidement, 1993). Two common types of non-parametric tests used for detecting trend in a time series are Mann-Kendall (MK) and Spearman's Rho (SR) test. However, the MK test has been popularly used to assess the significance of trends in hydro-meteorological time series (Yue et al., 2002 (2)).

Annual and monthly rainfall data have been fitted to the theoretical probability distributions and the best distributions describing the data at respective stations were determined. Mann-Kendall non-parametric test was performed to assess the significance of trend for monthly and annual rainfall totals in Burundi since rainfall data could not be represented by normal distribution.

In MK test, each value of $Y_{i,}$ i = 1, 2…n-1 is compared with all subsequent values $Y_{j,}$ j = i+1, i+2…n and the statistics S of Mann-Kendall is defined as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(Yj - Yi) \qquad \text{……………………………………… (3.16)}$$

Where Y_j are the sequential data values and n is the length of the data set.

$$\text{Sgn}(\Theta) = \begin{cases} 1 & \text{if } \Theta > 0 \\ 0 & \text{if } \Theta = 0 \\ -1 & \text{if } \Theta < 0 \end{cases} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; (3.17)$$

Where, sgn (Θ) = sgn ($Y_j - Y_i$)

Mann and Kendall (Yue et al, 2001 (1)) have documented that when n ≥ 8, the statistics S is approximately normally distributed with the mean and the variance as follows:

$$E(S) = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; (3.18)$$

$$V(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{n} ei * i(i-1)(2i+5)}{18} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; (3.19)$$

Where e_i is the number of ties of extent i and the statistics S represents the number of positive differences minus the number of negative differences for all the difference considered.

The standardized test statistics Z is computed by:

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{\text{var}(S)}} & \text{if } S>0 \\ 0 & \text{if } S=0 \\ \dfrac{S-1}{\sqrt{\text{var}(S)}} & \text{if } S<0 \end{cases} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; (3.20)$$

The Probability value (P-value) of the MK statistics S of sample data can be estimated using the normal cumulative distribution function as.

$$P = \frac{1}{\sqrt{2\Pi}} * \int_{-w}^{z} e\Lambda(-r\Lambda 2/2)\,dt \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; (3.21)$$

For independent sample data without trend the P value should be equal to 0.5, for the sample data with a large positive trend the P value should be closer to 1.0, whereas a large negative trend should yield P value closer to 0.0.

When the statistics S and Z values are positive, these indicate an upward trend, whereas negative values indicate downward trend in the rainfall series.

Mann-Kendall test is non-parametric test, which tests for a trend in time series without specifying whether the trend is linear or non-linear. The slope of a trend is estimated using the Theil-Sen approach (Yue et al, 2002 (2)), and it is computed as follows:

$$b = median \left[\frac{Yj - Yi}{j - i}\right], \qquad \text{.. (3.22)}$$

Where i should be less than j.

The slope "b" was estimated by the Theil-Sen approach (TSA) which is a robust estimate of the magnitude of a trend. This method has been popularly employed for identifying the slope of trends in hydrological time series (Yue et al, 2002 (1)).

In addition, Yue et al (2001) showed that the MK test requires a time series to be serially independent. The existence of serial correlation in time series will affect the ability of the test to correctly assess the significance of trends. They showed that the existence of positive serial increases tendency to reject the null hypothesis of no trend while it is true. In contrast, negative serial correlation underestimates the probability of detecting trends.

In order to detect a significant trend in a time series with significant serial correlation, a modified pre-whitening procedure, termed Trend-Free Pre-Whitening (TFPW) was proposed by Yue et al (2002 (1)):

§ The slope b of a trend in a sample data is estimated by Theil-Sen approach (TSA). If the slope is almost equal to zero, then it is not necessary to continue to conduct trend analysis. If it is different from zero, then it is assumed to be linear, and the sample data are de-trended by:

$$Y'_i = Y_i - T_i = Y_i - b*i \qquad \text{...(3.23)}$$

- § The lag-1 serial correlation coefficient r_i of the de-trended series Y'_i is computed and then the auto regressive model (AR) is removed from the Y'_i by:

$$X'_i = Y'_i - r_i * Y'_{i-1} \qquad \text{... (3.24)}$$

This Pre-whitening procedure after de-trending the series is referred to as the trend-free pre-whitening (TFPW) procedure. The residual series after applying the TFPW procedure should be an independent series.

- § The identified series T_i and the residual X'_i is blended by:

$$X_i = X'_i + T_i \qquad \text{.. (3.25)}$$

It is evident that the blended series X_i could preserve the true trend and is no longer influenced by effects of autocorrelation.

- § The MK test is applied to the blended series to assess the significance of the trend.

Because of the emphasis on agriculture production aspect in this study, rainfall trend analysis will be conducted on the months having low reliability of rainfall. In rainfed agriculture, low reliability of rainfall implies limited availability of water resources for crop production. Therefore, the months concerned by trend studies will be drown from the results in monthly rainfall variability analysis.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1. Characterization of rainfall in Burundi

4.1.1. Agro-climatic zonation

Monthly potential evapotranspiration values have been computed using equation 3.2 for the sixteen stations selected for the study (Appendix 3), and then mean annual PET obtained. Having the two components i.e. mean annual rainfall and mean annual potential evapotranspiration, the aridity index (A.I) was calculated and the results are presented in Appendix 4. Included in the Appendix is also the corresponding agro-climatic classification of the stations based on the UNESCO classification criteria.

From the results in Appendix 4, it can be deduced that all stations are characterized by an aridity index greater than 0.65, except Bujumbura and Mparambo with an aridity index between 0.50 and 0.65. Referring to the boundaries that define various degrees of aridity as adopted by UNESCO classification (Rodier, 1985), the first group is humid whereas the second one is dry sub-humid.

The following figure compares the mean annual amount of rainfall and the mean annual evapotranspiration on an average of a period of 30 years.

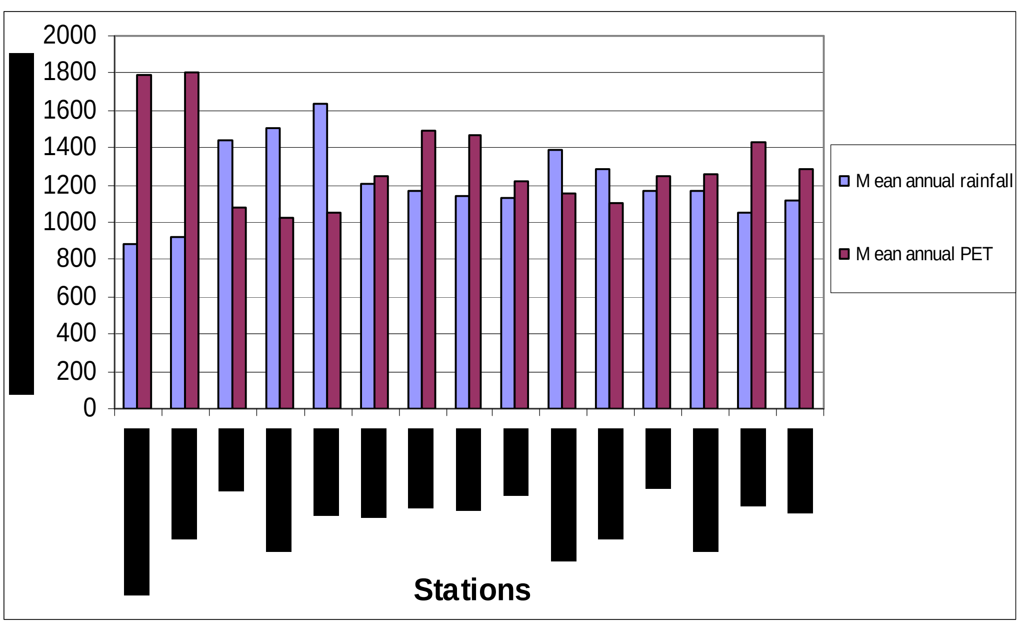

Figure 4.1: Mean annual rainfall and potential evapotranspiration.

From Figure 4.1 the following observations can be made: Bujumbura, Mparambo, Kinyinya, Musasa, Kirundo and Muyinga are the areas where the difference between mean annual evapotranspiration and mean annual rainfall is high through the period considered. Another situation which is different from the previous one is that the rainfall amount exceeds evapotranspiration in Gisozi, Rwegura, Mpota-Tora, Nyamusawga and Ruvyironza. The remaining part of the study area shows a non significant difference between mean annual rainfall and mean annual evapotranspiration.

This kind of information is helpful to have a view on the moisture deficit and the periods when the need for irrigation and other water resources management practices is high to supplement rainfed agriculture.

From the rainfall and potential evapotranspiration curves (Figure 4.1), it can be seen that the vulnerability to moisture deficit is different from place to place. In general, the highest value of potential evapotranspiration is found in areas which are hot, dry, windy and sunny (Imbo plain, Depressions of Moso and Bugesera), whereas the lowest values are observed in areas where it is cool, humid and cloudy with little or no wind (Crest Congo-Nile); in contrast with rainfall.

Based on the results in Figure 4.1, the demand in irrigation water and rainwater for crop production is high in the areas represented by the stations Bujumbura, Mparambo, Kinyinya, Musasa, Kirundo and Muyinga.

4.1.2. Range of annual rainfall

The range of annual rainfall has been computed using equation 3.6 and the results were compared to the annual range of evapotranspiration as follows.

Table 4.1. Range of annual rainfall and evapotranspiration of the weather stations.

Stations	Altitude (m)	Annual rainfall Range (mm)	Annual PET Range (mm)
Bujumbura-Airport	783	551.2	439.8
Makamba	1450	739.2	185.0
Mparambo	1509	695.0	331.4
Gisozi	2097	674.0	61.30
Mpota-Tora	2160	616.9	109.9
Rwegura	2302	545.6	82.50
Cankuzo	1652	735.3	412.6
Kinyinya	1308	878.9	228.9
Musasa	1260	702.7	623.5
Muriza	1616	823.3	220.2
Nyamuswaga	1720	796.5	723.3
Ruvyironza	1822	535.6	85.70
Karuzi	1600	926.3	130.9
Gitega-Airport	1645	770.7	126.0
Kirundo	1449	640.0	319.7
Muyinga	1756	761.4	134.9

From the results in Table 4.1, the annual range of rainfall is much higher than that of evapotranspiration for all the stations. This shows that rainfall is a highly variable climatic factor and success in rainfed agriculture largely depends on rainfall than evapotranspiration. Therefore, for the success of crop production much attention should be paid to rainfall variability analysis than evapotranspiration in the study area.

These extremes values of rainfall are of prime interest in agriculture as a basis for designing drainage system, estimation of water requirements for crops at different growth stages under rainfed agriculture.

4.1.3. Probability distributions of annual and monthly rainfall

Using FORTRAN program 90 Version 4.5 indicated in methodology part, the values of Ck, Cs, t_3 and t_4 were estimated and the table 4.2 summarizes the results for the stations Cankuzo, Kinyinya and Musasa, others are presented in Appendix 6.

Table 4.2. Monthly values of Ck, Cs, t_3 and t_4 for Cankuzo, Kinyinya and Musasa.

	Cankuzo				**Kinyinya**				**Musasa**			
	MRD		**L-MRD**		**MRD**		**L-MRD**		**MRD**		**L-MRD**	
Months	Cs	Ck	t_3	t_4	Cs	Ck	t_3	t_4	Cs	Ck	t_3	t_4
J	0.57	4.690	0.106	0.244	0.893	3.893	0.190	0.170	-0.314	3.333	-0.002	0.126
F	0.398	2.632	0.117	0.086	0.447	3.982	0.066	0.210	0.207	2.547	0.089	0.097
M	0.986	4.582	0.182	0.221	0.757	3.548	0.158	0.194	0.788	3.723	0.166	0.196
A	0.052	4.130	0.039	0.214	0.868	3.496	0.205	0.156	0.451	3.309	0.106	0.202
M	0.301	3.342	0.059	0.119	0.786	4.151	0.131	0.126	0.266	2.545	0.079	0.070
J	2.002	6.154	0.627	0.296	2.275	7.600	0.637	0.323	3.154	14.17	0.655	0.381
J	3.991	19.33	0.859	0.684	4.013	18.87	0.878	0.722	3.857	17.45	0.858	0.683
A	1.562	5.050	0.449	0.148	2.279	7.318	0.653	0.353	4.559	25.00	0.762	0.544
S	1.348	5.356	0.266	0.170	0.616	3.358	0.134	0.058	1.248	4.246	0.308	0.137
O	0.450	2.448	0.148	0.045	1.714	7.836	0.230	0.295	0.977	3.981	0.213	0.178
N	0.548	4.684	0.142	0.245	4.772	27.15	0.498	0.468	0.830	3.872	0.169	0.160
D	0.284	2.558	0.091	0.102	0.314	8.545	0.052	0.068	-0.061	2.837	0.046	0.075

After computation of these parameters, pairs of coefficients of skewness (Cs) and coefficient of kurtosis (Ck) are plotted on the Cs-Ck Moments Ratio Diagrams for each station (Figure 4.2). Similarly, pairs of t_3 and t_4 are plotted on L-Moments Ratio Diagrams for each station. Using these results of Ck, Cs for MRDs and t_3, t_4 for L-MRDS, the evaluation of parent distribution for rainfall data is estimated from the two graphs previously plotted (Figures 3.4 and 3.5). For the present study, the identification of parent distributions has been done using L-Moments Ratio Diagrams.

The table 4.3 summarizes the candidate distributions for monthly rainfall at sixteen stations selected for this study.

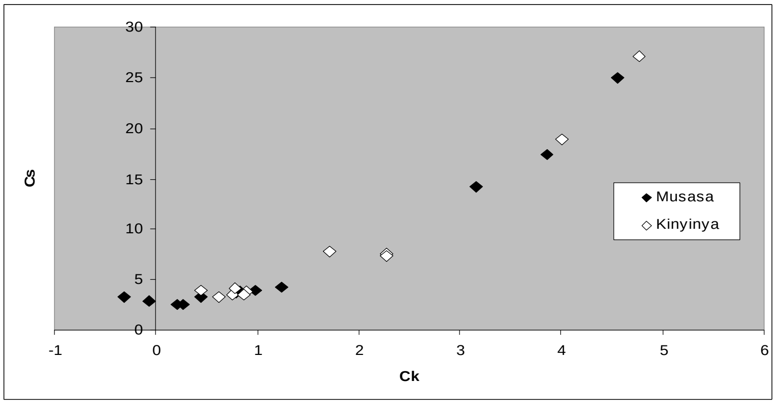

Figure 4.2: Ck-Cs diagram for two sample stations.

Table 4.3. Candidate distributions for monthly rainfall in Burundi.

Stations	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bujumbura	GEV	GEV	GEV	GLg	G-P	P III	OLB	P III	G-P	GEV	G-P	P III
Makamba	GLg	LgN	GLg	P III	G-P	P III	OLB	P III	P III	G-P	GLg	GLg
Mparambo	GLg	GLg	WLB	GEV	P III	P III	P III	P III	WLB	GLg	G-P	LgN
Gisozi	P III	WLB	GLg	GLg	GLg	P III	P III	P III	P III	GLg	GEV	GEV
Mpota-Tora	GLg	GLg	GLg	P III	GEV	P III	P III	GEV	G-P	GLg	GEV	GLg
Rwegura	GLg	P III	GLg	WLB	P III	G-P	G-P	P III	GLg	LgN	WLB	GLg
Cankuzo	GLg	P III	GLg	GLg	P III	P III	LgN	P III	WLB	G-P	GLg	P III
Kinyinya	GEV	GLg	GLg	WLB	P III	P III	P III	P III	G-P	GLg	GLg	P III
Musasa	G-P	P III	GLg	GLg	P III	P III	OLB	P III	P III	GEV	GEV	P III
Nyamuswaga	GLg	GEV	G-P	GLg	P III	P III	P III	GEV	GEV	GEV	GEV	GLg
Ruvyironza	G-P	GLg	GEV	GLg	GEV	P III	OLB	P III	P III	G-P	GLg	GLg
Karuzi	GEV	GLg	GLg	GLg	LgN	P III	OLB	P III	G-P	GEV	GLg	GLg
Gitega-Aero	GLg	GLg	GLg	P III	P III	P III	P III	OLB	G-P	P III	GEV	GLg
Kirundo	GLg	GLg	GEV	GLg	GEV	P III	P III	P III	G-P	GLg	G-P	LgN
Muyinga	GLg	P III	GLg	P III	LgN	P III	P III	P III	GLg	GEV	LgN	GLg

The designations in Table 4.3 are: GEV is Generalized extreme value distribution, GLg is Generalized Logistic distribution, P III is Pearson III distribution, G-P is Generalized Pareto distribution, LgN is Log-Normal distribution, WLB is Wakeby distribution and OLB is Overall lower bound distribution.

Monthly rainfall data were fitted to the theoretical distributions and the results are given in Table 4.3. Based on this table summarizing the results, monthly rainfall in Burundi is best described by the following probability distributions: Generalized Logistic, Generalized Extreme Value, Pearson III, Generalized Pareto, Log-normal, Wakeby, and overall lower bound distributions.

The same procedure has been followed to characterize distribution of the annual rainfall data and the results are presented in the table 4.4.

Table 4.4. Annual values of Ck, Cs, t_3 and t_4 for each station.

	MRD		L-MRD	
Stations	Cs	Ck	t_3	t_4
Bujumbura	0.941	5.045	0.129	0.340
Gitega	0.107	3.077	0.057	0.208
Gisozi	0.399	2.629	0.109	0.200
Cankuzo	0.234	3.111	0.067	0.252
Karuzi	0.045	2.614	0.026	0.132
Kinyinya	-0.249	3.340	-0.008	0.201
Kirundo	0.362	3.176	0.089	0.210
Makamba	0.015	2.347	0.024	0.138
Mparambo	-0.525	2.703	-0.081	0.168
Mpota-Tora	-0.265	2.702	-0.024	0.203
Muriza	-0.619	4.329	-0.072	0.248
Musasa	0.614	2.766	0.159	0.166
Muyinga	0.810	3.870	0.156	0.263
Nyamuswaga	0.104	2.444	0.050	0.150
Ruvyironza	0.145	2.409	0.060	0.183
Rwegura	0.735	7.996	0.085	0.335

For the present study, the identification of appropriate probability distributions has been done using L-Moments Ratio Diagrams and the probability distributions describing annual rainfall at different stations are summarized in the following table.

Table 4.5. Candidate distributions for annual rainfall in Burundi.

Stations	Candidate distributions		Stations	Candidate distributions
Bujumbura	LgN		Musasa	GEV
Makamba	GEV		Muriza	GLg
Mparambo	LgN		Nyamuswaga	GEV
Gisozi	GLg		Ruvyironza	GLg
Mpota-Tora	GLg		Karuzi	LgN
Rwegura	GLg		Gitega	GLg
Cankuzo	LgN		Kirundo	GLg
Kinyinya	GLg		Muyinga	GLg

Based on the results in Table 4.5, annual rainfall in Burundi is described by Log-normal, Generalized Extreme value, and Generalized Logistic distributions.

For predictive purpose, the results in Tables 4.3 and 4.5 above show that monthly and annual rainfall in Burundi cannot be described by similar probability distribution.

The probability distribution analysis of rainfall data is helpful in selection of statistical tests to be used for trend detection analysis; the use of parametric tests requires data series to be normally distributed.

4.1.4. Probability of a wet day

The monthly number of wet days (n_i) was counted for each station (Appendix 7) and Table 4.6 summarizes the values of mean monthly probability of a wet day obtained using equation 3.7 over the period taken in consideration for this study.

Table 4.6: Monthly probability of a wet day (> 1 mm).

Stations	J	F	M	A	M	J	J	A	S	O	N	D
Bujumbura	0.50	0.45	0.58	0.59	0.29	0.05	0.02	0.07	0.26	0.48	0.62	0.59
Makamba	0.61	0.51	0.57	0.65	0.33	0.05	0.01	0.06	0.19	0.40	0.57	0.65
Gisozi	0.70	0.66	0.67	0.74	0.46	0.08	0.02	0.08	0.28	0.55	0.76	0.77
Mpota-Tora	0.72	0.71	0.75	0.75	0.47	0.10	0.04	0.09	0.30	0.57	0.76	0.77
Rwegura	0.64	0.61	0.73	0.79	0.49	0.12	0.04	0.13	0.43	0.64	0.78	0.71
Cankuzo	0.56	0.59	0.55	0.63	0.33	0.03	0.02	0.06	0.24	0.41	0.61	0.63
Kinyinya	0.57	0.53	0.58	0.62	0.31	0.03	0.01	0.04	0.16	0.55	0.54	0.58
Musasa	0.57	0.52	0.57	0.62	0.34	0.04	0.01	0.03	0.17	0.51	0.56	0.63
Muriza	0.62	0.55	0.61	0.69	0.38	0.03	0.02	0.06	0.20	0.53	0.66	0.66
Nyamuswaga	0.58	0.50	0.62	0.67	0.40	0.07	0.03	0.08	0.31	0.56	0.69	0.66
Ruvyironza	0.70	0.64	0.64	0.69	0.34	0.06	0.02	0.06	0.21	0.52	0.70	0.73
Karuzi	0.50	0.45	0.51	0.55	0.33	0.03	0.01	0.03	0.19	0.52	0.59	0.55
Gitega	0.71	0.62	0.67	0.69	0.40	0.05	0.02	0.08	0.28	0.55	0.77	0.76
Kirundo	0.34	0.37	0.46	0.59	0.37	0.07	0.02	0.09	0.30	0.52	0.53	0.43
Muyinga	0.55	0.50	0.60	0.69	0.41	0.06	0.03	0.09	0.32	0.53	0.70	0.62

The mean monthly probability of a wet day versus time was plotted to identify the time when the station is likely to be dry or wet (Figure 4.3).

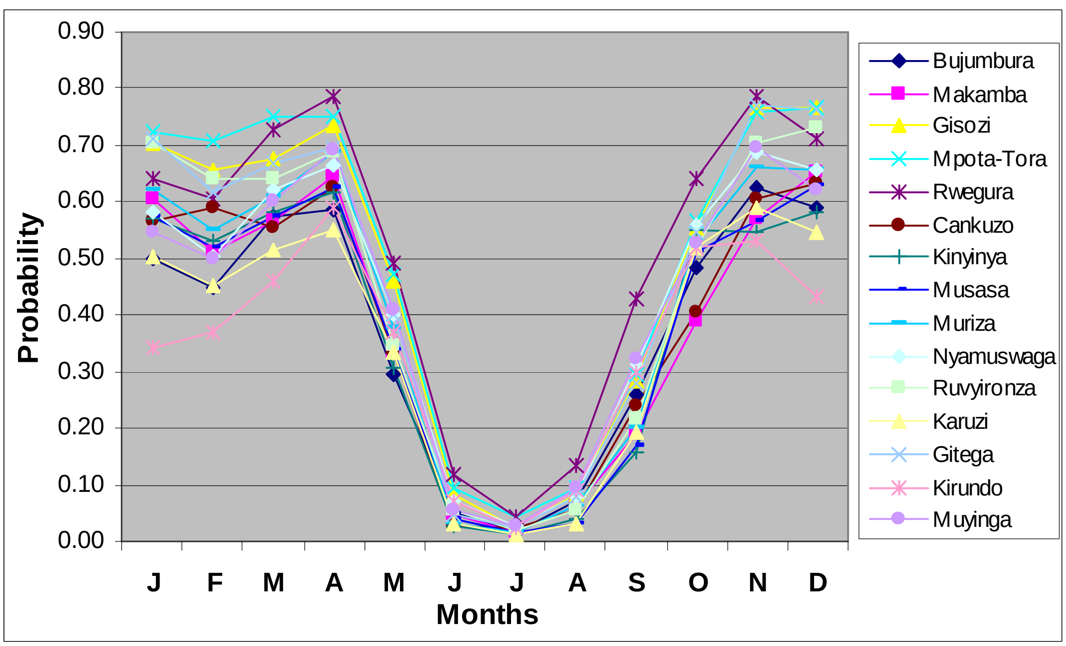

Figure 4.3: Probability of a wet day (>1 mm) versus time.

Figure 4.3 indicates that different curves representing the mean probability of a wet day versus time have similar trend with two peaks in April and November. For all the stations, the months of November, December, January, February, March and April are characterized by a high probability of a wet day (greater than 50 %), whereas it is too low in June, July and August (less than 10 %). In case of October, the probability is greater than 40% and sometimes exceeds 50 %. For the remaining part of year corresponding to May and September, the range of probability is variable; oscillating between 16 % and 49 % (Table 4.6). However, the probability in May remains greater than in September. Coming to the spatial distribution aspect, the probability of a wet day is maximum at the stations located in high elevation areas (Crest Congo-Nile), whereas the minimum probability of a wet day is found in low elevation areas (Imbo plain and depressions of Moso and Bugesera).

For more understanding of the frequency of rainy days, probability of a wet day exceeding 5 mm has been computed and the results are presented in Appendix 9.

The following probability plot shows clearly the rainfall pattern in term of frequency of daily rainfall of 5 mm or more in 30 years.

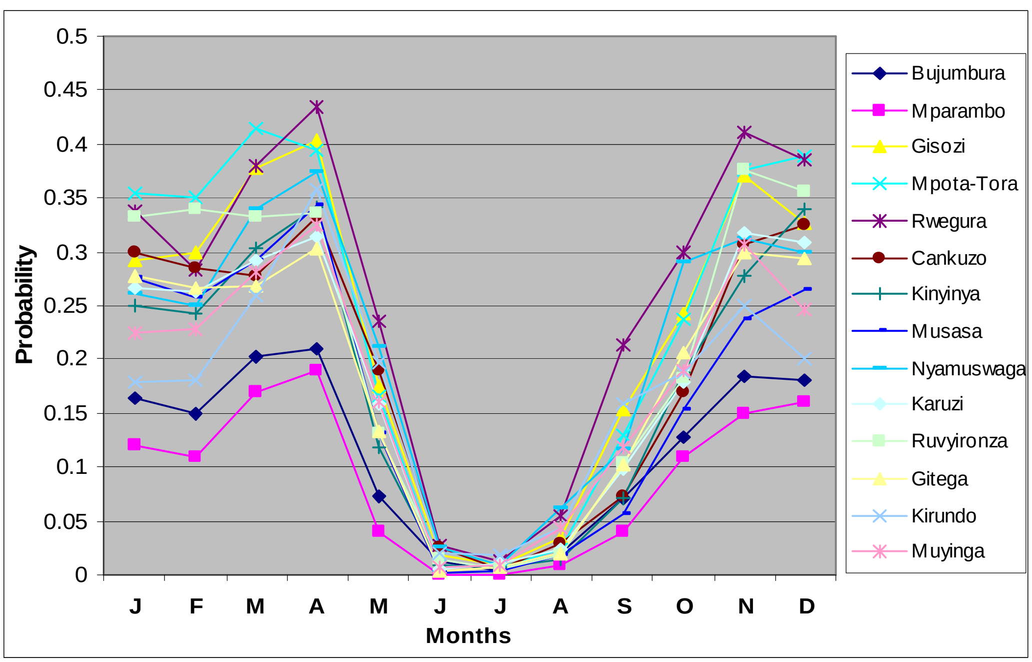

Figure 4.4: Probability of a wet day (>5 mm) versus time.

From the results in Figures 4.3 & 4.5, it has been shown that the probability plot of number of wet days (1 mm) follows similar pattern as the mean monthly rainfall distribution in a year. Figure 4.4 shows the same trend at different stations selected for this research. The shape of the previous curves (Figure 4.4) is similar as the one representing the probability of a wet day of 1 mm and more. The difference is that the probability of getting rainfall intensity of 5 mm is low than having rainfall of 1 mm. In general, the probability of occurrence of daily rainfall exceeding 5 mm is too low (less than 20 %) during the months of May, June, July, August, September, and October for most of stations except Gisozi, Mpota-Tora and Rwegura. From the same figure, the observation is that all stations record the peaks in April and November; meaning that the rainfall intensity is high during this period and runoff and erosion would be very high unless different soil and water conservation structures are implemented. For spatial analysis, rainfall is relatively high at the stations Gisozi, Mpota-Tora and Rwegura (all located in Crest Congo-Nile), whereas the frequency of daily rainfall of 5 mm is always very low within the year in Imbo plain represented by Bujumbura and Mparambo stations.

4.1.5. Exceedance probability and return period of annual rainfall

The annual rainfall which is expected at different exceedance probability levels and corresponding returns periods are presented in Table 4.7.

Table 4.7. Expected annual rainfall (mm) at different exceedence probability levels and corresponding return periods (years).

Exceedence prob (%)	25	33	50	67	75	80
Return period (years)	4	3	2	1.5	1.33	1.25
Bujumbura	791.4	775.6	760.4	728.8	702.6	664.1
Makamba	1523.4	1510.0	1372.7	1235.3	1217.2	1193.3
Mparambo	1047.1	1008.3	936.6	906.2	862.7	812.0
Gisozi	1560.0	1546.4	1395.9	1342.1	1307.2	1296.9
Mpota-Tora	1626.6	1613.2	1510.0	1425.6	1414.7	1352.8
Rwegura	1736.7	1734.4	1612.6	1523.7	1480.0	1455.3
Cankuzo	1276.4	1235.8	1183.8	1145.7	1123.5	1053.5
Kinyinya	1389.6	1268.9	1203.3	1052.2	1021.7	960.4
Musasa	1261.3	1220.7	1090.7	1015.0	995.3	973.5
Muriza	1264.4	1235.5	1154.2	1045.7	997.7	976.8
Nyamuswaga	1476.9	1455.6	1352.9	1200.0	1170.0	1121.1
Ruvyironza	1419.9	1388.8	1246.8	1203.6	1178.5	1167.1
Karuzi	1326.5	1317.7	1158.6	1022.7	958.5	823.7
Gitega-Aero	1259.2	1222.2	1259.2	1055.4	1034.4	1018.4
Kirundo	1162.1	1126.6	1057.2	947.0	941.1	923.3
Muyinga	1235.6	1157.2	1082.8	1050.3	1032.9	958.4

The 25% exceedence rainfall is expected on average to be exceeded in 1 out of 4 years, 33% in 1 out of 3 years, 50% in 2 years, 67 % in 2 out 3 years, 75% in 3 out of 4 years and 80% in 4 out of 5 years. A very high (or low) amount of rain that occurs, on average during few years every century, is said to have a very low probability of occurrence. This is usually expressed as the probability of exceedence (P) of a given amount of rainfall. If P is below 5%, it means that rainfall is exceptionally high, since it will be exceeded (on average) in only 5 years out of every 100. Likewise, values above 95% correspond to exceptionally dry conditions. The probability range from 5 to 20 and from 80 to 95 is termed unusual and values from 21 to 79 are considered normal. This statistical information helps in planning of water resources management projects under different scenarios. Depending upon the purpose of the project a certain probability of occurrence or exceedance is selected; for example in case of rainwater harvesting system 67% is usually considered.

4.2. Variability of monthly rainfall

The variability of monthly rainfall has been investigated using the coefficient of variation as defined in equation 3.10. From that equation, the computation of coefficient of variation involves the knowledge of the two components i.e. standard deviation and mean. The mean monthly values of rainfall data collected from sixteen stations selected as representative of the study area have been computed using equation 3.12 and the results are shown in Appendix 10. Figure 4.5 shows the mean monthly rainfall at all the stations considered in this study.

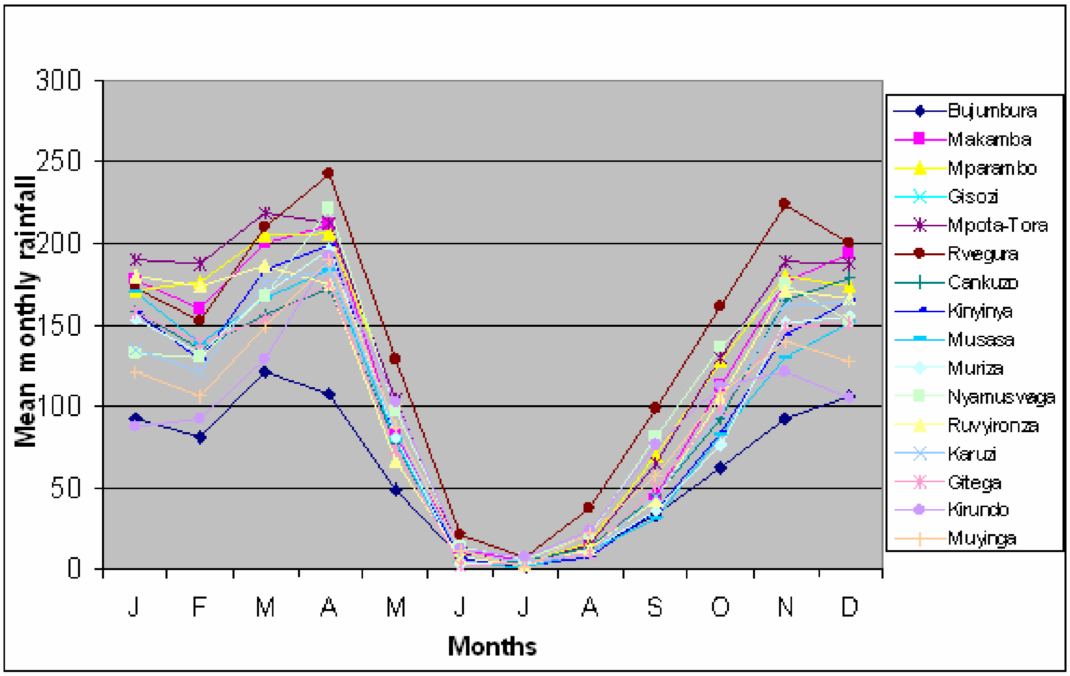

Figure 4.5: Trend of mean monthly rainfall within the study area.

The probability plot of number of wet days follows similar pattern as the monthly rainfall amount distribution in a year (Figure 4.3); meaning that there is a correlation between the mean monthly rainfall and the mean probability of getting a wet day. Also, the stations located in high elevation areas experience high average rainfall than other areas (Crest Congo-Nile). The minimum rainfall records are generally observed in low elevation areas such as in Imbo plain (Bujumbura) and depressions of Moso and Bugesera (Muyinga, Kirundo).

The second component of the coefficient of variation (i.e. standard deviation) has been calculated using the same data series and the results are presented in the Appendix 11. As the standard deviation has the same unit of measurements as the mean or the variable itself, it is rendered dimensionless by dividing by the mean value. This dimensionless ratio called *coefficient of variation* is a helpful statistic for describing the degree of variability of a variable from one data series. Appendix 12 shows the values of coefficient of variation computed using the two components mentioned above.

Figure 4.6 below shows the degree of monthly rainfall variability based on coefficient of variation for the sixteen selected stations.

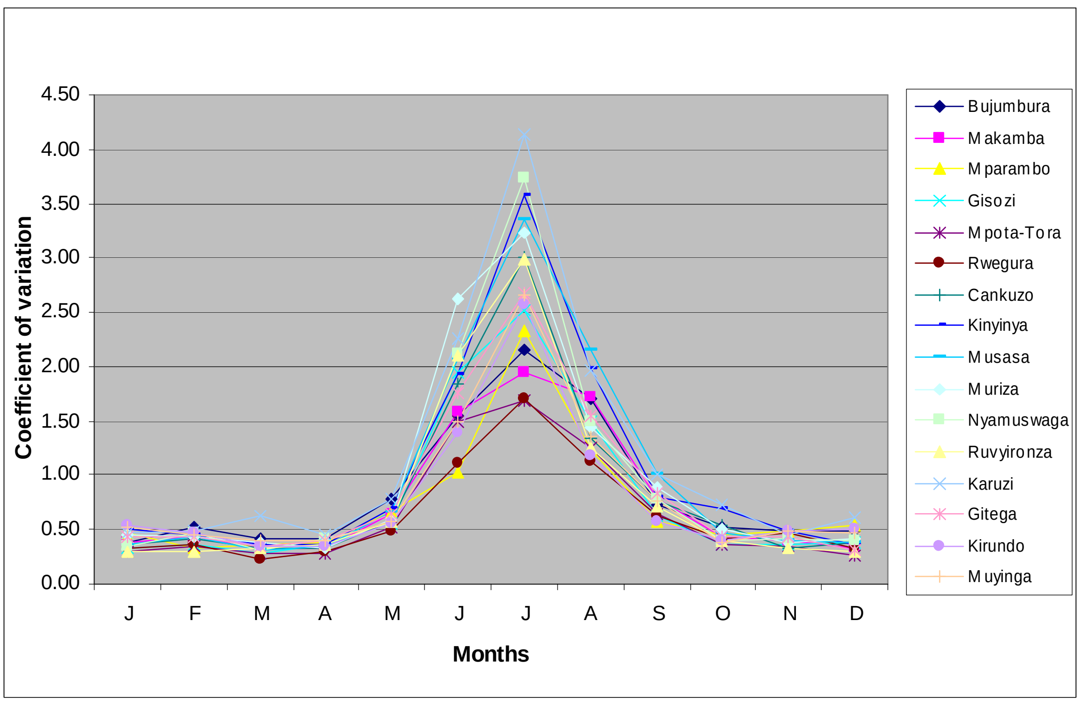

Figure 4.6: Variability of monthly rainfall.

The NMSA (1996) documented that coefficient of variation less than 0.20 is less variable, coefficient of variation between 0.20 and 0.50 is moderately variable and the coefficient of variation greater than 0.50 is high variable. According to the graph above representing the coefficient of variation in monthly rainfall data, it can be seen that some months are characterized by high variability (C.V>0.50) for all stations: May, June, July, August, September, and October sometimes (Appendix 12).

Observations show also that the rainfall variation generally increases with decreasing in monthly totals of rainfall and frequency of rainy days (Figures 4.3, 4.5 & 4.6). The reliability which is defined as: Reliability = 100 – C.V in % (Ogallo, 1981) shows that, the reliability of rainfall is high in the areas where the coefficient of variation is low. Similarly, the reliability of rainfall in months of May, June, July, August, September is low, and sometimes in October. For each station, coefficients of variation for these critical months in terms of rainwater resources availability are plotted on the graph 4.7.

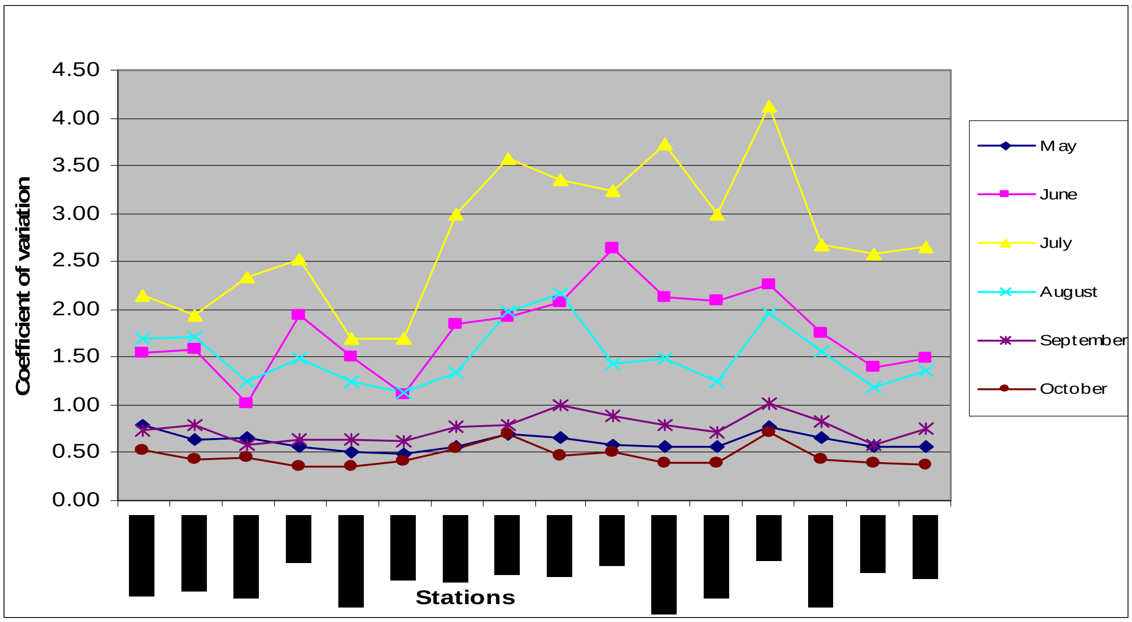

Figure 4.7: Rainfall variability for some critical months.

Referring to this graph, the reliability of rainfall is too low in June, July, August and September. The months of May and October show a moderate reliability of rainfall, October remaining more reliable. From the frequency of rainy days (>1mm) analysis point of view, the months of June, July and August are characterized by a very low probability of a wet day (less than 10%). In case of October, the probability ranges between 40 and 50%, for May and September it is oscillating between 16 and 49% (Table 4.6). The probability plot of number of wet days follows similar pattern as the monthly rainfall distribution (Figures 4.3 & 4.5); meaning that there is a correlation between mean monthly rainfall and the mean probability of getting a wet day. In general, rainfall pattern in Burundi is bimodal with two peaks in April and November for all stations (Figure 4.5).

Spatial analysis demonstrates that the areas located in high elevations altitude are less vulnerable to the variation of monthly rainfall, and rainfall intensity is also high compared to the other locations within the study area. The observations made previously show that the crop production in Burundi is almost difficult in June, July, August and September due to limited availability of rainwater resources. In case of May and October, plants may have problems in their different growth stages.

In fact, a dry spell of any length could occur at any stage of crop growth; however, there is higher potential for damage when it coincides with the most sensitive stages such as flowering (May) and grain filling (October). According to the crop calendar defining different operations activities (Table 2.2), the reliability of rainfall during these two months is an important factor for maize and beans production which are the most important crops grown in all regions of Burundi. For a country like Burundi, where rainfed agriculture is dominant, much attention should be paid to those two months to avoid risks due to the occurrence of perturbations in growing season for some crops. Using Thiessen polygons in Arcview GIS, the spatial variation of rainfall in the month of May is shown in Figure 4.8.

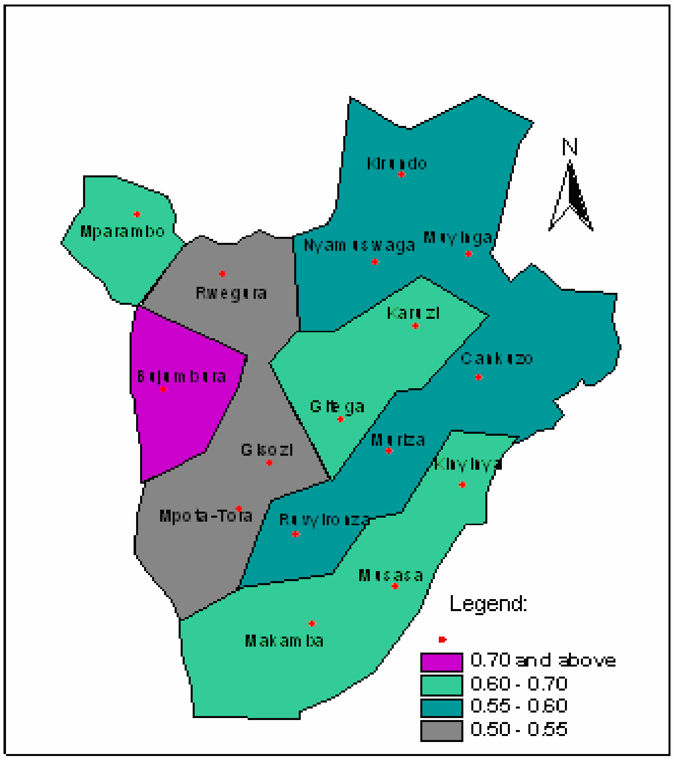

Figure 4.8: Spatial variability of rainfall in the month of May.

Figure 4.8 indicates how rainfall in the month of May varies in space within the study area based on the coefficient of variation. Spatial analysis allows to categorize the study area into four homogeneous regions; coefficient of variation ranging between:

0.50-0.55 (Region 1): Gisozi, Mpota-Tora and Rwegura

0.55-0.60 (Region 2): Ruvyironza, Muriza, Cankuzo, Muyinga, Nyamuswaga and Kirundo.

0.60-0.70 (Region 3): Makamba, Musasa, Kinyinya, Gitega, Karuzi and Mparambo.

0.70 and above (Region 4): Bujumbura.

From this spatial consideration, region 1 is less vulnerable to the effects of variation in rainfall of May compared with other regions.

Similarly, spatial analysis of rainfall variability distribution for October has been done and different regions are displayed in Figure 4.9.

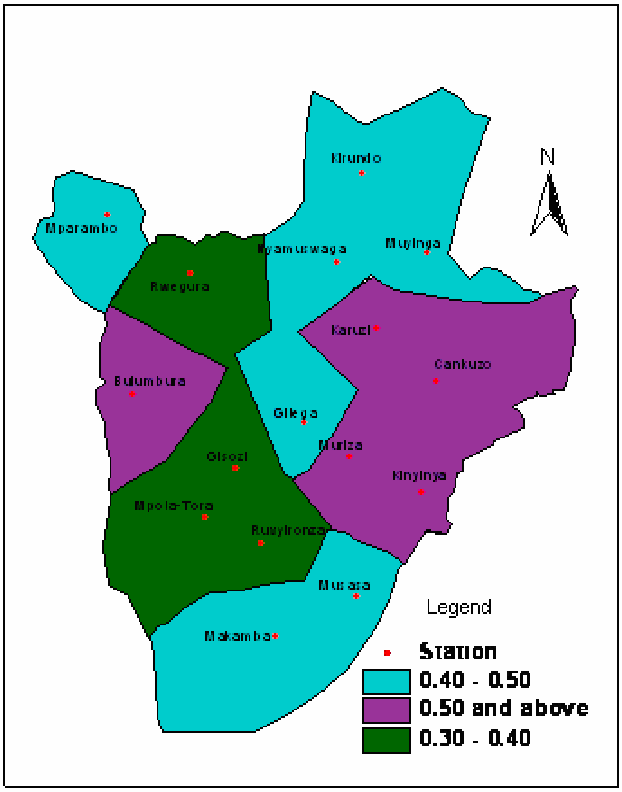

Figure 4.9: Spatial variability of rainfall in the month of October.

Figure 4.9 shows the existence of three regions on the basis of coefficient of variation for rainfall data of October; the following ranges define these regions.

0.30 – 0.40 (Region 1): Rwegura, Gisozi, Mpota-Tora and Ruvyironza.

0.40 – 0.50 (Region 2): Mparambo, Makamba, Musasa, Nyamuswaga, Gitega, Kirundo and Muyinga.

0.50 and above (Region 3): Bujumbura, Karuzi, Cankuzo, Muriza and Kinyinya.

The the two previous figures demonstrate that the entire country cannot be treated as homogeneous with respect to monthly rainfall variability. This indicates that even the possible adverse effects due to rainwater variability of any month may affect different locations accordingly.

4.3. Variability of annual rainfall

4.3.1. Coefficient of variation

As it has been done with monthly rainfall variability analysis, the variation of annual rainfall can be investigated using statistical parameter i.e. *coefficient of variation* and the results are shown in the following table.

Table 4.8. Coefficient of variation of annual rainfall data at different stations.

Stations	Mean	Standard deviation	Coefficient of variation
Bujumbura	765.19	122.43	0.16
Makamba	1385.01	221.60	0.16
Mparambo	923.72	138.56	0.15
Gisozi	1439.64	187.15	0.13
Mpota-Tora	1508.63	165.95	0.11
Rwegura	1633.23	212.32	0.13
Cankuzo	1202.23	180.33	0.15
Kinyinya	1171.64	281.19	0.24
Musasa	1148.87	206.80	0.18
Muriza	1126.56	236.58	0.21
Nyamuswaga	1346.27	215.40	0.16
Ruvyironza	1286.39	141.50	0.11
Karuzi	1171.58	292.90	0.25
Gitega-Aero	1164.73	186.36	0.16
Kirundo	1053.56	158.03	0.15
Muyinga	1121.09	179.37	0.16

From the results in Table 4.8, the coefficient of variation for annual rainfall data ranges between 0.11 and 0.25 at all the stations. These values of coefficient of variation indicate that annual rainfall in Burundi is not significantly variable with time. The spatial distribution aspect shows maximum value of coefficient of variation in Karuzi, Muriza and Kinyinya (greater than 0.20). The minimum coefficient of variation is observed in high elevation areas represented by Gisozi, Mpota-Tora, Rwegura and Ruvyironza (less than 0.15).

Figure 4.10 shows the degree of variability explained in annual rainfall as a function of elevation.

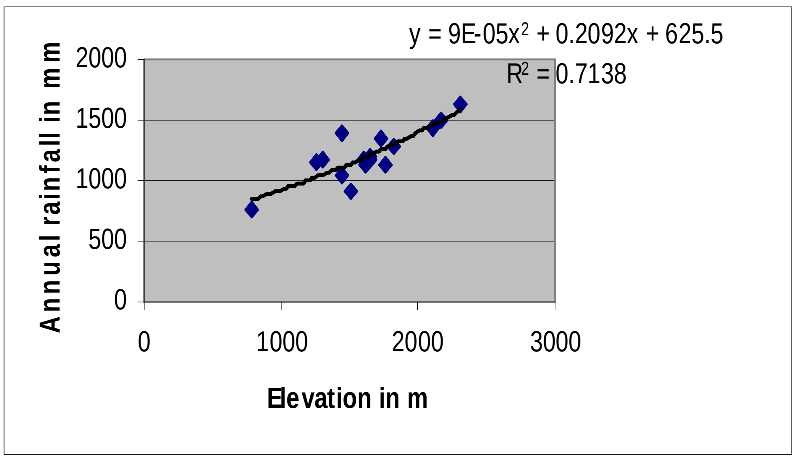

Figure 4.10: Correlation between annual rainfall and elevation

From Figure 4.10, correlation between elevation and annual rainfall exhibits best results for a second order polynomial fit where 71% of the rainfall can be explained by the elevation.

4.3.2. Simple climate departure index (SCDI)

The SCDI values for all stations have been computed using equation 3.13 and the results are shown in Appendix 13.

Figures 4.11 provide graphical representations of the SCDI values for each station over the period of study (1975-2004).

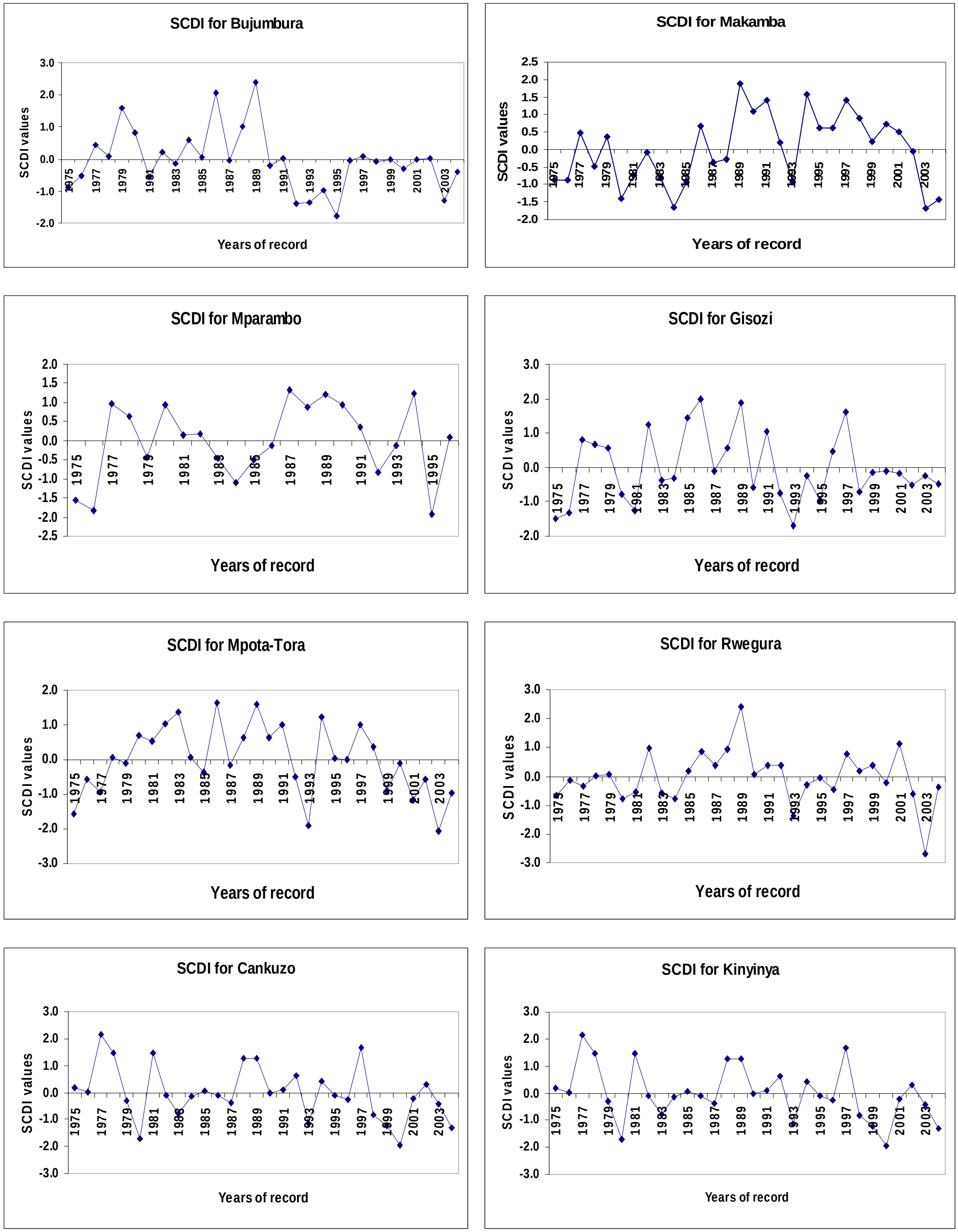

Figure 4.11: Simple climate departure index values for selected stations.

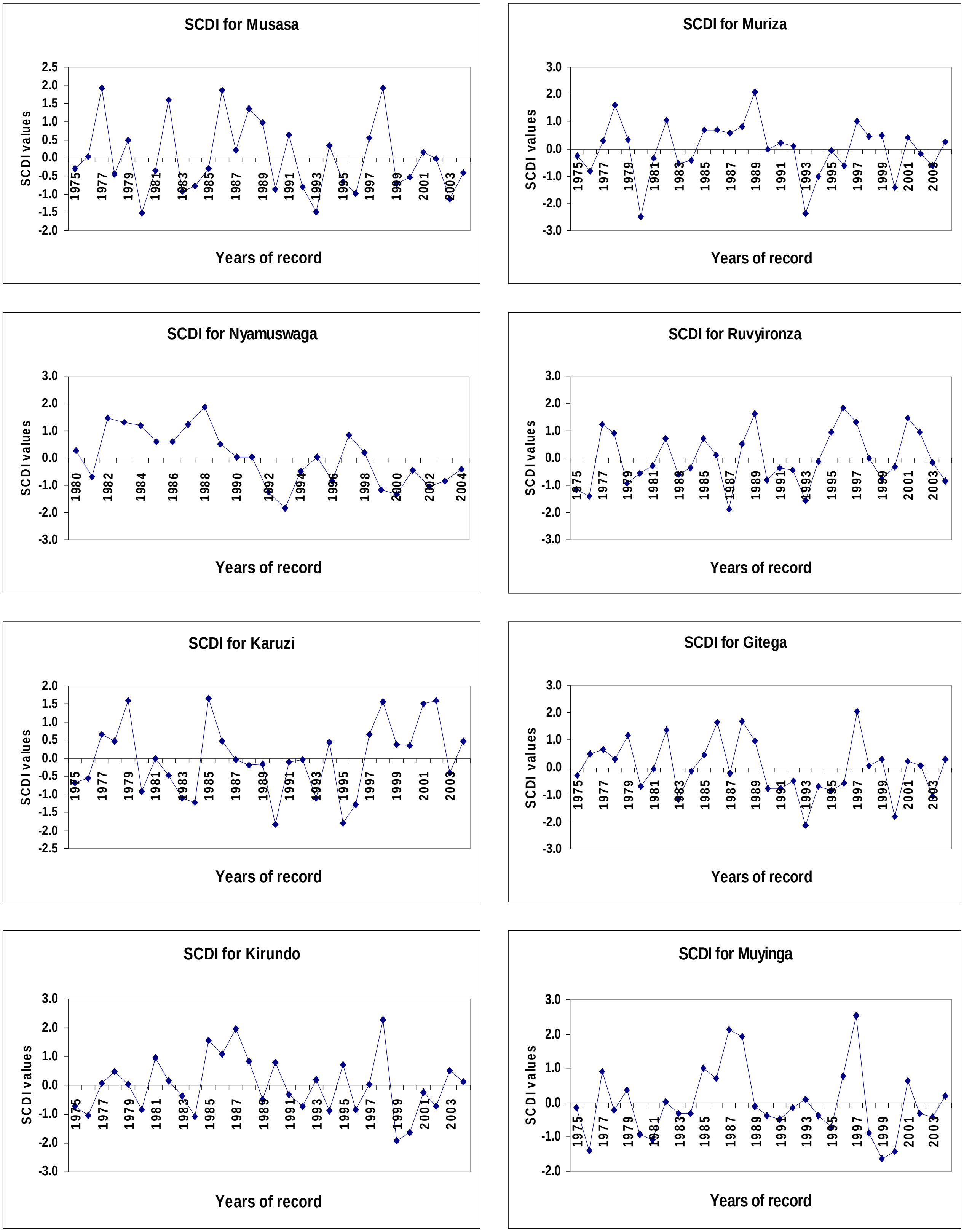

Figure 4.11: Continued.

For a distribution of annual rainfall without significant change, approximately all SCDI values should be within the interval ±3 (Ketema, 2006). From these graphs representing temporal distribution of SCDI values at different stations, it is clear that all SCDI values are oscillating within the range of -3 and +3, showing that the variation of annual rainfall in Burundi is low.

4.3.3. Moisture availability index (M.A.I)

From the results obtained using the two methods, variability analysis of annual rainfall demonstrates that it didn't change significantly with time. However, even if the annual variation is low, the expected annual rainfall at different exceedence probability levels in different locations of the study area indicates how annual rainfall change in space. Figure 4.12 plotted using the results in Table 4.7 shows different scenarios of expected annual rainfall and corresponding exceedance probability levels.

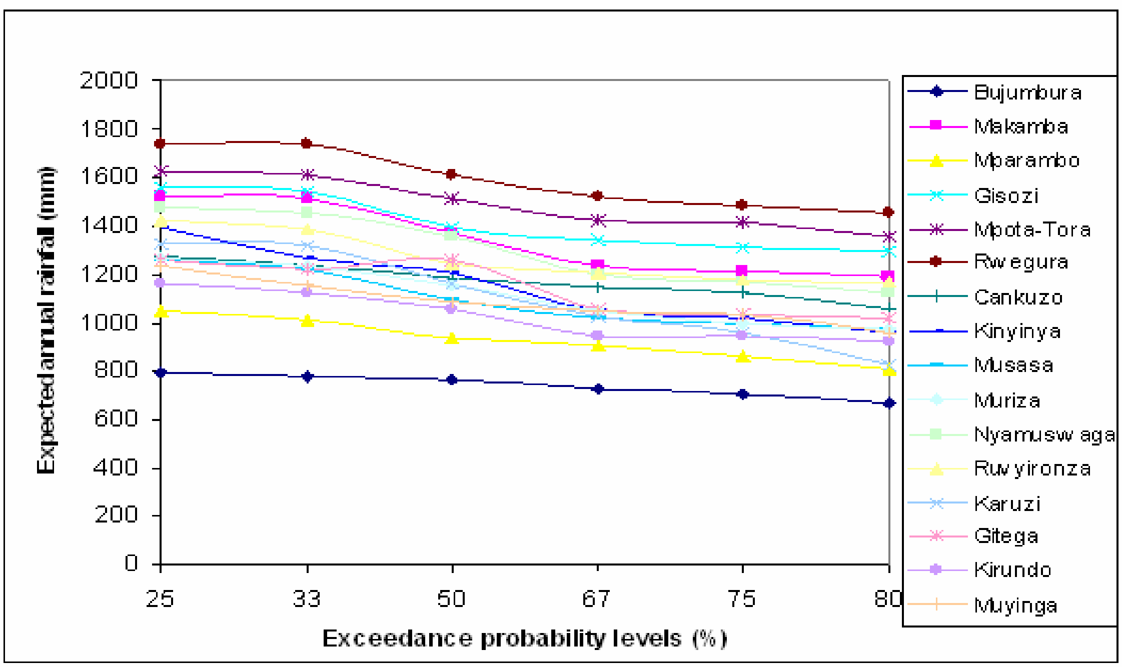

Figure 4.12: Expected rainfall in different locations at different exceedance probability levels.

Figure 4.12 demonstrates the spatial variation of annual rainfall at different scenarios. From the same Figure, it can be clearly seen that Bujumbura, Mparambo and Kirundo expect the minimum rainfall amount at all exceedance probability levels, whereas Rwegura, Mpota-Tora, Gisozi observe inverse situation. In our case for instance, while an amount of more than 1600 mm is expected at 25 % exceedence probability in Gisozi, only 800 mm annual rainfall is reached in Bujumbura at the same probability level. This spatial variation of annual rainfall can be expressed in terms of *Moisture availability index* (Hargreaves, 1975). The moisture availability index has been computed using equation 3.14.

Table 4.9. Moisture availability index determined from Hargreaves equation.

Exceedence prob (%)	25	33	50	67	75	80
Return period (years)	4.00	3.03	2.00	1.49	1.33	1.25
Bujumbura	44.27	43.39	42.54	40.77	39.31	37.15
Mparambo	58.01	55.86	51.89	50.20	47.79	44.98
Gisozi	144.70	143.43	129.47	124.48	121.25	120.29
Mpota-Tora	159.24	157.92	147.82	139.56	138.49	132.43
Rwegura	165.46	165.24	153.64	145.17	141.00	138.65
Cankuzo	102.18	98.93	94.77	91.72	89.94	84.34
Kinyinya	92.97	84.89	80.50	70.39	68.35	64.25
Musasa	86.15	83.38	74.50	69.33	67.98	66.49
Muriza	104.10	101.72	95.03	86.09	82.14	80.42
Nyamuswaga	127.17	125.34	116.50	103.33	100.75	96.54
Ruvyironza	128.37	125.55	112.72	108.81	106.54	105.51
Karuzi	106.76	106.06	93.25	82.31	77.15	66.30
Gitega-Aero	101.06	97.12	100.06	83.86	82.19	80.92
Kirundo	81.20	78.72	73.87	66.17	65.76	64.51
Muyinga	96.31	90.20	84.40	81.87	80.51	74.70

Based on the results summarized in Table 4.9 and Table 3.4 defining different classes of Moisture availability index values, the regionalization of the study area using Thiessen polygons in Arcview GIS is presented as follows.

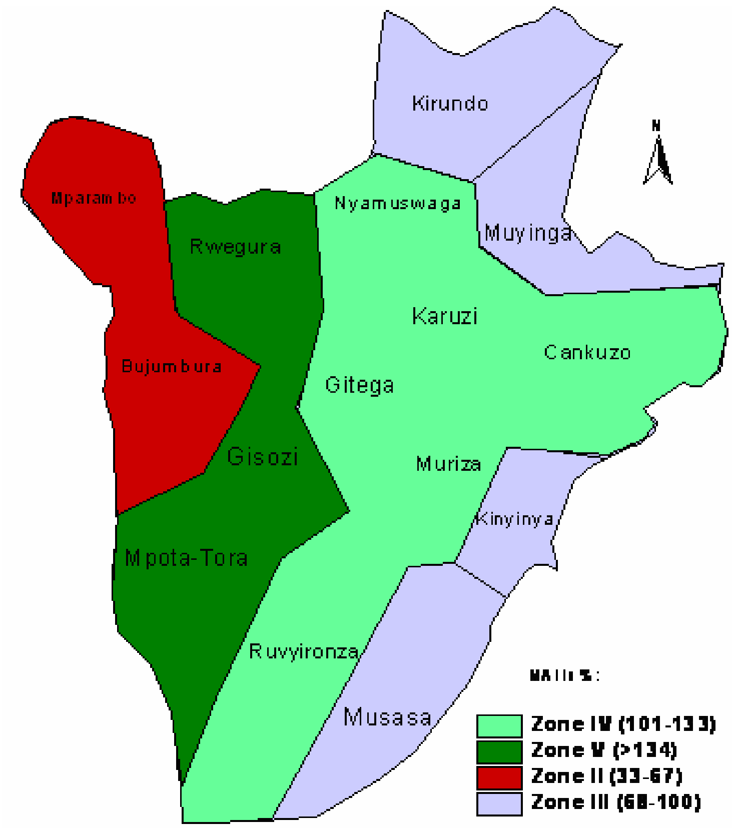

Figure 4.13: Regional moisture availability index map (25 % exceedance probability).

Figure 4.13 has been constructed based on M.A.I values computed using 25% dependable rainfall values of all stations selected for the study. The results show that the entire country can be classified into four homogeneous zones depending upon their moisture availability index: These are Zone II, Zone III, Zone IV and Zone V.

Refering to the classification in Table 3.4, areas with M.A.I less than 100% i.e. Zones II and III in our case can be considered as moisture deficient zones. The locations under these conditions are represented by the stations Bujumbura, Mparambo, Musasa, Kinyinya, Muyinga and Kirundo. The remaining two zones in the study area (Zones IV and Zone V) are not constrained in term of moisture availability and hence, the demand in irrigation water and rainwater for agriculture production varies also accordingly.

Figure 4.14 shows the Moisture availability index as a function of annual rainfall and evapotranspiration.

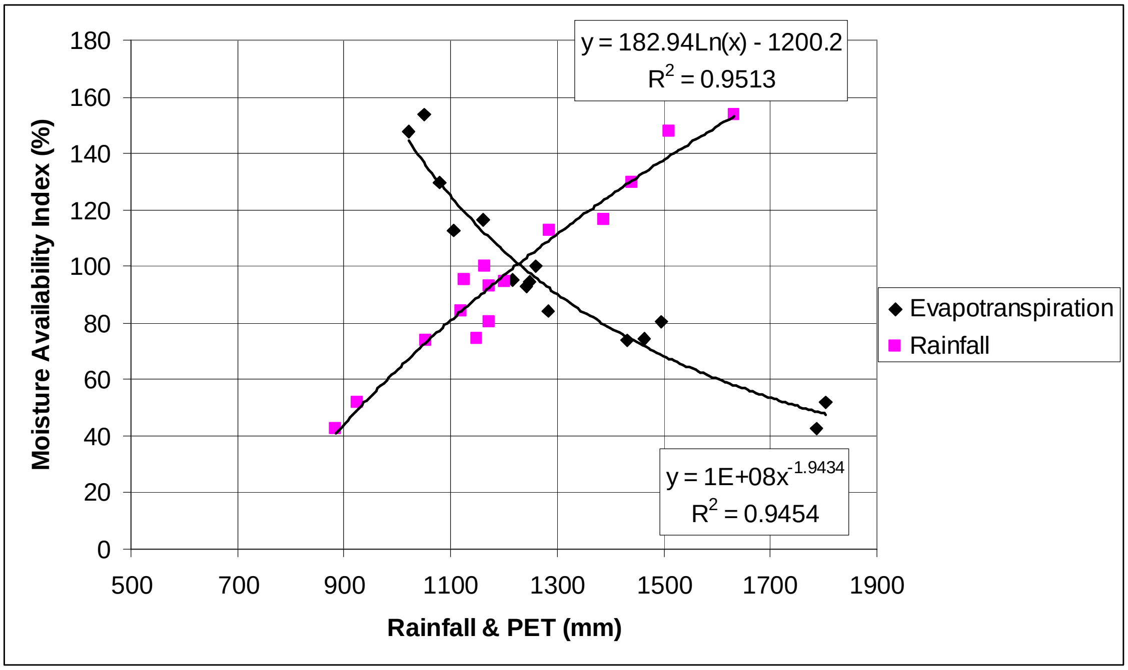

Figure 4.14: Annual Moisture availability index as influenced by rainfall and PET.

The higher the annual rainfall depth is the more will be the moisture availability index for an area, whereas the rate of evapotranspiration influences the moisture availability index (Figure 4.14) negatively.

4.4. Seasonal variability of rainfall

The monthly Gaussian Index values have been computed using equation 3.15 and the results for a sample station Bujumbura are presented in Table below; others are in Appendix 14.

Table 4.10. Monthly Gaussian Index values for Bujumbura station.

Year	J	F	M	A	M	J	J	A	S	O	N	D
1975	5.2	3.2	5.6	2.6	0.4	0.4	0.7	0.0	2.2	1.8	1.7	4.3
1976	3.6	3.5	2.7	3.3	1.6	0.2	0.0	0.9	2.3	2.5	2.2	4.6
1977	4.3	3.4	3.3	7.3	1.3	0.0	0.0	1.9	1.8	0.6	6.0	3.9
1978	3.2	2.9	8.8	6.1	0.9	0.4	0.0	1.1	0.7	1.1	2.6	4.2
1979	3.2	5.9	4.5	8.8	4.1	0.4	0.0	0.1	0.1	2.0	8.4	2.0
1980	4.6	1.0	2.9	3.5	4.3	0.1	0.0	0.0	1.8	2.2	4.9	9.7
1981	3.1	3.9	3.8	2.6	2.0	0.0	0.0	1.8	1.5	2.0	2.5	4.9
1982	2.7	2.8	3.1	6.0	3.1	0.4	0.0	0.1	0.7	3.1	5.0	6.6
1983	3.2	2.9	5.9	6.3	0.7	0.1	0.0	0.8	2.2	3.2	2.2	3.0
1984	6.7	3.3	4.5	4.3	1.6	0.0	0.3	0.1	0.4	2.3	4.6	6.9
1985	3.0	5.0	6.7	4.3	1.9	0.2	0.0	0.0	1.7	0.4	5.6	2.9
1986	5.0	3.8	5.9	9.5	1.1	1.5	0.0	0.0	1.6	3.7	4.8	5.0
1987	4.0	3.5	3.3	4.4	4.1	0.0	0.0	0.0	1.8	1.4	5.0	0.9
1988	5.5	1.8	3.6	4.9	0.3	0.0	0.0	1.9	1.3	3.9	5.8	6.4
1989	6.2	6.4	6.7	5.4	6.2	0.5	0.3	0.6	0.9	4.0	2.0	7.1
1990	2.8	6.8	3.1	4.7	2.9	0.0	0.0	0.0	2.0	3.7	2.3	1.8
1991	2.8	4.5	4.5	3.8	2.9	0.2	0.3	0.2	0.6	4.7	3.4	4.7
1992	2.4	3.6	4.0	2.1	4.1	0.3	0.0	0.0	0.6	1.3	3.4	2.8
1993	3.5	4.6	5.2	3.0	2.4	0.0	0.0	0.0	0.0	1.1	2.9	1.9
1994	6.7	0.5	2.4	4.3	1.4	0.0	0.0	0.0	0.3	2.5	4.1	4.3
1995	2.7	5.5	0.8	4.5	1.6	0.5	0.0	0.0	0.8	2.7	2.3	1.7
1996	4.8	1.7	8.9	3.3	0.3	0.8	0.0	0.1	1.6	4.2	2.1	2.9
1997	2.8	2.7	7.3	3.7	1.3	0.2	0.0	1.3	0.4	1.9	5.4	6.6
1998	4.2	4.6	8.6	2.9	1.9	0.8	0.2	0.1	0.9	0.5	1.3	2.2
1999	2.9	0.5	6.0	3.8	0.6	0.0	0.0	1.2	1.9	2.0	5.4	6.6
2000	4.2	1.5	6.2	1.7	0.0	0.0	0.0	0.0	0.1	1.6	8.4	6.1
2001	4.7	3.2	4.1	3.9	0.4	1.9	0.3	0.0	1.8	1.9	3.9	3.5
2002	5.5	4.8	5.0	3.2	1.4	0.0	0.0	0.0	0.2	1.9	2.3	5.4
2003	2.8	4.8	3.9	2.7	1.0	0.0	0.0	0.1	2.0	1.9	2.7	1.6
2004	4.1	0.8	6.4	3.8	0.0	0.0	0.0	0.1	1.9	1.5	1.8	7.4

As it has been stated in methodology part, the Gaussian Index gives more precise climatic classification and its rationality allows also an easily climatic identification by determining separately the numbers of dry and wet months for a given year. In rainfed agriculture, the dry season is considered to be a period with limited production. The occurrence of moisture stress during flowering, pollination, and grain-filling is harmful to most crops. Therefore, the knowledge of seasonal distribution of rainfall is an important element in order to have a view on water resources availability for crop production since rainwater resource is the main factor in rainfed agriculture. For the present case, the length of dry season for each year for the study period has been evaluated using monthly values of Gaussian Index. Table 4.11 shows the length of dry season (in months) for each year at different locations, the remaining period of the year is considered as rainy season.

Table 4.11. Length of dry season (in months) in different locations (1975-2004).

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1975	4	4	3	3	3		3	3			3	3			3
1976	4	4	3	3	2		3	4			3	3			3
1977	6	4	3	3	3		5	4			3	5			3
1978	6	4	3	3	3		5	5			4	3			3
1979	5	4	4	3	3	5	5	4	4		4	4			4
1980	4	3	3	3	2	4	3	4	4	3	3	4		3	4
1981	5	3	3	3	2	3	4	3	4	3	3	3		3	3
1982	4	3	3	4	2	3	4	4	4	3	4	4		3	3
1983	4	5	4	3	3	5	4	4	4	4	4	4		3	3
1984	5	3	3	4	2	5	4	5	5	3	5	3		4	3
1985	6	3	3	3	3	3	4	5	3	3	3	4		3	3
1986	5	4	3	3	2	4	4	4	4	4	3	4		4	4
1987	5	4	3	3	2	4	3	3	3	3	3	4		3	3
1988	5	4	3	3	2	4	5	4	3	4	4	4	4	3	5
1989	4	3	3	3	2	3	3	3	3	3	3	3	3	3	3
1990	4	4	3	3	3	3	4	3	3	3	4	4	3	3	3
1991	4	4	2	2	2	4	4	4	4	3	3	4	4	4	4
1992	5	5	3	3	3	3	4	4	4	4	4	4	4	3	4
1993	5	4	4	4	4	5	5	5	4	4	5	5	5	3	4
1994	5	4	3	4	4	4	4	4	4	4	3	4	4	4	4
1995	5	4	3	4	2	4	4	5	4	4	4	4	4	3	4
1996	5	3	3	3	2	3	5	4	4	4	4	4	4	4	3
1997	6	4	4	4	3	4	4	4	4	4	4	4	4	4	4
1998	6	4	3	3	3	4	4	4	4	4	4	4	4	4	4
1999	6	4	3	3	3	5	5	5	5	3	3	4	4	3	4
2000	6	4	5	5	3	6	5	5	6	4	4	6	5	4	5
2001	6	5	3	3	2	4	4	4	4	3	3	3	3	3	3
2002	6	4	3	4	3	5	6	5	5	3	5	4	5	4	4
2003	6	5	3	3	3	4	5	4	4	3	4	4	4	3	4
2004	6	5	4	4	4	5	4	5	4	4	4	4	4	4	5
Average	**5.1**	**3.9**	**3.2**	**3.3**	**2.7**	**4.1**	**4.2**	**4.1**	**4.0**	**3.5**	**3.7**	**3.9**	**4.0**	**3.5**	**3.6**

The designations in Table 4.11 are:

1-Bujumbura **2**-Mparambo **3**-Gisozi **4**-Mpota-Tora

5-Rwegura **6**-Cankuzo **7**-Kinyinya **8**-Musasa

9-Muriza **10**-Nyamuswaga **11**-Ruvyironza **12**-Karuzi

13-Gitega **14**-Kirundo **15**-Muyinga

From Table 4.11, it can be noted that the length of dry season in Burundi oscillates almost between three and five months depending on the location. The length of seasons has been estimated using monthly values of Gaussian Index, which is computed as a ratio of precipitation (P) to mean temperature (T). Therefore, the variation of this Index is attributed to the change in precipitations because the mean temperature throughout the study area is less variable with time (Appendix 15). From Table 4.10 and Appendix 14, the dry season is generally observed in June, July, August and September at all the stations, except in Crest Congo-Nile (Gisozi, Rwegura, Mpota-Tora) where September is sometimes wet. However, observations from the results show that the dry season is extended to May or/and October for some years. Knowledge of the length of dry season in rainfed agriculture is important to identify the period with limited water resources for crop production. Using Thiessen polygons in Arcview GIS, the spatial variation in length of dry season on average of 30 years is displayed in Figure 4.15.

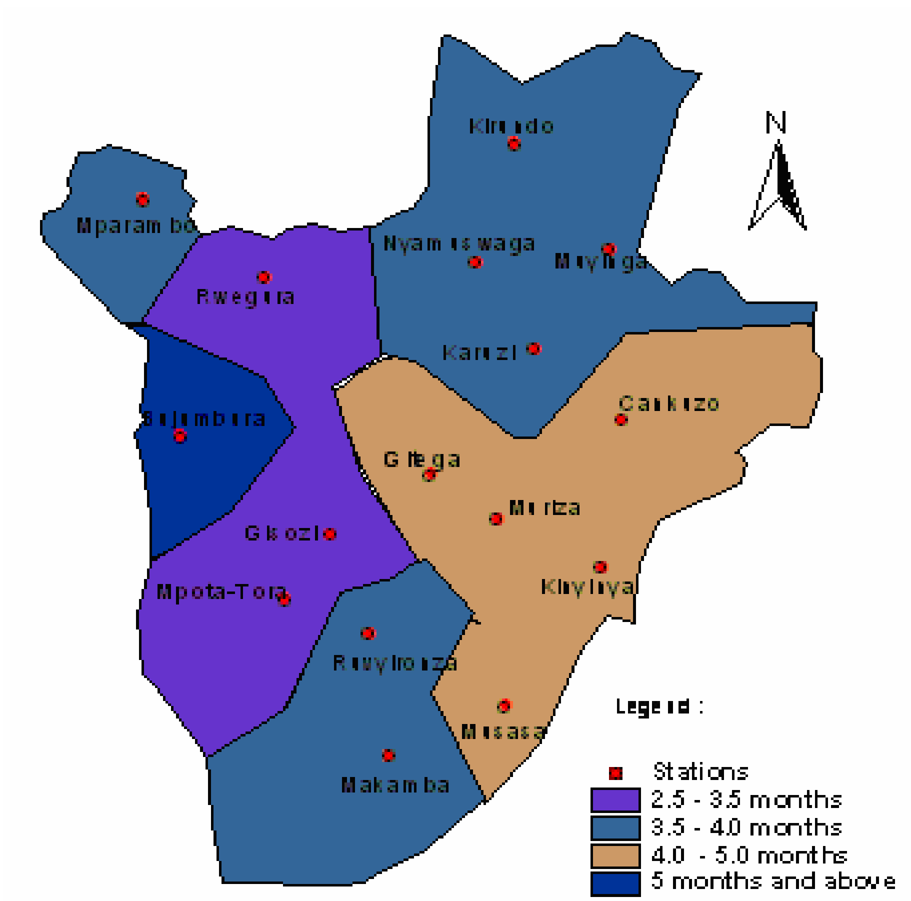

Figure 4.15: Spatial distribution of dry season within the study area.

From the monthly Gaussian Index values computed at different locations, the length of dry and rainy season was determined. On an average of 30 years, Figure 4.15 shows how the length of dry season differs from place to place within the study area. This information on growing season is necessary in areas where rainwater resource is mainly used for crop production. Based on the length of dry season, four regions were identified;

- 2.5–3.5 months (Region 1): Rwegura, Mpota-Tora and Gisozi.
- 3.5–4.0 months (Region 2): Makamba, Ruvyironza, Mparambo, Karuzi, Nyamuswaga, Kirundo and Muyinga.
- 4.0-5.0 months (Region 3): Cankuzo, Gitega, Muriza, Kinyinya and Musasa.
- 5.0 months and above (Region 4): Bujumbura.

4.4. Trend detection analysis

The procedure described in section 3.3.2.4 for the statistical test of Mann-Kendall is applied for trend detection on months identified to be subjected to low reliability of rainfall (i.e. high variability). Statistical properties and results of Mann-Kendall test for Bujumbura and Mparambo stations are presented in Table 4.12, others are in Appendix 16.

Table 4.12. Results of Mann-Kendall test for Bujumbura and Mparambo stations.

	Bujumbura				**Mparambo**			
Months	S	V	Z	P	S	V	Z	P
May	-107	3142	-1.89	0.03	-61	3142	-1.07	0.14
June	-46	3142	-0.80	0.21	-106	3142	-1.87	0.03
July	-44	3142	-0.77	0.22	-87	3142	-1.53	0.06
August	-75	3142	-1.32	0.09	50	3142	0.87	0.81
September	79	3142	1.39	0.68	71	3142	1.25	0.67
October	-31	3142	-0.54	0.30	-15	3142	-0.25	0.40

The last paragraphs have shown the degree of variability in monthly, annual and seasonal rainfall data series. The results show that some months and stations are subjected to high variability. From Figure 4.6, the months of May, June, July, August, September and October are therefore concerned by this analysis.

According to Mann-Kendall non-parametric test, for independent sample data without trend the P-value should equal to 0.50. For sample data with a large positive trend the P-value should be closer to 1.0 whereas a large negative trend should yield P-value closer to zero (Yue et Al, 2002). The same reference documented that when S and Z values are positive, these indicate an upward trend, negative values indicate downward trend in the rainfall series.

The Mann-Kendall statistics S, the standardized normal variate Z and P-values are given in Table 4.12. The following Table is derived from the statistical properties and results of Mann-Kendall test presented in Table 4.12 above.

Table 4.13. Trend detection analysis in monthly rainfall.

Months	May	June	July	August	September	October
Bujumbura	NT*	NT	NT	NT*	PT	NT
Mparambo	NT	NT*	NT*	PT	PT	NT
Gisozi	NT	NT	NT	NT	NT	NST
Mpota-Tora	NST	NT	PT	NT	NT	NT
Rwegura	NT	NT*	PT	NT	NST	PT
Cankuzo	NT	NT	NT	NT	NT	NT
Kinyinya	NT	NST	NT	NT	NT	NT
Musasa	NT*	NT	NT	NT	NST	NT
Muriza	NT	NST	NT	NT	NT	NT
Nyamuswaga	NT*	NT*	NT	NT*	NT*	NT*
Ruvyironza	NST	NT	NST	NT	PT	PT
Karuzi	NT	NT	PT	PT	NST	NT
Gitega	NT*	NT	NT	NT	NT*	NT
Kirundo	NT*	NT	NST	NT	NT	NT
Muyinga	NT	NST	NT*	NT*	NST	NT*

The designations in Table 4.13 are: NT - Negative trend (declining trend)
NT*- Significant negative trend
PT - Positive trend (increasing trend)
NST- Non significant trend

From Table 4.13, the observation is that most of rainfall series of the months considered show a negative trend; indicating a decline in these monthly rainfall series. However, the same results show that significant downward trend is only observed in Bujumbura (May, August), Mparambo (June, July), Rwegura (June), Musasa (May), Nyamuswaga (from May to October), Gitega (May, September), Kirundo (May) and Muyinga (July, August, October).

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1. Summary and conclusions

The present research work aims to analyze the spatial and temporal variability of rainfall over Burundi for agriculture purpose. The analysis of rainfall variability has been carried out at different time scales using the 1975-2004 rainfall data series of 30 years records collected from sixteen meteorological stations.

Investigation of annual rainfall variability in selected meteorological stations has been done based on coefficient of variation, simple climate departure index and moisture availability index. The results showed that the coefficient of variation is less than 0.25 in all stations. The second method of analysis provided the results of the values of Simple climate departure index oscillating between -3 and +3 in the whole study area. These two situations indicate that annual rainfall in Burundi didn't experience appreciable temporal variation. The spatial analysis aspect based on expected annual rainfall at different exceedance probability levels prove the annual rainfall change in space within the study area; meaning that rainwater resources availability differ from place to place. This spatial variation of annual rainfall has been expressed in term of moisture availability index as defined by Hargreaves. The results show that the entire country can be classified into four homogeneous zones depending upon their moisture availability index: These are Zone II, Zone III, Zone IV and Zone V. Referring to the Hagreaves classification, the Zones II and III are considered as moisture deficient zones. The locations under these conditions are represented by the stations Bujumbura, Mparambo, Musasa, Kinyinya, Muyinga and Kirundo. The remaining two zones in the study area (Zones IV and Zone V) are not constrained in term of moisture availability.

The seasonal variability of rainfall was evaluated using Gaussian Index which is based on the combination of average monthly temperature and total rainfall. This index allows an easy climatic identification by determining separately the number of dry and wet months for a given year. Therefore, the knowledge of seasonal distribution of rainfall is an important element in order to make informed decision on water resources available. It is found in 30 years, that the length of dry season in Burundi ranges between three and five months depending on the location. Therefore, four regions with corresponding meteorological stations can be identified based on the length of dry season: These are Region1 (2.5-3.5 months): Gisozi, Mpota-Tora and Rwegura; Region 2 (3.5-4.0 months): Makamba, Ruvyironza, Mparambo, Karuzi, Nyamuswaga, Kirundo and Muyinga; Region 3 (4.0-5.0 months): Cankuzo, Gitega, Muriza, Kinyinya and Musasa; Region 4 (5.0 months and above): Bujumbura. From monthly Gaussian Index values, the dry season is generally observed in June, July, August and September at all selected stations except the crest Congo-Nile where September is sometimes wet. Observations show that the dry season is sometimes extended to May or/and October.

The variability of monthly rainfall has been analyzed using coefficient of variation. Monthly rainfall data series from 1975 to 2004 were checked for variation both in space and time. From the results, monthly rainfall of May, June, July, August, September and October were found to be subjected to high variability (C.V>50%); meaning that the reliability of rainfall during this period is low. The remaining months of the year show less to moderate variation of rainfall. The observations from the same results indicate also that the rainfall variation generally increases with decreasing in monthly totals of rainfall and the frequency of rainy days.

From the seasonal variability analysis it was found that the months of June, July, August and September remain dry throughout the study area. Also, the probability of wet day analysis show that rainfall is distributed from October to May; the pattern is bimodal with two peaks in April and November. For agriculture purpose, much attention should be paid to the months of May and October because they are characterized by high variability while they correspond to the beginning and the end of growing season respectively. The fact is that occurrence of dry spells at beginning of the growing season (October) may affect seedling establishment and reduce plant population while dry spell during the flowering period (May) could lead to complete crop failure. The coefficient of variation at selected stations showed that monthly rainfall varies in space. Similarly, possible adverse effects from fluctuations in rainfall of May and October may differ from place to place.

From the variability analysis of monthly rainfall, it has been shown that some months were found to be subjected to high variability; indicating low reliability of rainfall. This aspect was identified to be an important element in areas where rainfed agriculture is the main system practiced in crop production. For predictive purpose, trend detection analysis was carried out. Monthly precipitations time series of selected stations showed negative trends indicating the decrease in precipitation, this trend was not statistically significant throughout the study area. However, the results show that significant downward trend is only observed in Bujumbura (May, August), Mparambo (June, July), Rwegura (June), Musasa (May), Nyamuswaga (from May to October), Gitega (May, September), Kirundo (May) and Muyinga (July, August, October).

In conclusion, investigation of rainfall variability at different time scales reveals spatial variability of rainfall in Burundi. The results from this analysis demonstrate that the entire country cannot be treated as homogeneous with respect to rainfall variability. Concerning the temporal variability, annual rainfall doesn't show significant change within the period considered. The seasonal variability analysis shows that the temporal distribution of the two main seasons is variable from year to year. From the results, the dry season is generally observed in June, July, August and September at all the stations. But on an average of 30 years the length of dry season ranges between three and five months, the deviation from this mean value is sometimes observed. Therefore, crop production can only be possible through supplementary irrigation practice. From monthly rainfall variability analysis, months of May, June, July, August, September and October were characterized by high variability in rainfall data series indicating low reliability of rainfall during this period. The remaining months of the year show less to moderate variability. These irregularities and fluctuations in rainfall time series are the main factor responsible for scarcity of water resources and prolonged droughts especially for crop production. The consequences may lead to severe food security and economical crises since a large proportion of Burundian population depends on agricultural sector.

In this study, much attention was focused on the importance of growing season; meaning the period favorable for crop production. Therefore, for these months identified to be subjected to low reliability of rainfall, trend detection analysis was carried out using non-parametric Mann-Kendall test.

Although many stations showed negative trend indicating the decrease in precipitation, this trend was statistically significant only for some stations.

According to the results, agriculture production in Burundi could not suffer from the quantity of rainwater recorded each year because the distribution of annual rainfall was not much variable with time. However, the eventual consequences may have origin in seasonal, monthly and spatial distribution of rainfall. The variability of seasonal and monthly rainfall affects water availability for crop production by reducing the length of growing season. Rainfall is concentrated in some rainy months; runoff and erosion would be very high under the absence of soil and water conservation techniques, the topography of most Burundian lands, the strong demographic growth that implies excessive pressure on the arable lands, degradation of natural resources.

5.2. Recommendations

Based on the results and conclusions presented above, the following recommendations are drown from the entire analysis.

1. The key challenge is to reduce water-related risks posed by monthly and seasonal rainfall variability. Therefore it is recommended to adopt strategies to collect and store rainwater for agriculture uses at a later time during dry spells instead of runoff being left to cause erosion in order to improve agriculture production.

2. To avoid the possible adverse effects on plants growth due to high variability of rainfall at the beginning (October) and the end (May) of growing season in Burundi, crop production system should be supplemented by other water resources management practices, including agronomic decisions like optimum date of sowing, fertilizer application and varietal choice.

3. National research institutions should try to introduce resistant crop varieties by utilizing genetic resources that can be better adapted to new seasonal rainfall regime and atmospheric conditions.

4. Because of the variability of rainfall in space within the study area, it is recommended to increase the spatial coverage by including more number of stations.

5. It is also suggested to extend the analysis to the other time scales such as daily or ten days period in order to see the effect of rainfall variability over short time intervals on crop production.

6. Further studies should be conducted to predict the future monthly and seasonal distribution of rainfall in Burundi.

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APPENDICES

Appendix 1: Approximations used for constructing the Moment Ratio Diagrams for some common distributions.

1. Uniform: Cs=0.0, Ck=1.8
2. Exponential: Cs=2.0, Ck= 9.0
3. Gumbel (EVI): Cs= 1.1396, Ck= 5.4002
4. Logistic: Cs= 0.0, Ck= 4.2
5. Normal: Cs= 0.0, Ck= 3.0
6. Lognormal: $Ck= 3 + 0.0256553\ Cs + 1.720551\ Cs^2 + 0.041755\ Cs^3 + 0.046052\ Cs^4 – 0.00478\ Cs^5 + 0.000196\ Cs^6$

7. Generalized Logistic:

$$Ck= 4.2 + 2.400505\ Cs^2 + 0.244133\ Cs^4 – 0.00933\ Cs^6 + 0.002322\ Cs^8$$

8. Generalized Extreme Value (GEV):

$$Ck= 2.695079 + 0.185768\ Cs + 1.753401\ Cs^2 + 0.110735\ Cs^3 + 0.037691\ Cs^4 + 0.0036\ Cs^5 + 0.00219\ Cs^6 + 0.000663\ Cs^7 + 0.0000\ Cs^8$$

9. Gamma and Pearson III: $Ck= 3 + 1.5\ Cs^2$

10. Generalized Pareto:

$$Ck= 1.8 + 0.292003\ Cs + 1.34141\ Cs^2 + 0.090727\ Cs^3 + 0.022421\ Cs^4 + 0.00400\ Cs^5 + 0.000681\ Cs^6 + 0.00089\ Cs^7 + 0.000056\ Cs^8$$

11. Weibul: same as GEV but with Cs replaced by -Cs

Appendix 2: Approximations used for constructing the L-Moment Ratio Diagrams for some common distributions.

1. Uniform: t3= 0, t4= 0
2. Exponential: t3= 1/3, t4= 1/6
3. Gumbel (EV1 (2)): t3= 0.1699, t4= 0.1504
4. Logistic: t3= 0, t4= 1/6
5. Normal: t3= 0, t4= 0.1226
6. Generalized Pareto: t4= t3(1+5t3) / (5+t3)
7. Generalized Logistic: t4= $(1+5t3^2)$ / 6
8. Generalized Extreme Value:

   $t4= 0.10701 + 0.11090\ t3 + 0.84838\ t3^2 – 0.06669\ t3^3 + 0.00567\ t3^4 – 0.04208\ t3^5 + 0.03763\ t3^6$

9. Gamma and Pearson III: $t4= 0.1224 + 0.30115\ t3^2 + 0.95812\ t3^4 – 0.57488\ t3^6 + 0.19383\ t3^8$
10. Lognormal (two and three parameters):

    $t4= 0.12282 + 0.77518\ t3^2 + 0.12279\ t3^4 – 0.13638\ t3^6 + 0.11368t3^8$

11. Wakeby lower bound: $t4= -0.07347 + 0.14443\ t3 + 1.03879\ t3^2 – 0.14602\ t3^3 + 0.03357\ t3^4$
12. Overall lower bound: $t4= -o.25 + 1.25\ t3^2$

Appendix 3: Potential Evapotranspiration values computed using Thornthwaite Method.

Bujumbura-Aero

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1975	141.0	155.7	140.5	146.4	146.8	129.3	121.4	134.5	143.8	146.8	141.9	137.5
1976	143.8	146.4	141.0	148.5	139.4	126.1	121.4	132.5	159.8	150.9	141.5	150.2
1977	146.7	164.6	145.1	147.7	143.8	134.4	127.5	141.6	165.6	172.4	147.1	144.8
1978	154.2	169.6	151.9	151.5	142.3	136.0	120.3	134.4	158.9	161.5	148.2	143.5
1979	148.0	167.9	151.3	151.6	143.1	135.2	120.0	140.4	168.0	163.1	151.9	143.0
1980	155.5	170.0	151.9	156.2	145.9	135.7	120.3	131.2	167.1	156.2	146.4	142.1
1981	145.4	166.1	150.4	164.3	150.8	139.7	122.9	141.5	145.3	157.1	164.5	144.0
1982	148.6	166.0	153.1	157.6	145.2	135.6	118.6	135.5	175.4	150.2	146.1	158.3
1983	159.5	185.2	160.4	162.3	158.2	146.8	135.4	142.0	156.4	150.4	147.7	141.7
1984	141.8	159.1	143.5	157.0	139.5	129.2	125.4	136.4	167.6	166.8	145.1	144.8
1985	153.0	159.3	152.4	153.1	148.8	134.2	115.7	133.0	161.4	176.8	158.7	147.7
1986	148.8	165.0	141.1	157.3	149.9	129.6	113.1	133.3	159.1	161.0	140.1	144.2
1987	143.8	168.9	159.2	165.5	151.0	145.1	129.8	143.8	167.6	160.9	160.8	164.7
1988	151.5	179.2	157.5	163.9	155.4	148.2	133.7	144.7	156.9	151.5	150.1	134.5
1989	143.4	155.7	146.5	153.5	139.9	130.2	122.4	137.6	161.6	147.2	158.5	146.0
1990	149.4	172.8	144.4	175.4	148.3	139.9	121.9	143.1	157.8	157.7	159.6	146.6
1991	160.6	182.1	154.9	156.5	151.6	152.1	122.8	137.3	157.7	136.4	141.9	142.8
1992	153.5	167.7	153.9	147.1	148.2	149.3	119.6	128.7	171.1	164.2	155.8	150.5
1993	158.9	171.9	143.6	155.6	152.1	149.0	120.5	145.6	165.5	181.6	164.9	152.1
1994	142.0	179.9	153.6	169.3	158.8	144.4	127.9	146.6	188.0	153.5	160.9	155.5
1995	167.7	193.3	156.4	163.8	151.5	160.4	133.5	134.6	178.4	154.4	168.9	157.8
1996	152.3	175.3	159.8	166.5	164.6	144.6	136.5	123.0	169.4	164.4	157.6	155.2
1997	164.9	205.1	155.5	157.8	145.5	146.8	131.7	148.5	184.9	168.0	166.3	148.7
1998	166.7	190.2	169.7	180.1	167.3	141.6	133.1	144.3	169.2	161.4	163.9	151.3
1999	156.4	192.8	151.3	152.7	153.0	143.2	127.9	143.8	160.7	153.4	148.1	148.7
2000	154.3	165.2	141.9	160.4	144.4	131.3	129.4	148.2	184.6	169.1	152.7	159.2
2001	145.5	162.8	150.8	166.9	157.1	137.4	129.3	134.5	163.1	160.5	140.3	161.7
2002	151.9	187.0	140.7	126.2	125.2	116.8	112.2	117.0	132.9	142.8	127.2	128.0
2003	173.2	197.1	150.8	125.8	124.3	111.9	96.5	106.6	121.6	125.8	119.3	112.5
2004	166.6	175.1	168.4	113.1	112.4	99.0	91.0	106.9	119.3	119.7	114.6	112.7

Makamba

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1987	106.3	121.9	106.2	131.9	119.3	113.1	121.4	136.9	155.2	139.1	137.9	135.5
1988	139.5	169.8	148.0	150.5	141.7	148.1	139.9	144.6	157.9	0.0	0.0	0.0
1990	112.2	118.1	103.1	116.3	105.0	107.0	100.4	114.1	126.4	127.4	117.6	103.4
1991	111.8	127.7	117.8	110.9	106.3	107.8	94.4	113.1	131.9	105.8	112.1	108.4
1992	109.0	127.3	118.1	115.5	106.5	107.3	95.0	110.3	135.8	122.8	115.5	104.9
1993	106.3	117.5	107.4	116.0	104.5	101.6	98.1	117.0	138.2	155.6	124.6	112.7
1994	111.4	124.6	111.2	117.4	109.5	107.9	101.2	116.5	138.8	117.1	112.9	112.2
1995	115.0	122.3	116.8	119.3	108.7	107.0	104.5	122.2	134.6	123.5	108.9	113.9
1996	107.3	124.2	114.0	118.4	114.7	106.9	105.5	116.8	123.3	124.6	123.0	108.7
1997	109.6	121.2	119.0	108.7	96.5	105.5	107.8	126.6	158.2	130.0	116.9	107.3
1998	110.3	136.5	123.3	127.3	114.2	107.9	103.6	116.3	134.1	122.8	125.9	109.2
1999	113.1	134.9	107.9	114.6	109.9	108.9	102.7	115.0	124.8	127.3	114.6	112.0

Mparambo

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1966	146.3	161.8	154.9	152.7	148.0	139.1	127.4	140.0	158.6	142.9	157.2	135.4
1967	149.2	172.0	164.9	157.9	151.3	137.6	122.0	126.2	158.7	154.7	141.4	133.1
1968	141.8	163.8	135.7	150.7	138.9	136.6	122.1	129.8	168.0	158.6	144.1	147.9
1969	149.5	164.9	155.2	162.6	142.7	143.3	125.1	139.3	173.5	161.7	148.9	158.7
1970	153.9	175.7	148.7	152.0	141.2	135.5	131.4	139.5	156.7	157.5	164.4	148.2
1971	154.3	148.2	138.8	143.2	135.6	125.9	116.4	128.9	144.0	146.3	149.6	134.5
1972	122.6	150.1	141.9	140.6	134.2	134.0	110.1	132.5	255.5	285.4	196.6	145.4
1973	150.3	183.9	143.0	147.8	140.3	124.6	116.7	134.3	163.9	151.3	158.3	134.3
1974	127.8	147.1	143.6	143.4	133.2	147.5	113.1	127.2	165.3	169.7	161.1	125.1
1975	128.7	156.3	146.6	150.1	141.6	154.6	133.7	140.1	145.4	160.1	155.4	143.4
1976	148.0	140.1	141.4	144.0	142.9	133.7	121.3	135.7	164.5	157.1	156.1	154.1
1977	155.4	164.9	142.0	149.7	143.0	137.9	129.0	144.0	165.6	157.9	142.9	146.9
1978	156.9	175.6	147.4	147.6	146.0	140.8	122.6	132.9	163.1	162.0	149.4	159.1
1979	148.7	171.4	164.6	153.2	141.1	134.9	117.2	136.7	161.2	159.6	163.0	142.7
1980	128.2	158.9	142.2	162.4	151.9	143.2	130.8	137.1	179.8	158.8	153.4	144.3
1981	147.7	162.7	154.9	167.6	147.9	136.9	122.0	144.6	154.5	157.2	165.2	145.3
1982	138.7	157.8	151.4	152.3	150.9	142.4	122.5	139.0	188.2	151.9	161.6	160.4
1983	166.3	200.0	162.3	163.6	154.7	151.7	136.3	147.3	168.9	151.7	160.7	144.5
1984	140.0	152.5	141.1	150.2	146.9	137.3	128.2	135.7	164.8	158.6	149.5	151.5
1985	148.1	162.6	149.5	155.2	142.1	133.5	114.4	123.3	157.9	176.4	160.0	158.6
1986	151.3	160.2	137.7	158.4	147.9	138.0	111.3	138.1	158.6	160.1	142.1	141.9
1987	140.0	167.8	157.3	158.8	150.0	139.9	122.8	147.9	172.4	173.4	171.9	174.6
1988	152.8	179.9	155.5	162.3	158.6	145.4	131.8	144.5	160.5	154.2	163.2	142.5
1989	141.5	154.8	146.1	154.0	145.8	137.3	118.8	133.5	164.5	154.6	171.0	151.9
1990	141.6	182.1	159.7	179.5	155.8	152.0	125.7	152.5	166.3	168.9	167.4	153.7
1991	155.7	180.4	159.9	160.3	154.2	151.5	121.6	136.4	167.1	148.6	138.7	151.4
1992	160.5	177.6	163.0	171.9	148.6	150.2	116.5	128.5	181.4	170.4	161.7	144.4
1993	154.7	178.2	139.8	155.6	151.7	140.7	107.3	141.4	163.2	175.9	154.0	165.3
1994	165.2	192.6	163.0	170.7	165.7	162.9	141.4	156.9	188.6	166.6	164.5	158.9
1995	152.2	172.0	135.2	156.8	147.4	152.9	121.8	134.2	170.0	158.3	166.0	152.6
1996	147.4	164.0	135.5	153.7	149.2	150.8	118.4	130.7	162.6	153.2	153.9	141.4

Gisozi												
Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1975	90.9	99.7	88.6	93.7	82.1	75.5	74.1	81.0	87.2	88.7	96.4	88.4
1976	90.5	93.1	89.7	90.7	81.4	74.9	76.6	83.9	97.0	96.1	92.5	93.4
1977	89.3	103.6	89.2	90.7	82.5	76.2	76.9	86.8	96.3	98.7	92.3	91.3
1978	94.2	103.5	90.7	94.5	82.8	76.3	74.9	86.2	97.4	92.9	87.4	90.0
1979	90.0	100.7	90.5	92.8	83.0	74.7	74.0	89.8	102.5	99.4	95.4	87.9
1980	94.6	103.1	89.4	96.1	84.0	79.2	74.0	84.7	98.5	93.5	91.7	89.3
1981	90.3	100.4	88.4	94.2	84.4	78.2	75.6	88.1	93.7	95.1	95.7	90.3
1982	90.8	100.0	87.7	91.0	84.6	78.9	74.3	82.7	102.6	91.3	89.5	91.0
1983	91.3	105.8	94.3	92.2	85.3	84.1	82.6	85.4	97.5	90.2	90.5	86.5
1984	91.2	99.3	91.0	93.2	81.1	76.4	77.0	85.8	96.8	94.5	89.8	90.6
1985	94.8	99.9	92.2	90.6	81.0	76.7	74.7	83.3	93.1	95.8	92.8	89.3
1986	91.0	105.0	88.5	91.0	83.2	73.3	71.0	90.5	93.8	95.0	90.2	86.9
1987	88.0	99.7	94.8	97.6	86.5	79.8	83.8	90.2	99.2	93.1	95.2	95.5
1988	95.5	105.7	92.4	95.7	84.0	82.4	78.3	84.5	95.0	89.2	91.9	86.0
1989	88.6	96.2	87.2	91.4	82.7	75.5	75.6	84.2	94.3	92.8	99.3	90.5
1990	90.8	101.1	90.4	97.9	84.1	78.6	74.2	85.9	95.8	94.1	94.7	88.4
1991	92.1	105.1	93.0	91.7	86.9	89.4	69.6	86.2	96.8	85.0	89.8	90.5
1992	90.1	104.4	94.6	100.2	83.6	80.9	71.5	81.9	97.1	94.1	94.2	88.4
1993	91.2	99.1	85.2	91.3	83.8	76.2	72.2	84.7	99.5	102.0	105.8	95.0
1994	92.0	103.9	88.5	96.4	91.6	75.8	73.1	83.9	102.1	90.9	92.0	92.1
1995	94.7	100.6	91.5	91.3	84.3	80.8	75.2	86.8	97.7	94.6	97.9	91.0
1996	88.8	100.9	92.2	95.7	86.8	77.2	76.2	85.0	95.8	94.8	93.9	90.0
1997	90.8	100.2	92.7	88.0	83.1	78.0	73.4	88.9	109.5	98.9	95.4	89.5
1998	95.1	112.7	99.8	104.1	88.3	77.9	73.6	82.3	99.5	89.8	96.4	88.1
1999	94.6	107.4	89.7	90.0	83.2	79.1	75.7	86.4	92.9	92.1	91.8	91.4
2000	91.2	93.7	87.2	92.0	87.3	78.8	78.7	86.2	105.0	99.3	95.8	93.0
2001	91.5	101.4	88.9	99.8	81.6	74.9	74.4	85.6	95.3	99.1	94.7	95.1
2002	92.3	109.6	89.6	95.0	84.8	77.6	82.2	88.6	99.0	96.7	91.3	90.0
2003	95.6	106.5	91.5	91.4	86.7	75.7	73.2	85.1	97.1	95.8	97.5	91.0
2004	96.0	100.3	94.6	89.5	81.9	78.2	77.6	90.4	95.2	97.2	93.6	92.3

Mpota-Tora

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1975	80.9	87.9	94.4	85.4	78.6	78.8	73.4	70.1	77.6	83.2	88.9	79.7
1976	81.8	90.3	92.9	83.0	75.1	71.7	70.8	77.3	89.6	82.9	88.6	83.6
1977	84.3	89.3	99.1	83.7	79.0	72.3	72.6	80.0	92.2	81.6	86.3	86.8
1978	91.5	99.0	88.5	90.2	81.1	77.3	77.5	87.0	90.3	84.5	91.1	91.0
1979	87.5	98.5	91.0	86.6	75.3	75.8	73.7	86.5	88.9	84.4	88.4	90.9
1980	89.0	98.7	90.8	94.8	76.2	71.4	69.0	77.9	81.3	80.7	87.7	86.1
1981	115.6	92.4	85.2	82.8	82.3	70.8	68.4	72.9	95.0	76.4	86.3	88.1
1982	91.7	98.7	88.2	84.3	76.7	64.6	66.2	75.3	88.3	81.7	86.5	80.4
1983	95.4	104.8	89.3	91.8	86.3	79.4	73.6	86.1	79.4	83.9	87.0	88.0
1984	88.4	98.5	88.0	86.5	81.3	73.1	74.3	86.1	81.0	80.5	87.0	84.5
1985	82.2	87.9	85.6	86.3	75.0	71.1	77.9	77.6	82.6	86.7	89.9	86.1
1986	85.1	97.7	87.7	84.1	77.8	72.2	74.6	78.8	88.2	85.4	89.0	86.3
1987	89.8	98.6	90.7	89.8	83.6	76.3	72.6	75.9	83.9	86.6	93.0	88.3
1988	92.2	98.4	87.9	90.8	81.7	75.7	73.2	83.1	84.5	86.8	89.2	87.6
1989	89.0	95.3	83.1	87.6	80.8	73.7	72.4	78.9	85.7	86.7	93.8	88.6
1990	83.8	94.7	90.2	93.6	82.6	75.5	69.9	79.1	92.5	84.4	91.1	89.4
1991	91.1	97.7	82.8	83.8	87.3	77.7	75.6	79.7	81.5	83.3	88.6	89.3
1992	86.9	99.6	87.7	90.2	79.5	80.6	72.8	75.3	86.5	83.7	89.0	87.4
1993	88.5	97.2	81.9	86.8	79.1	76.5	69.2	84.6	90.0	84.5	94.7	89.7
1994	94.7	110.5	91.7	19.4	79.2	76.7	78.0	88.6	91.1	88.6	96.3	97.4
1995	90.1	98.0	83.8	87.0	83.4	79.9	78.1	79.1	85.0	87.3	94.1	85.0
1996	89.3	96.7	85.6	91.9	81.1	76.8	75.8	75.6	87.7	85.3	90.3	86.8
1997	88.0	96.2	83.8	87.1	81.4	75.0	78.1	88.3	87.2	84.4	92.4	91.2
1998	98.5	109.6	93.5	97.5	87.0	73.0	73.0	80.0	83.0	84.6	86.4	85.0
1999	93.8	90.4	84.1	89.5	82.9	75.8	66.8	84.7	89.2	77.7	90.0	89.3
2000	85.0	89.2	83.0	90.1	79.0	76.3	74.6	87.4	89.8	86.5	91.5	93.7
2001	94.7	95.0	84.9	86.4	80.0	73.7	76.0	77.7	85.7	86.8	94.0	89.8
2002	95.2	99.2	84.4	92.9	84.0	76.3	75.4	83.8	89.1	81.2	89.0	89.4
2003	97.3	102.1	87.1	90.8	87.5	83.3	79.0	82.4	94.9	94.9	99.3	90.0
2004	92.7	97.5	90.5	86.5	81.7	75.3	68.5	81.5	88.9	91.2	91.0	89.2

Rwegura

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1975	86.9	96.7	82.6	82.8	80.7	80.7	76.3	80.9	80.0	83.8	91.2	85.3
1976	87.2	90.3	88.0	86.1	80.7	79.2	76.9	81.5	88.2	92.7	90.2	87.5
1977	84.9	98.0	86.4	85.8	81.0	81.1	78.1	82.2	92.9	95.1	85.2	87.7
1978	90.5	100.5	84.8	86.6	79.1	79.6	76.5	87.1	94.7	88.1	84.7	84.0
1979	85.5	95.8	90.8	84.7	78.2	77.4	68.2	91.8	102.0	95.7	88.6	83.8
1980	89.4	100.0	86.0	89.9	80.4	82.1	77.7	84.3	94.5	89.6	86.8	83.7
1981	89.8	97.9	85.0	86.5	77.9	80.3	77.8	83.0	86.6	87.9	88.5	87.3
1982	86.9	96.9	87.4	82.5	73.4	81.2	82.2	89.9	92.3	77.0	87.9	89.7
1983	91.2	104.5	91.8	85.2	85.1	85.8	79.7	81.8	91.1	93.5	93.3	81.3
1984	81.4	98.1	91.3	88.3	85.1	81.3	76.9	86.6	95.2	87.8	82.4	87.2
1985	88.3	92.3	98.5	85.0	79.2	79.8	76.8	83.9	88.1	90.0	90.5	85.9
1986	88.2	99.4	84.8	85.4	80.9	77.6	76.4	93.8	93.7	91.0	90.0	87.8
1987	86.9	106.2	91.7	93.9	91.2	81.1	84.2	86.6	94.6	91.0	85.4	92.6
1988	87.8	104.8	89.7	91.3	84.3	82.3	79.9	83.1	89.7	87.1	87.9	80.2
1989	84.9	95.3	86.1	85.8	79.2	76.2	75.2	84.9	91.1	87.0	94.1	87.7
1990	89.7	99.7	88.7	95.7	87.0	88.1	80.4	89.3	52.9	90.7	91.9	86.2
1991	90.0	104.1	93.0	90.0	82.9	87.1	73.6	88.2	95.8	80.2	87.2	85.2
1992	90.4	97.4	91.2	91.2	82.3	82.7	75.9	86.3	96.3	89.2	87.5	82.5
1993	82.9	92.8	81.2	88.3	81.5	79.7	77.7	83.6	104.4	102.6	99.4	103.5
1994	89.5	97.2	87.1	90.6	82.1	80.8	78.8	86.5	102.4	87.1	87.5	88.2
1995	87.9	97.9	87.9	88.0	80.9	86.7	80.3	92.4	99.4	87.1	93.2	87.6
1996	87.5	97.9	88.4	89.5	84.5	77.4	78.3	85.5	94.1	90.4	90.1	88.9
1997	86.6	98.1	89.9	84.4	79.7	82.5	78.8	93.3	111.2	92.1	89.2	84.0
1998	91.6	105.9	96.5	95.9	87.5	83.9	72.9	86.8	99.0	87.9	94.4	88.0
1999	88.2	107.3	86.3	87.4	82.5	83.4	79.6	81.0	92.0	89.8	87.7	86.0
2000	89.0	108.9	82.2	87.7	87.5	82.7	81.1	89.9	103.2	90.1	88.0	86.3
2001	82.1	99.8	85.7	92.7	82.8	81.1	77.8	89.0	96.0	90.1	92.1	90.3
2002	90.9	108.4	90.7	91.5	82.0	81.5	77.6	86.3	93.0	89.3	89.4	86.9
2003	85.5	97.3	86.2	86.1	80.0	79.3	75.5	84.2	90.9	87.2	87.2	84.8
2004	86.3	98.1	86.9	86.9	80.7	80.1	76.3	85.0	91.7	88.0	88.0	85.5

Cankuzo

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1979	102.0	111.9	103.9	102.8	98.6	89.0	94.8	118.7	134.6	125.3	111.8	97.5
1980	104.3	118.2	100.6	102.3	98.1	96.5	99.2	114.0	129.5	119.8	104.9	101.5
1981	103.8	117.1	101.8	108.1	97.1	99.3	100.9	112.9	118.4	113.4	113.1	101.0
1982	87.4	121.6	98.0	104.8	99.9	87.6	17.0	98.6	19.9	18.1	90.0	88.9
1983	102.3	126.8	118.5	108.9	109.4	112.0	113.4	114.2	125.8	107.2	101.8	104.0
1984	93.9	110.8	105.0	106.3	103.6	101.5	101.9	112.8	131.3	113.2	99.3	98.8
1985	110.5	117.9	103.7	108.8	107.8	108.1	112.1	102.1	92.2	89.7	86.1	79.9
1986	100.8	111.3	98.9	103.9	98.5	90.3	94.3	119.3	125.0	116.9	102.5	93.9
1987	94.0	106.2	105.5	112.7	104.0	97.8	112.1	124.5	126.0	117.6	108.2	111.7
1988	99.5	122.3	102.5	109.4	103.2	107.9	103.8	110.8	122.9	109.5	104.5	97.3
1989	96.7	106.1	99.5	103.4	98.6	93.0	96.0	111.9	114.9	111.2	112.2	100.9
1990	104.8	109.6	103.3	110.9	100.2	99.3	97.6	109.9	122.5	117.9	107.2	96.0
1991	100.7	113.0	108.6	104.9	101.1	101.8	91.2	112.9	123.7	101.1	102.4	94.9
1992	103.7	111.5	111.2	108.0	100.3	101.5	95.0	107.6	120.6	108.0	105.5	96.1
1993	97.9	108.7	95.0	106.7	97.4	96.9	96.8	110.4	134.1	135.6	116.0	107.0
1994	98.2	110.2	97.9	105.7	99.7	100.4	101.3	110.4	140.1	109.7	99.3	98.7
1995	101.9	106.5	102.1	103.9	96.9	99.7	100.1	119.1	128.6	113.1	107.1	101.4
1996	97.9	108.7	101.3	105.3	104.8	94.7	97.8	110.5	115.3	111.5	105.1	104.4
1997	97.7	106.7	107.8	95.8	90.8	96.6	95.0	115.0	146.1	128.7	99.3	92.4
1998	99.3	118.7	109.5	107.9	97.5	92.9	90.8	108.7	124.2	112.0	111.2	99.3
1999	99.0	124.2	95.1	99.4	98.8	95.4	93.2	103.8	114.4	109.1	99.1	95.9
2000	95.8	99.6	90.9	100.9	104.6	99.0	96.7	110.3	126.2	117.5	100.7	92.2
2001	87.8	107.3	93.9	104.3	95.0	93.2	91.6	105.3	106.6	104.2	101.0	97.2
2002	90.6	109.5	94.8	97.4	93.4	90.6	99.5	108.1	125.3	115.1	92.6	93.1
2003	97.9	116.7	96.0	98.2	95.6	90.7	92.6	102.5	117.5	111.5	101.1	93.8
2004	98.1	103.2	98.7	93.8	92.9	93.0	95.3	107.8	107.0	112.6	96.1	90.6

Kinyinya

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1975	122.5	145.5	135.0	133.5	124.7	124.6	112.1	129.2	157.4	136.5	143.3	134.2
1976	115.5	132.5	111.4	118.9	109.8	101.5	99.8	110.6	122.5	122.4	124.2	111.7
1977	113.5	110.9	118.3	114.9	109.7	104.6	106.6	120.1	143.9	143.7	119.4	119.3
1978	122.8	144.6	115.3	116.4	110.5	98.4	94.5	117.0	143.1	130.8	113.1	103.1
1979	119.3	133.2	116.2	125.7	115.9	107.3	100.6	125.7	148.5	149.1	118.5	117.9
1980	125.1	136.6	122.7	125.3	116.8	102.2	103.1	128.2	149.3	146.7	134.0	118.1
1981	123.0	138.2	121.3	128.2	116.2	90.6	106.3	131.1	156.6	138.3	138.6	120.2
1982	119.5	132.0	118.5	124.6	114.1	106.1	109.5	133.3	138.3	141.3	143.3	125.2
1983	118.3	133.7	123.5	123.3	110.5	107.8	98.1	117.9	156.0	127.2	120.4	130.9
1984	117.9	146.8	130.4	126.5	122.8	117.9	115.2	127.3	146.7	129.1	115.6	115.8
1985	111.5	131.2	121.9	123.1	112.9	106.9	114.2	125.9	142.5	137.1	121.6	121.5
1986	122.8	129.6	126.7	120.9	110.1	103.6	99.5	116.2	139.3	150.7	135.9	120.1
1987	122.1	134.1	112.4	120.9	113.4	97.7	94.3	126.4	152.2	146.5	125.0	115.4
1988	118.5	143.4	122.4	127.1	116.6	118.5	109.3	125.7	144.0	134.8	124.1	110.4
1989	116.5	126.5	116.2	117.3	108.2	100.6	101.4	124.7	136.6	137.9	139.2	121.2
1990	127.5	130.1	113.5	129.9	114.5	109.8	100.5	124.9	143.0	145.1	129.1	112.4
1991	120.9	134.3	125.4	120.4	114.9	114.8	103.4	126.6	142.5	122.1	121.6	121.6
1992	123.8	133.6	129.8	128.2	114.9	114.2	94.8	104.7	143.6	143.4	137.0	118.9
1993	123.1	131.3	112.4	125.5	111.4	107.8	95.4	125.6	149.1	152.3	144.6	142.1
1994	118.3	135.2	121.4	119.1	119.0	108.2	107.1	127.6	167.7	136.8	122.4	121.0
1995	129.1	131.5	125.1	121.3	115.7	108.8	107.1	129.3	147.3	138.7	135.1	127.6
1996	120.9	127.4	117.2	117.6	123.1	108.0	106.3	116.3	142.9	153.9	143.3	129.5
1997	122.1	132.5	131.0	121.5	110.0	108.5	97.4	120.2	164.4	143.2	123.5	122.1
1998	120.0	150.0	129.4	135.2	124.6	110.2	103.2	127.7	156.0	138.0	150.5	125.2
1999	121.6	145.4	117.8	123.1	116.1	110.6	107.5	128.2	145.3	142.8	126.6	122.3
2000	122.0	128.5	114.8	117.2	125.0	113.6	112.5	137.8	151.0	151.7	135.4	122.7
2001	115.3	135.7	119.1	127.3	115.4	109.3	101.3	123.8	142.6	135.0	139.2	126.5
2002	121.0	140.8	113.1	126.9	116.9	106.0	112.9	131.3	156.2	152.8	123.0	122.4
2003	137.1	160.9	128.9	126.8	125.7	120.6	104.7	131.4	161.2	147.0	143.4	121.9
2004	123.6	141.2	124.7	114.8	119.5	112.7	114.1	121.0	138.8	138.7	123.6	116.0

Musasa

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1975	120.7	132.2	116.0	122.1	108.2	95.7	94.8	105.6	125.4	125.9	125.3	114.7
1976	116.3	118.5	146.4	115.2	105.6	93.9	92.5	111.7	140.4	136.2	125.1	118.5
1977	113.8	131.4	116.2	114.6	104.3	93.3	88.1	118.8	150.7	157.3	129.3	117.8
1978	120.9	134.1	121.0	127.5	111.8	102.6	87.5	105.7	134.6	137.6	115.5	110.6
1979	115.7	126.7	122.1	122.7	107.1	109.0	88.3	109.4	134.7	140.5	134.5	116.5
1980	124.4	133.0	113.1	122.8	115.3	105.8	95.5	96.9	151.0	143.8	131.5	125.2
1981	123.8	138.2	122.1	121.7	113.0	96.8	92.7	120.2	135.4	131.7	135.3	126.7
1982	130.2	130.4	118.0	122.0	109.3	101.8	91.7	108.2	147.5	129.9	128.9	122.7
1983	118.3	130.5	130.0	131.1	123.2	115.2	106.2	106.8	139.8	132.0	127.1	121.8
1984	117.9	133.4	124.5	127.6	110.2	98.4	107.9	119.3	136.3	130.9	117.0	117.9
1985	120.6	127.3	120.3	122.4	105.4	100.9	90.7	107.4	140.5	145.3	128.0	119.1
1986	119.0	127.0	115.7	124.3	112.2	93.6	86.1	112.4	139.7	141.0	126.0	118.2
1987	115.9	135.5	124.8	126.9	112.0	102.3	99.2	116.9	149.0	131.3	131.2	128.8
1988	120.1	138.8	121.5	128.1	110.6	108.9	102.7	117.7	134.3	132.1	126.2	116.4
1989	118.8	132.1	118.9	121.3	108.0	96.9	93.3	115.3	136.5	139.6	135.1	124.4
1990	126.9	129.7	120.6	139.0	113.2	103.1	91.9	115.2	137.2	131.2	128.0	112.0
1991	108.9	127.0	115.2	143.1	105.4	115.0	99.0	123.1	259.0	108.0	112.6	110.7
1992	107.5	128.0	127.7	122.5	111.7	119.8	107.5	123.4	146.8	135.5	125.4	111.5
1993	111.2	130.3	113.8	119.6	111.7	113.7	107.5	125.0	155.5	159.6	134.4	122.0
1994	116.3	131.3	122.2	120.4	110.8	119.7	113.2	130.0	161.5	124.3	113.7	115.2
1995	120.1	126.2	121.3	116.5	110.2	120.8	117.6	137.1	154.4	133.0	126.0	120.7
1996	114.4	128.8	114.8	114.7	116.2	117.0	114.7	129.8	128.8	131.8	118.7	112.1
1997	121.1	131.4	129.9	118.5	107.1	105.1	97.2	113.9	158.8	146.6	130.4	123.9
1998	128.6	155.6	142.9	141.9	124.8	104.0	100.4	115.2	149.6	135.3	137.0	119.8
1999	122.0	146.5	117.6	121.5	112.5	102.9	97.5	125.7	136.2	142.1	127.7	124.8
2000	122.7	130.1	118.2	117.2	122.6	110.3	100.7	124.3	156.4	152.9	137.5	122.0
2001	120.4	140.7	126.3	126.9	114.8	103.8	97.8	115.2	140.5	131.5	135.6	129.6
2002	119.1	132.3	122.1	124.0	111.6	105.3	98.3	116.4	146.3	136.3	127.4	119.3
2003	115.8	151.7	125.7	125.5	120.2	106.5	95.9	121.3	160.9	152.3	144.6	124.6
2004	119.0	132.9	122.2	124.0	111.9	105.3	98.2	116.6	146.8	136.9	127.9	119.5

Muriza

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1979	100.3	115.7	99.4	106.8	94.7	81.8	78.2	94.9	108.6	103.1	108.5	99.8
1980	103.8	104.4	98.8	103.1	92.0	83.1	80.7	96.1	112.4	107.8	101.6	99.7
1981	94.1	103.8	95.3	101.2	89.4	76.0	101.2	122.4	132.5	116.1	103.8	97.2
1982	93.7	106.6	98.4	100.7	92.1	80.2	78.0	95.7	111.6	109.6	101.2	97.7
1983	99.4	118.4	106.8	101.3	94.7	88.0	86.9	95.8	105.2	102.3	100.3	94.4
1984	93.0	104.8	98.1	102.9	87.1	83.5	86.2	94.9	109.4	106.4	101.4	98.5
1985	99.7	113.4	101.8	103.1	88.6	81.2	78.5	90.7	108.6	114.2	106.9	98.2
1986	102.5	109.2	95.1	103.4	93.8	75.8	74.1	93.0	108.9	111.6	104.5	96.5
1987	98.9	109.2	104.4	109.6	96.7	87.2	91.1	102.0	116.6	104.0	107.3	102.1
1988	102.0	113.1	103.2	108.3	91.7	91.8	85.9	96.3	107.9	105.5	101.3	93.8
1989	101.2	107.2	99.2	101.0	89.6	79.5	78.6	94.1	104.9	106.1	110.6	99.6
1990	100.7	109.5	97.3	109.6	91.0	83.9	74.8	95.1	108.2	125.6	107.5	95.1
1991	98.9	112.5	102.1	103.4	97.6	90.5	75.7	91.5	103.6	97.7	97.7	103.0
1992	100.5	112.6	106.3	109.9	94.2	90.9	77.2	86.6	105.8	108.7	105.0	96.9
1993	102.9	111.3	93.9	103.3	92.6	84.1	75.5	93.3	106.6	101.1	97.6	120.6
1994	115.5	122.7	113.0	118.6	110.9	98.9	97.0	108.9	136.8	124.3	120.5	118.4
1995	102.8	110.5	103.5	105.3	96.8	88.9	82.6	95.0	115.0	114.1	113.1	99.6
1996	98.1	111.2	103.0	112.6	100.5	87.9	85.9	90.0	108.9	111.9	112.1	104.5
1997	102.6	109.7	110.5	105.2	92.5	87.0	78.9	97.3	127.5	118.7	112.5	104.8
1998	107.6	131.6	117.0	122.2	104.6	85.2	80.9	92.5	111.1	106.9	112.0	102.6
1999	104.2	120.9	98.0	104.0	93.1	86.8	80.6	102.0	109.1	106.7	105.1	105.2
2000	102.1	108.6	99.1	100.8	99.2	87.2	84.7	93.2	120.6	119.0	112.9	103.1
2001	102.6	108.6	99.1	105.6	93.2	82.3	80.9	88.5	107.9	108.7	110.5	105.7
2002	105.9	109.1	105.0	108.5	98.2	82.0	87.0	98.9	120.4	118.2	111.4	109.3
2003	102.8	113.4	112.1	114.8	109.0	92.6	87.1	104.0	128.5	104.5	113.2	103.1
2004	101.1	111.6	102.0	106.1	94.8	84.9	82.1	95.8	112.8	104.9	103.9	101.4

Nyamuswaga

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1980	111.5	116.8	92.8	97.0	90.1	75.8	80.3	82.2	113.5	110.2	106.7	106.7
1981	102.5	113.3	107.6	116.3	101.9	87.9	74.2	95.4	100.5	107.6	105.5	107.3
1983	119.0	136.9	107.1	117.3	64.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1986	0.0	150.0	0.0	0.0	158.4	0.0	0.0	0.0	142.0	144.4	140.0	134.8
1987	117.5	140.9	124.5	133.2	119.3	114.7	101.8	111.0	125.3	0.0	0.0	0.0
1988	0.0	164.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	143.9	152.7	147.9
1989	111.8	121.2	105.2	111.4	96.1	90.1	86.0	91.9	106.2	52.7	111.3	105.9
1990	104.9	128.1	107.9	120.0	101.1	83.4	70.6	88.7	98.7	102.1	109.2	103.3
1991	103.8	119.5	111.2	109.9	105.8	103.1	78.2	84.4	95.6	99.4	99.9	104.9
1992	105.3	119.3	109.3	117.5	99.4	94.7	74.1	80.1	102.8	103.5	104.1	101.6
1993	102.2	116.5	101.0	107.1	102.6	88.4	71.3	96.2	90.1	113.2	109.6	103.3
1994	103.5	116.1	101.2	106.7	103.3	82.8	75.4	78.7	111.8	103.8	107.1	108.8
1995	113.6	121.3	112.8	111.5	101.5	93.6	81.2	82.2	101.2	104.1	106.8	95.9
1996	103.3	115.9	106.3	109.3	100.5	88.6	81.7	81.8	108.4	104.1	118.8	105.9
1997	106.6	113.7	107.0	111.1	101.2	87.2	77.1	89.6	110.2	104.8	110.4	111.0
1998	113.5	137.9	118.5	124.3	112.2	87.7	81.3	87.8	105.7	98.8	105.8	94.7
1999	106.3	117.0	103.0	105.3	95.4	85.4	76.1	99.2	104.5	99.3	99.9	103.7
2000	103.4	104.1	97.0	106.7	100.7	86.5	77.5	91.8	105.3	108.0	113.7	110.4
2001	103.9	116.1	114.0	110.0	98.6	84.5	81.1	87.4	102.5	103.7	107.1	105.0
2002	106.8	144.2	104.4	110.2	107.2	85.3	81.3	88.2	105.3	100.1	102.8	103.0
2003	110.6	116.2	102.2	110.1	105.0	90.7	80.8	92.2	108.1	108.2	108.8	103.5
2004	107.5	115.9	113.9	109.8	96.9	80.3	77.5	95.5	106.7	107.3	105.2	108.1

Gitega

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1988	104.9	119.9	106.1	107.4	97.3	93.4	92.7	95.9	107.1	96.8	103.6	95.4
1989	105.5	111.3	99.9	101.2	91.6	85.4	87.2	98.7	105.1	99.6	108.7	101.3
1990	104.4	112.3	98.8	110.3	96.9	91.9	85.5	100.7	109.4	106.4	105.9	96.5
1991	102.1	117.4	106.0	104.1	99.8	99.0	81.2	96.9	109.8	96.8	97.7	102.7
1992	103.5	116.6	108.5	110.5	95.4	96.6	84.0	100.3	111.2	106.0	103.2	97.1
1993	107.9	118.5	102.8	108.4	102.4	95.2	89.7	104.6	118.8	129.3	109.5	106.9
1994	107.1	118.2	102.4	103.6	99.4	92.3	86.8	98.0	108.2	105.2	104.1	102.2
1995	108.9	114.6	105.1	106.4	93.1	94.8	91.1	100.6	118.7	108.1	110.4	99.5
1996	96.4	115.9	107.3	109.3	104.2	93.8	93.2	99.6	112.3	109.2	103.6	97.0
1997	104.6	113.7	108.1	99.5	92.8	89.8	97.4	103.5	123.2	114.0	107.7	102.4
1998	106.6	135.5	115.6	120.1	109.3	95.9	91.1	97.7	110.0	110.5	113.3	104.3
1999	111.5	126.2	101.6	106.7	98.0	95.5	90.3	105.2	110.9	110.7	103.8	104.7
2000	106.1	110.9	101.8	109.3	106.5	98.3	95.5	107.2	108.3	119.9	113.4	108.9
2001	106.1	120.8	103.5	93.9	100.4	95.3	91.1	99.5	111.8	118.5	109.8	109.5
2002	104.1	121.3	109.0	108.5	106.3	99.5	101.2	106.5	127.3	121.3	107.7	108.8
2003	113.7	127.5	106.9	111.1	103.7	94.3	90.7	105.5	122.3	116.5	112.8	103.8
2004	116.4	120.1	112.4	102.8	99.1	92.7	92.2	108.8	115.2	116.2	105.0	109.4

Ruvyironza

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1975	95.7	102.2	94.8	98.5	85.1	70.7	71.5	78.5	89.1	93.2	93.8	93.9
1976	94.1	98.3	93.4	95.8	85.3	70.9	71.4	82.3	100.5	97.6	92.0	92.4
1977	94.3	108.0	94.1	95.0	83.6	74.1	71.0	84.5	97.2	99.0	96.8	92.5
1978	97.8	105.7	98.5	101.9	84.0	73.8	68.8	80.0	93.4	94.9	89.6	96.0
1979	93.9	110.0	95.9	101.4	87.9	73.8	69.6	84.5	93.9	97.8	99.2	92.4
1980	99.3	105.5	93.6	99.1	87.7	75.3	70.7	83.9	100.6	96.3	91.5	93.8
1981	93.0	105.2	96.6	96.6	88.4	73.4	77.4	89.7	91.6	96.7	95.6	92.5
1982	92.8	101.8	93.6	94.7	87.7	75.1	68.5	81.8	106.5	95.8	93.0	92.1
1983	93.7	113.6	101.1	100.6	89.3	82.6	79.0	82.1	95.2	92.8	91.5	85.1
1984	95.0	94.0	96.6	98.5	82.7	73.7	76.2	84.1	97.6	97.7	93.8	94.2
1985	93.9	106.9	96.7	96.8	82.6	73.5	68.4	79.3	95.3	99.7	98.5	93.9
1986	93.9	102.0	88.9	97.9	88.4	68.8	62.8	83.9	98.9	100.5	100.7	96.0
1987	99.6	108.1	97.4	104.1	89.2	78.8	78.1	87.5	98.6	93.6	96.4	96.9
1988	100.1	112.5	101.4	101.4	83.9	79.3	73.0	82.8	91.9	92.7	95.6	92.2
1989	99.3	104.6	96.6	95.4	83.9	72.9	71.0	79.9	89.5	88.6	99.8	93.1
1990	92.2	103.6	92.0	104.7	84.4	77.9	68.8	87.0	100.3	96.6	101.3	93.7
1991	98.3	111.6	95.0	100.1	92.9	87.1	69.4	78.1	93.8	91.5	90.9	96.9
1992	93.6	107.0	102.5	103.1	87.0	84.0	68.1	76.3	96.7	93.9	97.9	92.8
1993	96.6	107.6	91.7	94.8	88.2	76.5	69.1	86.4	97.2	103.2	104.5	95.6
1994	98.7	113.9	97.3	95.1	86.2	73.9	70.5	81.1	106.5	95.3	96.1	98.1
1995	100.1	108.5	97.4	97.9	90.4	81.1	74.7	83.0	99.1	99.6	98.1	90.5
1996	95.6	108.2	100.8	102.7	91.3	80.2	75.2	80.1	95.7	98.6	96.0	93.9
1997	97.4	106.5	101.4	95.2	84.0	77.2	69.5	85.7	109.6	104.1	103.9	97.4
1998	102.2	123.5	105.3	112.2	95.7	76.6	74.4	83.0	96.7	93.1	99.6	90.4
1999	97.0	111.3	97.1	98.2	88.2	82.3	74.3	92.2	95.2	94.5	90.7	93.2
2000	93.3	102.5	91.1	93.0	86.9	77.9	73.1	84.1	102.6	109.2	104.0	100.5
2001	100.6	107.3	95.9	99.9	86.1	77.6	77.8	84.2	94.9	95.1	97.7	99.7
2002	99.0	117.5	98.1	101.7	89.9	76.5	76.9	92.1	103.1	103.3	95.4	94.1
2003	101.7	110.1	96.9	99.5	93.4	79.1	70.9	85.0	101.3	102.5	103.2	94.9
2004	104.2	110.5	103.2	97.0	83.0	77.5	71.4	88.3	99.3	100.0	93.8	99.7

Karuzi

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1975	111.7	105.4	99.0	104.0	108.5	105.0	103.5	115.7	125.6	109.0	94.4	96.6
1976	105.3	120.4	100.6	98.7	88.2	91.9	89.7	101.0	107.5	102.2	109.3	106.9
1977	95.2	110.5	98.7	103.7	100.0	95.3	104.9	111.3	131.0	130.4	102.9	100.6
1978	108.1	112.0	103.8	100.7	99.7	103.8	98.7	99.6	113.7	103.4	101.9	106.9
1979	103.6	114.8	98.9	106.4	96.5	91.4	89.2	96.9	121.0	132.8	104.6	102.3
1980	94.6	103.4	100.3	110.2	100.4	113.7	96.4	108.0	119.0	113.7	99.3	97.7
1981	97.1	105.6	96.4	100.9	101.2	96.9	94.0	100.6	109.3	106.8	115.8	105.1
1982	108.8	121.9	114.7	105.2	99.7	112.9	106.1	115.4	125.1	98.8	98.9	104.4
1983	97.2	120.5	110.8	112.9	99.6	93.9	93.1	107.8	123.7	119.3	102.5	100.3
1984	101.3	121.7	103.2	113.4	99.5	95.0	93.6	105.5	115.4	112.1	114.5	100.3
1985	111.0	116.8	104.3	98.1	99.9	89.6	94.4	104.6	112.9	107.9	102.0	94.8
1986	102.5	113.1	101.6	108.3	97.0	96.6	91.6	98.7	108.4	117.1	112.6	101.1
1987	97.2	120.5	110.8	112.9	99.6	93.9	93.1	107.8	123.7	119.3	102.5	100.3
1988	101.3	121.7	103.2	113.4	99.5	95.0	93.6	105.5	115.4	112.1	114.5	100.3
1989	111.0	116.8	104.3	98.1	99.9	89.6	94.4	104.6	112.9	107.9	102.0	94.8
1990	96.3	112.8	101.7	105.8	101.1	94.3	132.4	105.8	109.2	108.1	105.8	103.1
1991	105.8	117.3	106.9	108.0	98.7	100.6	83.8	97.3	110.5	97.7	102.5	101.9
1992	105.5	114.8	106.4	107.5	96.9	100.0	87.6	93.3	110.6	107.3	102.8	96.3
1993	103.6	107.2	93.6	102.9	99.4	96.9	86.4	98.4	107.9	120.9	111.0	93.1
1994	104.2	108.8	97.3	103.3	99.3	93.5	90.1	98.0	124.0	99.9	97.9	95.8
1995	95.4	105.2	99.7	99.7	94.4	97.5	93.4	97.4	125.8	97.8	99.5	96.4
1996	92.9	105.2	94.2	104.5	96.3	91.6	90.2	96.9	108.5	111.3	101.7	105.7
1997	101.2	102.6	104.4	93.3	88.9	93.6	89.9	103.7	120.5	110.8	100.3	94.5
1998	98.3	108.5	96.9	108.9	104.9	96.8	91.5	99.3	117.0	101.6	108.7	97.2
1999	105.1	123.5	91.1	90.2	92.7	90.6	85.1	95.8	107.8	105.7	96.0	97.4
2000	99.5	97.6	89.1	95.7	101.3	99.1	95.7	105.2	116.9	106.4	97.0	100.5
2001	97.2	108.9	102.0	107.5	96.5	95.8	88.6	103.3	104.5	95.3	105.2	96.7
2002	98.0	123.0	98.7	101.0	99.4	96.1	97.3	98.0	111.0	108.3	100.2	95.9
2003	101.3	122.8	99.9	101.1	99.0	97.2	95.3	100.8	112.4	111.9	106.4	100.2
2004	103.1	106.6	102.8	105.7	104.1	97.8	93.9	111.0	117.6	117.7	104.3	114.0

Kirundo

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1980	117.9	133.3	113.2	120.4	109.1	117.6	114.8	127.6	133.1	119.7	105.1	108.9
1981	126.3	144.0	125.4	134.2	125.3	132.1	127.0	135.2	111.5	54.7	110.1	117.0
1982	116.3	126.4	123.3	117.4	110.7	121.2	102.7	126.5	125.7	111.0	119.0	113.1
1983	119.2	140.8	132.8	118.3	118.0	126.4	109.6	124.9	125.3	111.2	108.1	104.4
1984	112.0	123.2	115.0	111.3	114.0	114.9	112.7	126.4	128.4	113.1	101.1	108.3
1985	108.5	120.7	112.7	108.9	111.7	111.9	108.0	134.2	135.0	117.1	114.9	106.7
1986	115.1	123.9	104.7	108.3	107.3	102.8	102.1	124.1	129.4	116.1	107.3	103.7
1987	126.6	152.1	135.0	142.1	131.6	135.2	138.3	149.9	142.0	129.8	126.4	122.6
1988	111.9	134.6	112.8	111.9	112.9	114.6	112.3	112.0	130.7	118.6	118.2	113.6
1989	109.5	120.4	106.4	110.0	103.8	102.3	106.1	118.7	113.8	106.4	112.8	101.5
1990	102.4	117.9	100.6	115.7	99.7	111.8	112.1	127.0	133.8	120.7	119.2	107.8
1991	116.3	126.4	123.3	117.4	110.7	121.2	102.7	126.5	125.7	111.0	119.0	113.1
1992	118.8	138.8	130.1	121.3	110.5	112.5	108.0	123.1	134.0	119.2	112.2	105.3
1993	121.5	133.0	113.3	129.9	115.9	117.6	120.2	113.1	151.5	109.1	118.1	115.9
1994	112.9	135.0	109.6	112.7	113.1	113.2	112.4	123.8	152.0	115.3	117.5	116.1
1995	123.1	127.9	121.6	116.8	112.6	118.6	115.2	133.3	141.2	119.5	118.4	110.4
1996	126.8	140.8	108.7	111.8	106.7	110.1	104.9	117.6	128.6	109.6	107.7	109.5
1997	115.9	137.3	128.2	115.0	109.0	114.9	112.8	132.2	155.0	121.2	107.3	121.4
1998	113.5	140.4	126.1	126.1	120.9	118.4	113.6	122.5	124.9	112.7	117.5	112.2
1999	114.4	147.3	108.6	114.9	113.9	121.3	115.2	119.2	123.7	116.2	111.3	107.5
2000	112.7	121.0	105.4	113.1	119.8	122.6	126.0	155.1	146.2	130.8	123.8	121.6
2001	112.3	136.7	113.5	126.3	116.4	116.6	115.7	121.2	125.0	124.8	119.0	116.9
2002	119.1	134.1	117.2	106.5	111.1	110.1	111.1	125.5	130.9	121.1	107.9	123.3
2003	123.0	157.4	120.7	130.8	112.9	116.9	114.2	129.9	143.2	123.6	123.7	124.4
2004	127.3	154.0	111.4	112.7	107.7	111.1	107.6	108.9	141.7	118.6	108.3	128.0

Muyinga

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1975	106.8	115.3	98.2	105.8	101.5	99.4	95.2	108.3	104.6	100.5	106.8	101.4
1976	105.5	103.4	103.4	100.6	99.3	97.8	100.6	111.6	115.7	117.5	108.9	103.8
1977	98.7	111.4	102.1	99.8	98.0	100.8	104.1	111.7	123.5	129.8	103.5	105.4
1978	107.1	121.5	103.0	105.6	98.7	102.2	101.9	116.9	126.3	111.1	102.9	88.9
1979	105.6	115.3	108.8	101.8	95.6	93.7	98.3	117.5	133.2	124.7	111.9	100.0
1980	108.6	124.9	104.6	108.8	101.9	106.8	98.4	112.1	127.1	117.2	102.0	100.2
1981	109.3	118.4	105.0	107.0	98.6	105.8	104.1	111.0	113.9	111.2	110.4	104.5
1982	104.2	121.4	108.7	102.1	93.8	103.0	100.5	114.2	126.7	105.7	102.0	105.1
1983	113.3	131.0	112.9	106.5	104.3	110.7	111.0	110.8	115.6	101.8	102.7	98.1
1984	99.8	116.3	106.2	103.0	102.7	96.4	98.2	110.5	122.3	107.9	98.7	103.3
1985	108.0	112.7	105.9	96.8	95.7	101.3	97.8	107.2	115.8	110.4	106.7	101.5
1986	101.7	115.2	99.2	97.9	94.7	95.5	93.2	117.7	125.7	115.0	102.0	97.4
1987	97.4	117.9	105.7	107.1	95.8	102.8	111.6	115.9	122.2	114.6	106.2	114.0
1988	103.3	126.7	105.0	104.1	102.6	103.6	104.4	106.5	115.4	103.6	106.6	96.8
1989	98.8	110.1	98.1	101.9	95.0	91.6	96.1	108.5	112.4	93.4	116.8	105.4
1990	109.8	112.8	94.0	110.6	102.0	104.1	100.5	105.2	118.0	110.7	108.9	98.8
1991	105.2	119.4	111.3	103.5	104.2	111.9	99.2	116.9	58.6	103.6	108.2	105.5
1992	107.9	115.0	113.7	106.8	99.3	108.2	98.7	109.3	117.9	113.2	107.8	99.4
1993	102.9	118.9	100.9	104.6	102.0	103.9	98.8	108.1	132.3	130.8	115.4	105.9
1994	104.8	118.1	98.9	105.4	98.0	108.7	100.7	111.4	138.7	106.5	99.2	102.1
1995	107.0	107.2	108.9	104.7	95.9	111.9	106.7	118.6	126.0	109.8	108.5	102.9
1996	105.5	115.1	101.8	104.5	104.0	103.8	102.4	111.0	113.1	105.1	101.5	103.5
1997	98.7	119.6	111.5	99.6	96.0	109.7	96.6	122.0	141.6	113.8	96.0	91.1
1998	105.2	124.0	110.8	109.2	104.1	102.6	101.3	110.0	119.6	106.7	111.9	101.8
1999	104.8	135.2	96.7	97.9	96.4	99.8	95.3	96.5	111.7	105.7	97.6	95.3
2000	101.3	110.8	92.2	99.6	101.8	98.4	98.6	110.2	124.4	108.7	98.8	98.6
2001	90.3	112.3	94.7	103.2	94.4	98.3	93.3	101.2	105.6	110.0	108.5	111.4
2002	102.6	135.0	106.4	104.2	103.8	112.2	114.2	93.6	116.2	112.8	113.4	89.6
2003	117.9	138.7	109.9	110.8	101.5	105.1	101.5	115.2	120.7	117.7	114.0	105.2
2004	107.4	113.1	107.3	98.3	103.5	99.8	102.9	115.2	116.5	114.3	108.3	109.8

Appendix 4: Agro-climatic zonation of meteorological stations.

Stations	Mean annual rainfall (mm)	Mean annual PET (mm)	Aridity Index	Zonation
Bujumbura-Aero	885.19	1787.55	0.50	Dry sub-humid
Mparambo	923.72	1805.11	0.51	Dry sub-humid
Makamba	1385.01	1393.37	0.99	Humid
Gisozi	1439.64	1078.13	1.34	Humid
Mpota-Tora	1508.63	1021.50	1.48	Humid
Rwegura	1633.23	1049.63	1.56	Humid
Cankuzo	1202.23	1249.14	0.96	Humid
Kinyinya	1171.64	1494.72	0.78	Humid
Musasa	1148.87	1464.10	0.78	Humid
Muriza	1126.56	1214.60	0.93	Humid
Nyamuswaga	1388.88	1161.32	1.20	Humid
Ruvyironza	1286.39	1106.13	1.16	Humid
Karuzi	1171.58	1242.45	0.94	Humid
Gitega-Aero	1164.73	1258.48	0.93	Humid
Kirundo	1053.56	1431.20	0.74	Humid
Muyinga	1121.09	1282.93	0.87	Humid

Appendix 5: Mean daylight hours (N) for different latitudes for the 15th of the month.

Northern Hemisphere												Lat	Southern Hemisphere											
Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	deg	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
0.0	6.6	11.0	15.6	21.3	24.0	24.0	17.6	12.8	8.3	2.3	0.0	70	24.0	17.4	13.0	8.4	2.7	0.0	0.0	6.4	11.2	15.7	21.7	24.0
2.1	7.3	11.1	15.3	19.7	24.0	22.3	17.0	12.7	8.7	4.1	0.0	68	21.9	16.7	12.9	8.7	4.3	0.0	1.7	7.0	11.3	15.3	19.9	24.0
3.9	7.8	11.2	14.9	18.7	22.0	20.3	16.4	12.7	9.0	5.2	1.9	66	20.1	16.2	12.8	9.1	5.3	2.0	3.7	7.6	11.3	15.0	18.8	22.1
5.0	8.2	11.2	14.7	17.9	20.3	19.2	16.0	12.6	9.3	6.0	3.7	64	19.0	15.8	12.8	9.3	6.1	3.7	4.8	8.0	11.4	14.7	18.0	20.3
5.7	8.5	11.3	14.4	17.3	19.2	18.4	15.7	12.6	9.5	6.6	4.8	62	18.3	15.5	12.7	9.6	6.7	4.8	5.6	8.3	11.4	14.5	17.4	19.2
6.4	8.8	11.4	14.2	16.8	18.4	17.7	15.3	12.5	9.7	7.1	5.6	60	17.6	15.2	12.6	9.8	7.2	5.6	6.3	8.7	11.5	14.3	16.9	18.4
6.9	9.1	11.4	14.1	16.4	17.8	17.2	15.1	12.5	9.8	7.5	6.2	58	17.1	14.9	12.6	9.9	7.6	6.2	6.8	8.9	11.5	14.1	16.5	17.8
7.3	9.3	11.5	13.9	16.0	17.3	16.8	14.8	12.4	10.1	7.8	6.7	56	16.7	14.7	12.5	10.1	8.0	6.7	7.2	9.2	11.6	13.9	16.1	17.3
7.7	9.5	11.5	13.8	15.7	16.8	16.4	14.6	12.4	10.2	8.2	7.1	54	16.3	14.5	12.5	10.2	8.3	7.2	7.6	9.4	11.6	13.8	15.8	16.9
8.0	9.7	11.5	13.6	15.4	16.5	16.0	14.4	12.4	10.3	8.5	7.5	52	16.0	14.3	12.5	10.4	8.6	7.5	8.0	9.6	11.6	13.7	15.5	16.5
8.3	9.8	11.6	13.5	15.2	16.1	15.7	14.3	12.3	10.4	8.7	7.9	50	15.7	14.2	12.4	10.5	8.8	7.9	8.3	9.7	11.7	13.6	15.3	16.1
8.6	10.0	11.6	13.4	15.0	15.8	15.5	14.1	12.3	10.6	9.0	8.2	48	15.4	14.0	12.4	10.6	9.0	8.2	8.5	9.9	11.7	13.4	15.0	15.8
8.8	10.1	11.6	13.3	14.8	15.5	15.2	14.0	12.3	10.7	9.2	8.5	46	15.2	13.9	12.4	10.7	9.2	8.5	8.8	10.0	11.7	13.3	14.8	15.5
9.1	10.3	11.6	13.2	14.6	15.3	15.0	13.8	12.3	10.7	9.4	8.7	44	14.9	13.7	12.4	10.8	9.4	8.7	9.0	10.2	11.7	13.3	14.6	15.3
9.3	10.4	11.7	13.2	14.4	15.0	14.8	13.7	12.3	10.8	9.6	9.0	42	14.7	13.6	12.3	10.8	9.6	9.0	9.2	10.3	11.7	13.2	14.4	15.0
9.5	10.5	11.7	13.1	14.2	14.8	14.6	13.6	12.2	10.9	9.7	9.2	40	14.5	13.5	12.3	10.9	9.8	9.2	9.4	10.4	11.8	13.1	14.3	14.8
9.6	10.6	11.7	13.0	14.1	14.6	14.4	13.5	12.2	11.0	9.9	9.4	38	14.4	13.4	12.3	11.0	9.9	9.4	9.6	10.5	11.8	13.0	14.1	14.6
9.8	10.7	11.7	12.9	13.9	14.4	14.2	13.4	12.2	11.1	10.1	9.6	36	14.2	13.3	12.3	11.1	10.1	9.6	9.8	10.6	11.8	12.9	13.9	14.4
10.0	10.8	11.8	12.9	13.8	14.3	14.1	13.3	12.2	11.1	10.2	9.7	34	14.0	13.2	12.2	11.1	10.2	9.7	9.9	10.7	11.8	12.9	13.8	14.3
10.1	10.9	11.8	12.8	13.6	14.1	13.9	13.2	12.2	11.2	10.3	9.9	32	13.9	13.1	12.2	11.2	10.4	9.9	10.1	10.8	11.8	12.8	13.7	14.1
10.3	11.0	11.8	12.7	13.5	13.9	13.8	13.1	12.2	11.3	10.5	10.1	30	13.7	13.0	12.2	11.3	10.5	10.1	10.2	10.9	11.8	12.7	13.5	13.9
10.4	11.0	11.8	12.7	13.4	13.8	13.6	13.0	12.2	11.3	10.6	10.2	28	13.6	13.0	12.2	11.3	10.6	10.2	10.4	11.0	11.8	12.7	13.4	13.8
10.5	11.1	11.8	12.6	13.3	13.6	13.5	12.9	12.1	11.4	10.7	10.4	26	13.5	12.9	12.2	11.4	10.7	10.4	10.5	11.1	11.9	12.6	13.3	13.6
10.7	11.2	11.8	12.6	13.2	13.5	13.3	12.8	12.1	11.4	10.8	10.5	24	13.3	12.8	12.2	11.4	10.8	10.5	10.7	11.2	11.9	12.6	13.2	13.5
10.8	11.3	11.9	12.5	13.1	13.3	13.2	12.8	12.1	11.5	10.9	10.7	22	13.2	12.7	12.1	11.5	10.9	10.7	10.8	11.2	11.9	12.5	13.1	13.3
10.9	11.3	11.9	12.5	12.9	13.2	13.1	12.7	12.1	11.5	11.0	10.8	20	13.1	12.7	12.1	11.5	11.1	10.8	10.9	11.3	11.9	12.5	13.0	13.2
11.0	11.4	11.9	12.4	12.8	13.1	13.0	12.6	12.1	11.6	11.1	10.9	18	13.0	12.6	12.1	11.6	11.2	10.9	11.0	11.4	11.9	12.4	12.9	13.1
11.1	11.5	11.9	12.4	12.7	12.9	12.9	12.5	12.1	11.6	11.2	11.1	16	12.9	12.5	12.1	11.6	11.3	11.1	11.1	11.5	11.9	12.4	12.8	12.9
11.3	11.6	11.9	12.3	12.6	12.8	12.8	12.5	12.1	11.7	11.3	11.2	14	12.7	12.4	12.1	11.7	11.4	11.2	11.2	11.5	11.9	12.3	12.7	12.8
11.4	11.6	11.9	12.3	12.6	12.7	12.6	12.4	12.1	11.7	11.4	11.3	12	12.6	12.4	12.1	11.7	11.4	11.3	11.4	11.6	11.9	12.3	12.6	12.7
11.5	11.7	11.9	12.2	12.5	12.6	12.5	12.3	12.1	11.8	11.5	11.4	10	12.5	12.3	12.1	11.8	11.5	11.4	11.5	11.7	11.9	12.2	12.5	12.6
11.6	11.7	11.9	12.2	12.4	12.5	12.4	12.3	12.0	11.8	11.6	11.5	8	12.4	12.3	12.1	11.8	11.6	11.5	11.6	11.7	12.0	12.2	12.4	12.5
11.7	11.8	12.0	12.1	12.3	12.3	12.3	12.2	12.0	11.9	11.7	11.7	6	12.3	12.2	12.0	11.9	11.7	11.7	11.7	11.8	12.0	12.1	12.3	12.3
11.8	11.9	12.0	12.1	12.2	12.2	12.2	12.1	12.0	11.9	11.8	11.8	4	12.2	12.1	12.0	11.9	11.8	11.8	11.8	11.9	12.0	12.1	12.2	12.2
11.9	11.9	12.0	12.0	12.1	12.1	12.1	12.1	12.0	12.0	11.9	11.9	2	12.1	12.1	12.0	12.0	11.9	11.9	11.9	11.9	12.0	12.0	12.1	12.1
12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0

Appendix 6: Monthly values of Ck, Cs, t_3 and t_4 for each station.

	Bujumbura-aero				Makamba				Mparambo			
	MRD		L-MRD		MRD		L-MRD		MRD		L-MRD	
Months	Cs	Ck	t3	t4	Cs	Ck	t3	t4	Cs	Ck	t3	t4
J	0.038	2.720	0.038	0.123	-0.132	3.747	0.034	0.202	0.112	3.142	0.039	0.172
F	0.103	2.603	0.046	0.112	1.755	6.592	0.335	0.221	0.991	5.448	0.157	0.278
M	0.409	3.079	0.120	0.136	1.060	4.410	0.195	0.185	0.472	2.871	0.119	0.117
A	1.210	4.712	0.239	0.218	0.857	3.664	0.196	0.120	0.659	4.164	0.095	0.137
M	0.760	3.084	0.200	0.070	0.047	2.439	0.021	0.034	0.419	2.442	0.130	0.074
J	2.505	9.970	0.508	0.260	3.308	15.41	0.662	0.399	0.968	3.372	0.280	0.060
J	2.581	10.11	0.691	0.384	3.191	12.29	0.830	0.619	3.426	16.47	0.668	0.390
A	1.914	6.114	0.575	0.245	1.057	3.062	0.380	0.052	1.064	3.061	0.356	0.056
S	0.742	3.724	0.147	0.068	0.714	3.376	0.165	0.126	0.536	3.618	0.092	0.106
O	0.531	3.444	0.108	0.119	-0.184	2.325	-0.02	0.071	0.269	3.255	0.058	0.167
N	0.883	3.541	0.207	0.089	0.949	4.465	0.17	0.216	0.585	2.431	0.179	0.055
D	0.360	2.742	0.091	0.070	2.481	12.17	0.243	0.299	0.856	4.710	0.125	0.156

	Gisozi				Mpota-Tora				Rwegura			
	MRD		L-MRD		MRD		L-MRD		MRD		L-MRD	
Months	Cs	Ck	t3	t4	Cs	Ck	t3	t4	Cs	Ck	t3	t4
J	0.259	2.718	0.070	0.106	0.179	2.777	0.060	0.153	0.171	3.437	0.045	0.181
F	0.195	2.184	0.077	0.070	1.241	6.051	0.172	0.237	0.286	2.405	0.110	0.096
M	0.815	4.203	0.136	0.188	0.826	4.572	0.128	0.246	0.701	3.944	0.147	0.226
A	0.820	4.167	0.184	0.182	0.164	2.213	0.072	0.067	0.303	2.437	0.105	0.113
M	0.606	3.465	0.133	0.174	0.013	2.745	0.013	0.111	0.102	2.636	0.035	0.086
J	3.132	14.19	0.627	0.361	2.913	13.49	0.457	0.251	1.538	5.325	0.347	0.168
J	3.466	15.53	0.741	0.486	3.082	5.882	0.544	0.323	2.042	6.902	0.594	0.263
A	2.024	7.741	0.491	0.180	3.308	4.421	0.462	0.399	1.305	4.626	0.341	0.095
S	0.261	2.672	0.068	0.083	1.538	5.544	0.287	0.316	0.939	4.341	0.187	0.182
O	0.015	3.036	0.058	0.151	0.214	3.103	0.156	0.151	-0.169	3.010	-0.020	0.165
N	0.584	2.951	0.157	0.145	0.336	2.764	0.072	0.126	3.714	19.31	0.432	0.357
D	0.597	2.903	0.143	0.141	0.503	3.591	0.216	0.222	0.542	3.584	0.099	0.185

	Muyinga			Nyamuswaga				Ruvyironza			
	MRD		L-MRD	MRD		L-MRD		MRD		L-MRD	
Months	Cs	Ck	t3	Cs	Ck	t3	t4	Cs	Ck	t3	t4
J	1.584	6.306	0.275	0.719	3.457	0.176	0.190	-0.090	2.664	-0.004	0.117
F	0.353	2.441	0.114	0.562	3.216	0.141	0.143	0.529	4.845	0.107	0.322
M	0.241	3.154	0.094	0.322	1.976	0.124	0.043	0.188	2.464	0.066	0.094
A	0.366	2.449	0.114	2.411	11.19	0.308	0.247	0.031	2.920	0.031	0.155
M	0.870	3.536	0.213	0.403	2.610	0.126	0.101	0.314	3.135	0.074	0.136
J	1.448	4.107	0.493	3.508	16.70	0.649	0.401	3.308	15.41	0.662	0.399
J	2.711	9.124	0.787	4.704	25.14	0.859	0.706	3.191	12.29	0.830	0.619
A	1.769	5.978	0.442	2.549	10.41	0.524	0.268	1.057	3.062	0.380	0.052
S	1.330	5.109	0.229	1.518	5.624	0.319	0.216	0.714	3.376	0.165	0.126
O	0.399	2.709	0.113	0.101	2.697	0.055	0.132	-0.184	2.325	-0.020	0.071
N	1.115	4.169	0.246	0.784	2.975	0.215	0.122	0.949	4.465	0.170	0.216
D	2.072	10.97	0.141	2.481	12.17	0.243	0.299	1.203	4.591	0.233	0.222

	Kinyinya				Gitega				Kirundo			
	MRD		L-MRD		MRD		L-MRD		MRD		L-MRD	
Months	Cs	Ck	t3	t4	Cs	Ck	t3	t4	Cs	Ck	t3	t4
J	1.142	4.199	0.253	0.209	0.871	3.635	0.218	0.195	2.156	11.16	0.202	0.286
F	2.445	11.24	0.333	0.266	0.621	5.003	0.076	0.216	0.202	3.136	0.059	0.194
M	1.870	7.734	0.263	0.260	0.784	5.523	0.083	0.243	0.793	3.706	0.156	0.141
A	1.124	4.488	0.226	0.203	0.497	2.287	0.160	0.063	0.888	4.175	0.156	0.188
M	1.146	3.971	0.262	0.162	0.335	2.447	0.101	0.056	0.418	2.783	0.110	0.132
J	3.024	12.24	0.708	0.439	2.018	6.815	0.586	0.250	1.914	6.456	0.472	0.214
J	4.662	25.11	0.913	0.794	2.817	10.19	0.795	0.552	3.756	18.23	0.737	0.499
A	2.789	11.34	0.636	0.348	1.362	3.356	0.509	0.133	1.923	6.114	0.575	0.265
S	1.603	5.867	0.322	0.162	0.601	2.609	0.184	0.041	0.754	4.254	0.147	0.068
O	1.268	5.273	0.244	0.161	-0.068	2.724	0.042	0.096	0.269	3.255	0.058	0.167
N	1.283	6.339	0.183	0.223	0.136	2.773	0.072	0.124	0.585	2.431	0.179	0.055
D	0.856	4.710	0.091	0.070	0.046	4.013	0.063	0.258	0.808	4.621	0.145	0.265

Appendix 7: Mean monthly number of wet days (> 1mm).

Stations	J	F	M	A	M	J	J	A	S	O	N	D
Bujumbura	15	13	18	18	9	2	1	2	8	15	19	18
Makamba	19	15	18	19	10	1	0	2	6	12	17	20
Gisozi	22	19	21	22	14	3	1	3	9	17	23	24
Mpota-Tora	22	21	23	23	15	3	1	3	9	17	23	24
Rwegura	20	18	23	24	16	4	1	4	13	20	24	22
Cankuzo	18	14	17	19	10	1	1	2	7	13	18	20
Kinyinya	15	12	18	19	9	1	0	1	5	11	16	18
Musasa	18	15	18	19	11	1	0	1	5	12	17	20
Muriza	19	16	19	21	12	1	1	2	6	13	20	20
Nyamuswaga	18	15	19	20	12	2	1	2	9	17	21	20
Ruvyironza	22	19	20	21	11	2	1	2	6	15	21	23
Karuzi	16	13	16	17	10	1	0	1	6	12	18	17
Gitega-Aero	22	18	21	21	12	1	1	2	8	17	23	24
Kirundo	11	11	14	18	11	2	1	3	9	14	16	13
Muyinga	17	15	19	21	13	2	1	3	10	16	21	19

Appendix 8: Mean monthly number of wet day (>5mm).

Stations	J	F	M	A	M	J	J	A	S	O	N	D
Bujumbura	5.1	4.19	6.29	6.3	2.29	0.4	0.1	0.62	2.14	4	5.5	5.6
Mparambo	5.56	5.6	7.4	7.1	4.4	1.1	0.1	0.8	2.2	5.1	6.1	5.9
Gisozi	9.05	8.4	11.7	12	5.45	0.6	0.3	1.05	4.6	7.5	11	10
Mpota-Tora	11.0	9.8	12.9	12	5.15	0.3	0.2	0.75	3.9	7.4	11	12
Rwegura	10.5	7.9	11.8	13	7.3	0.8	0.4	1.7	6.4	9.3	12	12
Cankuzo	9.29	7.95	8.62	10	5.86	0.8	0.1	0.9	2.19	5.3	9.2	10
Kinyinya	7.75	6.8	9.1	10	3.65	0.3	0.2	0.45	2.15	5.8	8.3	11
Musasa	8.55	7.18	9.05	10	4.05	0.0	0.1	0.59	1.68	4.7	7.1	8.2
Nyamuswaga	8.07	7.0	10.5	11	6.57	0.8	0.3	1.93	3.64	9.0	9.4	9.3
Karuzi	8.24	7.38	9.05	9.4	4.9	0.1	0.3	0.76	2.95	5.5	9.5	9.6
Ruvyironza	10.3	9.5	10.3	10	4.1	0.5	0.2	0.55	3.1	5.7	11	11
Gitega	8.62	7.48	8.33	9.1	4.14	0.1	0.2	0.62	3.05	6.4	9.0	9.1
Kirundo	5.52	5.05	8.05	11	6.1	0.6	0.6	1.33	4.76	5.8	7.5	6.2
Muyinga	6.95	6.38	8.71	9.8	4.95	0.2	0.3	1.33	3.57	5.9	9.2	7.6

Appendix 9: Mean monthly probability of a wet day (> 5 mm).

Stations	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bujumbura	0.16	0.15	0.20	0.20	0.07	0.01	0.00	0.02	0.07	0.13	0.18	0.18
Mparambo	0.12	0.11	0.17	0.19	0.04	0.0	0.0	0.01	0.04	0.11	0.15	0.16
Gisozi	0.29	0.30	0.38	0.40	0.18	0.02	0.01	0.03	0.15	0.24	0.37	0.33
Mpota-Tora	0.35	0.35	0.41	0.39	0.17	0.01	0.01	0.02	0.13	0.24	0.38	0.39
Rwegura	0.34	0.28	0.38	0.44	0.20	0.03	0.01	0.05	0.21	0.30	0.41	0.39
Cankuzo	0.30	0.28	0.28	0.33	0.19	0.03	0.00	0.03	0.07	0.17	0.31	0.33
Kinyinya	0.25	0.24	0.30	0.34	0.12	0.01	0.01	0.01	0.07	0.19	0.28	0.34
Musasa	0.28	0.26	0.28	0.29	0.13	0.00	0.00	0.02	0.06	0.15	0.24	0.27
Nyamuswaga	0.26	0.25	0.34	0.35	0.21	0.03	0.01	0.06	0.12	0.19	0.31	0.30
Karuzi	0.27	0.26	0.29	0.31	0.16	0.00	0.01	0.02	0.10	0.18	0.32	0.31
Ruvyironza	0.33	0.34	0.33	0.34	0.13	0.02	0.00	0.02	0.10	0.18	0.38	0.36
Gitega	0.28	0.27	0.27	0.30	0.13	0.00	0.01	0.02	0.10	0.18	0.30	0.29
Kirundo	0.18	0.18	0.26	0.27	0.20	0.02	0.02	0.04	0.16	0.19	0.25	0.20
Muyinga	0.22	0.23	0.28	0.28	0.16	0.01	0.01	0.04	0.12	0.19	0.27	0.25

Appendix 10: Mean monthly rainfall at different meteorological stations.

Stations	J	F	M	A	M	J	J	A	S	O	N	D
Bujumbura	92.8	80.9	120.7	107.0	48.5	7.3	1.7	11.1	34.3	62.0	92.8	106.2
Makamba	176.9	160.1	200.5	211.3	82.1	12.3	4.7	13.6	44.6	112.2	176.4	193.2
Mparambo	115.8	97.6	131.3	134.2	91.5	20.1	5.6	17.8	48.7	90.2	105.1	96.1
Gisozi	170.8	176.2	204.5	206.3	103.6	9.5	3.2	15.7	70.1	127.0	179.5	173.2
Mpota-Tora	190.0	187.6	219.2	211.9	103.9	9.9	4.2	14.8	64.8	129.4	189.1	187.6
Rwegura	172.9	153.1	210.4	242.9	129.0	21.4	7.2	36.9	98.4	161.8	223.4	200.0
Cankuzo	158.5	135.2	156.5	172.5	77.3	3.2	4.8	13.2	44.5	91.9	165.3	179.3
Kinyinya	158.0	128.7	183.7	198.4	80.2	5.7	2.2	7.2	35.7	83.7	143.5	165.2
Musasa	169.7	138.3	165.8	183.7	79.1	4.2	1.6	10.7	31.0	82.9	130.5	151.3
Muriza	153.2	132.0	168.5	195.9	80.8	4.1	4.1	10.8	36.4	76.7	150.9	155.3
Nyamuswaga	132.5	130.5	167.4	221.5	97.6	14.0	5.9	21.5	81.6	136.8	175.5	153.1
Ruvyironza	180.3	173.5	185.8	174.6	65.7	7.1	2.8	12.0	42.5	104.4	171.3	166.4
Karuzi	134.4	120.7	176.4	183.4	85.2	8.2	4.4	10.5	45.5	96.3	162.4	163.7
Gitega-Aero	157.5	139.1	153.8	175.0	73.3	2.8	3.8	9.9	51.5	99.0	148.5	150.7
Kirundo	87.9	91.9	129.1	192.1	102.1	12.9	7.1	23.8	76.2	112.4	121.0	105.2
Muyinga	121.4	106.2	148.6	190.0	88.1	11.3	1.5	22.1	56.9	108.1	139.9	127.0

Appendix 11: Standard deviation of monthly rainfall data series.

Stations	J	F	M	A	M	J	J	A	S	O	N	D
Bujumbura	35.9	42.4	49.4	44.2	38.0	11.3	3.7	18.8	25.3	32.6	45.1	51.9
Makamba	66.4	70.8	66.6	68.1	52.6	19.4	9.0	26.0	35.2	48.8	71.2	64.7
Mparambo	54.2	33.0	48.1	52.4	60.5	20.6	13.2	22.1	28.0	40.3	51.9	52.2
Gisozi	55.1	62.9	56.1	77.0	58.3	18.5	8.1	23.5	44.3	45.9	64.0	65.6
Mpota-Tora	57.2	64.3	60.1	58.7	53.7	14.9	7.1	18.5	41.4	46.9	66.3	50.4
Rwegura	56.3	56.5	46.1	72.4	63.3	23.9	12.2	41.8	61.3	66.7	150.1	64.3
Cankuzo	58.8	57.2	50.9	56.8	44.4	6.0	14.4	17.5	34.0	50.2	53.5	68.3
Kinyinya	78.6	58.9	67.1	73.7	56.3	11.0	7.8	14.2	28.4	57.8	69.4	60.4
Musasa	61.6	61.1	50.4	62.2	51.9	8.6	5.4	30.6	31.1	39.2	52.5	59.0
Muriza	68.0	56.5	64.4	65.9	47.6	10.8	13.4	15.5	32.3	39.2	57.9	66.0
Nyamuswaga	47.1	60.4	53.4	114.6	55.0	29.6	22.1	31.9	64.4	54.1	73.2	61.8
Ruvyironza	51.9	49.8	61.5	64.8	37.7	14.8	8.3	15.0	30.7	41.6	57.9	48.1
Karuzi	63.8	59.7	110.4	101.8	66.3	18.4	18.0	20.6	45.8	69.6	90.5	100.9
Gitega-Aero	67.5	59.4	54.1	71.0	47.7	4.9	10.1	15.4	42.9	42.5	64.5	45.9
Kirundo	47.9	42.6	45.6	65.9	47.0	17.9	18.2	28.0	40.3	44.9	58.1	53.2
Muyinga	63.0	48.9	59.9	75.6	50.1	16.8	4.0	29.8	43.2	40.4	69.0	58.7

Appendix 12: Coefficient of variation in monthly rainfall data at different stations.

Stations	J	F	M	A	M	J	J	A	S	O	N	D
Bujumbura	0.39	0.52	0.41	0.41	0.78	1.55	2.16	1.70	0.74	0.53	0.49	0.49
Makamba	0.38	0.44	0.33	0.32	0.64	1.58	1.94	1.72	0.79	0.44	0.40	0.33
Mparambo	0.47	0.34	0.37	0.39	0.66	1.02	2.33	1.24	0.58	0.45	0.49	0.54
Gisozi	0.32	0.36	0.27	0.37	0.54	1.95	2.52	1.50	0.63	0.36	0.36	0.38
Mpota-Tora	0.30	0.34	0.27	0.28	0.52	1.50	1.69	1.25	0.64	0.36	0.35	0.27
Rwegura	0.33	0.37	0.22	0.30	0.51	1.11	1.70	1.13	0.62	0.40	0.47	0.32
Cankuzo	0.37	0.42	0.33	0.33	0.57	1.85	3.00	1.33	0.76	0.55	0.32	0.38
Kinyinya	0.50	0.46	0.37	0.37	0.70	1.92	3.58	1.97	0.80	0.59	0.48	0.37
Musasa	0.36	0.44	0.30	0.34	0.66	2.06	3.36	2.16	1.00	0.47	0.40	0.39
Muriza	0.44	0.43	0.38	0.34	0.59	2.63	3.24	1.44	0.89	0.51	0.38	0.42
Nyamuswaga	0.36	0.46	0.32	0.42	0.56	2.12	3.73	1.49	0.79	0.41	0.42	0.40
Ruvyironza	0.29	0.29	0.33	0.37	0.57	2.10	2.99	1.25	0.72	0.40	0.34	0.29
Karuzi	0.47	0.49	0.63	0.45	0.68	2.26	4.13	1.96	1.01	0.56	0.46	0.62
Gitega-Aero	0.43	0.43	0.35	0.41	0.65	1.75	2.68	1.55	0.83	0.43	0.43	0.30
Kirundo	0.54	0.46	0.35	0.34	0.56	1.39	2.57	1.18	0.58	0.46	0.48	0.51
Muyinga	0.52	0.46	0.40	0.40	0.57	1.49	2.65	1.35	0.76	0.43	0.49	0.46

Appendix 13: Simple climate departure index (SCDI) for annual rainfall data.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1975	-0.9	-0.9	-1.6	-1.5	-1.6	-0.7	0.2	-1.1	-0.3	-0.3		-1.2	-0.7	-0.3	-0.7	-0.1
1976	-0.5	-0.9	-1.8	-1.3	-0.6	-0.1	0.0	-0.8	0.0	-0.8		-1.4	-0.6	0.5	-1.0	-1.4
1977	0.4	0.5	1.0	0.8	-0.9	-0.3	2.2	-0.8	1.9	0.3		1.3	0.7	0.7	0.1	0.9
1978	0.1	-0.5	0.6	0.7	0.1	0.0	1.5	0.9	-0.4	1.6		0.9	0.5	0.3	0.5	-0.2
1979	1.6	0.4	-0.4	0.6	-0.1	0.1	-0.3	0.5	0.5	0.3		-0.9	1.6	1.2	0.0	0.4
1980	0.8	-1.4	0.9	-0.8	0.7	-0.8	-1.7	0.1	-1.5	-2.5	0.3	-0.6	-0.9	-0.7	-0.9	-0.9
1981	-0.5	-0.7	0.1	-1.2	0.5	-0.5	1.5	-0.4	-0.4	-0.3	-0.7	-0.3	0.0	-0.1	1.0	-1.1
1982	0.2	-0.1	0.2	1.2	1.0	1.0	-0.1	0.8	1.6	1.0	1.5	0.7	-0.5	1.4	0.1	0.0
1983	-0.1	-0.8	-0.5	-0.4	1.4	-0.6	-0.8	-0.4	-0.9	-0.5	1.3	-0.6	-1.1	-1.2	-0.3	-0.3
1984	0.6	-1.7	-1.1	-0.3	0.1	-0.8	-0.1	-0.6	-0.8	-0.4	1.2	-0.4	-1.2	-0.1	-1.1	-0.3
1985	0.0	-0.9	-0.5	1.4	-0.4	0.2	0.1	1.0	-0.3	0.7	0.6	0.7	1.7	0.5	1.6	1.0
1986	2.1	0.7	-0.1	2.0	1.6	0.8	-0.1	0.9	1.9	0.7	0.6	0.1	0.5	1.6	1.1	0.7
1987	0.0	-0.4	1.3	-0.1	-0.2	0.4	-0.4	0.3	0.2	0.6	1.2	-1.9	0.0	-0.2	2.0	2.1
1988	1.0	-0.3	0.9	0.6	0.6	0.9	1.3	-0.5	1.4	0.8	1.9	0.5	-0.2	1.7	0.8	1.9
1989	2.4	1.9	1.2	1.9	1.6	3.4	1.3	1.4	1.0	2.1	0.5	1.6	-0.2	1.0	-0.5	-0.1
1990	-0.2	1.1	0.9	-0.6	0.6	0.0	0.0	0.2	-0.9	0.0	0.0	-0.8	-1.8	-0.8	0.8	-0.4
1991	0.0	1.4	0.4	1.0	1.0	0.4	0.1	0.2	0.6	0.2	0.0	-0.3	-0.1	-0.8	-0.3	-0.5
1992	-1.4	0.2	-0.8	-0.7	-0.5	0.4	0.6	-0.3	-0.8	0.1	-1.2	-0.5	0.0	-0.5	-0.7	-0.2
1993	-1.4	-0.9	-0.1	-1.7	-1.9	-1.4	-1.2	-1.7	-1.5	-2.4	-1.8	-1.6	-1.1	-2.1	0.2	0.1
1994	-1.0	1.6	1.2	-0.2	1.2	-0.3	0.4	0.2	0.4	-1.0	-0.5	-0.1	0.4	-0.7	-0.9	-0.4
1995	-1.8	0.6	-1.9	-1.0	0.0	-0.1	-0.1	2.0	-0.7	-0.1	0.0	1.0	-1.8	-0.8	0.7	-0.7
1996	0.0	0.6	0.1	0.5	0.0	-0.5	-0.2	0.2	-1.0	-0.6	-0.8	1.8	-1.3	-0.6	-0.9	0.8
1997	0.1	1.4		1.6	1.0	0.8	1.7	1.6	0.6	1.0	0.8	1.3	0.7	2.0	0.0	2.5
1998	-0.1	0.9		-0.7	0.4	0.2	-0.8	1.0	1.9	0.5	0.2	0.0	1.6	0.1	2.3	-0.9
1999	0.0	0.2		-0.2	-0.9	0.4	-1.2	0.1	-0.7	0.5	-1.2	-0.7	0.4	0.3	-1.9	-1.6
2000	-0.3	0.7		-0.1	-0.1	-0.2	-2.0	-0.4	-0.5	-1.4	-1.3	-0.3	0.4	-1.8	-1.6	-1.4
2001	0.0	0.5		-0.2	-1.2	1.1	-0.2	0.1	0.1	0.4	-0.4	1.5	1.5	0.2	-0.2	0.6
2002	0.0	-0.1		-0.5	-0.6	-0.6	0.3	-0.5	0.0	-0.2	-1.1	1.0	1.6	0.0	-0.7	-0.3
2003	-1.3	-1.7		-0.3	-2.1	-2.7	-0.4	-2.0	-1.1	-0.6	-0.8	-0.2	-0.4	-1.0	0.5	-0.4
2004	-0.4	-1.4		-0.5	-1.0	-0.4	-1.3	-2.2	-0.4	0.3	-0.4	-0.8	0.5	0.3	0.1	0.2

Legend: 1-Bujumbura **2**-Makamba **3**-Mparambo **4**-Gisozi **5**-Mpota-Tora

6-Rwegura **7**-Cankuzo **8**-Kinyinya **9**-Musasa **10**-Muriza

11-Nyamuswaga **12**-Ruvyironza **13**-Karuzi **14**-Gitega **15**-Kirundo

16-Muyinga

Appendix 14: Monthly Gaussian Index values at different locations.

Makamba

Year	J	F	M	A	M	J	J	A	S	O	N	D
1987	9.7	4.6	6.9	12.3	4.2	0.0	0.0	0.0	4.3	4.3	5.5	7.2
1988	9.7	5.2	10.0	12.2	0.3	0.0	0.0	2.5	0.1	4.1	6.6	7.2
1989	10.3	9.0	17.4	7.7	5.9	2.0	0.1	0.37	2.8	6.3	8.2	11.0
1990	6.0	19.4	12.0	7.3	6.1	0.0	0.0	0.0	4.8	5.5	8.9	8.3
1991	9.5	12.1	5.1	14.5	9.6	3.3	0.9	0.0	1.6	8.6	6.3	7.7
1992	5.3	9.9	11.0	7.1	4.4	0.2	0.0	0.0	1.9	8.3	9.5	10.4
1993	8.5	6.8	7.8	6.8	6.9	0.7	0.0	1.0	0.1	3.2	8.8	6.0
1994	15.0	11.0	9.2	8.2	4.0	0.7	0.7	0.9	1.9	8.6	15.6	10.1
1995	13.2	6.0	9.0	9.8	6.2	1.2	0.3	0.0	0.6	10.5	7.7	6.7
1996	10.2	8.1	17.6	8.9	2.5	0.3	0.0	0.3	4.0	4.8	8.3	6.5
1997	12.3	8.3	6.6	13.0	7.4	0.5	0.0	0.0	0.9	6.3	16.3	8.4
1998	8.8	14.9	11.7	10.8	6.5	1.0	0.2	1.0	1.7	7.6	2.7	5.5
1999	13.8	5.0	9.5	5.0	1.3	0.0	0.0	3.3	6.1	3.1	10.3	10.6
2000	6.0	10.5	12.8	7.3	0.4	0.0	0.2	0.0	0.2	4.9	15.6	11.5
2001	6.2	7.2	13.4	6.8	3.3	0.5	2.0	0.8	3.8	3.4	5.8	16.5
2002	12.8	4.6	11.8	13.5	0.4	0.0	0.0	0.0	0.9	2.5	9.4	8.5
2003	7.9	4.5	8.9	6.6	2.1	0.0	0.0	0.1	0.7	3.5	5.4	7.5
2004	0.7	5.2	8.7	13.8	0.2	0.0	0.0	0.0	4.5	2.1	5.3	10.4

Cankuzo

Year	J	F	M	A	M	J	J	A	S	O	N	D
1979	9.3	7.1	6.7	10.6	5.1	1.1	0.0	0.0	0.5	1.9	8.6	7.4
1980	8.3	4.4	4.9	4.7	2.5	0.1	0.0	0.0	3.0	1.6	9.1	6.6
1981	9.7	7.4	10.2	9.8	9.1	0.0	0.0	3.2	1.8	3.4	6.7	12.6
1982	6.6	10.9	20.1	28.1	15.6	1.4	1.0	0.0	3.2	13.0	31.6	20.0
1983	4.7	7.5	5.2	10.3	2.0	0.0	0.0	1.7	1.4	5.7	13.3	6.1
1984	13.6	4.6	8.5	8.3	1.0	0.0	1.0	0.5	1.8	4.1	12.0	5.1
1985	6.8	9.9	20.6	23.0	7.3	0.0	0.0	0.6	4.4	3.1	9.1	8.2
1986	7.5	8.9	5.2	10.5	4.4	0.1	0.0	0.1	1.1	6.3	8.2	9.1
1987	9.8	3.0	7.4	8.4	3.7	0.0	0.0	0.5	2.8	1.7	15.5	3.7
1988	16.5	2.2	13.1	14.6	2.5	0.0	0.1	2.0	1.2	6.1	6.2	8.0
1989	13.4	10.8	8.1	6.9	4.0	0.3	0.0	1.5	3.9	4.6	9.3	11.2
1990	1.7	13.5	14.5	6.3	5.2	0.0	0.0	0.4	2.4	2.7	5.0	9.1
1991	8.3	8.4	6.1	7.2	4.8	0.4	0.0	0.0	0.6	8.6	7.4	11.1
1992	5.6	11.4	5.5	7.1	6.7	0.0	0.0	0.0	2.2	7.4	7.4	13.7
1993	9.1	4.9	8.7	8.1	3.8	0.0	0.0	0.6	0.0	1.1	7.8	6.2
1994	8.4	7.2	6.8	7.3	4.7	0.0	0.0	0.5	1.5	8.6	6.7	14.0
1995	6.4	11.8	5.2	11.2	5.8	0.8	0.0	0.0	0.2	5.1	10.2	3.8
1996	7.8	7.3	7.0	7.8	2.7	0.0	0.0	1.8	5.0	3.2	6.6	9.3
1997	8.4	6.3	5.6	11.7	6.1	0.1	0.0	0.0	0.2	8.6	14.3	16.7
1998	10.7	9.3	8.0	6.2	3.7	1.1	0.0	0.0	0.6	6.3	1.9	5.7
1999	5.1	2.7	10.3	8.0	1.6	0.0	0.0	1.7	3.2	1.1	7.4	11.0
2000	5.1	4.3	11.6	1.8	0.8	0.1	0.0	0.0	0.4	1.5	9.4	11.0
2001	11.6	7.0	9.2	4.9	1.3	0.0	2.4	0.8	7.7	6.0	6.7	5.4
2002	9.8	3.3	6.8	15.2	6.0	0.0	0.0	0.0	1.0	1.4	11.6	13.1
2003	7.9	6.2	9.2	9.0	3.0	0.0	0.0	0.0	1.7	3.4	7.9	11.2
2004	7.6	4.0	3.5	11.3	0.0	0.0	0.0	0.2	2.5	1.5	6.5	16.1

Mparambo

Year	J	F	M	A	M	J	J	A	S	O	N	D
1966	3.3	4.3	4.5	5.2	0.5	0.3	0.0	2.6	2.3	4.3	4.0	3.9
1967	4.0	4.0	2.7	3.1	8.3	1.9	0.2	0.0	2.0	2.7	5.9	2.7
1968	6.9	3.3	6.0	7.6	4.7	1.9	0.2	0.0	1.5	2.2	3.4	2.9
1969	7.9	4.0	7.0	3.2	2.7	0.0	0.0	0.0	1.0	4.0	2.7	3.8
1970	5.1	3.8	7.8	7.0	2.5	1.2	0.5	0.6	0.9	5.2	3.5	4.9
1971	2.9	3.6	3.6	7.1	6.7	0.3	0.6	1.6	1.5	3.5	3.9	3.4
1972	5.3	3.7	2.9	7.6	1.8	3.0	0.0	0.6	0.4	3.9	6.5	4.7
1973	3.6	4.3	2.7	4.5	7.7	0.0	0.3	0.0	4.7	4.5	4.6	4.9
1974	5.3	3.2	4.7	4.9	4.3	2.4	1.2	0.2	2.0	1.3	5.2	2.0
1975	4.3	1.4	9.4	3.5	0.8	0.8	0.3	0.0	2.9	1.2	1.9	3.5
1976	1.1	3.5	5.6	2.5	3.3	0.5	0.0	1.8	3.3	1.6	2.2	2.1
1977	4.3	6.2	4.5	8.2	2.9	1.2	0.0	1.9	2.5	0.8	6.5	3.8
1978	3.8	3.9	6.6	4.5	4.8	0.0	0.0	0.9	1.4	3.8	5.8	5.9
1979	3.3	4.2	5.3	6.0	5.1	1.4	0.0	0.1	0.3	3.3	4.8	1.7
1980	5.2	3.2	6.4	2.3	7.1	0.3	0.0	0.1	1.7	3.7	7.7	5.6
1981	5.7	5.1	3.9	4.7	4.2	0.6	0.0	1.0	3.2	2.8	2.0	5.5
1982	5.9	2.8	3.0	6.8	2.9	0.2	0.0	0.1	2.0	4.6	5.6	4.8
1983	1.8	2.2	7.3	6.6	1.0	1.4	0.0	1.1	2.7	4.1	2.6	3.9
1984	4.2	3.6	3.8	4.1	0.5	0.0	1.3	1.9	0.4	3.0	5.8	3.7
1985	2.7	2.4	4.6	11.3	3.1	1.0	0.0	0.0	3.0	1.0	2.9	3.1
1986	4.7	3.6	3.4	7.9	2.1	0.0	0.0	0.0	1.4	6.4	3.8	4.0
1987	7.7	3.5	8.3	4.3	6.4	1.4	0.1	0.5	2.0	3.0	6.2	1.2
1988	5.4	4.7	5.7	5.1	1.9	0.0	3.0	2.8	1.8	3.5	3.2	5.4
1989	5.9	5.3	5.8	6.1	8.0	0.3	0.8	0.4	0.6	3.3	5.3	3.1
1990	7.5	3.2	7.9	4.3	1.6	0.0	0.0	1.0	2.6	3.1	2.7	8.6
1991	2.5	3.5	5.4	6.9	6.0	1.1	0.4	0.2	1.0	7.5	2.6	2.5
1992	2.0	2.6	4.8	6.4	5.2	0.5	0.0	0.0	0.9	4.3	3.2	2.8
1993	5.4	7.7	6.8	5.7	3.0	0.2	0.0	1.8	0.5	1.5	3.1	1.4
1994	4.2	5.6	7.4	5.4	3.5	0.8	0.0	0.0	1.8	5.3	2.8	4.9
1995	4.2	3.6	4.8	2.9	2.0	0.0	0.0	0.2	1.5	3.6	2.5	1.7
1996	5.3	1.8	10.2	3.8	0.5	2.0	0.0	1.6	2.0	3.4	2.2	2.9

Gisozi

Year	J	F	M	A	M	J	J	A	S	O	N	D
1975	6.4	9.8	11.4	9.8	6.1	0.0	1.6	0.0	2.6	8.2	8.2	7.8
1976	5.6	10.0	11.9	10.3	6.8	0.1	0.1	1.7	4.1	5.7	9.2	6.0
1977	12.8	9.7	12.2	17.4	7.6	0.4	0.0	3.2	6.2	1.4	17.7	6.8
1978	7.3	10.6	18.0	12.7	2.3	0.6	0.0	1.7	5.6	11.2	12.1	11.1
1979	7.6	17.2	11.1	17.4	6.4	1.4	0.0	0.0	0.5	6.7	12.7	11.2
1980	4.9	8.8	8.5	8.6	9.8	0.1	0.0	0.0	4.7	10.8	11.1	9.9
1981	11.9	4.7	10.8	8.0	3.5	0.0	0.0	2.0	5.0	5.3	5.8	11.5
1982	8.2	5.7	12.7	20.4	12.9	0.7	0.0	0.0	2.3	6.0	15.9	17.0
1983	4.7	12.5	12.7	10.6	6.6	0.1	0.4	1.5	1.5	12.1	9.4	9.0
1984	10.9	9.4	10.1	9.3	4.8	0.0	2.5	2.1	1.5	8.9	12.8	11.2
1985	7.9	15.5	14.0	25.9	3.6	0.3	0.0	0.0	5.0	6.9	13.0	10.7
1986	15.3	14.1	9.5	19.3	9.0	0.0	0.0	0.0	4.9	5.5	16.9	15.4
1987	17.8	9.2	9.1	10.7	4.4	0.1	0.0	0.3	7.8	7.9	4.6	10.3
1988	12.6	12.8	13.1	16.8	1.8	0.0	0.4	2.1	5.7	7.4	8.8	9.9
1989	13.7	7.7	22.4	12.4	6.7	1.0	0.1	0.0	6.1	6.9	12.8	19.0
1990	6.6	15.8	13.3	7.2	6.0	0.0	0.5	1.7	6.6	6.6	9.3	6.0
1991	12.3	12.9	7.0	12.4	13.1	2.5	0.0	0.0	4.1	13.6	9.0	10.9
1992	8.3	13.1	8.4	9.1	5.4	5.7	0.0	0.0	1.7	9.7	8.1	7.6
1993	9.5	7.3	9.2	9.3	10.8	0.1	0.0	0.3	0.0	6.6	7.8	5.8
1994	9.1	14.0	9.0	7.1	6.2	0.8	0.0	0.1	3.0	7.6	15.7	9.8
1995	7.6	7.7	12.2	10.6	7.5	2.4	0.0	0.0	0.6	10.4	10.9	4.6
1996	11.7	15.8	17.9	10.8	2.8	0.0	0.0	0.9	9.3	2.8	6.8	11.6
1997	8.6	4.4	14.2	17.4	8.7	1.6	0.0	0.8	0.5	10.2	19.4	17.4
1998	11.2	8.9	13.1	7.1	7.6	0.2	0.4	0.5	2.4	6.2	4.9	5.0
1999	11.3	5.5	15.2	10.3	3.1	0.0	0.0	1.7	4.2	5.3	11.5	14.9
2000	9.0	17.0	14.2	3.4	0.9	0.0	0.0	0.0	0.9	4.8	16.4	17.4
2001	14.9	7.4	7.0	12.4	7.0	0.2	0.4	0.6	9.5	8.0	6.2	6.1
2002	13.2	5.8	10.0	15.0	4.6	0.0	0.0	0.0	4.1	5.8	9.5	10.4
2003	9.7	10.5	11.8	13.8	5.7	0.2	0.0	0.1	5.9	7.2	8.2	6.3
2004	13.5	8.2	14.0	12.7	0.3	0.0	0.0	0.1	6.5	3.6	8.8	11.3

Mpota-Tora

Year	J	F	M	A	M	J	J	A	S	O	N	D
1975	9.3	8.1	11.2	11.2	7.2	0.1	1.3	0.0	6.5	8.6	7.5	8.8
1976	6.9	13.2	7.7	18.3	4.0	0.3	0.0	0.8	6.8	3.9	12.6	16.3
1977	10.3	10.5	10.3	11.0	7.9	0.1	0.0	1.9	5.4	4.7	13.3	8.3
1978	5.2	10.9	13.3	16.5	11.0	0.0	0.0	0.9	3.1	9.1	17.0	13.0
1979	9.8	12.7	10.3	18.6	6.0	2.8	0.0	0.3	0.1	4.6	12.4	15.3
1980	11.4	13.8	6.5	10.1	12.7	0.0	0.0	0.0	7.3	10.0	13.9	14.8
1981	14.1	8.6	10.3	12.9	7.0	0.1	0.0	1.7	7.0	8.1	8.5	15.4
1982	15.0	10.4	9.6	18.5	9.7	1.3	0.0	0.3	1.4	9.3	14.8	15.9
1983	7.2	13.7	17.5	12.8	9.7	0.0	0.5	2.0	5.9	16.0	10.4	12.0
1984	11.9	13.7	11.5	7.8	5.4	0.0	1.0	1.8	2.0	10.2	14.5	12.0
1985	12.9	8.5	10.4	16.6	8.2	0.5	0.0	0.0	4.5	8.1	12.1	8.8
1986	11.4	14.4	10.7	21.3	14.2	0.4	0.0	0.2	5.6	7.4	14.6	10.9
1987	15.9	9.6	6.9	14.4	6.3	0.4	0.0	1.3	9.5	10.8	12.0	9.0
1988	16.3	10.8	14.1	18.0	2.5	0.3	0.4	2.9	2.2	8.1	9.4	16.7
1989	13.7	12.4	24.6	11.3	8.5	2.0	0.1	0.5	4.1	9.0	10.9	17.1
1990	8.2	25.3	15.0	9.4	8.1	0.0	0.0	0.0	6.4	7.9	11.8	10.4
1991	12.3	16.2	7.1	19.8	12.5	4.6	1.2	0.0	5.3	11.4	8.3	9.9
1992	7.1	13.1	14.9	9.4	6.1	0.2	0.0	0.0	2.7	11.8	12.8	13.5
1993	11.0	8.9	10.6	9.4	9.5	1.0	0.0	1.4	0.1	5.0	11.8	7.9
1994	19.6	13.8	12.2	33.8	0.0	1.0	1.0	1.2	2.9	12.1	20.4	13.0
1995	17.4	7.9	12.5	13.4	8.4	1.7	0.4	0.0	0.9	14.5	9.7	9.2
1996	13.2	10.8	24.0	11.8	3.5	0.4	0.0	0.5	5.6	6.8	11.4	8.6
1997	16.2	11.0	9.2	17.2	9.6	0.7	0.0	0.1	1.4	9.0	21.4	10.6
1998	10.7	18.8	15.3	14.0	8.6	1.4	0.2	1.4	2.5	10.5	3.8	7.3
1999	12.9	7.3	12.9	6.7	1.8	0.0	0.0	5.0	8.5	4.8	13.8	14.0
2000	8.2	14.9	18.2	9.9	0.5	0.0	0.3	0.0	0.3	7.4	20.8	15.0
2001	13.0	10.2	11.0	10.7	3.4	0.5	1.9	2.0	6.0	5.8	7.7	11.4
2002	15.9	4.4	16.4	16.4	4.3	0.0	0.0	0.0	1.4	5.5	11.6	12.3
2003	11.0	9.4	13.3	11.8	5.6	0.3	0.1	0.5	3.2	5.8	4.4	4.9
2004	10.7	11.2	13.1	15.4	0.3	0.0	0.2	0.1	7.6	3.9	8.0	13.8

Rwegura

Year	J	F	M	A	M	J	J	A	S	O	N	D
1975	10.6	6.3	12.9	20.6	6.6	0.9	0.9	0.3	3.9	13.4	6.7	13.0
1976	5.6	7.8	13.4	14.9	11.2	1.7	1.6	5.7	8.8	8.8	10.3	12.4
1977	10.4	7.3	11.9	12.4	7.1	0.5	1.4	5.9	0.7	3.8	20.3	16.1
1978	7.5	10.2	21.5	15.1	5.3	0.9	0.0	2.0	5.0	10.5	10.5	15.2
1979	14.8	14.8	9.4	17.8	14.6	2.5	0.0	0.8	1.6	6.7	8.3	13.8
1980	9.6	8.7	11.0	8.7	9.9	4.6	0.0	0.6	4.5	11.0	11.6	8.5
1981	9.7	4.0	11.9	14.0	12.0	0.3	0.0	7.6	6.5	10.0	8.6	10.4
1982	10.5	4.4	13.0	23.0	11.7	2.6	0.0	0.3	9.7	11.6	22.3	14.9
1983	4.3	6.1	11.9	20.0	5.7	0.9	0.0	1.8	4.6	12.0	9.0	13.3
1984	15.2	7.4	13.5	11.8	2.4	0.0	1.3	4.0	4.9	10.6	12.0	5.8
1985	14.6	13.5	10.9	22.9	5.2	1.4	0.0	0.0	9.2	3.0	15.5	9.7
1986	9.5	15.5	10.4	21.6	10.3	2.8	0.0	0.1	7.4	17.2	14.6	7.2
1987	11.5	6.9	9.1	13.2	11.3	0.6	0.2	4.3	11.8	5.2	18.8	10.5
1988	15.2	12.1	14.9	23.8	2.4	0.0	0.0	5.8	4.9	12.1	10.7	15.8
1989	14.2	10.9	17.9	13.3	9.5	6.6	1.6	1.8	4.9	13.0	56.8	12.3
1990	3.9	14.3	13.2	16.1	4.7	0.2	0.0	1.8	15.3	9.8	12.5	14.0
1991	10.8	10.3	10.0	20.6	16.8	2.4	0.1	0.3	4.5	14.7	7.2	9.5
1992	8.8	11.1	14.1	14.4	9.8	2.0	0.0	0.0	3.9	15.0	13.1	15.1
1993	9.6	14.0	13.2	8.0	10.3	0.9	0.5	2.3	0.5	1.6	8.3	6.9
1994	6.7	9.2	14.8	11.3	8.0	0.1	0.0	0.1	1.7	11.4	17.9	13.1
1995	10.3	6.8	12.5	12.1	12.6	4.6	0.1	0.0	5.1	12.9	10.4	6.1
1996	6.8	13.7	16.0	11.7	2.2	0.5	0.1	2.8	9.0	7.7	10.7	11.0
1997	10.0	7.8	7.1	23.2	9.7	0.7	0.2	2.2	1.2	10.3	11.6	22.4
1998	12.9	14.5	15.6	14.1	8.8	1.4	1.1	0.1	7.6	8.1	6.1	7.4
1999	12.2	8.1	18.0	12.6	1.8	0.6	0.0	10.5	5.8	3.9	13.6	12.8
2000	8.6	8.9	13.1	7.3	5.4	0.0	0.0	0.4	2.3	8.8	12.9	19.4
2001	14.0	7.6	11.9	9.4	9.2	1.7	1.9	4.2	15.6	10.4	11.6	18.3
2002	18.7	7.4	9.4	15.2	6.2	0.0	0.0	0.0	3.6	6.4	11.0	11.0
2003	9.8	7.9	12.7	14.3	9.3	0.6	0.0	0.0	3.6	10.8	18.9	12.3
2004	10.6	9.6	13.4	14.1	0.0	0.0	1.3	1.1	12.1	6.2	10.7	16.9

Kinyinya

Year	J	F	M	A	M	J	J	A	S	O	N	D
1975	3.0	2.7	8.1	6.6	3.1	0.0	1.1	0.0	8.9	8.8	10.0	19.0
1976	3.1	5.0	6.7	8.7	3.3	0.0	0.1	0.2	3.6	3.7	5.3	5.5
1977	6.9	5.6	7.8	7.4	6.6	0.0	0.0	0.0	1.2	1.8	0.0	7.7
1978	10.0	7.3	15.6	7.7	1.9	0.0	0.0	0.1	2.0	3.4	10.0	8.9
1979	8.0	8.6	8.3	13.3	1.9	0.3	0.0	0.0	0.0	3.3	6.2	10.0
1980	6.5	6.0	8.3	7.0	5.0	0.0	0.0	0.0	2.5	2.2	7.9	8.8
1981	4.5	3.6	8.4	9.3	3.6	0.0	0.0	1.3	1.1	3.3	4.5	8.3
1982	7.1	4.4	4.0	11.4	6.5	0.4	0.0	0.0	2.0	6.4	9.6	10.6
1983	3.8	6.5	4.2	10.5	1.4	0.0	0.0	2.1	0.2	5.9	6.4	7.6
1984	7.5	5.9	4.7	7.0	2.6	0.0	0.1	1.6	0.4	3.5	6.3	6.2
1985	4.7	8.0	10.3	16.9	4.6	0.0	0.0	0.0	1.3	3.2	11.3	6.3
1986	8.5	6.0	7.6	12.6	4.6	0.0	0.0	0.0	1.0	3.5	10.3	10.6
1987	11.4	5.4	11.0	8.7	2.4	0.0	0.0	0.1	4.8	2.6	8.0	3.8
1988	6.1	4.5	9.2	7.3	0.9	0.4	0.0	0.7	1.9	4.9	5.0	5.7
1989	10.6	4.5	15.9	10.6	5.9	1.2	0.0	0.2	2.3	6.4	2.3	12.8
1990	2.7	11.6	8.6	11.2	4.6	0.0	0.0	0.0	1.1	3.3	6.6	6.3
1991	11.6	6.5	5.6	7.2	11.2	0.2	0.0	0.0	0.7	4.7	5.2	3.7
1992	6.6	7.1	7.6	8.9	3.2	0.3	0.0	0.0	1.8	2.7	6.1	4.4
1993	6.6	7.1	7.6	5.9	4.3	0.0	0.0	0.3	0.0	0.0	5.9	7.3
1994	4.4	7.2	8.4	5.0	5.0	0.0	0.1	0.2	1.8	3.7	9.9	8.8
1995	13.0	6.5	6.8	17.1	6.7	2.0	0.0	0.0	0.4	7.5	5.9	5.3
1996	8.8	9.6	13.4	8.1	0.2	0.1	0.0	0.4	3.2	0.4	2.3	9.1
1997	4.5	4.9	5.8	13.6	5.9	1.1	0.0	0.0	0.0	6.4	14.8	14.2
1998	17.0	12.2	10.1	8.7	5.2	0.4	0.0	0.0	0.5	4.1	1.6	4.9
1999	6.3	1.4	13.5	6.5	2.3	0.0	0.0	1.8	1.1	0.7	9.8	10.7
2000	6.6	5.9	9.0	4.6	0.2	0.0	0.0	0.0	0.0	4.0	9.0	8.1
2001	13.9	2.2	10.4	4.3	4.1	1.7	1.8	0.1	2.8	1.3	4.8	5.7
2002	7.4	6.9	4.7	12.6	0.9	0.0	0.0	0.0	0.1	0.8	4.0	8.8
2003	4.1	1.8	4.0	5.3	0.7	0.0	0.0	0.0	1.7	2.8	2.2	3.2
2004	2.0	1.0	6.5	7.6	0.0	0.0	0.0	0.0	2.6	2.1	3.7	7.7

Musasa

Year	J	F	M	A	M	J	J	A	S	O	N	D
1975	6.0	4.4	9.0	8.2	5.4	0.0	0.1	0.0	2.8	3.4	3.3	8.3
1976	8.8	9.5	8.4	8.1	4.9	0.0	0.1	0.1	1.4	2.8	4.7	4.8
1977	10.7	9.4	9.3	11.8	6.3	0.1	0.0	0.8	0.6	2.4	7.8	12.6
1978	4.4	7.8	6.2	11.2	0.7	0.0	0.0	0.6	0.7	4.2	6.2	7.0
1979	11.8	5.9	11.4	8.4	5.1	0.4	0.0	0.0	0.0	2.6	4.1	8.0
1980	4.9	7.4	4.0	3.7	4.4	0.0	0.0	0.0	0.7	4.0	4.1	4.9
1981	8.8	1.9	11.0	7.4	5.0	0.1	0.0	0.5	2.8	2.2	2.6	6.7
1982	7.4	11.2	6.1	8.1	6.4	0.4	0.0	0.0	0.9	7.5	10.3	9.2
1983	6.7	7.0	5.0	7.8	4.0	0.0	0.0	1.2	1.1	2.8	4.1	3.9
1984	7.4	4.6	6.9	7.6	1.8	0.0	0.0	1.0	0.3	5.6	6.4	4.0
1985	4.6	9.5	8.1	7.8	1.4	0.0	0.0	0.0	1.4	3.3	6.3	7.8
1986	8.6	5.1	7.2	14.7	9.0	0.0	0.0	0.0	0.7	2.6	12.8	10.2
1987	9.6	4.3	8.2	9.3	5.0	0.0	0.0	0.0	3.8	2.6	5.8	5.5
1988	10.6	6.4	8.3	10.6	1.6	0.0	0.0	7.5	1.2	5.2	6.1	7.5
1989	12.3	6.9	13.0	4.9	5.2	2.1	0.0	0.0	1.2	3.3	8.2	4.7
1990	4.5	10.2	6.2	3.6	2.1	0.0	0.0	0.3	2.7	4.0	5.1	5.8
1991	12.8	8.7	3.9	7.3	7.6	1.0	0.1	0.0	0.9	5.4	5.7	5.9
1992	6.1	3.8	6.1	9.5	2.1	0.4	0.0	0.0	0.1	2.6	5.5	9.8
1993	4.7	6.1	8.5	5.6	5.5	0.0	0.0	0.0	0.1	1.6	2.9	3.8
1994	0.5	11.6	5.5	6.3	8.1	0.0	0.0	0.0	1.8	5.2	6.5	10.9
1995	7.9	7.8	7.1	14.8	2.0	0.1	0.0	0.0	0.0	1.4	5.0	0.5
1996	10.6	4.2	6.4	6.8	0.3	0.1	1.2	0.1	3.1	3.1	4.0	4.5
1997	8.6	4.0	6.8	9.9	2.1	0.8	0.0	0.0	0.0	5.3	7.8	9.5
1998	12.0	10.5	12.1	8.5	4.4	0.1	0.0	0.0	0.7	5.1	3.6	4.7
1999	7.8	1.1	8.5	7.8	1.7	0.1	0.0	2.2	1.7	1.2	8.9	5.0
2000	6.5	4.2	8.8	5.7	0.0	0.0	0.0	0.0	0.0	4.4	7.4	9.8
2001	9.1	4.4	6.1	8.5	3.8	0.4	0.8	0.5	1.9	3.3	2.3	8.6
2002	7.3	2.2	7.2	12.9	1.6	0.0	0.0	0.0	0.0	2.3	8.6	9.5
2003	5.0	4.0	5.3	8.2	3.8	0.0	0.0	0.0	0.4	3.8	4.6	5.6
2004	9.7	6.6	5.5	4.1	0.0	0.0	0.0	0.0	4.0	1.4	6.9	10.5

Muriza

Year	J	F	M	A	M	J	J	A	S	O	N	D
1979	10.6	11.4	6.7	15.3	5.4	0.6	0.0	0.0	0.2	3.6	4.7	7.1
1980	4.3	4.4	4.1	9.7	6.4	0.0	0.0	0.0	0.0	3.9	7.3	8.1
1981	6.0	2.3	11.2	9.2	1.9	0.0	0.0	2.3	1.1	2.5	6.1	12.5
1982	4.5	4.4	4.6	15.0	8.8	0.4	0.0	0.0	0.9	5.0	15.7	13.8
1983	3.4	6.3	5.3	12.8	2.1	0.0	0.0	1.7	1.1	5.0	6.1	9.2
1984	9.4	6.7	9.8	7.0	0.9	0.0	1.0	2.0	0.9	4.0	9.5	5.0
1985	10.7	11.1	12.3	13.8	4.1	0.0	0.0	0.0	2.7	3.3	5.6	4.7
1986	9.2	5.1	8.5	14.5	5.2	0.2	0.0	0.0	1.3	7.2	10.6	7.5
1987	12.5	6.9	7.9	10.6	4.4	0.0	0.0	0.0	7.1	1.1	10.6	4.1
1988	9.9	4.8	9.6	13.4	2.7	0.0	0.0	2.7	1.7	3.2	9.3	12.4
1989	20.0	6.9	14.5	12.4	6.0	3.2	0.0	0.1	1.7	3.3	7.3	11.4
1990	1.6	15.1	11.0	8.7	2.6	0.0	0.0	0.2	2.4	5.8	6.8	4.6
1991	6.2	5.4	5.2	9.9	11.1	1.5	0.0	0.0	0.8	6.0	9.5	7.9
1992	6.7	11.5	10.8	10.3	2.9	0.0	0.0	0.0	0.5	3.9	7.7	6.0
1993	7.1	8.5	3.8	4.5	5.8	0.0	0.0	0.7	0.0	4.1	8.3	7.6
1994	8.1	7.3	8.3	6.3	6.1	0.0	0.0	1.7	2.0	5.3	12.7	12.3
1995	8.8	8.9	7.4	11.3	5.8	0.2	0.0	0.0	1.0	5.9	3.9	4.0
1996	5.0	7.7	11.1	7.0	3.5	0.0	0.0	0.9	1.9	3.7	5.3	2.7
1997	6.0	3.7	6.3	15.5	7.3	0.8	0.1	0.0	1.0	8.2	11.6	9.0
1998	13.2	10.1	13.4	5.9	7.8	0.0	0.0	0.2	0.7	2.6	3.2	3.5
1999	8.6	3.4	15.6	6.9	5.7	0.0	0.0	1.3	1.0	1.5	9.4	11.6
2000	4.0	8.2	5.8	3.3	0.0	0.0	0.0	0.0	0.4	1.5	11.3	6.7
2001	9.1	5.5	12.6	7.9	1.4	0.0	3.4	0.9	4.8	3.3	6.6	9.2
2002	8.2	6.0	5.4	15.6	3.7	0.0	0.0	0.0	0.1	0.4	6.8	9.0
2003	7.2	6.2	7.3	8.2	2.9	0.0	0.0	0.0	1.7	4.3	5.4	7.0
2004	10.2	2.2	9.3	14.6	0.1	0.0	0.0	0.1	3.9	3.3	5.2	13.3

Gitega

Year	J	F	M	A	M	J	J	A	S	O	N	D
1988	15.7	7.0	9.1	15.1	1.3	0.0	1.7	1.5	3.3	6.2	6.5	9.6
1989	8.0	7.6	17.1	11.9	4.0	1.1	0.0	0.6	2.6	5.2	6.2	7.0
1990	1.9	8.9	9.8	6.9	2.9	0.0	0.0	0.0	4.6	4.0	7.5	6.5
1991	8.1	1.6	6.9	7.0	9.4	0.8	0.1	0.0	0.6	5.5	8.3	5.3
1992	6.4	6.5	8.4	9.8	2.5	0.1	0.0	0.0	0.7	4.2	8.9	7.6
1993	6.4	9.5	7.9	5.0	3.3	0.0	0.0	0.1	0.0	0.1	8.1	7.0
1994	6.6	7.3	7.3	7.4	2.4	0.3	0.0	2.0	0.7	6.1	5.8	7.4
1995	7.5	4.8	5.0	8.3	7.2	0.5	0.0	0.0	0.6	7.7	4.9	4.8
1996	6.8	8.8	9.2	8.9	1.2	0.1	0.0	0.6	2.5	3.2	5.7	7.1
1997	16.3	1.2	7.3	14.7	6.8	0.5	0.0	0.0	0.3	6.5	13.1	12.6
1998	11.5	14.8	11.5	5.4	5.5	0.4	0.0	0.0	0.5	3.4	1.9	1.8
1999	8.3	8.2	10.4	5.4	1.9	0.0	0.0	1.8	4.4	2.1	10.8	8.4
2000	3.6	3.7	4.7	3.7	0.3	0.0	0.0	0.0	0.3	4.2	10.2	6.6
2001	11.5	6.1	8.0	6.5	2.9	0.0	2.0	1.7	4.8	3.5	5.9	7.6
2002	8.0	4.9	6.3	14.4	1.8	0.0	0.0	0.0	0.0	3.8	7.2	11.4
2003	10.1	4.1	4.9	3.8	2.5	0.0	0.0	0.0	1.7	3.4	4.3	6.8
2004	4.9	8.4	8.1	14.2	0.0	0.0	0.0	0.0	5.0	2.4	10.0	7.4

Nyamuswaga

Year	J	F	M	A	M	J	J	A	S	O	N	D
1980	7.1	9.0	8.5	7.0	6.5	0.1	0.0	0.0	6.4	9.7	14.5	4.7
1981	6.9	3.4	6.9	9.6	5.5	0.4	0.0	1.8	5.0	6.8	3.8	9.7
1982	10.9	6.4	6.9	14.7	10.1	0.4	0.0	0.0	3.4	12.1	12.9	8.5
1983	3.1	9.6	10.8	11.2	8.1	0.2	0.2	1.7	0.7	10.3	17.1	8.4
1984	11.1	5.8	7.8	7.8	1.1	0.0	1.3	4.2	14.3	9.0	14.7	5.9
1985	5.8	8.4	6.9	16.5	2.9	0.9	0.0	0.9	6.5	7.6	11.0	8.8
1986	9.0	10.7	11.2	16.9	7.4	0.0	0.0	0.2	2.0	5.7	5.7	5.9
1987	10.9	4.7	6.6	15.6	3.8	2.0	0.0	0.0	9.2	6.4	17.4	3.9
1988	7.4	6.3	10.5	34.0	1.6	0.0	0.3	1.6	4.6	10.7	5.8	7.4
1989	6.0	6.7	10.9	8.4	4.6	8.2	0.1	0.6	1.8	10.9	8.0	11.5
1990	4.9	13.8	12.6	4.4	2.2	0.0	0.0	0.0	10.1	5.6	5.4	9.9
1991	8.1	2.3	6.4	15.4	8.4	1.5	0.1	0.2	3.0	7.2	11.4	5.8
1992	3.7	5.7	6.5	9.8	4.1	0.4	0.0	0.0	1.9	6.3	9.0	8.3
1993	5.8	7.8	5.0	8.6	4.0	0.1	0.0	1.9	0.2	2.3	7.4	6.5
1994	6.3	4.6	11.0	7.6	4.9	0.0	0.0	0.1	2.0	10.0	8.0	9.8
1995	5.0	5.5	4.6	12.5	8.0	1.7	0.0	0.1	1.8	12.1	7.2	9.1
1996	6.4	11.6	12.6	5.4	1.7	0.3	0.0	1.6	4.1	5.1	4.6	6.1
1997	7.3	1.8	7.1	9.8	8.3	1.5	0.1	1.5	1.3	8.5	8.7	19.7
1998	11.9	9.0	11.8	8.3	2.9	1.1	0.0	0.0	1.8	6.4	6.6	7.7
1999	5.6	3.4	9.4	6.3	3.5	0.0	0.0	2.0	4.2	3.4	7.0	7.5
2000	5.0	4.0	11.6	6.2	2.6	0.0	0.0	0.1	1.3	2.3	13.0	8.8
2001	5.4	6.8	6.1	6.0	6.2	0.1	1.8	0.6	9.0	6.4	6.0	6.0
2002	7.7	4.3	5.6	10.7	5.0	0.0	0.0	0.0	3.4	3.4	9.6	7.2
2003	6.3	6.3	5.9	11.7	4.6	0.0	0.1	0.8	3.2	7.0	4.8	8.7
2004	8.3	11.3	12.9	10.7	0.0	0.0	0.2	0.2	3.0	3.7	8.9	4.6

Ruvyironza

Year	J	F	M	A	M	J	J	A	S	O	N	D
1975	6.3	6.7	15.1	7.3	5.0	0.2	2.1	0.0	3.9	6.4	8.0	5.5
1976	12.0	11.7	6.1	11.1	4.1	0.0	0.0	0.6	2.2	3.8	5.9	6.6
1977	14.0	10.2	10.8	15.1	3.4	0.0	0.0	1.8	2.5	3.1	15.3	8.7
1978	7.8	9.7	14.2	10.8	2.4	0.0	0.0	1.1	1.9	6.6	14.9	12.4
1979	11.0	9.0	6.9	15.8	2.6	0.2	0.0	0.0	0.0	4.0	5.6	10.3
1980	6.7	10.9	10.1	3.6	7.4	0.5	0.0	0.1	2.9	7.6	10.1	9.5
1981	8.2	9.0	11.8	8.6	4.0	0.0	0.0	1.2	4.9	3.6	11.4	9.2
1982	12.0	8.8	9.9	12.3	7.5	0.6	0.0	0.0	0.7	8.5	11.2	10.1
1983	5.9	15.2	6.2	10.1	2.8	0.1	0.0	1.8	1.7	6.8	9.0	8.4
1984	11.7	11.7	5.6	9.2	1.2	0.0	0.2	1.9	0.7	7.3	10.1	12.7
1985	9.8	8.8	15.4	17.0	3.2	0.0	0.0	0.0	2.6	7.0	8.7	7.5
1986	12.7	10.0	10.2	12.1	4.3	0.0	0.0	0.4	3.7	2.9	11.8	7.5
1987	11.8	7.1	6.2	3.4	5.1	0.3	0.0	0.2	3.9	5.1	6.8	6.7
1988	15.9	7.6	12.5	11.8	1.7	0.2	0.0	3.0	1.8	3.0	10.2	9.0
1989	11.6	13.6	16.9	5.6	6.3	1.9	0.0	1.8	4.5	6.3	7.3	10.7
1990	4.3	16.0	13.4	9.5	3.2	0.0	0.0	0.9	1.7	6.1	4.9	6.8
1991	9.4	10.0	5.6	9.4	5.5	1.9	0.0	1.2	3.8	7.6	8.3	7.7
1992	7.5	16.5	5.1	7.8	3.3	0.4	0.1	0.0	0.1	7.6	11.6	9.5
1993	10.3	8.4	11.6	6.9	6.0	0.0	0.0	0.2	0.1	1.6	8.0	7.0
1994	8.7	8.6	14.0	7.4	4.6	0.0	0.0	0.2	2.2	7.0	9.7	9.0
1995	12.5	9.6	10.5	11.3	6.1	1.4	0.0	0.0	0.8	9.2	9.7	8.8
1996	12.8	10.1	17.0	11.3	1.5	0.0	2.1	1.6	4.8	7.1	7.4	11.3
1997	10.2	9.8	6.5	11.2	4.1	1.7	0.0	0.0	1.0	7.6	13.6	16.3
1998	11.9	8.2	9.6	13.2	4.1	0.2	0.0	0.0	0.5	8.4	4.7	7.2
1999	13.7	7.3	13.1	7.0	1.9	0.0	0.0	2.4	2.4	1.6	9.5	7.9
2000	8.7	10.3	8.2	2.9	0.2	0.0	0.0	0.0	2.3	4.4	18.7	13.6
2001	10.5	9.9	11.2	9.8	4.8	0.0	0.9	0.1	6.9	4.9	10.0	10.3
2002	14.3	2.8	8.9	15.5	0.7	0.0	0.0	0.0	1.0	3.8	15.3	16.2
2003	6.0	5.7	11.5	9.0	4.7	0.0	0.0	0.4	2.0	4.1	8.1	10.0
2004	7.2	10.1	9.1	7.3	0.0	1.1	0.0	0.1	5.9	3.6	10.6	9.6

Karuzi

Year	J	F	M	A	M	J	J	A	S	O	N	D
1975	3.6	5.2	7.5	6.6	2.7	0.2	1.7	0.0	4.0	5.8	3.5	8.1
1976	7.7	5.0	6.6	8.4	4.6	1.8	0.0	0.0	3.0	2.5	7.2	5.3
1977	13.5	6.1	4.2	21.0	8.9	0.0	0.0	0.0	1.4	0.6	7.9	7.2
1978	6.0	4.5	12.9	8.1	4.7	0.4	0.0	0.2	3.9	9.2	7.0	10.9
1979	5.3	11.0	28.7	16.6	3.2	0.6	0.0	0.0	0.3	2.4	12.1	5.8
1980	6.3	4.1	3.1	5.3	8.7	0.0	0.0	0.0	1.9	2.2	7.3	6.7
1981	5.8	4.4	11.2	3.0	12.8	0.0	0.0	0.7	2.3	7.8	3.2	9.5
1982	5.1	3.8	6.9	10.9	4.8	0.0	0.0	0.0	0.4	4.4	10.7	4.5
1983	2.1	5.5	4.8	6.1	0.6	0.0	0.0	2.8	1.5	2.3	7.0	8.5
1984	6.8	7.1	3.5	8.3	0.9	0.0	0.0	2.3	0.6	2.3	5.8	1.6
1985	3.1	4.3	3.4	25.0	2.0	0.0	0.0	0.0	8.6	10.1	15.1	16.8
1986	15.7	8.1	5.3	17.3	2.5	0.0	0.0	0.0	0.3	4.5	6.8	6.6
1987	8.5	3.2	8.6	9.1	4.8	0.0	0.0	0.1	2.0	7.8	12.3	1.6
1988	8.9	3.1	9.1	11.0	1.0	0.0	0.1	1.2	3.7	6.7	3.1	8.0
1989	6.1	3.0	9.6	6.3	3.7	4.5	0.0	0.8	1.2	5.3	7.7	10.2
1990	3.4	7.7	11.2	3.6	1.2	0.0	0.0	0.2	3.2	4.8	8.3	8.4
1991	3.9	8.1	10.5	6.6	11.0	1.2	0.0	0.0	0.8	4.7	5.4	6.4
1992	3.9	5.8	8.1	13.6	3.5	0.2	0.0	0.0	0.5	10.3	8.2	5.8
1993	11.0	6.4	8.2	7.3	5.4	0.1	0.0	1.0	0.0	0.4	8.2	3.6
1994	5.6	6.8	6.9	8.7	3.0	3.2	0.0	0.0	0.1	1.1	5.0	29.8
1995	4.9	5.7	1.7	2.2	4.2	0.6	0.0	0.0	1.3	3.3	2.2	6.5
1996	7.5	6.2	3.7	3.7	0.9	0.0	0.0	0.9	5.3	2.7	6.2	3.6
1997	6.0	7.0	8.5	9.3	6.9	0.6	0.0	0.5	0.2	6.7	11.5	16.8
1998	10.9	19.1	24.5	11.1	3.6	0.1	0.0	0.0	2.0	5.7	4.1	6.0
1999	5.2	4.6	12.5	9.9	1.9	0.0	0.0	1.8	2.9	2.3	15.2	11.5
2000	6.3	9.9	10.6	3.6	1.4	0.0	0.0	0.0	0.1	1.2	26.0	11.2
2001	9.4	5.4	6.4	6.6	6.2	0.0	2.0	0.0	9.5	7.2	10.9	10.9
2002	14.7	4.0	13.9	13.3	6.6	0.0	0.0	0.0	0.4	3.8	13.9	11.9
2003	5.5	3.5	8.9	9.5	5.3	0.0	0.0	0.1	1.7	4.7	6.9	7.1
2004	7.9	9.8	13.8	12.5	0.2	0.0	0.0	0.5	4.0	2.6	7.2	8.4

Kirundo

Year	J	F	M	A	M	J	J	A	S	O	N	D
1980	3.0	4.7	3.6	4.2	8.0	0.3	0.0	0.0	5.1	4.1	7.1	3.2
1981	3.3	2.7	11.3	7.4	7.2	0.3	0.0	2.0	10.2	11.1	3.5	5.7
1982	2.2	1.5	4.0	5.9	4.9	0.8	0.3	0.1	7.3	6.7	9.0	7.8
1983	0.6	4.1	3.4	10.8	5.5	0.5	0.0	1.8	3.8	4.9	5.2	5.2
1984	5.6	3.5	6.6	7.0	1.4	0.0	0.6	0.8	4.9	5.0	4.5	2.4
1985	4.4	8.6	4.2	17.6	2.5	0.8	0.0	0.0	5.6	6.5	4.8	6.6
1986	4.6	3.5	7.2	17.5	3.3	1.8	0.0	0.0	1.9	9.7	5.6	3.8
1987	5.3	4.4	7.9	6.3	4.4	0.1	0.0	0.4	2.6	8.0	12.5	12.8
1988	3.6	3.9	7.2	13.1	2.0	0.1	0.0	3.8	2.6	8.4	8.7	4.0
1989	3.4	4.6	5.2	6.9	3.9	1.4	1.5	1.6	2.7	4.2	4.7	6.4
1990	4.4	8.1	5.7	8.9	5.5	0.0	0.0	0.5	2.9	5.5	9.0	6.2
1991	4.9	4.0	4.1	7.9	9.6	0.8	0.2	0.0	1.3	7.1	3.7	3.7
1992	1.2	1.4	6.0	9.4	4.5	2.1	0.0	0.0	1.1	5.4	5.3	7.6
1993	4.4	6.2	6.6	7.4	4.8	0.1	0.0	2.0	2.6	4.7	5.3	6.2
1994	3.7	4.5	6.0	6.5	5.7	0.0	0.2	1.3	0.8	5.6	8.8	4.7
1995	2.5	4.6	3.7	10.6	5.4	3.3	0.0	0.0	1.7	6.8	5.5	4.8
1996	3.1	4.8	5.6	10.3	2.0	0.2	0.0	1.1	3.4	3.5	4.6	5.0
1997	4.2	1.0	5.4	10.9	6.3	0.1	0.0	0.9	0.3	4.9	11.2	2.3
1998	13.1	6.4	6.2	8.9	5.2	1.1	0.4	0.1	1.8	4.7	1.9	10.4
1999	2.8	0.5	9.3	4.7	3.9	0.0	0.0	2.0	4.9	3.3	3.3	1.3
2000	1.7	3.5	7.7	5.0	2.5	0.0	0.0	0.0	1.4	3.5	4.2	7.6
2001	7.0	1.7	3.1	6.2	3.0	0.3	1.8	1.6	5.8	5.9	3.7	4.6
2002	4.9	4.3	8.0	9.0	6.3	0.0	0.0	0.0	2.0	2.9	0.6	2.7
2003	5.8	3.8	6.0	12.7	4.8	0.1	0.4	1.7	3.4	3.4	4.9	2.6
2004	3.2	7.5	7.1	10.2	1.2	0.0	0.2	0.0	3.8	2.8	7.4	5.4

Muyinga

Year	J	F	M	A	M	J	J	A	S	O	N	D
1975	6.0	4.6	6.3	8.9	3.8	0.0	0.7	0.1	8.4	6.4	3.8	7.4
1976	2.7	4.7	4.7	7.6	2.5	0.0	0.6	1.0	2.6	3.2	6.7	7.8
1977	9.4	3.9	7.5	17.1	6.5	0.1	0.0	1.8	2.9	2.1	8.9	5.5
1978	4.6	4.9	12.7	9.8	3.3	0.1	0.0	1.2	2.3	5.7	3.8	6.3
1979	13.1	7.2	5.2	10.5	3.9	1.3	0.0	0.0	1.3	2.9	6.7	7.3
1980	4.1	3.8	5.7	5.7	3.5	1.1	0.0	0.6	1.8	5.2	7.9	7.0
1981	3.9	3.6	7.8	6.4	4.2	0.0	0.0	1.9	3.0	4.3	4.6	3.0
1982	5.9	1.2	5.6	11.1	6.4	0.6	0.2	0.0	2.9	4.2	11.7	7.5
1983	2.0	7.9	7.1	11.5	3.4	0.0	0.0	1.8	3.6	5.1	5.0	4.2
1984	3.7	3.4	6.1	3.6	0.5	0.0	0.7	5.5	3.1	8.5	15.5	3.4
1985	5.7	10.7	3.9	13.2	4.1	0.0	0.0	0.3	5.0	6.3	10.1	7.6
1986	6.0	5.1	8.3	18.1	3.0	1.9	0.0	0.1	1.4	8.8	8.6	2.7
1987	7.5	3.3	11.8	10.6	9.5	1.4	0.0	0.1	6.7	4.7	16.8	3.1
1988	16.5	8.1	8.5	14.4	1.9	0.3	0.0	2.0	1.5	9.5	4.1	6.6
1989	1.7	9.0	6.3	6.0	7.6	3.2	0.0	1.3	2.0	5.1	4.3	10.0
1990	3.5	9.7	7.8	5.5	3.3	0.0	0.0	0.9	3.9	5.1	5.6	7.9
1991	4.7	4.3	6.9	7.6	8.1	2.0	0.0	1.1	1.1	7.3	5.4	4.0
1992	5.3	6.9	4.9	15.5	2.2	0.4	0.0	0.0	1.7	5.7	3.4	7.4
1993	11.1	2.5	7.6	13.3	3.9	0.0	0.0	1.7	0.0	4.0	4.1	7.2
1994	5.4	4.1	8.3	5.7	4.5	0.0	0.0	0.4	0.1	6.7	11.5	6.7
1995	4.3	8.0	3.3	8.2	6.6	1.8	0.0	0.0	2.0	3.7	5.9	5.7
1996	4.3	5.6	13.9	4.6	7.0	0.0	0.1	2.0	3.5	5.6	5.4	7.8
1997	7.0	3.1	9.7	15.5	4.9	0.2	0.0	1.1	0.7	6.4	11.5	19.4
1998	9.4	6.4	11.1	6.2	2.3	0.4	0.0	0.0	2.0	3.5	2.9	2.9
1999	5.1	5.6	0.8	13.2	3.7	2.0	0.0	0.0	0.9	2.0	2.7	6.5
2000	4.5	1.9	12.0	4.6	1.1	0.1	0.0	0.0	0.5	4.3	7.4	8.9
2001	6.9	7.0	7.6	7.3	2.9	0.1	0.0	0.1	9.2	5.3	11.4	3.5
2002	7.2	1.9	7.8	9.5	5.2	0.0	0.0	0.0	0.8	2.4	7.1	8.6
2003	5.8	3.0	3.9	9.9	5.4	0.0	0.0	0.9	2.0	4.8	5.7	6.6
2004	6.9	8.5	12.1	11.7	1.8	0.0	0.0	0.1	2.0	4.2	6.6	3.8

Appendix 15: Variation of mean temperature within the study area.

Stations	J	F	M	A	M	J	J	A	S	O	N	D
Bujumbura	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Makamba	0.02	0.03	0.03	0.03	0.03	0.03	0.05	0.03	0.03	0.03	0.03	0.06
Mparambo	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.04	0.02	0.03
Gisozi	0.02	0.03	0.03	0.03	0.02	0.03	0.03	0.02	0.03	0.03	0.03	0.02
Mpota-Tora	0.08	0.04	0.15	0.13	0.14	0.06	0.03	0.04	0.03	0.02	0.02	0.03
Rwegura	0.02	0.04	0.03	0.03	0.04	0.03	0.03	0.03	0.08	0.04	0.03	0.04
Cankuzo	0.03	0.13	0.18	0.18	0.18	0.18	0.19	0.13	0.13	0.13	0.15	0.13
Kinyinya	0.02	0.03	0.02	0.02	0.02	0.03	0.03	0.03	0.13	0.13	0.12	0.13
Musasa	0.02	0.03	0.03	0.02	0.02	0.03	0.04	0.03	0.06	0.03	0.03	0.02
Muriza	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.07	0.03	0.03
Nyamuswaga	0.02	0.04	0.03	0.03	0.04	0.04	0.03	0.03	0.03	0.07	0.02	0.02
Ruvyironza	0.03	0.04	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.03	0.03	0.02
Karuzi	0.03	0.04	0.03	0.04	0.03	0.03	0.05	0.03	0.03	0.04	0.03	0.03
Gitega-Aero	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.04	0.03	0.03
Kirundo	0.03	0.04	0.04	0.03	0.02	0.03	0.03	0.16	0.09	0.08	0.08	0.08
Muyinga	0.03	0.03	0.03	0.02	0.02	0.03	0.03	0.03	0.07	0.04	0.03	0.03

Appendix 16: Results of Mann-Kendall test for the months considered.

	Gisozi				Mpota-Tora			
Months	S	V	Z	P	S	V	Z	P
May	-35	3142	-0.61	0.27	8	3142	0.12	0.55
June	-37	3142	-0.64	0.26	-69	3142	-1.21	0.11
July	-33	3142	-0.57	0.28	48	3142	0.84	0.80
August	-34	3142	-0.59	0.28	-35	3142	-0.61	0.27
September	-31	3142	-0.54	0.30	-51	3142	-0.89	0.19
October	32	3142	0.55	0.51	-29	3142	-0.50	0.31

	Rwegura				Cankuzo			
Months	S	V	Z	P	S	V	Z	P
May	-43	3142	-0.75	0.23	-66	3142	-1.16	0.12
June	-86	3142	-1.52	0.06	-59	3142	-1.03	0.15
July	44	3142	0.77	0.78	-50	3142	-0.87	0.19
August	-42	3142	-0.73	0.23	-51	3142	-0.89	0.19
September	41	3142	0.71	0.56	-31	3142	-0.54	0.30
October	25	3142	0.43	0.67	-67	3142	-1.18	0.12

	Kinyinya				Musasa			
Months	S	V	Z	P	S	V	Z	P
May	-47	3142	-0.82	0.21	-115	3142	-2.03	0.02
June	64	3142	1.12	0.57	-22	3142	-0.37	0.35
July	-35	3142	-0.61	0.27	-14	3142	-0.23	0.41
August	-32	3142	-0.55	0.29	-57	3142	-1.00	0.16
September	-52	3142	-0.91	0.18	7.0	3142	0.11	0.54
October	-29	3142	-0.50	0.31	-23	3142	-0.39	0.35

	Muriza				Ruvyironza			
Months	S	V	Z	P	S	V	Z	P
May	-44	3142	-0.77	0.22	-1.0	3142	0.00	0.50
June	9	3142	0.14	0.56	-29	3142	-0.50	0.31
July	-49	3142	-0.86	0.20	0.0	3142	0.00	0.50
August	-34	3142	-0.59	0.28	-52	3142	-0.91	0.18
September	-51	3142	-0.89	0.19	22	3142	0.37	0.65
October	-25	3142	-0.43	0.33	67	3142	1.18	0.68

	Karuzi				Gitega			
Months	S	V	Z	P	S	V	Z	P
May	-19	3142	-0.32	0.37	-81	3142	-1.43	0.08
June	-42	3142	-0.73	0.23	-5	3142	-0.07	0.47
July	16	3142	0.27	0.61	-46	3142	-0.80	0.21
August	44	3142	0.77	0.68	-64	3142	-1.12	0.13
September	-1.0	3142	0.00	0.50	-93	3142	-1.64	0.05
October	-8.0	3142	-0.12	0.45	-23	3142	-0.39	0.35

	Kirundo				Muyinga			
Months	S	V	Z	P	S	V	Z	P
May	-82	3142	-1.45	0.07	-26	3142	-0.45	0.33
June	-43	3142	-0.75	0.23	16	3142	0.27	0.51
July	55	3142	0.96	0.53	-78	3142	-1.37	0.08
August	-28	3142	-0.48	0.32	-87	3142	-1.53	0.06
September	-49	3142	-0.86	0.20	3.0	3142	0.04	0.51
October	-47	3142	-0.82	0.21	-80	3142	-1.41	0.08

	Nyamuswaga			
Months	S	V	Z	P
May	-161	3142	-2.85	0.002
June	-131	3142	-2.32	0.01
July	-29	3142	-0.50	0.309
August	-122	3142	-2.16	0.015
September	-179	3142	-3.18	7E-04
October	-241	3142	-4.28	9E-06