Environment and Ecology Research 6(1): 12-32, 2018 http://www.hrpub.org
DOI: 10.13189/eer.2018.060102

Forecast of Agricultural Calendar for Maize (Zea Mays) from Global Circulation Model in the Ruzizi Area (DRC)

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Abstract The world is facing several major challenges that regarding answer to the current economic crisis and the development of appropriate strategies to mitigate the adverse effects of climate change. The objective of the study is to identify climate risks for maize and the development of an agricultural calendar from a global circulation model. From meteorological data, an agro-climatic analysis was performed during the period 1995-2013 and a forecast from 2015 to 2045 has been done. The results showed that maize is facing major agro-climatic risks from the shortening of the vegetative growth period consecutive to a screeching halt rains before the end of the rainy season which is one of the major agro-climatic constraints. From predicting Echam-5 model, the agricultural calendar was adjusted to avoid the drop in rainfall observed in October and plan the sowing period at the end of October instead of September.

Keywords Models, Maize, Climate Change, Forecast

1. Introduction

1.1. Background

Maize is vital for the food security of many vulnerable populations (Bruinsma, 2009). It is also an important crop for its impact in the economy as a commodity. As any other crop, maize production is sensitive to climate, and climate is changing in ranges that are expected to alter maize crop efficiency (Adams et al., 1998; FAO, 2012). It is therefore important that we understand how maize growth will be affected by changing climate factors. Given that future climate may be different in many maize cropping regions from what has ever been observed, especially as far as temperature and [CO_2] are concerned, process-based models are therefore essential tools to address that question.

In the Ruzizi plain maize is the most cultivated cereal. The maize growing area accounts for three-quarters of the total area of the province of South Kivu. Since the 2000s, the area planted with maize has been steadily increased. The emergence of improved seed producers and seed farms is strongly demanded both within and outside the country, including neighboring countries such as Rwanda and Burundi. Today, Maize enters the culinary habits and especially becomes a raw material for the breweries. It is mainly intended for self-consumption and provides variable cash income depending on the farm. Corn residues are also an important source of animal feed. Finally, from a food-based crop, maize has gradually become a cash crop with greater receptivity to technical improvements. However, maize cultivation is an agricultural activity sensitive to the vagaries of climate and weather (DGPER, 2010)

The very heavy rains and the flooded fields everywhere in the hamlets and villages of Ruzizi area are the main topics of farmers' conversations. Finding water standing in their fields after heavy rains are common; their fields were actually flooded was less so. Their main concerns are the young age of their crops, paddy, and maize, and the already retarded growth due to a long drought in the past period.

The farmers, whose fields were heavy black clay soil, feared possible damages to their crops. That turned out to be the case. The roots and stems of the 30–40-days-old maize decayed. Their leaves turned yellow, as did the paddy leaves. Other crops, such as chili, were also badly affected (Winarto and Stigter 2011).

These surprising facts were examples of a real risk resulting from an increase of climate variability and climate-related extreme events as consequences of climate change (see OXFAM 2009). The question remains, therefore, how to help farmers respond better to these phenomena, which they are currently unable to cope with. Direct experience and empirical observations are the main means of learning in the local domain of knowledge. Without directly seeing, feeling, and experiencing the phenomena they encounter in daily life, they will not have any confidence or belief in their own or other people's interpretation and sayings (see Winarto 2004; 2010).

Phenomena of climate change and variability cannot be observed directly by farmers themselves, and the impact on farmers' lives cannot easily be predicted or anticipated. On the other hand, farmers can rely on their memories and recent experience to develop their expectations of the future, and this shapes their knowledge of climate phenomena and their understanding of climate information (see Roncoli *et al.* 2003, 181) [1]. As also argued by Peterson and Broad (2009, 78) [2].

1.2. Problem Statement

While the seasonal variability of weather is a major source of production risks (Fraisse et al., 2006), significant benefits have arisen from the use of seasonal climate forecasts. Nonetheless, it is now widely accepted that the existence of predictable climate variability and impacts is necessary but not sufficient to achieve effective use of seasonal forecasts (Podesta et al., 2002). The realization of such benefits has been shown to require deliberate efforts to design and implement effective mechanisms for using climate information in the service of society. Several empirical studies have identified theoretical and practical obstacles to the use of climate information and forecasts (for example, Mjelde et al., 1998; Stern and Easterling, 1999; Agrawala et al., 2001).

Weather plays an important role in agricultural production. It has a profound influence on crop growth, development and yields; on the incidence of pests and diseases; on water needs; and on fertilizer requirements. This is due to differences in nutrient mobilization as a result of water stresses, as well as the timeliness and effectiveness of preventive measures and cultural operations with crops.

Occurrences of erratic weather are beyond human control. It is possible, however, to adapt to or mitigate the effects of adverse weather if a forecast of the expected weather can be obtained in time. Rural proverbs abound in rules of thumb for anticipation of local weather and timing of agricultural operations in light of expected weather. Basu (1953) found no scientific basis for anticipation of weather in many of the popular proverbs and folklore. In a recent study, Banerjee et al. (2003) arrived at conclusions similar to that of Basu (1953). The proverbs and local lore show, however, that farmers have been keen to know in advance the likely weather situations for crop operations from time immemorial. Agronomic strategies to cope with changing weather are available. For example, delays in the start of crop season can be countered by using short-duration varieties or crops and thicker sowings. Once the crop season starts, however, the resources and technology get committed and the only option left then is to adopt crop-cultural practices to minimize the effects of mid-seasonal hazardous weather phenomena, while relying on advance notice of their occurrence. For example, resorting to irrigation or lighting trash fires can prevent the effects of frosts. Thus, medium range weather forecasts with a validity period that enables farmers to organize and carry out appropriate cultural operations to cope with or take advantage of the forecasted weather are clearly useful. The rapid advances in information technology and its spread to rural areas provide better opportunities to meet the rising demand among farmers for timely and accurate weather forecasts.

Otherwise, the region of the Ruzizi plain is located in an agropastoral zone characterized by a recent strong anthropization. Nearly 90% of the population practices subsistence agriculture (KITAKYA, 2007). This agriculture, vital for the local population, is closely dependent on the rainfall regime and its excesses, which affect agricultural yields at different scales of time and space. Unfortunately, the rainfall characteristics of these rainfall events are poorly studied as they influence the evolution of local ecosystems.

All these phenomena, supposedly extreme by the local population, are not argued objectively on scientific grounds. NEW et al. (2006) and AGUILAR et al. (2009) state that there is a lack of information on trends in rainfall and climate extremes in many regions across developing countries. SOLOMON et al. (2007) and OZER et al. (2009) also estimate that rainfall indices are still too little studied in the DRC and sub-Saharan Africa in general.

MAHÉ (1993) points out that the equatorial zone is a highly contrasted hydrological environment and that it remains linked to the complexity of the ocean-atmosphere system that generates precipitation, a complexity due to its position straddling the two hemispheres. Despite the often dramatic consequences of rainfall fluctuations on agriculture and the environment in the Ruzizi plain, its variability remains poorly known, as are the extreme values in its chronological series. On the other hand, it should be noted that the strong anthropization in the Ruzizi plain area by the presence of refugees followed by a significant degradation of natural resources would only accentuate this climatic variability and / or its impacts in the region.

It is therefore necessary to carefully analyze the seasonal cycle of rainfall. Indeed, the interest of this type of study lies in the fact that extreme events could become more frequent due to global warming (HOUGHTON et al., 2001) and that it should be considered now. There is currently a strong scientific interest in the field of climatic extremes because they show some important non-linearities and their economic and social consequences on human activity are potentially (NAVEAU et al., 2005).

The question of the effects of anthropogenic climate change on Climatic conditions could only be approached relatively recently, due to the need to develop appropriate methodological tools. The analysis of their results could make it possible to understand how ecosystems (and socio-ecosystems) react to rare but extreme environmental disturbances. In the Ruzizi plain, in recent years, Early in the dry seasons, even if not very marked.

It is therefore understandable that any disturbance of the hydrological regime may in the short term Vulnerable populations already facing water supply problems. As anthropization marks its pace and is growing to the extent that it can now be seen in the Ruzizi plain, vulnerability may increase. Early warning attention should be given to the potential risk in the event of a change in rainfall patterns and, consequently, to the hydrological regime which will require the rehabilitation of the ever-changing socio-ecosystems. This implies an understanding of the rainfall regime in the context of an increase in the rapid demography of the Ruzizi plain is not accompanied by appropriate adjustments, particularly in the field of water management in the broad sense of the term. This study therefore deals with a characterization of the rainfall events, temperature and evapotranspiration of the Ruzizi plain, the prediction of the irrigation schedule. Thus, time series at different time steps have been established. The results of this study will be able to find a direct application at the local level, particularly in the manifestations of climatic phenomena, the occurrence of floods and in the context of activities related to agriculture in the Ruzuzi plain.

1.3. Research Issues

How climatological factors, in particular, the importance and temporal distribution of precipitation, temperature, evapotranspiration, have an effect on the agricultural calendar, growth and yield of maize in the Ruzizi?

1.4. Objectives

- To analyze the climatic factors in particular distributions of rainfall, temperature and evapotranspiration and their effects on the cycle of maize.
- Making a choice of climate model which will be used for the adjustment of the agricultural calendar for maize.

2. Literature Reviews

In human history, the need to understand climate change has never been more urgent and important than in the 21st century, especially in tropical areas where deforestation and extinction of species are relatively more important and living conditions , More precarious (Bush and Flenley, 2007). These phenomena are even more acute in Africa where deforestation is very important. The importance of temporal variability in Africa is due to the fact that climatic parameters, which are supposed to vary over time due to the global seasonal cycle of the planet, also show different trends in different regions. Understanding and predicting these annual, decadal or multi-decadal variations in the recent past has become a challenge for African climate specialists (AMMA ISSC, 2005, Janicot et al., 2008). The development of methods for the prediction of climatic variations over the long term has grown prodigiously (Folland et al., 1991, Stockdale et al., 1998, Washington and Downing, 1999). But this did not identify the root causes of the drastic decline in rainfall in Africa (Rowell et al., 1995, Xue and Shukla, 1998).

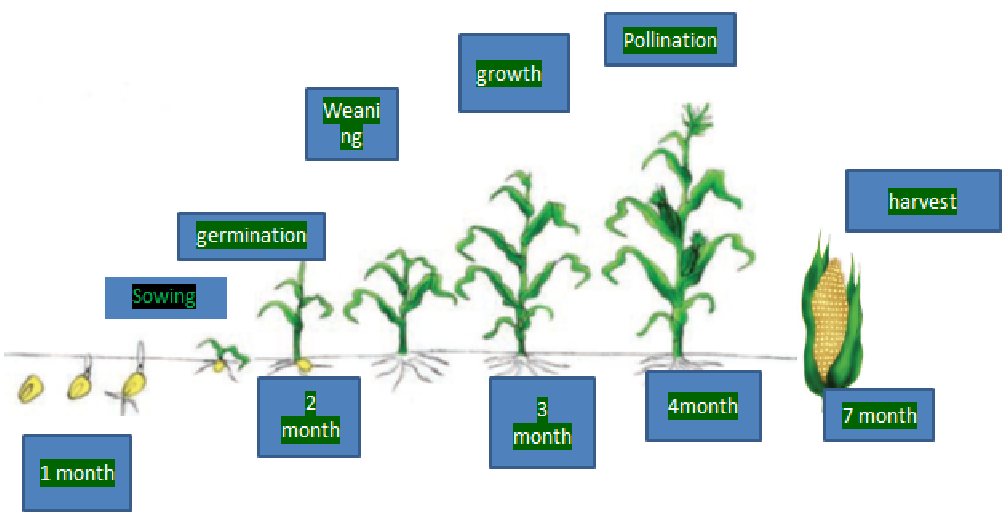


Figure 1. Development of the belated variety of the Maize

2.1. Definitions of Climate, Climate Change and Climate Variability

This sub-section briefly explains the difference between climate, climate change and climate variability and shows the influences of weather producing system on long rainy season in Ruzizi area.

Climate: This is the long-term average weather conditions (usually taken over a period of more than 30 years as defined by the World Meteorological Organization, (WMO) of a region including typical weather patterns such as the frequency and intensity of storms, cold spells, and heat waves **(IPCC, 2007b).**

Climate Change: Climate change in IPCC usage refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods (IPCC, 2007b, WMO, 2014).

Climate Variability: Variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. The term is often used to denote deviations of climatic statistics over a given period of time (e.g. a month, season or year) from the long-term statistics relating to the corresponding calendar period. In this sense, climate variability is measured by those deviations, which are usually termed anomalies. Variability could be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability) (IPCC, 2007b, WMO, 2014). 6

A key difference between climate variability and change is in persistence of anomalous conditions. For instance, an event or sequence of events occurs that has never been witnessed before (or recorded before), such as flood or drought. If such a season does not recur within the next 30 years, we would call it an exceptional year, but not an indication of change **(WMO, 2014).**

The Intergovernmental Panel on Climate Change **(IPCC) (2001)** defines climate change as a statistically significant change in the average state of the climate or in its persistent variation over a long period of time (decades or more). Under the terms of Article 1, paragraph 2, of the United Nations Framework Convention on Climate Change **(UNFCCC) (1992),** climate change refers to "climate changes that are attributed directly or indirectly to human activity that alters Composition of the global atmosphere and in addition to the natural variability of the climate observed in comparable periods ".

2.2. Modified Functioning Ecosystems

Atmospheric carbon is the essential component of the process of photosynthesis, which governs the growth of plants. A dubbing of the carbon sequester in carbon dioxide leads in theory to an increase in photosynthesis, a decrease in the transpiration of the plants and, consequently, an Increase in the biomass produced and potential yields for plants of agricultural interest. The efficiency of converting light energy into biomass and water efficiency are increased, so the potential productivity of plant cover is increased.

This positive response of photosynthesis to a carbon enrichment of the atmosphere depends, however, on different factors. The type of carbonated metabolism, temperature and water availability interferes with the increase in photosynthesis consequent on an increase in the content In carbon, for example, whereas C3 plants (rice, wheat, beet, pea, ect), which predominate in temperate zones, strongly respond to an increase in atmospheric carbon tensor in the considered concentration range, Of C4 plants (sorghum, sugar cane) has an enrichment of the atmosphere is very low in excess of 400 parts per million, current content of the atmosphere **(Malezieux, 2004).**

Corn is a demanding water plant. In addition, it is more sensitive to drought (Sarr et al., 1999) than other dry cereals such as millet and sorghum. The water requirements of maize increase with cycle length and type of climate. Depending on climatic conditions, it takes between 400 mm and 800 mm of well distributed rain to close its cycle with a temperature sum of 1500 to 1800 degree days (Doorenbos and Kassam, 1980). However, excess water can cause Root rot and asphyxia of maize plants. Corn yields depend more on the availability of water resources during the critical phases of development than the total cumulative rainfall over the entire cycle (Robelin, 1963).

2.3. Effects of Climate Change on the Agricultural Sector

If the biology of plant and animal species is disrupted, their dynamics, interaction, equilibrium and ultimately their geographical distribution are likely to change. These changes will affect wild species, crop species, but also pests and diseases Natural ecosystems, subject to a change in species balance and increased competition with agriculture, may deteriorate or even disappear in fragile areas, such as in some estuaries, deltas and lagoons subject to the rise of the sea level **(Malézieux, 2004).**

2.4. Direct Effects on Yields: Rainfed Crops and Irrigated Crops

Changes in rainfed crop yields arise only from changes in precipitation and temperatures; In irrigated crops, they come only from changes in temperature. In developing countries, yield reductions predominate for most crops without CO_2 fertilization.

Irrigated wheat and rice are hit particularly hard. On average, yields are less affected in developed countries than in developing countries. In fact, in developed countries and for only a few crops, climate change can even lead to higher yields. In the calculation of projections, the East Asia and Pacific region includes both largely temperate China and tropical South-East Asia, masking differences in Effects of climate change specific to these two regions with different climate.

In China some crops behave reasonably well because future high temperatures are favorable where current temperatures are close to the low threshold of the optimum temperature range for these crops. The yields of important crops of Asiedu South-East fall substantially in both scenarios, except in case of efficient CO_2 fertilization in farmers' fields.

South Asia is hit particularly hard by climate change. For almost all crops, this is the region with the greatest drop in yield. With CO_2 fertilization, yield reductions are lower, and in some of these regions, there are some increases in yield compared to 2000 **(Gerald C, Nel et al., 2009). [11]**

2.5. Indirect Effects: Irrigated Crops

Climate change will have a direct impact on the availability of water for irrigated crops. Domestic renewable water resources (IRW) are water available from precipitation. Both climate models show more precipitation on land than it would be without climate change.

In the NCAR scenario, all regions show an increase in IRW. In the CSIRO scenario, the average increase in IRWs is lower than in the NCAR, with a decline of around 4% for the Middle East and North Africa regions and sub-Saharan Africa. In addition to changes in precipitation, higher temperatures caused by climate change increase crop water requirements. The ratio of water consumption to needs is called IWSR (reliability of irrigation water supplies). The lower this ratio, the more the water deficit weighs on the yield of irrigated crops. In the developing country group, the IWSR improves in the NCAR scenario but worsens in the CSIRO scenario. However, the effects of climate change vary greatly across regions **(Gerald et al, 2009).**

2.6. The SRES Emissions Scenarios

A1. The A1 storyline and scenario family describe a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: 17

- Fossil intensive (A1FI)
- Non - fossil energy sources (A1T), or
- Balance across all sources (A1B)

(balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

A2. The A2 storyline and scenario family describe a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological changes are more fragmented and slower than in other storylines.

B1. The B1 storyline and scenario family describe a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

B2. The B2 storyline and scenario family describe a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels (IPCC, 2000).

2.7. Climate Change in Facing to Agricultural Calendar in Different African Regions

The analysis of the annual cumulative rainfall of the 1979-2008 series showed that in 80 years the cumulative rainfall is still ≥ 620 mm in the Sudano-Sahelian zone and can even reach values of more than 900 mm in the Sudanian zone. Doorenbos and Kassam (1980) showed that the total water requirements of maize varied between 500 and 800 mm of rainfall. In Burkina Faso, they range between 415 mm in the Sudanian zone and 544 mm in the Sahelian zone (Barry, 2007). In the study area, maize water requirements throughout its cycle will be met annually by total rainfall. The satisfaction of the total water requirements of maize by considering the total rainfall amounts does not therefore constitute a risk for maize cultivation in the Sudanian and Sudano-Sahelian zones of Burkina Faso. A recent study by Kambire et al. (2010) in Burkina Faso showed that grain yield was not affected by rainfall during the first two months of the maize development cycle. Rather, the rainfall of the third month after sowing and the application of nitrogen fertilization explain the variability of yields. Analysis of the length of the season showed that 80% of the years it is ≥ 90 to 100 days approximately in Sudano-Sahelian zone. This length can reach 140 days or more in the Sudanian zone. The length of the rainy season is sufficient in more than 80% of the years so that maize crops of 100 days in the Sudanian zone and 90 days in the Sudano-Sahelian zone normally close their cycle. The results of the campaign start dates show that the rainy season is mostly settled before the 30th of May in the Sudanian zone and before the beginning of June in the Sudano-Sahelian zone. The relatively high values of the standard deviations of the start dates from the end dates indicate a greater interannual variability of the wintering facility.

It has been noted that in recent years the beginnings and ends of rainy seasons have become less and less predictable for farmers (Sivakumar, 1988, Diop, 1996, Diouf et al., 2000). Analysis of dry sequences at the beginning of the cycle shows that maize can be sown from May in the Sudanian zone and from the first dekad of June in the Sudano-Sahelian zone. However, cross-analysis of probabilities of occurrence of dry sequences ≥ 10 days, 30 days after sowing and during corn bloom allowed us to locate the favorable seeding period for maize from the third dekad of May for the area Sudanian and the first dekad of June for the Sudano-Sahelian zone. These results confirm the dates of recommendations on the sowing dates of maize in Burkina Faso (Sanou, 1989). Knowledge of the date favorable to sowing makes it possible to reduce the risks of resorestation or occurrence of water stress that is harmful to the vegetative phase. Indeed, the work of Pindard (2000) showed that even if maize can tolerate a water stress during periods of upstream migration and until the first silks are released, dry episodes constitute a constraint for the installation and the good Development of maize.

In Togo, Poss et al. (1998) have Demonstrated that if water requirements at the Flowering corn are satisfied unless 60%, yields become very low, Irrespective of the water conditions on The rest of the cycle.

3. Materials and Methods

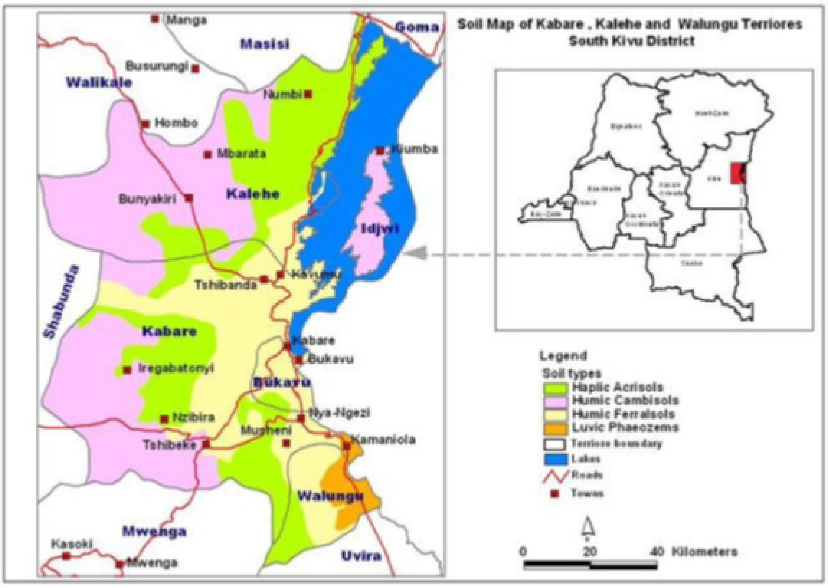
3.1. Description of the Study Area

D'après la classification de Koppen, le climat de la plaine de la Ruzizi appartient au type (AW4) c'est-à-dire à un climat de 4 mois (juin à septembre) au cours des quels les précipitations n'atteignent pas 500 mm **(Germain ,1952**), la température varie entre 18°C minimum et 29°C maximum. La saison des pluies s'étend d'octobre à mai et la saison sèche de juin à septembre.

La répartition annuelle des précipitations est irrégulière. En effet, il n'est pas rare que la saison sèche se prolonge jusqu'en novembre et lorsqu'il arrive de pleuvoir, l'agressivité des premières précipitations ainsi que les ruissellements ne permettent pas au sol de profiter l'apport en eau **(Mango, 1996).**

L'humidité relative moyenne annuelle est d'environ 70%. On rencontre une saison à faible humidité relatif (55-66%) de juin en octobre et une saison à haute humidité relative (supérieure à 70%) d'octobre en mai. Le régime de l'humidité relative est asynchrone avec le cycle de la précipitation, ce qui veut dire que ce n'est pas le mois le plus sec ou le plus pluvieux qui présente le plus faible ou le plus fort pourcentage d'humidité relative mais le mois qui suit.

L'insolation moyenne annuelle dans la plaine de la Ruzizi est. de l'ordre de 50% de l'insolation astronomiquement possible. Ainsi, la période d'insolation maximale (supérieure à 50%) coïncide avec la saison sèche. Elle est suivie par une période d'insolation minimale (41%) en novembre et décembre **(Mashika, 1994).**



Source: INEAC/ dorsale du kivu

Figure 2. Shows the soils map of South Kivu

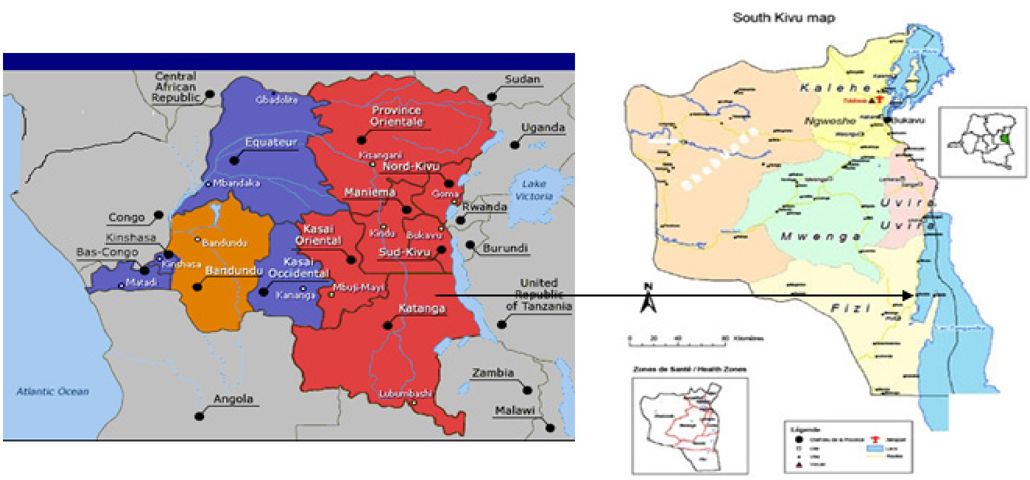


Figure 3. Map of DR Congo

3.2. Collect Data

Several levels of information were considered for structuring data and the construction of a simulation unit. The impact assessment of climate change on agriculture required the collection of detailed data on climate and on agricultural production.

3.3. Data Sources and Quality Assessment

The monthly meteorological data were obtained from Mparambo station and CRH Uvira for a period p of 30 years (1995-2015). These include monthly rainfall, minimum and maximum temperatures and transpiration. Data will be captured into Microsoft Excel 2007. The monthly time series from the station were plotted to identify obvious outliers, which will excluded from the data series.

Outliers will be detected using the weatherMan in DSSAT. In fact, WeatherMan is the program for importing, analyzing, and exporting climate data. In addition, the program has a built-in function that can read weather data with different system of measurement **(Arnold, 2010).**

3.4. Quality Control and Homogeneity Test

The data used in this study will carefully analyze in order to identify missing values and eliminate outlying observations. The homogeneity of the data series of Mparambo weather station will be checked by using R analytical tool **(Xuebin and Feng, 2004).**

In fact, the lack of homogeneity may be due to records of station moves, changes in instrumentation, problems with instrumentation, sensor calibration and maintenance logs, changes in surrounding environmental characteristics and structures, observing practices, and other similar features **(Nathaniel, 1998).**

3.5. Trend Analysis

The mathematical equations for each month over a period of 30 next years for data from local stations were generated in the Eviews software. To find an equation corresponding to a valid series the data was calibrated by a DICKEY-FULLER UNIT ROOT test, so the ADF statistical test should be greater than the standard value of the critical value which is 5%. The maximum proportion beyond which the forecast should be false, called "Bias Proportion" is 0.000000, or if the prediction tends to be false, it is Y (t-1) = AR1.Y (t- Above this value it should be considered as false, the square mean is observed for each month called Root Mean square, then the equations were reproduced in the Excel workbook to generate a time series to observe the trends.

Table showing the series of equations used for the time series, hence t-1 means taking into account the sampling in the last month of the previous year to predict.

Table 1. Represents the mathematical equations for the maximum temperature

MOIS	EQUATIONS	carré moyen racinaire	proprtion biaisé
janvier	Y(t-1)=-0,058792*Yt+30,62429	0,694774	
fevrier	Y(t-1)=-0,177633*Yt+30,89191	0,9793395	0,000 000
mars	Y(t-1)=-0,210226*Yt+30,82833	0,623535	0,000 000
avril	Y(t-1)=0,045523*Yt+30,48877	0,707566	0,000 000
mai	Y(t-1)=0,184806*Yt+30,49450	0,642031	0,000 000
juin	Y(t-1)=-0,120882*Yt+30,94216	0,773083	0,000 000
juillet	Y(t-1)=-0,207184*Yt+31,24777	0,700629	0,000 000
août	Y(t-1)=0,157041*Yt+32,37005	0,599347	0,000 000
septembre	Y(t-1)=0,117312*Yt+33,05158	0,884737	0,000 000
octobre	Y(t-1)=-0,230340*Yt+32,44837	1,084828	0,000 000
novembre	Y(t-1)=-0,07023*Yt+31,16024	0,817444	0,000 000
décembre	Y(t-1)=-0,262055*Yt+30,63597	0,803169	0,000 000

Table 1 illustrates the equations of the time series used for the maximum temperature from local stations

Table 2. Represents mathematical equations for the prediction of precipitation

	PRECIPITATIONS		
MOIS	Equations	carré moyen racinaire	proportion biaiser
janvier	Y(t-1)=0,224797*Yt+108,4772	40.32006	0,000 000
fevrier	Y(t-1)=-0,066284*Yt+94,11365	30,05604	0,000 000
mars	Y(t-1)=0,013715*Yt+130,7687	43,4719	0,000 000
avril	Y(t-1)=-0,060212*Yt+131,7180	47,75268	0,000 000
mai	Y(t-1)=-0,202451*Yt+92,13295	53,34168	0,000 000
juin	Y(t-1)=-0,416687*Yt+18,77353	16,89012	0,000 000
juillet	Y(t-1)=0,089607*Yt+6,736667	13,92609	0,000 000
août	Y(t-1)=0,004891*Yt+18,81907	22,2765	0,000 000
septembre	Y(t-1)=-0,000176*Yt+45,75321	25,175	0,000 000
octobre	Y(t-1)=0,027318*Yt+86,37850	39,85819	0,000 000
novembre	Y(t-1)=0,130611*Yt+98,18367	39,52793	0,000 000
décembre	Y(t-1)=-0,222218*Yt+89,89614	37,18065	0,000 000

Table 2: Represents mathematical equations for the prediction of precipitation

Table 2 illustrates the mathematical equations for the time series of precipitation from local stations.

Table 3. Represents the mathematical equations for the prediction of the minimum temperature

MOIS	TEMPERATURE MINIMAL EQUATIONS	carré moyen racinaire	proportion biaiser
janvier	Y(t-1)=0,079144*Yt+17,45406	0,936596	0,000 000
fevrier	Y(t-1)=0,161483*Yt+17,48373	0,927278	0,000 000
mars	Y(t-1)=0,051269*Yt+17,65646	0,733105	0,000 000
avril	Y(t-1)=0,370812*Yt+18,06097	0,802654	0,000 000
mai	Y(t-1)=0,558915*Yt+17,87701	0,673993	0,000 000
juin	Y(t-1)=0,045211*Yt+16,08191	0,735121	0,000 000
juillet	Y(t-1)=0,300466*Yt+14,43829	0,77431	0,000 000
août	Y(t-1)=0,216106*Yt+15,00200	0,889945	0,000 000
septembre	Y(t-1)=-0,062222*Yt+0,871074	0,871074	0,000 000
octobre	Y(t-1)=-0,106339*Yt+17,53122	1,465306	0,000 000
novembre	Y(t-1)=-0,072668*Yt+17,56443	0,79531	0,000 000
décembre	Y(t-1)=0,284522*Yt+17,57276	0,68044	0,000 000

Table 3: Represents the mathematical equations for the prediction of the minimum temperature

Table 3 illustrates the equations for the minimum local station temperature

Development of the Agricultural Calendar

To better establish an agricultural calendar and determine the water requirements for corn we used the CROPWAT 8.0 software. The agricultural calendar had been generated by the data here models with a forecast close to the data of the local stations. The results were obtained using the climatic data (maximum and minimum temperature, precipitation) obtained from the site http://www.gismap.ciat.cgiar.org/MarkSimGCM; Maize crop data provided by FAO and soil data, with the plain mostly sandy loam soil.

For this purpose, we have determined the water requirements and the irrigation schedule for the years 2015 and 2045. We used the scenario A1B considered intermediate and whose data are closest to those provided by the data of the local stations taking as a starting point the station of LUBARIKA from CLIMWAT.

3.6. CROPWAT of Model Inputs

The Cropwater model was created by the FAO Land and Water Development Division (Italy), with support from the Institute of Irrigation and Development Studies in Southampton (United Kingdom) and the National Water Research Center (Egypt). It has been described by **Doorenbos and Pruitt (1977), Smith *et al.* (1992), and Allen *et al.* (1998).** The model's input and output data can be classified in four categories: *(1)* climatic data (monthly rainfall, mean monthly maximum and minimum air temperatures, relative humidity, hours of sunshine, wind speed at 2 m, potential evapotranspiration estimated according to the Penman-Monteith equation); *(2)* agricultural crop data (crop type, sowing period, standard crop coefficient, plant development stages, root depth, plant withering point, plant response capability, crop yields, plant height); *(3)* soil data (soil type, maximum rain infiltration rate, maximum root depth, initial soil humidity conditions); and *(4)* irrigation data (e.g., the criteria for implementing irrigation programs).

The Cropwater model can calculate evapotranspiration for crops in two ways: by using the evapotranspiration of reference calculated by the Penman-Monteith equation, or by using the evapotranspiration obtained by direct measurement. In the present study, the evapotranspiration of reference (ETo), was calculated by the Penman-Monteith method, where input consists of maximum and minimum air temperatures, air humidity, sunshine duration and wind speed. Evapotranspiration of crops (ETc) during the growing season is determined as the product of evapotranspiration of reference (ETo) and crop coefficient (Kc) (**Equation 1; Allen *et al.*, 1998):[15]** ETc = ETo * Kc (Eq. 1) Crop coefficient values for each time lapse are estimated by linear interpolation of Kc values for each stage of crop development.

The Cropwat is an aid to the management of irrigation, it was developed by the FAO in 1992, based on the modified Penman - Monteith formula. Using the original Penman-Monteith equation and the aerodynamic and surface resistance equations, the FAO Penman-Monteith method for estimating ETo can be expressed as:

(+ +)

Or:

Eto: reference evapotranspiration [mm day-1],

Rn: net radiation at the surface of the culture [MJ m-2 day-1],

G: density of heat flux in the soil [MJ m-2 day-1],

T: mean daily air temperature at a height of 2 m [° C]

U2: wind speed at a height of 2 m [m s-1],

Es: saturating vapor pressure [kPa],

Ea: actual vapor pressure [kPa],

Es-ea: saturating vapor pressure deficit [kPa],
D: slope of saturation vapor pressure curve [kPa ° C-1],
G: psychrometric constant [kPa ° C-1].

It allows the calculation of the water needs of crops and the quantities of irrigation water; Based on FAO-24 and 33 Irrigation and Drainage Bulletins. It also offers the opportunity to develop an irrigation schedule for various cropping practices, and to assess the effects of water shortage on crops and the efficiency of different irrigation practices (Boudjelal, 2007) .CROPWAT 8.0 is a computer program for calculating crop water requirements and irrigation needs based on soil data, climate and crop. In addition, the program allows the development of irrigation schemes for different management conditions and calculation of clean water supply for different crop types

Entering Culture Data

For these data, we used those available in the cropwat database by choosing those that correspond to the crop studied. The sowing dates used are those of the study environment for the crop according to the corresponding model.

Table 4. Represents maize crop data

DONNEE GENERAL SUR LA CULTURE	PHASE ET VALEUR	PHASE ET VALEUR2	PHASE ET VALEUR3	PHASE ET VALEUR4	PHASE ET V
DONNEE GENERAL SUR LA CULTURE					
LACULTURE	MAïS				
DATE DE PLANTATION	le 28/9				
PHASE JOURS	Initiale:20	Croissance :35	mis-saison:40	Arriere-saison:30	totale:125
KS VALEURS	0.3	1.20	0.35		
Profondeur racinaire	0,3		1.00		
Epouisement maximum	0,55		0,55	0,8	
Reponse de rendement	0,4	0,4	1,3	0,5	1,25
Hauteur de la culture			2.00		

Soil Related Data

Table 5. Reproduces soil data from the study environment

DONNEES GENERAL SUR LE SOL	VALEUR
Nom du sol:RED SANDY LOAM	
Eau disponible total(CC(PF)	140mm/metre
Taux d'infiltration maximum de l'eau de pluies	30mm/jours
profondeur maximum d'enrecinement	900 centimetres
epuisement de la teneur en eau inititiale(en%)	0%
Eau disponible initiale	140mm/metre

- Soil data are not included in the calculation of water requirements, but are necessary in the cropwat software for the rest of the work. For this purpose, the cropwat soil database is used by selecting the soils corresponding to the soils of the study environment.
- The entry data for the model are precipitation, maximum temperature and minimum temperature of the ECHAM-5 model.

Statistical Tests Used

The data obtained was encoded in Excel workbook. Analysis of variance for the comparison of averages between scenarios and years for different data obtained; Statistica software. The chosen significance level was 5

4. Results and Discussion

Maps of changes in the DRC according to the Echam-5 model for the period 2015-2045

Change in Precipitation

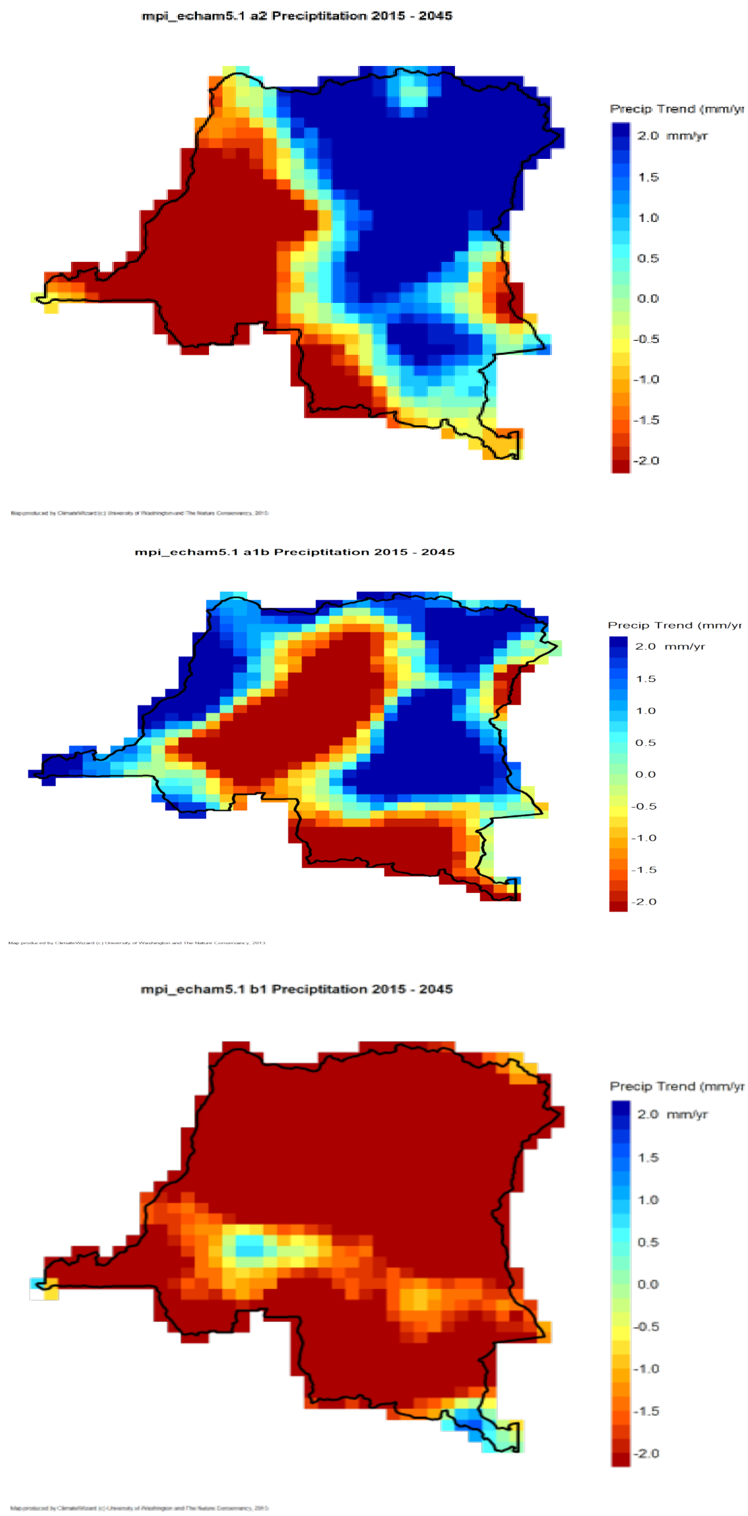


Figure 4. The change in scenario 1, AIB at B1 precipitation from 2015 to 2045

From this figure, scenario A2 has a tendency to increase by 2 mm of rain per year in the northeastern part of the country. The reverse trend is observed in the southwestern part, where a decrease of 2 mm in annual rainfall is observed. In other parts of the country the variation is in a varied range. Scenario A1B, on the other hand, has some variability in the distribution of changes. An increase in precipitation is observed in the eastern part and more to the west of the country. On the other hand, there is a decrease in the center and in the southeast. Scenario B1, in turn, has a decrease in precipitation of about 2mm / year throughout the country. In the central and southern parts there is a slight increase in precipitation. It can therefore be concluded that in some parts of the country there will be an increase in the amount of precipitation and in others a decrease in rainfall.

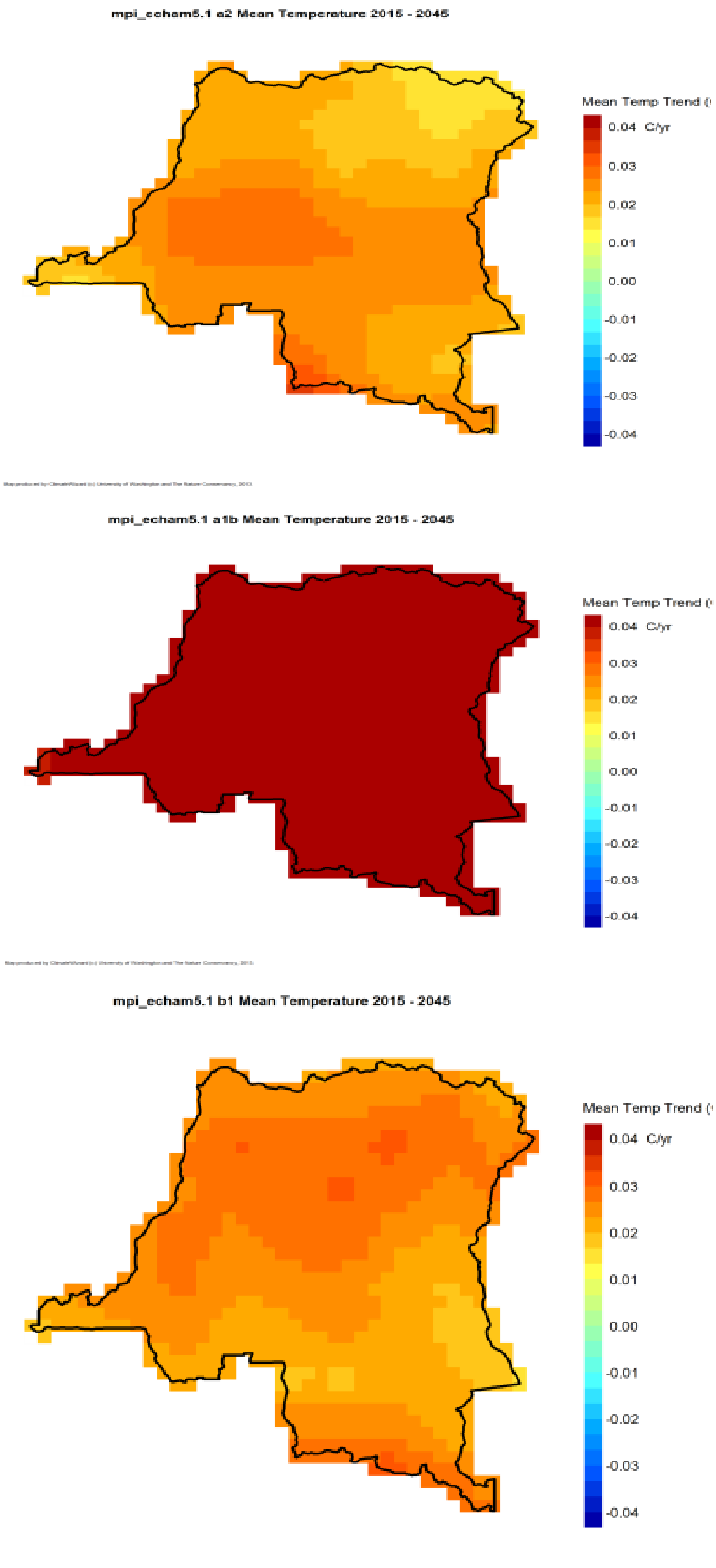


Figure 5. The variation of scenario temperatures A1, AIB at B1 from 2015 to 2045

From the 3 figures above, it can be seen that the first scenario shows an increase varying between 0.03 ° C-0.04 ° C per year for the whole country. The trend in scenario A1B shows an increase of more than 0.04 ° C for the whole country. Scenario B1 in turn shows the same trend as scenario B1.

It can therefore be said that overall there will be an increase in temperatures throughout the Congolese territory.

Data Provided by the Local Station (from 1965 to 1995)

Figure 6 shows the results of the quantity and the distribution of rainfall in the RUZIZI plain for the period 1965 to 1995. Observing the graph we note that over time there is great variability in the distribution of precipitation. There is also an increase in the amount of precipitation. For the different years the months of July and August were marked by a pronounced dryness of less than 7 mm for all years. For the year 1965 we notice a more or less balanced distribution of precipitation for the different months. The year 1975 was marked by a significant amount of precipitation in March (225.5mm). For 1985 and 1995, this situation was observed successively for April (275.5 mm) and December (277.7 mm). We note in all a very great variability in the distribution of precipitation.

From the above it may be said that in the whole of the reality of the plain there is an increase in the quantity of precipitation with a modification in its distribution. It follows that the data provided by the models do not deviate much from the reality of the local environment.

For the ensemble, the presence of precipitation has varied greatly during the last 11 years, this graph shows the presence of precipitation in January to May for most of the years and the dry period to summer Known in the months of June to the month of September, when the resumption of precipitation was observed from October to December. The considerable amount of precipitation was known in January to the month of April While other months experienced a fall in rainfall.

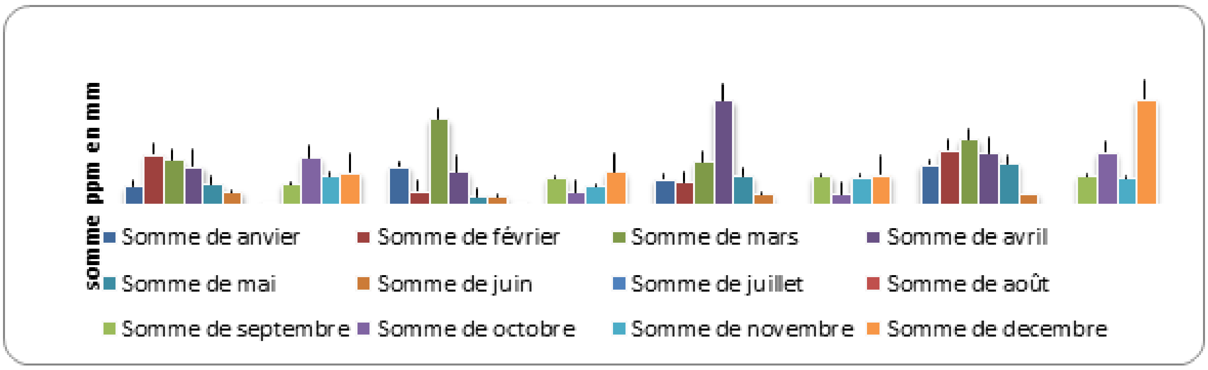


Figure 6. The local precipitation data for the Mparambo station from 1965 to 1995

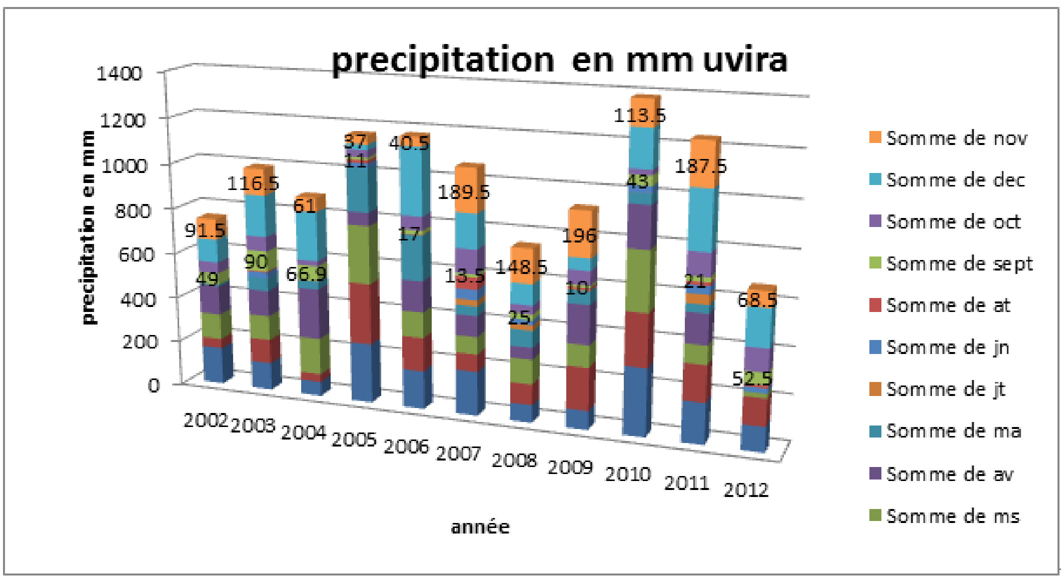


Figure7. The evolution and the distribution of precipitations, CRH-UVIRA station (2002-2012)

Predictions of local stations show a change in rainfall, indicating that precipitation occurs between September and May between 132 mm and 76 mm of rainfall, after which four seasons should be observed as the dry season, August.

Compared to the model forecasts, the rainy season will show a sum of precipitation distributed over a 9-month period, from September to May and between. In June, July and October will be observed a dry period of the year and this for all the years as well as the scenarios. Nevertheless there is a tendency in falls suddenly during the month of October in the distributions those that can hinder the cycles of the culture because maize is a crop that is very sensitive to the drought (Sarr et al. , 1999) There is a fall in the precipitation heights for the years 2015 and 2045 compared to the other years. The climate model approaching local station forecasts is the echam-5 model in Scenario B1**.**

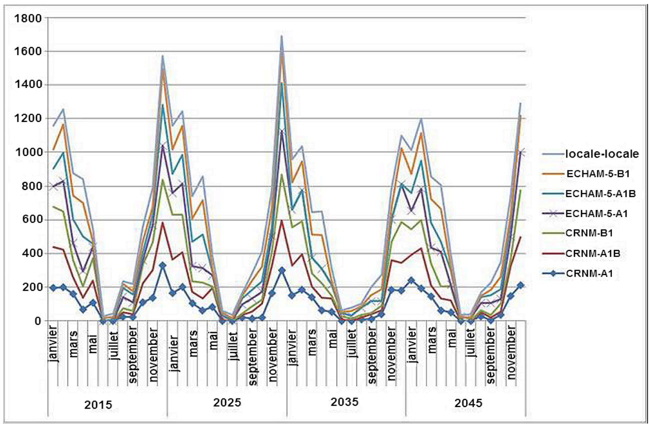


Figure 8. Forecasting of precipitation between climate models and local stations

Table 6. Maximum means temperatures for local station data Climate models

Moyenne de TEMP MAX		Modeles scenarios									
		Average			CRNM						locale
ANNEE	MOIS	A1	B1	A1B	A1	B1	A1B	A1	B1	A1B	locale
2015	janvier		29,6241935	29,9387097	30,383871	29,9580645	29,9580645	29,9964286	29,9142857	29,925	29,5099365
	fevrier	30,5785714	30,3785714	30,5285714	31,0392857	30,925	29,9580645	31,783871	31,0516129	31,0387097	27,1881241
	mars	30,9935484	31,2225806	31,0451613	31,4967742	31,5935484	30,925	30,3466667	29,94	29,7466667	26,9158965
	avril	30,2866667	29,96	29,6933333	30,7333333	30,3633333	31,5935484	30,7290323	31,1483871	30,8129032	31,795517
	mai	30,983871	31,0129032	30,9935484	31,0096774	30,5451613	30,3633333	28,1766667	27,9033333	28,0133333	33,451396
	juin	28,02	27,72	27,7833333	28,2666667	27,9066667	27,9066667	32,2580645	31,5322581	31,7290323	28,4471714
	juillet	31,6548387	31,8935484	31,4483871	32,0354839	31,8419355	31,8419355	30,2709677	29,8032258	29,9451613	27,2827258
	août	30,0677419	30,2032258	29,9290323	30,7	31,0129032	31,0129032	31,4633333	30,8866667	30,4733333	35,1909229
	septembre	31,51	31,27	31,4266667	32,3233333	32,6566667	32,6566667	30,3451613	30,483871	30,5645161	34,9105242
	octobre	31,1096774	30,916129	31,1032258	31,7451613	31,4129032	31,4129032	30,99	30,85	30,6666667	28,6766617
	novembre	31,1633333	30,9733333	31,2433333	31,7451613	32,05	32,05	32,3	31,5612903	31,8193548	32,8851597
	décembre	31,7967742	32,2064516	31,6709677	32,3612903	32,2096774	32,2096774	29,0870968	29,3322581	29,0612903	26,2222655
Total 2015		30,7422748	30,5388562	30,5670225	31,1533365	31,039655	30,9907303	30,6456074	30,3672657	30,3163306	30,2063584
2045	janvier	30,8225806	30,6419355	30,2870968	31,016129	30,4032258	30,6	30,016129	29,9483871	29,9258065	28,9238018
	fevrier	31,5428571	31,5928571	31,3428571	31,8821429	31,9428571	31,4535714	31,5642857	31,4464286	31,1642857	26,2322048
	mars	31,9516129	31,6483871	31,5483871	32,616129	31,316129	31,9483871	32,4129032	32,3	31,8935484	25,4732009
	avril	30,8333333	30,9733333	31,03	31,3233333	31,6333333	30,9166667	31,4433333	31,3366667	30,89	31,942907
	mai	32,2354839	31,5451613	31,4548387	32,4258065	31,2677419	31,5419355	32,5677419	31,9064516	32,0580645	37,40766
	juin	29,0866667	28,7433333	28,6166667	28,94	29,68	28,4666667	29,3933333	29,5366667	29,1857143	27,6051895
	juillet	32,4516129	32,4516129	32,3193548	32,8225806	31,516129	32,1709677	33,083871	33,2645161	32,8354839	25,8848444
	août	31,116129	31,0612903	30,9483871	31,516129	32,1806452	31,2709677	31,7741935	31,3387097	31,316129	38,4005035
	septembre	32,3666667	32,2833333	32,1633333	33,19	33,1466667	32,6	32,9666667	32,2366667	32,23	37,4442385
	octobre	32,1290323	31,7258065	31,5483871	32,8225806	32,0709677	32,0806452	31,9967742	32	31,4612903	26,3734984
	novembre	32,1433333	31,9666667	31,5866667	32,5366667	33,4633333	32,0266667	32,4566667	32,7870968	31,55	33,5139336
	décembre	32,7096774	32,8419355	32,5790323	33,0612903	32,6	32,6548387	32,616129			24,2746711
Total 2045		31,6157488	31,4563044	31,3849261	32,0127323	31,7684191	31,4776094	31,857669	31,6455991	31,3191202	30,2897211

An increase of one degree for all the scenarios of the average model will be observed between the year 2015 and the year ie 30,7 ° C and 31,6 for the scenarios A1,30,5 and 31,4 ° C for The scenarios A1B and 30.5 ° C and 31.3 ° C in scenarios B1. For the scenario group at the level of the CNRM model, scenarios A1 will have to record an average temperature of 31.1 ° C in 2015 and 32 ° C in 2045, while in scenario A1B the maximum mean temperature will range from 30.9 ° C in 2015 to 31.7 ° C in 2045, while in scenario B1 the average annual temperature will be 31 ° C And 31.4 ° C. At the level of the ECHAM-5 model scenarios A1 should have a maximum moisture temperature of 30.6 ° C for the year 2015 and 31.4 ° C for the year 2045, the scenarios of the A1B group will have an average temperature Annual of 30.3 in 2015 and 31.6 ° C in 2045 in turn scenario B1 will have a maximum average between 30.3 ° C and 31.3 ° C.

At the local stations the average annual temperature will have to vary between 30 between the year 2015 and the year 2045.

At the level of the Average model the minimum average temperature will have to increase by one degree between the year 2015 and the year 2045, ie 18 ° C and 19 ° C for all the scenarios and will have to be maintained at 19 ° C in the CNRM model. At the level of the echam-5 model, the minimum average temperature will have to resume at a rate of 18 ° C for the year 2015 and 19 ° C for the year 2045. At the local station level, a minimum average temperature of 19, 5 ° C.

Table 7. Prediction of minimum mean temperature between climate models and local stations

Moyenne de TEMP MIN		Modeles scenarios									
		Average			CRNM			ECHAM-5			locale
ANNEE	MOIS	A1	A1B	B1	A1	A1B	B1	A1	A1B	B1	locale
2015	janvier		20,0096774	19,8887097	20,7129032	20,5483871	20,5483871	19,9129032	19,7032258	19,8645161	18,9541687
	fevrier	18,9928571	19,0678571	18,675	19,8357143	19,5392857	19,5392857	18,425	18,6071429	18,5714286	20,8507758
	mars	19,4774194	19,5387097	19,6129032	20,3032258	20,3548387	20,3548387	19,8451613	19,5322581	19,3709677	18,6106072
	avril	20,05	19,8866667	19,9533333	20,7166667	20,7166667	20,7166667	20,05	19,9633333	19,8633333	28,7052041
	mai	20,2096774	20,4548387	19,9322581	20,6709677	20,0516129	20,0516129	19,7258065	19,8225806	19,8354839	16
	juin	14,9066667	14,7566667	14,8566667	15,3466667	15,3733333	15,3733333	14,8666667	14,6666667	14,7333333	20,6398688
	juillet	17,8645161	17,6709677	18,0322581	18,7193548	18,5483871	18,5483871	17,9419355	17,6483871	17,4870968	19,1377916
	août	15,4064516	15,5548387	15,7193548	16,4419355	16,7032258	16,7032258	16,0580645	15,4483871	15,1967742	17,9626522
	septembre	17,91	17,7866667	17,49	18,6766667	18,0733333	18,0733333	17,17	17,1233333	17,3633333	15,8461557
	octobre	17,4193548	17,5258065	17,5548387	18,2806452	18,3354839	18,3354839	17,2387097	17,0645161	17,0677419	16,3745259
	novembre	19,25	19,2266667	19,4266667	20,17	20,5166667	20,5166667	19,49	19,1833333	19,13	24,560867
	décembre	21,0354839	20,8967742	21,1451613	21,9354839	21,6903226	21,6903226	20,9774194	20,9225806	20,8741935	16,8426647
Total 2015		18,4111297	18,5313447	18,6289123	19,3175192	19,2042953	19,2042953	18,4751389	18,3071454	18,2798502	19,5404402
2045	janvier	20,9193548	20,7419355	20,4290323	21,2451613	20,6516129	20,8677419	21,0258065	20,6806452	20,4645161	18,9541687
	fevrier	19,95	19,8607143	19,5892857	20,2357143	20,2678571	19,8428571	19,6928571	19,6678571	19,4321429	20,8507758
	mars	20,4741935	20,4419355	20,183871	20,7225806	19,9064516	20,1741935	20,4870968	20,6677419	20,5	18,6106072
	avril	21,0933333	21,05	20,7566667	21,0133333	21,29	20,6033333	21,5066667	21,0666667	20,9033333	28,7052042
	mai	21,2516129	21,0709677	20,8032258	21,316129	20,3580645	20,616129	20,8935484	20,916129	20,5419355	16
	juin	16,2066667	16,1433333	15,7566667	15,9933333	16,2966667	15,5333333	16,2933333	16,0266667	15,3928571	20,6398688
	juillet	18,983871	19,0967742	18,6193548	19,083871	18,4290323	18,5645161	19,0290323	18,9032258	18,5451613	19,1377916
	août	16,8225806	16,8193548	16,3483871	17,2096774	18,1870968	16,3612903	17,683871	16,9612903	16,5580645	17,9626522
	septembre	19,03	18,7166667	18,4833333	19,1433333	18,66	18,6633333	18,46	18,55	18,3033333	15,8461557
	octobre	18,5225806	18,4193548	18,116129	18,8548387	18,5419355	18,3225806	18,4	18,3290323	17,9967742	16,3745259
	novembre	20,2733333	20,1433333	19,9066667	20,4766667	21,3	20,04	20,7733333	20,1366667	19,76	24,560867
	décembre	21,8870968	21,8741935	20,3436627	22,0935484	21,7677419	21,6580645	21,7225806	21,8709677		16,8426647
Total 2045		19,6178853	19,531547	19,2061496	19,4452198	19,782349	19,6380383		19,6640105	19,4814075	19,3755181

Agricultural Plan 2015-2045

Need for Water from Maize Cultivation

Year 2015

The water requirement for the maize crop for 2015

Table 9 shows the variation in non-standard evapotranspiration (ETc1 in mm / day and ETc2 in mm per decade), effective rainfall and irrigation needs in relation to the growth phases of the maize crop for the year 2015.

For the initiation phase the ETc2 is> effective precipitation. This necessitates a need for irrigation. During the growth phase we notice a clear increase in irrigation needs because ETc2 is considerably higher than effective precipitation. The mid-season phase also shows a need for irrigation because we also find that the ETC2 is> to effective precipitation. The out-of-season phase shows a need for nil irrigation because for this there is an opposite effect.

Table 8. Water requirements of maize crops for the year 2015

Mois	Décade	Phase	Kc coeff	ETc mm/jour	ETc mm/dec	Pluie eff. mm/dec	Bes. Irr. mm/dec
Sep	3	Init	0.30	1.30	3.9	4.0	3.9
Oct	1	Init	0.30	1.28	12.8	8.3	4.5
Oct	2	Crois	0.31	1.31	13.1	4.7	8.4
Oct	3	Crois	0.52	2.10	23.1	12.5	10.6
Nov	1	Crois	0.77	3.05	30.5	21.8	8.7
Nov	2	Crois	1.01	3.90	39.0	28.4	10.6
Nov	3	Mi-sais	1.14	4.44	44.4	34.0	10.4
Déc	1	Mi-sais	1.14	4.47	44.7	42.4	2.3
Déc	2	Mi-sais	1.14	4.49	44.9	49.5	0.0
Déc	3	Mi-sais	1.14	4.43	48.8	43.6	5.1
Jan	1	Arr-sais	1.00	3.82	38.2	34.0	4.1
Jan	2	Arr-sais	0.73	2.77	27.7	28.4	0.0
Jan	3	Arr-sais	0.47	1.78	17.8	30.1	0.0

Table 9. Water requirements of maize crop for the year 2015

	Valeurs			
PHASE	**Somme de Bes,Irr,**	**Somme de Pluie eff,**	**Somme de ETc2**	**Somme de Etc**
Arr-sais	4,1	92,5	83,7	8,37
Crois	38,3	67,4	105,7	10,36
Init	8,4	12,3	16,7	2,58
Mi-sais	17,8	169,5	182,8	17,83
Total général	**68,6**	**341,7**	**388,9**	**39,14**

Table 10. The water requirement for the maize crop for the year 2045

Mois	Décade	Phase	Kc coeff	ETc mm/jour	ETc mm/dec	Pluie eff. mm/dec	Bes. Irr. mm/dec
Sep	3	Init	0.30	1.34	4.0	5.5	4.0
Oct	1	Init	0.30	1.32	13.2	8.7	4.4
Oct	2	Crois	0.31	1.36	13.6	2.8	10.8
Oct	3	Crois	0.51	2.17	23.8	13.5	10.4
Nov	1	Crois	0.77	3.15	31.5	27.3	4.2
Nov	2	Crois	1.00	4.03	40.3	36.8	3.5
Nov	3	Mi-sais	1.14	4.55	45.5	40.5	4.9
Déc	1	Mi-sais	1.14	4.54	45.4	46.5	0.0
Déc	2	Mi-sais	1.14	4.53	45.3	52.4	0.0
Déc	3	Mi-sais	1.14	4.47	49.2	45.0	4.2
Jan	1	Arr-sais	0.99	3.86	38.6	33.4	5.2
Jan	2	Arr-sais	0.73	2.80	28.0	26.0	2.0
Jan	3	Arr-sais	0.47	1.82	18.2	28.8	0.0

Table 11 shows the variation in non-standard evapotranspiration, effective rainfall and irrigation requirements for crop growth phases for the year 2045. For the initiation phase we find that water requirements are low because that the sum of Effective Rain (in mm / decade) is greater than the sum ETc2 (mm / decade).

During the growth phase there is an increase in irrigation needs because we find that effective rainfall is lower than ETc2. For the mid-season and after-season phases, irrigation requirements are less important because we note a certain balance between actual rainfall and ETc2.

Irrigation Schedule

Year 2015 scenario A1B

Figure 9 shows the variation in the irrigation schedule as a function of the soil water retention capacity and the development of the crop. Here we take into account the readily available water (RAM) and the total available water (TAM). The water content is expressed as root depletion in this case.

Looking at the graph we find that the RAM and the TAM evolve with the capacity of retention of the soil. They increase with the water holding capacity until the 55th day after planting and then the TAM stays constant until harvesting contrary to the RAM which continues to increase from the 95th. If we observe the exhaustion we see that it increases at a certain period (from the 25th day to the 100th day after planting). This period corresponds to the time when a significant amount of precipitation falls.

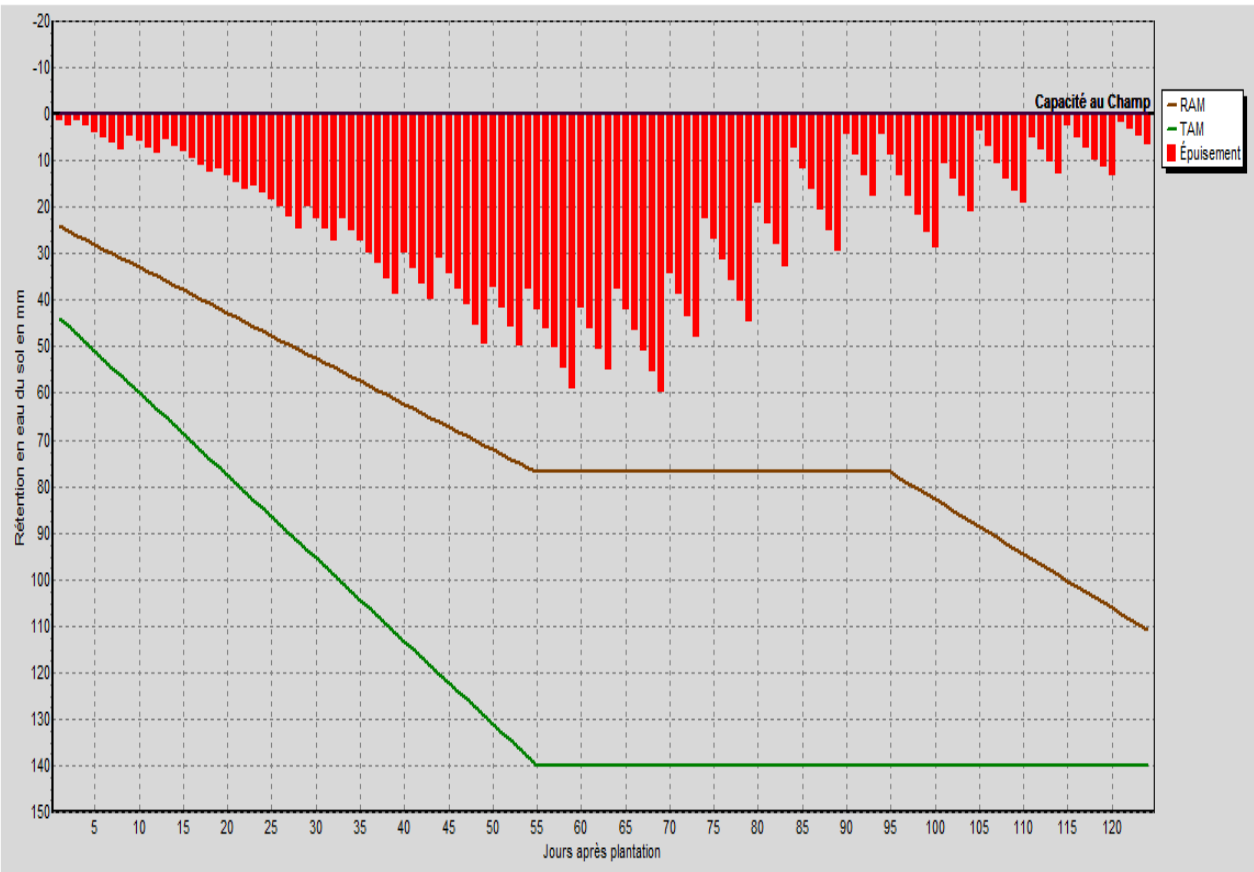


Figure 9. The irrigation schedule for the cultivation of maize for the year 2015 in scenario A1B

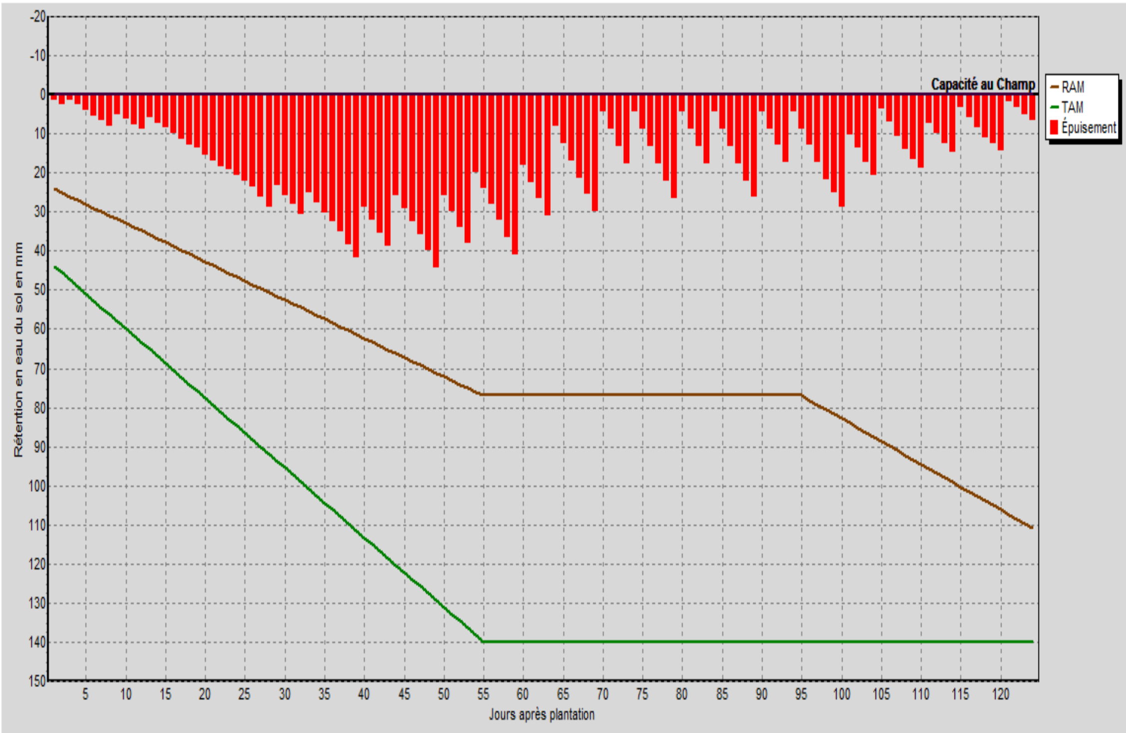


Figure 10. The irrigation schedule for the cultivation of maize for the year 2045 in scenarios A1B

Projection 2045 scenario A1B

Figure 10 shows the variation in irrigation scheduling for the year 2045. Unlike the previous graph, depletion increases earlier (from the 15th day) and is at a somewhat lower level. The variation of the RAM and TAM is identical to that of the year 2015. For this year we have a slightly more balanced distribution of precipitation.

Agricultural Calendar

Table 11. Is the result of the prediction of the ECHAM-5 MODEL in scenario A1

SAISON	MOIS	STADE
A	SEPTEMBRE	semis
	OCTOBRE	1ier sarclage
	NOVEMBRE	
	DECEMBRE	2iem sarclage et récolte
	JANVIER	Préparation du sol
B		
	FEVRIER	semis
	MARS	sarclages
	AVRIL	sarclage
	MAIS	récoltes

5. Discussion of Results

Climate change can affect agriculture in a variety of ways. Beyond certain temperature thresholds, agricultural yields may decrease, as the acceleration of the growth process is accompanied by lower grain production (william, 2008).

From this analysis, it appears that the climatic variables (mean maximum and minimum temperatures, and precipitation) will show significant variations in its distribution according to the scenarios over the next thirty years: 2015-2045 as the ECHA- 5 compared to local station results.

According to Germain, 1952 The rainy season stretched from October to May and the dry season from June to September earlier (cf precipitation of local stations), also according to surveys conducted in 2010 (Mutalemba, 2010) the agricultural calendar Undergoes a strong change. Our results show that the rainy season in the Ruzizi plain should start in September but a fall in precipitation should be observed in October, the rainy month will be December to May. The sum Rainfall will vary from 100mm in November to 178mm in February for the ECHAM-5 model. The mean annual temperature in the plain of the RUZIZI was 24 ° C, the maximum and minimum average temperatures reached 27 ° C and 30 ° C with an amplitude of 11 ° C. Our study shows a variation of the maximum and minimum mean temperature between 19 ° C and 31 ° C for the ECHAM-5 model.

In recent years, however, some climate economists have tended to downplay them, even thinking that a few degrees Celsius may be beneficial to agriculture, but the increase in temperature also changes the ability of plants to retain and use moisture. The evaporation of the soil accelerates and the leaves of the plants lose more moisture, a double effect called "evapotranspiration". As global warming can cause more precipitation, the net impact of rising temperatures on water availability depends on the rate of increase in evapotranspiration and precipitation. In general, evapotranspiration is the fastest growing (william, 2008)

Precipitation will have to increase every year between 2015 and 2045 and will be spread over eight months over the whole year, from January to May and from September to the month Of December and over the entire period each year will be represented by four months which will be considered as dry season of June, July, August and November.

Maize is a demanding plant in light. It also has fairly high temperature requirements at germination. This is possible below 10 ° C, fertilization is disturbed as soon as it exceeds 35 ° C. (Depending on Guy, 1984). The decrease in temperature and the increase in altitude causes the elongation Of the vegetative cycle to produce a good yield maize requires a rainfall of 600 to 900 mm well distributed during the vegetation, it can adapt well to all the ecological conditions with an average temperature of 24 ° C. Carbon, the main cause of climate change, can promote agriculture by improving the net photosynthesis of many important crops, "C3 plants" (wheat, rice, soybeans, etc.). However, scientists are far from certain of the benefits of fertilization due to carbon dioxide (carbon fertilization). On the other hand, it is not very useful for C4 crops (sugarcane, maize, etc.), which in value account for about a quarter of all crops **(Nyabyenda, 2005).**

As regards the agricultural calendar, we found that for the year 2015 the period from the 25th day after planting to the 100th day will correspond to the maximum depletion period, this is due to the fact that this period corresponds to The one where we have a water deficit, hence the importance of irrigation. We have found that for the year 2045 the depletion of the root reserve will take place early but will be of less intensity if we consider the same date of Sowing than in 2015. The exhaustion decreases because in 2045 we have a large amount of Precipitation and a more or less balanced distribution.

These effects can be explained by the fact that the effects of climate change on agriculture result in a change in the distribution of rainfall, necessitating changes in the cropping calendar. Climate change will cause difficulties for farmers to locate their agricultural practices, as time indicators relating to the seasons have lost all reference.

6. Conclusions

Maize is a crop with High sensitivity to both water deficit and excess water. In sub-Saharan Africa, Particularly in Ruzizi are, there are several climate risks associated with temporal variability of rainfall, Season's parameters, to the resurgence of Phenomena such as heavy rains. All These factors, depending on the wintering profile, May constitute a climatic constraint Maize productivity. The aim of this work is to determine the comparison in the prediction between the global models of atmospheric circulation and the regional and local model in order to evaluate the evolution of climatic parameters (temperature, Rainfall and radiation) and their impact on the agricultural calendar of maize and the availability of water for crops between 2015 and 2045. Thus, research was conducted using different meteorological Region considered the Ruzizi plain as a medium.

The model cham-5 is more adapted than other models presented in the work to the situation of the Ruzizi plain due to their adaptation to the data of the local weather stations. The model shows a strong variation of precipitation in During the year and allows to adjust the calendar, it presents 2 cropping season, among other things season A which begins in September until December, season B begins in February until month may. The calendar shows a fall in precipitation in October, which shows a shift in the date of sowing in maize.

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