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**MASTER RESEARCH PROGRAM ON CLIMATE CHANGE AND HUMAN SECURITY**

# CLIMATE VARIABILITY AND RICE PRODUCTION IN MALI: A CASE STUDY OF ''OFFICE RIZ SÉGOU'

Thesis N°………………..

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## DEDICATION

To

- My father Siaka DEMBELE and my mother Sata DEMBELE for all their sacrifices

- My grand-mother Safiatou SANOGO, brothers and sisters

# ABSTRACT

Agriculture is a major aspect of the food systems, which is affected by climate variability. This study assessed the effect of climate variability on rice production in “Office Riz Ségou” (ORS), Mali from 1980 to 2014. The methods used include linear and multiple regression analysis of times series data on hydro-climatic parameters (temperature, rainfall, humidity and river flow) and descriptive statistics which was used to analyse farmers’ perception and adaptation measures. The results from analysis of hydro-climatic factors show an increasing trend at 1% significant level with the exception of rainfall. Correlation between rice production and hydro-climatic parameters shows that rice production is not directly dependent on these parameters. Also, there is a weak relationship between hydro-climatic parameters and rice production. However, the results of multiple regression analysis show that the effect of temperature on rice production is significant at 5% while, other parameters are not significant. Most of the households (86%) considered drought as the main cause of decrease in rice productivity in ORS while, 55.3% considered deforestation as the main cause of climate change. The majority of the households (98%) indicated that they do not use any coping/adaptation strategies to drought but creation of drainage system and the use of improved seeds were considered as the main adaptation strategies to flood in the study area.


**Keywords:** Climate variability, rice production, Office-Riz-Ségou, trend analysis

# RESUME

L'agriculture est un aspect majeur des systèmes alimentaires, elle est affectée par la variabilité climatique. Cette étude a évalué l'effet de la variabilité climatique sur la production du riz de 1980 à 2014. Les méthodes utilisées comprennent l'analyse de régression multiple et linéaire des séries chronologiques des données sur les paramètres hydro-climatiques (température, pluviométrie, humidité et la crue du fleuve); la statistique descriptive a été utilisée pour l'analyse de la perception et l'adaptation riziculteur. Les résultats obtenus de l'analyse des paramètres hydro-climatiques ont montré une augmentation significative au seuil de 1%, à l'exception de la pluviométrie. La corrélation entre la production du riz et les paramètres hydro-climatiques montre que la production du riz ne dépend pas directement de ces paramètres. Il excite également une faible relation entre les paramètres et la production du riz. Cependant, les résultats de l'analyse de régression multiple ont montré que l'effet de la température sur la production du riz est significatif au seuil de 5%, alors que les autres paramètres ne sont pas significatifs. La plus part des ménages (86%) considèrent que la sècheresse est la cause principale de la diminution de la production de riz à l'ORS tandis que 55,3% considèrent la déforestation comme la cause principale du changement climatique. La majorité des ménages (98%) ont indiqué ne pas disposer de stratégies d'adaptation à la sécheresse mais la création d'un système de drainage et l'utilisation de semences améliorées ont été considérés comme les principales stratégies d'adaptation à l'inondation dans la zone d'étude.



**Mots-clés**: La variabilité du climat, la production du riz, Office-Riz-Ségou, analyse des tendances

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| AGRA: | Alliance for a Green Revolution in Africa |
| $CO_2$: | Carbon Dioxide |
| DADP: | Delta State Agricultural Development Programme |
| FAO: | Food and agricultural organization |
| GDP: | Gross Domestic Product |
| IPCC: | Intergovernmental Panel on Climate Change |
| IPCC-AR4: | Intergovernmental Panel on Climate Change Assessment Report four |
| IPCC-TAR: | Intergovernmental Panel on Climate Change third Assessment Report |
| LOSSA: | Laboratory of Optics, Spectroscopy and Science of Atmosphere |
| MRP: | Master Research Program |
| MSU: | Michigan State University |
| ORM: | Office Riz Mopti |
| ORS: | Office Riz Ségou |
| RPGH: | *Recensement General de la Population et de l'Habitat du Mali* |
| SSA: | Sub-Sahara Africa |
| UNFCCC: | United Nations Framework Convention on Climate Change |
| UNICEF: | United Nations International Children's Emergency Fund |
| USAID: | United States Agency for International Development |
| USGS: | United States Geological Survey |
| WASCAL: | West Africa Science Service Center on Climate Change and Adapted Land Use |
| WDI: | World Development Indicators |

# CHAPTER ONE

# INTRODUCTION

## 1.1.Problem Statement

Climate variability is not a new phenomenon in the world (Trenberth and Dai, 2000). The rise in temperature of the earth surface and atmosphere, rising of sea level (for example, due to melting of glacier), wind speed, flooding due to heavy rainfall, fluctuation in rainfall, drought and declining ground water are all clear evidence of climate change and variation (Kumar and Sharma, 2013). According to *Intergovernmental Panel on Climate Change* (*IPCC*), changes in climate can be caused by natural factors but these changes result mostly from human activities (for example, anthropogenic emission of greenhouse gases). Furthermore, factors such as a high population growth rate, rapid increase of urbanization and economic development, swift industrialization, transport, infrastructure, reduction in forest area are generally due to human activities. Such activities contribute to climate change (Ahmad *et al*., 2011).

Agriculture is an important sector in the economy of many countries and it accounts for about one third of Africa's Gross Domestic Product (GDP). It also employs about 75% of the total labor force and is the main source of livelihood for rural people (*EU*, 2007). In many Sub-Saharan African (SSA) countries, agriculture accounts for about 60% of the economically active population (WDI, 2006, cited in Chijioke *et al.*, 2011). In addition, agriculture is the back-bone of most West African countries, including Mali. It accounts for about 40% of Malian GDP (AGRA, 2013).

However, because agriculture in West Africa is predominantly rain-fed, it is highly dependent on climatic conditions. According to IPCC WG II (2014), climate change without adaptation will adversely affect the major crops (wheat, rice, and maize) in the tropic (such as Mali) and temperate regions. Furthermore, climate change is the greatest threat to agricultural productivity and food security in the 21$^{st}$ century, especially in developing countries, due to their low capacity to effectively cope with a possible decrease in yields, among others (Nellemann *et al.*, 2009, cited in Pedercini, 2012). Clearly, developing countries are most vulnerable to climate conditions, compared to developed countries. Developing countries are more vulnerable because of low level of technological progress, like inadequate resources to mitigate the adverse effects of climate change on agriculture and high dependence on agriculture for livelihood (Nath and Behera, 2011). This would increase the severity of disparities in food grain yields between developed and developing countries (Fischer *et al.*, 2005, cited in Kumar and Sharma, 2013). The Assessment Report of the Intergovernmental Panel on Climate Change (IPCC-AR4) highlighted the vulnerability of African agriculture and all who depend on it for food security and livelihood (IPCC, 2007). Thus, it is very pertinent to look at how climatic conditions would affect crop production in Mali, especially rice production in Office Riz Ségou.

Meanwhile, the future climate projection in the West African region is highly uncertain, especially rainfall (IPCC, 2013). The main crops produced in Mali are millet, rice and sorghum. Moreover, the National Adaptation Program of Action for Mali has identified agriculture, health, fisheries, energy and water as the sectors being most at risk of climate change. Also, agriculture is the main activity of rural people in Mali. However, weather and climate hazards like droughts and flood have led to disastrous consequences for the livelihood of farmers. The geophysical, location of Mali shows that about half of the country is located in the arid zone and therefore unsuitable for agricultural activities; such limitations in agricultural production makes the country vulnerable to the effects of a changing climate and variability.

According to Verburg *et al.* (2009), the increased risk of seasonal droughts and limited access to water resources will negatively affect rice production. Furthermore, high temperatures reduce cold dry season production levels, while intensive storms increase runoff and negatively affect rice production. In addition, climate variability affects water availability and quality in Niger River, which will directly reduce both rice and livestock production (Verburg *et al.*, 2009).

Furthermore, it is projected that by the end of the 21$^{st}$ century, there may be a rise in temperature from 1.5 to 4.5$^{o}$C, while precipitation will decrease in the sub-tropics and Sahelian zone, and extreme events will become more frequent (IPCC, 2007). However, the increase in $CO_2$ concentration in the atmosphere is likely to have positive effects on rice yield (Basak *et al*., 2010). Wassmann and Dobermann (2007) projected that for every 75 part per million (ppm) increase in $CO_2$ concentration, rice yields will increase by 0.5 t ha$^{-1}$, but yield will decrease by 0.6 t ha$^{-1}$ for every 1°C increase in temperature. Figure 1.1 shows the relationship between rice production (yield and weight), mean day/night air temperature and $CO_2$ concentration of 330 and 660 µmol/mol in five separate experiments.

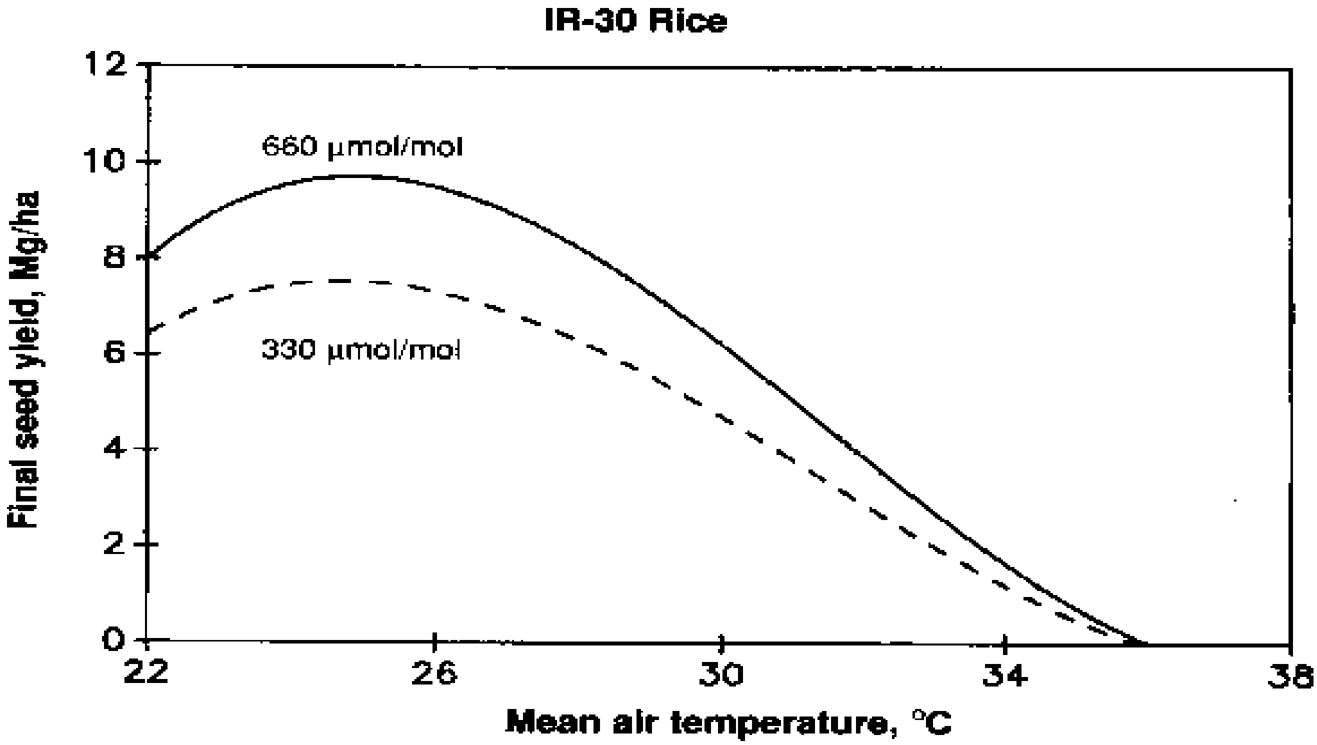


**Figure 1.1.** Relationship between rice, mean day/night air temperature and $CO_2$ concentration in five separate experiments

**Source: FAO, 1996**

‘‘Office Riz Ségou” is one of the major rice production areas in Mali after Office du Niger. Meanwhile, River Niger is the main source of irrigation channel of ORS. The change in climate and its related effects on the availability and quality of river water is a significant problem in the area: it could adversely affect rice production. Rainfall variability and its related drought and flood may reduce rice production in ‘‘Office Riz Ségou”.

The long term relationship between inter-annual variability in temperature, rainfall, runoff and annual yields of the most important food crops in Office Riz Ségou need to be investigated. The study intends to analyze the effect of climate variability on household’s welfare, agricultural income and farm revenue in the area. The effect of climate variability and change on rice production needs to be investigated in Office Riz Ségou, Mali.

## 1.2.Research Objectives

The aim of this study is to investigate the effect of hydro-climatic parameters on rice production in Office Riz Ségou.

The specific objectives of this study are to:

- analyze the trend of rainfall, humidity, temperature and river flow and find the nature of correlation between each variable and rice production in Office Riz Ségou,
- determine the effects of hydro-climatic parameters (rainfall, humidity, temperature and river flow) on rice production in Office Riz Ségou,
- assess farmers' perception on climate variability and change in the study area

## 1.3.Research Questions

In order to achieve the above objectives, this study seeks to answer the following questions:

- What is the nature of changes in rainfall, humidity, temperature and river flow in the study area?
- How is rice production affected by the fluctuation of the hydro-climatic factors?
- What is the farmers' level of awareness on climate variability and change?

## 1.4. Research Hypotheses

The research hypotheses supporting this study are:

- ✓ hydro-climatic factors are some of the underlying causes that influence rice production;
- ✓ farmers have a good perception of climate variability and change indicators;

## 1.5.Plan of the Thesis

This thesis consists of five chapters. The first chapter addresses the problem statement, the research objectives, the research questions and the plan of the thesis. The second chapter covers literature review on the topic and addresses the relationship between climate conditions, rice production and food security. The third chapter deals with the study area, the methods and material used in the study for data collection and analysis. The fourth chapter covers the results (findings) and discussion of the research work. The fifth chapter deals with conclusions and recommendations on the basis of the findings.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1. Climate Variability and Change

The Intergovernmental Panel on Climate Change (IPCC) defines climate change as “a change in the state of the climate that can be identified (e.g., by 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” (IPCC, 2007). The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.” Climate variability refers to 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 (IPCC, 2001). In light of this definition, climate variability can be viewed as year to year variation of climate conditions (Dinse, 2011).

Since the early 1990s, the IPCC has provided evidence of accelerated global warming and climate change. The IPCC’s Fifth Assessment Report (AR5) presents new evidence of climate change (IPCC, 2013) with an increase in the number of hot days and nights over a long-period. The global mean temperature showed an increase of 0.78 (0.72 to 0.85) °C over the period of 162 years (1850 to 2012), and currently the predictions of global average temperature increase will be between 1.5°C to 4.5°C by the end of 21$^{st}$ century (IPCC, 2013). In Africa, global warming is likely to be even larger than the global annual mean warming, and this is across all seasons on continent (IPCC, 2013). Since 1975, temperatures have increased by more than 0.8° Celsius (°C) across most of Mali (U.S. Geological Survey, 2012).

According to IPCC (2007), the significant increase in rainfall has been observed in the central and northern Asia, northern Europe, and in the eastern parts of North and South America, while a decrease has been observed in the Sahel (IPCC, 2007). Climate change is a reality that is affecting rural livelihoods in West Africa particularly in Sahelian countries. It presents a growing challenge in the region, as in many other parts of the African continent and elsewhere (Jalloh *et al.*, 2013, cited in Traoré, 2014). Climate change is likely to reduce the major crop yields such as rice, sorghum and millet in India (Gupta *et al.*, 2012, cited in Kumar and Sharma, 2014). Climate variability will have consequences for the marginalized and poor groups in which the majority depends on agriculture for their livelihoods with a low adaptive capacity to the climate conditions. The most vulnerable areas to climate effect in Mali is the northern part while its southern part has medium vulnerability to climate effect (USAID, 2014).

### 2.2. Climate Change and Crop Production

Changes in rainfall patterns and increasing temperatures have an effect on crop yield. They directly affect water availability and indirectly affect irrigation channel. There is a strong linkage between crop production, food availability and food accessibility, which determine whether an individual, a household or even a given nation has food security (Chijioke *et al.*, 2011). According to Knox *et al.* (2012), "Climate change is a serious threat to crop productivity in regions that are already food insecure". It is projected that climate change will have an effect on eight major crops in Africa and South Asia.

According to Maikasuwa and Ango (2013), climate change affects crop production in four ways: changes in temperature and precipitation have decreasing effects on crop productions, increased $CO_2$ in the atmosphere is expected to have positive effect on crop productions, runoff and unavailability of water decrease crop production. Increase in temperature above 3ºC is expected to have negative effects on crop production in all regions (IPCC, 2007); for any increased of 1ºC of the mean temperature, the yield of major crops will decreased by 5-7% (Matthews *et al*., 1997, cited in Ayinde *et al.*, 2013).

The major crop production in Mali are rice, millet, sorghum, cotton and other vegetables crops. The country has three main climatic zones, namely, Sahelian zone, Saharan zone and Sudanic zone. Millet, sorghum and rice are generally growing in the Sahelian zone. Pastoralism is the only viable livelihood in the Saharan zone, while cotton, rice, millet, sorghum, groundnuts and vegetables are predominant in the Sudanic area (Pedercini, *et al*., 2012). The effect of climate change on crops yields depend on agro-climatic zones in Mali. However, changes in climate have an effect on all the climatic zones in Mali (Pedercini, *et al*., 2012).

Crop production is one aspect of food systems affected by climate variability and change. Climate is a primary determinant of agricultural productivity. So, any changes in climate will influence crop growth and yield (Knox *et al*., 2012). This is because crop production does not only deal with how the crop consumed are produced, but it also employs many people in Mali, where over 85 percent of the people depend on farming and low trade for their livelihoods. Any change of climate affects water availability and crop production in Office Riz Ségou which will have a significant ripple effect resulting not only in the reduction of food availability but will equally increase market prices in the country.

## 2.3. Concept of Food Security

There are several definitions of food security. Food and Agricultural Organization (FAO) defines it as when "all the members of the society have access to the food according to their needs, either from their own production, or from the market or from transfer mechanism of the government" (cited in Kumar and Sharma, 2013). Coleman-Jensen *et al.* (2014) define food security as "access by all people at all times to enough food for an active, healthy life".

According to the FAO (2008), "Food security exists when all people at all times have physical or economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life". This definition is similar to the previous one. Food security consists of these four components: food availability, food accessibility, food utilization and food stability (FAO, 2008).

- Availability is related to crop production and its importation;
- Accessibility depends on the level of household income to purchase food at prevailing prices or to have sufficient farming land**;**
- Stability refers to the ability of food over long period of time in the country;
- Food utilization refers to households' use of the food to which they have access and individuals' ability to absorb nutrients.

## 2.4. Food and Nutrition Security

The concept of nutrition security emerged with the recognition of the necessity to include nutritional aspects into food security. Food and nutrition security are about ensuring that everybody is able to have access to sufficient, affordable and nutritious food. Weingärtner (2004) further developed a definition of food and nutrition security as a condition under which adequate food (quantity, quality, safety, socio-cultural acceptability) is available and accessible for and satisfactorily utilized by all individuals at all times to live a healthy and happy life (cited in Pangaribowo, 2014). Therefore, "food and nutrition security exists when all people at all times have physical, social and economic access to food, which is consumed in sufficient quantity and quality to meet their dietary needs and food preferences” (Wüstefeld, 2013).

### 2.5. Climate Change, Food Security, Poverty and Hunger

There is a strong relationship between food system and climate. Any fluctuation of climate may affect the world food systems. Food security is directly related to climatic conditions; any change of climate can directly affect a country’s ability to feed its population (Ahmad *et al*., 2011 cited in Kumar & Sharma, 2013). Changes in climate affects all four pillars of food security i.e., food availability, food accessibility, food utilization and food stability (FAO, 2008). Thus, climate change is a critical element for assessing household or national food security. According to FAO (2008), climate change will affect food security through its effects on all components of global, national and local food systems. Climate change will bring an effect on crop production and will affect food availability (Chijioke *et al.*, 2011).

Availability of food products is affected by climate condition via its effects on crop yields, crop pests and diseases, and soil fertility. It is also affected by climate change indirectly via its effects on economic growth, income distribution and agricultural demand. This will have effects on both rural and urban locations where supply chains are disrupted through production losses and increase in market prices (FAO, 2008). Higher fluctuation in crop yields and food supplies may negatively affect food stability. Food stability, crop yields and food supplies are adversely affected due to variations of climatic parameters (Greg *et al*., 2011).

Climate change will also affect food accessibility through the ability of individuals, communities and countries to obtain sufficient quantities of good-quality food. A threat to food utilization that reduces nutritional value of the food, changes in climate may adversely affect human health by increasing the circulation of diseases in geographical areas. Agricultural output in developing countries may decrease by 20 percent due to climate change. Equally, the yields in developing countries may decline by 15% due to climate change (FAO, 2008, cited in Greg *et al*., 2011). Through climate change, hunger and malnutrition will increase in most areas, especially in rural areas because they mainly depend on agriculture.

Agricultural productivity is an important part of food security which is an integral part of reducing poverty and hunger. Therefore, “climate change and poverty are interconnected in many ways such as increase in temperature leading to a warmer climate may increase the spread of diseases like malaria; and finally it may lead to an increase in extra burden on poor people resulting to an increased poverty" (Kumar and Sharma, 2013). Rainfall variability and its related drought or flooding can damage households' assets for those who are depending on agriculture production for their livelihood; it can lead to increment in poverty and may seriously threaten food security in many countries (Oluoko-Odingo and Alice, 2009, cited in Kumar and Sharma, 2013). "The results of climate change pose a serious threat of hunger, food insecurity, poverty, and malnutrition" (Belloumi, 2014). Climate variability, agriculture productivity, food security, undernourishment and poverty are directly linked to each other and there are relative threats to all the components of human security (Hollaender, 2010, cited in Kumar, 2013).

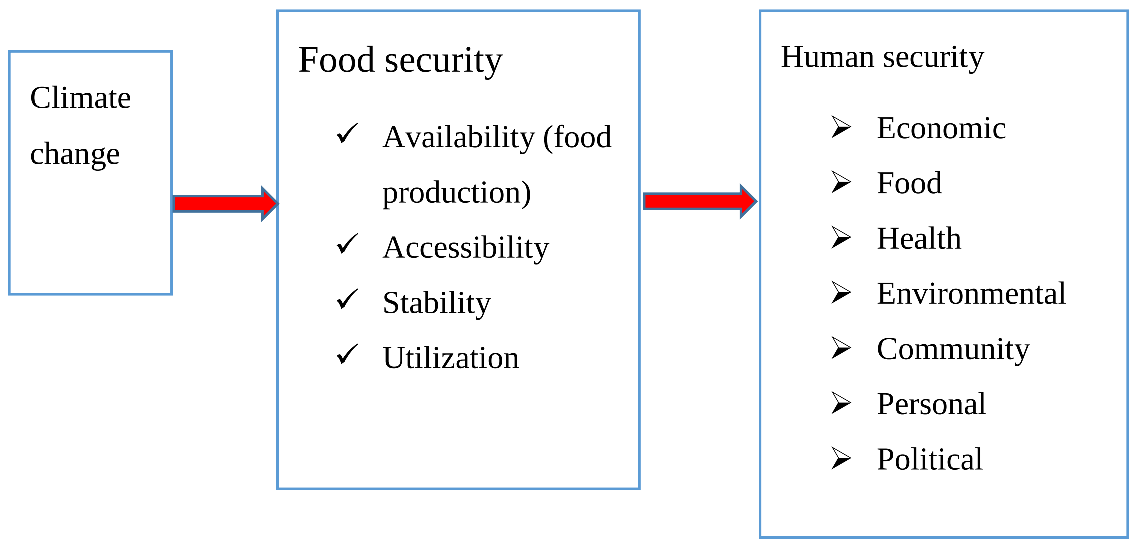


**Figure 2.1**: Relationship between climate change, food production, food security and human security **(Adapted from FAO, 2008)**

### 2.6. Effect of Climate Change on Rice Production

Global warming (rise in temperature mainly due to carbon dioxide emissions) and variability in rainfall patterns are expected to affect rice production and its availability. Carbon dioxide is an essential component of photosynthesis and as such an increase of $CO_2$ in the atmosphere is expected to increase plant growth. Projections for the future climate condition are surrounded by significant uncertainties. Most studies on the increase of temperature and climate change scenarios predict the decline in precipitation patterns. Future open water evaporation rates are expected to increase due to the threat of a changing climate (Helfer, 2012). Drought and extreme rainfall as a result of climate have a negative effect on rice yields (Auffhammer et al., 2011). Climate change is expected to significantly affect the productivity of rice systems and thus the nutrition and livelihood of millions of people (FAO, 2007).

Heat waves coinciding with the sensitive production stage can result in serious damage to rice production especially in some tropical and subtropical regions. Increase of temperature beyond the normal may adversely influence the growth duration of rice crop and its growth pattern. It equally reduces grain filling duration and increases the respiratory losses as well as reduces the yield and grain quality (Basak *et al.*, 2010, Mohanty, 2013). Therefore, increases in minimum temperature have negative effects on rice yield. With an increase of 1$^{o}$C of temperature, there will be a 10% decrease in grain yield and biomass (Ranuzzi and Srivastava, 2012; Mohanty, 2013). According to Geethalashmi *et al.* (2011), rice production has declined by 41% with 4$^{o}$C increase in temperature in Tamil Nadu, India (cited in Kumar *et al.*, 2014). In addition, increase in minimum temperature up to 1$^{o}$C leads to a decrease in yield of rice by 3% and 10% in Punjab, India (Hundal and Prabhjyot-Kaur, 2007 cited in Kumar et al., 2014).

Rainfall variability is one of the most important factors that limits the yield of rain-fed rice cultivation. Variability in the onset of the rainy season leads to variation in the beginning of the planting season in rain-fed rice cultivation. According to Basak *et al.* (2010), variations of rainfall have an effect on rice yield. Fluctuation of rainfall and its related floods and droughts caused 82.4% of the total Philippino rice losses from 1970 to 1990 (Lansigan *et al.*, 2000, cited in Krishna, 2014). Niger River, the main source of irrigation channel in ‘‘Office Riz Ségou”, is affected by climate change through the fluctuation of rainfall. The water discharge of the Niger River has an average decline in the range of 40-60% in river flow since 1970 (Verburg *et al.*, 2009).

In addition, the water availability in the Niger River depends on rainfall, which is very unpredictable. The models do not agree on their predictions of climate change for West African region, but the inter-annual variability in the amount of rainfall will increase, especially in Sahelian countries (Traoré, 2014). This has negative effects on the water flow of the River Niger, which reduces water availability for irrigation.

Changes in climate and its relative effects may adversely affect rice production system in “Office Riz Ségou”. Rice production system in the area is called “controlled submersion rice”. There are two main stages for rice grown in ORS:

- The first stage, in which rice is developed from rain water, is called "rain stage". Thus plowing, sowing and weeding are related to rainfall conditions.
- Second stage, in which rice is developed through input water (irrigation), is based on river system.

However, both stages are complementary for a good rice production in ORS. It is necessary that these two stages take place in good conditions. If one of the stage is affected, rice production is compromised. That is why rice production system is very uncertain in the area: risks related to decrease of rainfall (drought) and uncertainties related to the rising of Niger River as a result of heavy rainfall. All these hazards are generally due to changes of climate factors (ORS, 2010).

## 2.7. Adaptation Strategies to Climate Change

IPCC defines adaptation as "adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderately harm or exploit beneficial opportunities" (IPCC TAR, 2001). Based on this definition, adaptation to climate change can be defined as the ability of humans or nature to respond or cope with changes of climatic conditions. However, human activities cause climate change. The selection of appropriate rice varieties deserves consideration for adaptation to climate change (FAO, 2007).

According to Nwalieji and Onwubuya (2012), adaptation measures such as the use of improved varieties, resistant varieties to flood and drought, the moderate use of agro-chemicals and fertilizers and diversification in crop production contribute to the reduction of the effects of climatic conditions on rice production.

## 2.8. Review of Theoretical Methods

To evaluate the effect of climate variability on crop production, the weather-crop yield-forecasting model was applied to estimate prospective production of Aus rice in Jessore and Rajshahi districts of Bangladesh by Rahman *et al.* (2005), by using the linear multiple regression models. In order to evaluate climatic effects on rice crop production and measure production efficiency due to climate change in Bangladesh, the multiple regression model and stochastic frontier model were used. The linear multiple regression models was used by Dahal and Routray (2011) to identify associations between soil and production variables. Furthermore, Ogbuene (2010) used the multiple regression model to evaluate the effect of meteorological parameters on rice yield in Nigeria. In addition, Ammani et al. (2012) used multiple regression analysis to evaluate the effect of climate change and maize production in Kaduna State, Nigeria.

Nyanga *et al.* (2011) conducted a study on some farmers in Zambia to ascertain their perception on climate change. The results show that most farmers perceived no change in the duration of the hot season but noted reduction in the rainy season duration. Semi-structured interviews were used by Nzeadibe *et al.* (2011) to assess farmers' perception of climate via randomly collected quantitative information in Niger Delta Region of Nigeria. It was observed that the farmers were unaware of available mitigation measures for climate change effects. Aphunu and Otoikhian (2008) also assessed farmers' perception of the effectiveness of extension agents of Delta State Agricultural Development Programme (DADP) in Nigeria. To access farmers' perception of climatic conditions in Uganda, household survey was carried out, using a standard structured questionnaire and the survey established that most of the respondents were aware of changes in the climate (Nellemann *et al*., 2013).

The present study has adapted the model used by Rahman *et al.* (2005), to analyse the effect of hydro-climatic factors and rice production in ORS, Mali. To assess farmers' perception of climate variability/change in the study area, we adapted the sampling method of Aphunu and Otoikhian (2008) and Nzeadibe *et al.* (2011).

# CHAPTER THREE

# MATERIALS AND METHODS

## 3.1. Study Area

Ségou region is an administrative area in Mali, located in the centre of the country with an area surface of approximately 64,821 $km^2$ (around 5% of Mali). It has a population of about 2,336,255 inhabitants (RPGH, 2009). The Ségou region is characterized by a semi-arid climate, and has two seasons: a dry season and a rainy season. The rainy season starts in June and ends in September and the average yearly rainfall is about 513 mm. The main economic activity of the region is agriculture (e.g. cropping and cattle raising).

‘‘Office Riz Ségou” is located in the central part of Mali, Ségou. It is a public administrative area which was created in 1991 for agricultural activities. The area of intervention of the ‘‘Office Riz Ségou” is located in the middle valley of the River Niger, the main source of irrigation channel for approximately 34,076 hectares in the ORS. ORS covers 234 villages located in the districts of Ségou, comprising 23 rural municipalities and totaling 259,588 inhabitants (ORS, 2003). The main crops produced are rice, millet, sorghum, maize and groundnut; vegetable are also produced in the area. ORS includes 3 rural development areas, with 7 agricultural sectors. Most of the arable land for growing rice are controlled by the ORS. Indeed, over 90% of rice growing areas in Mali are located in the Central Delta of the Niger River, where are located the Office du Niger, the ORS and ORM. However, it is estimated that the irrigation channel of ORS is under the expertise of the extension officers and not well adapted to be easily used by the farmers.

The present study focuses on the district of Ségou, located at 13$^o$35’ North, 6$^o$15’ West, with specific emphasis on the following two villages: Soké and Konodimini. According to the chiefs of Soké and Konodimini, more than 90% and about 90% of the farmers produced rice and some other crops. The figure 3.1 below shows the map of the study area.

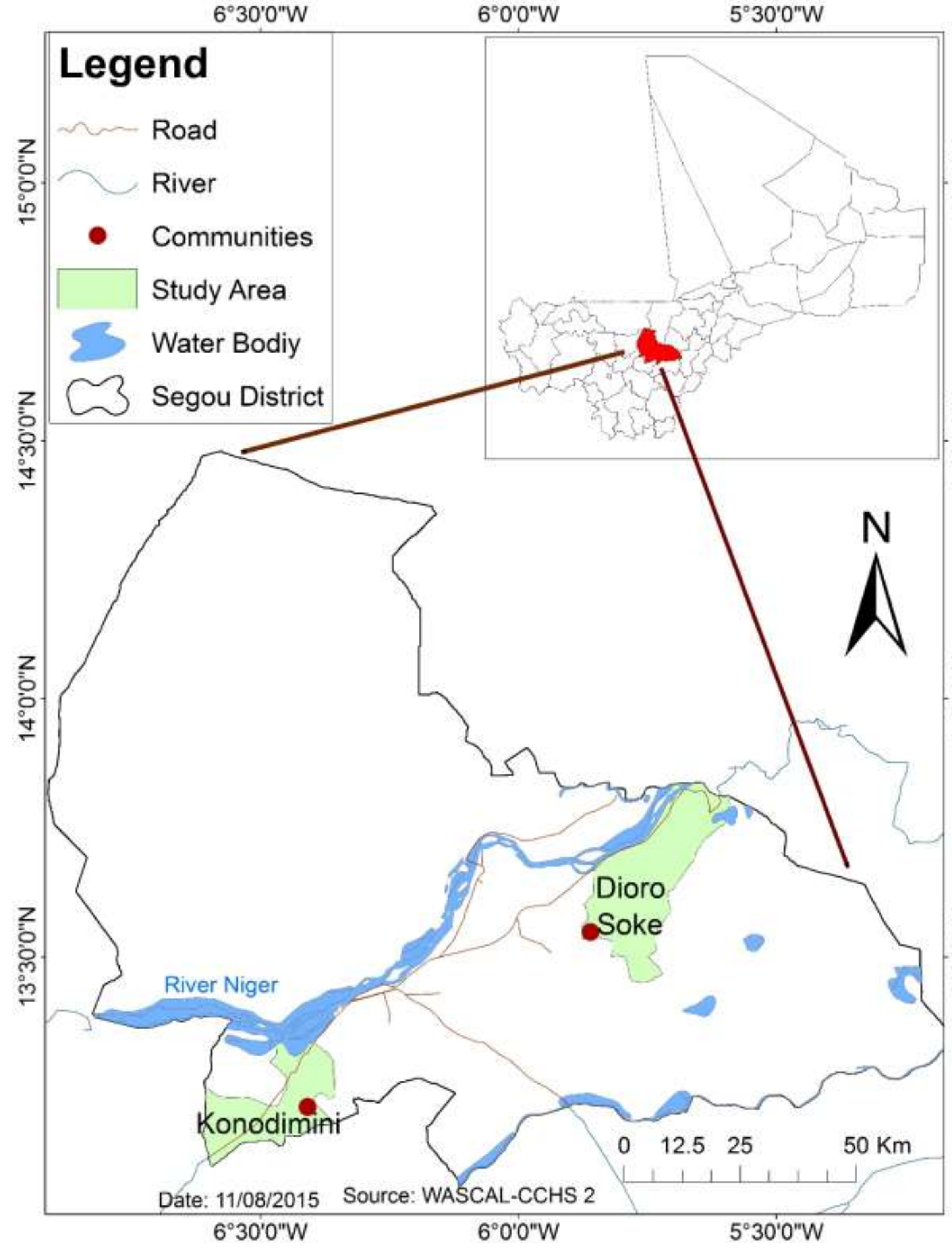


**Figure 3.1**: Location of the study area

## 3.2. Sampling Procedure and Data Collection

### 3.2.1. Primary Data

The study employed a multistage sampling technique. In the first stage, the villages of Soké and Konodimini were randomly selected from the 234 villages that make up "Office Riz Ségou". It was confirmed by the chiefs that about 90% of the households are rice farmers. In the second stage, 63 and 87 heads of household who were at least 30 years old and had about 10 years' experience in rice production were randomly selected in Soké and Konodimini, respectively. Hence, a total of 150 households were sampled for this study.

These surveys collected information based on socio-economic characteristics, farmers' perception of climate, education information, effect of climate change and adaptative strategies to climate change.

This research adopted an exploratory approach, by using predominantly qualitative methods to examine the research questions in order to determine farmers' perception. In order to ensure primary data quality, research assistants were recruited and trained to administer questionnaires before going to the field. They were familiar with the local language. The questionnaires were pre-tested in order to identify the gaps before the field survey.

### 3.2.2. Secondary Data

Climate data used in this study are monthly values of minimum and maximum temperatures, mean precipitation (rainfall), River Niger water level, rice production and minimum and maximum humidity amounts sorted by decades for the whole time series.  Climatic data are obtained from the Mali meteorological agency (Mali Météo). The table 3.1 below shows the description of secondary data.

**Table 3.1:** Description of secondary data

| Data | Sources | periods |
|---|---|---|
| Monthly and annual minimum and maximum temperature. | Meteorological Agency of Mali | 1980-2014 |
| Monthly and annual rainfall. | Meteorological Agency of Mali | 1980-2014 |
| Monthly and annual minimum and maximum humidity. | Meteorological Agency of Mali | 1980-2014 |
| Monthly and annual minimum and maximum river flow | Hydrological Agency of Mali | 1980-2013 |
| Annual rice production, yield and areas data. | Office Riz Ségou (O-R-S) | 1992-2013 |
| Documents, articles, report, etc. | Different offices and online sites | Not determined |

### 3.4. Data Analysis

The annual temperature, rainfall, humidity and river flow were analyzed using SPSS in order to determine the trends. In addition, correlation between hydro-climatic parameters and rice production were analyzed. The standardized anomalies of hydro-climatic factors and rice production data were calculated and graphically presented to evaluate inter-annual relationship between them. RClimdex was used to make the multiple regression analysis between hydro-climatic factors and rice production. SPSS was used for descriptive statistics on climate parameters, rice production data and socio-economic data.

### 3.5. Analytical Techniques

#### 3.5.1. Trend Analysis

Trend analysis for temperature, humidity, River Niger flow and rainfall was done by using time series data to project future results for these variables. Trend analysis of a time series refers to the magnitude of trend and its statistical significance. The magnitude of trend in a time series was determined by using regression analysis in order to know if the trend is significant or not. This method assumes a linear trend in the time series. Regression analysis was conducted with time as the independent variable and rainfall, humidity, temperature or river flow as the dependent variable. The regression analysis was carried out directly on the time series or on the anomalies (Jain and Kumar, 2012). This study is based on regression analysis because it helps us to identify the anomalies. A linear regression equation is stated as follows:

$$\boldsymbol{Y = ax + b} \qquad \textbf{3.1}$$

Where: $\boldsymbol{b}$ (the intercept) and $\boldsymbol{a}$ (the slope) can be fitted by regression. The linear trend value represented by the slope of the simple least-square regression line provides the rate of rise in the variable.

### 3.5.2. Multiple Regression Model

Rice production function (Rahman et al., 2005) that was used in this study is given as:

$$\boldsymbol{Y}_i = \sum_{\boldsymbol{i}}^{\boldsymbol{n}} . \sum_{\boldsymbol{j}}^{\boldsymbol{k}} \boldsymbol{\beta j W} ij + \mu_i \qquad \textbf{3.2}$$

Where: $\boldsymbol{y_i}$ is rice production, w is the hydro-climatic variables, b are the coefficients of the relevant variables, $\beta_0$ is the constant and $\boldsymbol{\mu_i}$ is the disturbance term (error).

The explicit formulation of the model was:

$$\boldsymbol{Y = \beta_0 + \beta_1 R_t + \beta_2 T_t + \beta_3 H_t + \beta_4 RF_t + \mu_t} \qquad \textbf{3.3}$$

Where:

$\boldsymbol{Y_t}$**:** is the production (for instance, output in ORS) for farm **I** = 1… **n** (=22);

$\boldsymbol{T_t}$**:** is the mean temperature (measure in degrees Celsius) experienced by annual average;

$\boldsymbol{P_t}$**:** is mean precipitation (measure in millimeters) experienced annual;

$\boldsymbol{H_t}$**:** is the relative humidity experienced by annually average;

$\boldsymbol{RF_t}$**:** is the river flow experienced by annual average;

$\boldsymbol{\beta_k}$**:** is the vector of the **k**=0……..4 parameters to be estimated; and

$\boldsymbol{\mu_t}$**:** is a normally distributed error term. Furthermore, if for instance $\beta_1 \mathcal{E} (0, 1)$, then $(\partial Y_t / \partial T_t) > 0$, and $(\partial^2 Y_t / \partial T_t^2) \leq 0$ (i.e. there are diminishing return to temperature).

### 3.5.3. Farmers' Perception

Farmers' ability to perceive climate variability and change and its effects on rice yield in ''Office Riz Ségou" and their capacity to adapt are one of the main objectives of this study. The accuracy of farmers' perception on climate change and their long-term perception on changes in temperature and precipitation are assessed. Survey method used a questionnaire as a tool. The data collected from field was used to draw charts which was generally in percentages. The above mentioned statistical software was used to analyze the data.

# CHAPTER FOUR
# RESULTS AND DISCUSION

## 4.1. Trend of Hydro-Climatic Parameters

### 4.1.1. Inter-annual Variability of Rainfall

Figure 4.1 shows the analysis of climate data for 35 years. The data was collected from the national meteorological station, Bamako, Mali. The results show four main peaks of rainfall respectively in 1988, 1994, 1999 and 2010, indicating abundant water supply in the study area during those years. Furthermore, there are some variations in the trend. For example, yearly rainfall decreased in 1982, 1987, 2002 and 2007. Similarly, the results indicate that 1982 has the least amount of rainfall which shows the occurrence of drought, in line with the general drought in Mali (Diallo *et al.*, 2011). In general, there is no significant trend of rainfall with p-value equal to 0.08522 and the co-efficient of determination ($R^2 = 0.08771$). The inter-annual variability of rainfall may threaten ecosystem services in Niger River, which is the main source of irrigation channel in the area.

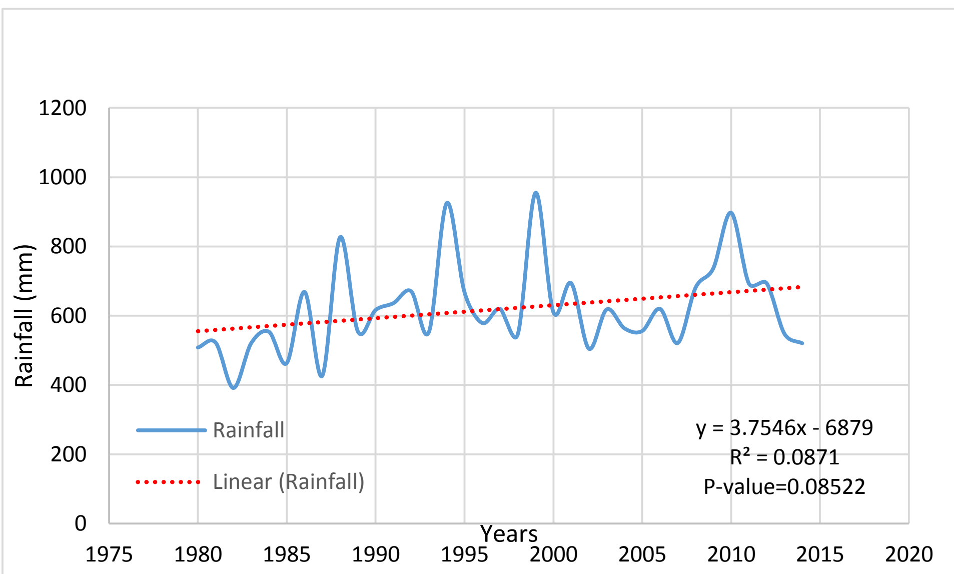


**Figure 4.1:** Inter-annual variability of rainfall (1980-2014)

### 4.1.2. Anomaly of Inter-annual Variability of Rainfall

The analysis of 35 years climatic data shows an inter-annual anomaly of rainfall (see Figure 4.2). The Figure also shows that the rainfall was below normal from 1980 to 1985 while there was a huge fluctuation in inter-annual rainfall pattern from 1986 to 2001. The drought spell was realized from 2002 to 2007 when the rainfall was below the normal. There was rainfall recovery between late 2000 and early 2010 but 2013 and 2014 show a decrease in rainfall. Therefore, considering the moving average of 5 years' time interval, four major changes in rainfall trend have been identified. From 1984 to 1992 and 2004 to 2009, the rainfall is below the normal, while the rainfall is above normal from 1994 to 2003 and from 2010 to 2014.

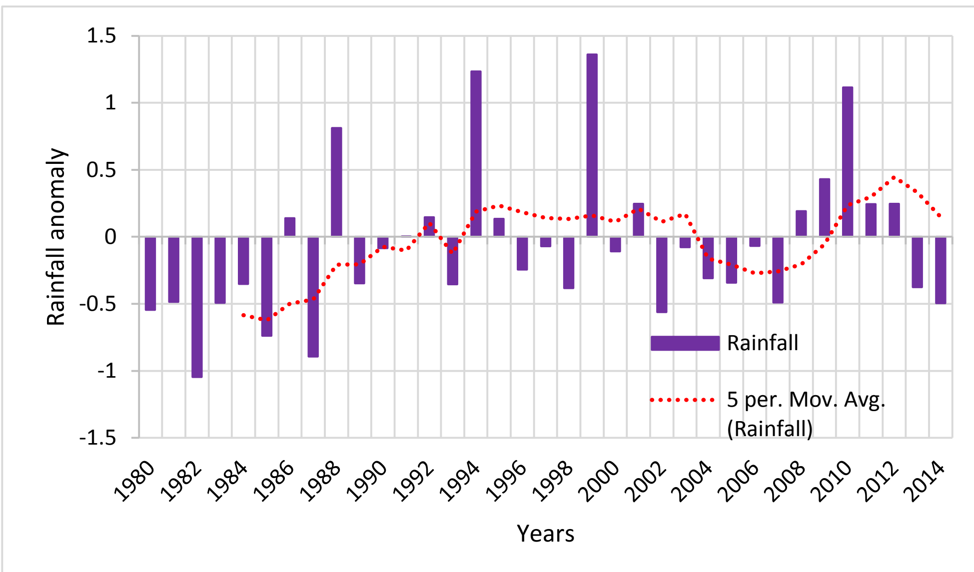


**Figure 4.2:** Anomaly of rainfall time's series (1980-2014)

### 4.1.3. Seasonal Variability of Monthly Rainfall

Figure 4.3 shows the average monthly rainfall from January to December. From January to April the amount of the rainfall is almost closer to zero and it is considered as the dry period in the Sahel, including Mali. There is a progressive increase in rainfall from May to July with an increase in August and a decrease in October. Also, Figure 4.3 shows less rainfall during the harmattan period (November and December). Therefore, the rainy season in the study area runs from May to October with its peaks in August. The monthly variability of the rainfall variation as shown in figure 4.3

indicates that the rainfall is unevenly distributed during the period of the study which follows the normal rainfall pattern of Sudano-Sahel savannah. The distribution of rainfall in the study area is similar to the findings of previous study conducted by Nicholson (2005) who found out that the rainfall pattern in the Sahel is not stable.

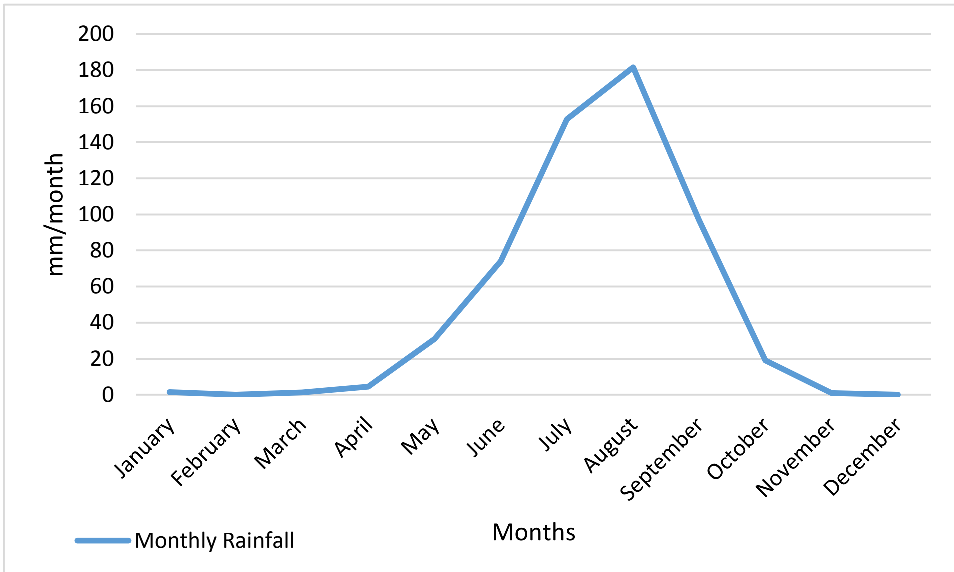


**Figure 4.3:** Monthly rainfall seasonal variability (1980-2014)

### 4.1.4. Variation in Temperature

Figure 4.4 shows the average temperature of Ségou station which is characterized by inter-annual variability. Two periods of variation can be noted: the first period is from 1980 to 1995 where the temperature is lower and the second period, which runs from 1996 to 2014 with higher temperature is higher. There is an exceptional year (1987) in the first period when the temperature is as high as what can be seen in the second phase. Similarly, there are two years (1999 and 2012) in the second phase in which the temperature is as low as the maximum temperature in the first phase. In general, the temperature shows an increasing trend, with the co-efficient of determination ($R^2$ = 0.3528). This finding is similar to the findings by US Geological Survey (2012). Furthermore, this result confirms the findings of IPCC (2013) which show that the global mean temperature has increased to about 0.78°C in the last 60 decades and it is expected to increase. In addition, the trend of average minimum and maximum temperature anomalies from 1961 to 1990 in four stations (Niamey, Tillabery "Niger", Fada "Burkina Faso" and Ndjamana "Chad") showed an increasing trend (Sarr *et al*., 2015). The trend of temperature shows an increase of 0.59°C and p-value equals to 0.00017: the trend of temperature in the study area is significant.

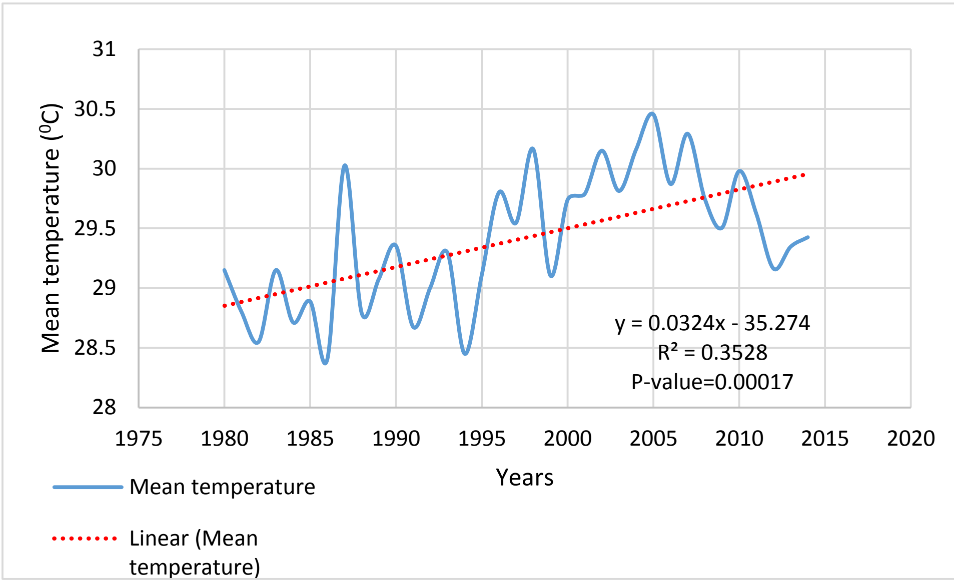


**Figure 4.4:** Inter-annual variability of mean temperature (1980-2014)

### 4.1.5. Variation in Temperature Anomaly

Figure 4.5 shows two phases of anomaly in mean temperature. From 1980 to 1995, temperature is below the normal, except in 1987 while it is above the normal from 1996 to 2011, except in 1999. By using the moving average of 5 years times' interval, two (2) main changes are noted in temperature trend: it is below normal from 1984 to 1998 and above the normal from 1998 to 2014. This explains the starting point of increasing temperature in the study area.

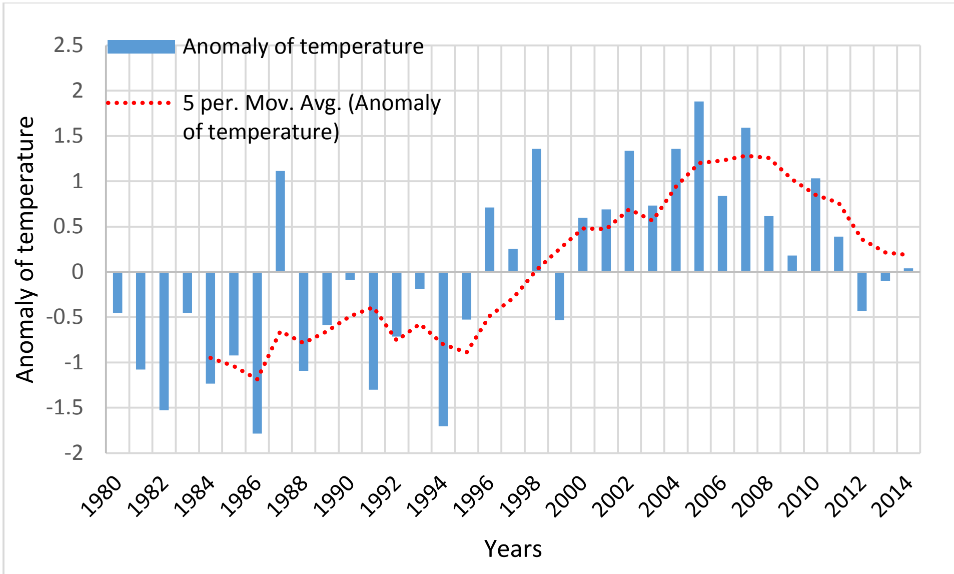


**Figure 4.5:** Anomaly of inter-annual mean temperature (1980-2014)

### 4.1.6. Trend of Humidity

Figure 4.6 shows a fluctuation in relative humidity from the beginning of the trend to the end. The fluctuation in this trend can be divided into two parts: the peak of humidity of 46% from 1982 to 1988 and 52% from 1988 to 2013, except in 1993, 1996, 2002 and 2008. Also, humidity pattern in the study area is characterized by an inter-annual variability of humidity and an increasing trend, with the co-efficient of determination ($R^2 = 0.2264$). The increasing trend of humidity in study area is significant because p-value is equal to 0.003868. Therefore, an increasing trend of humidity pattern has been observed for the last 35 years.

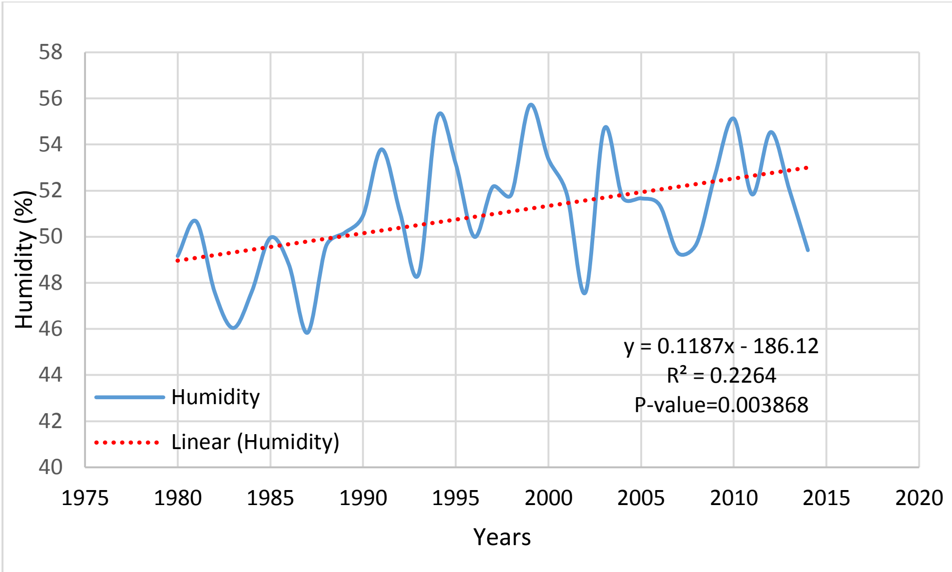


**Figure 4.6:** Variation of inter-annual relative humidity (1980-2014)

### 4.1.7. Anomaly Variation in Relative Humidity

Figure 4.7 below shows the analysis of average humidity and enormous variation from 2007 to 2014. It can be clearly seen in Figure 4.7 that from 1980 to 1990, humidity is below the normal and from 1991 to 2006 humidity is above the normal, with the exceptional of years 1993, 1996 and 2002 in which the average relative humidity is below the normal. There are fluctuations in average relative humidity from 2007 to 2014. Therefore, three (3) main changes have been observed by using the moving average of 5 years interval. From 1984 to 1992 the trend of humidity is below the normal; the trend is above normal from 1993 to 2014 and it is normal (equal to 0) in 2009.

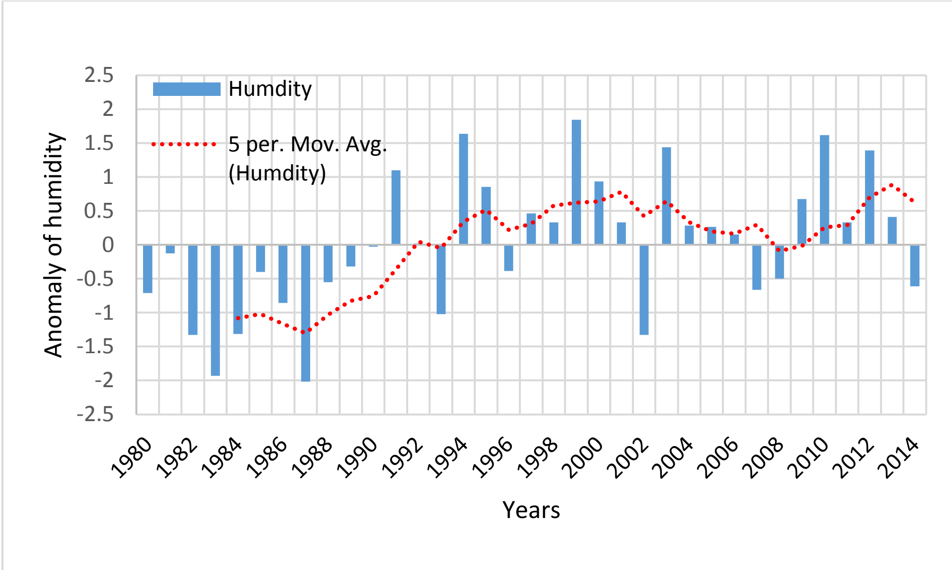


**Figure 4.7:** Anomaly of inter-annual mean humidity (1980-2014).

### 4.1.8. Trend of River Flow

The analysis of the mean flow of River Niger for Kirango station shows an inter-annual variability as depicted by Figure 4.8. This Figure shows two (2) periods of variation: 1980 to 1993, in which the river flow is lower than the second period which starts from 1994 to 2013. Figure 4.8 also shows one main peak in the starting point of the second period in 1994, where the river flow is the highest and 1984 indicating the lowest river flow. Generally, the linear trend shows an increasing trend, with the co-efficient of determination ($R^2 = 0.2205$) and p-value is equal to 0.0051, showing that the increasing trend is statistically significant. This result is not in line with the findings of Roudier et al. (2014) who establish that river flow is not consistent from station to station in Volta River but a negative trend is projected in the Gambia and Volta River.

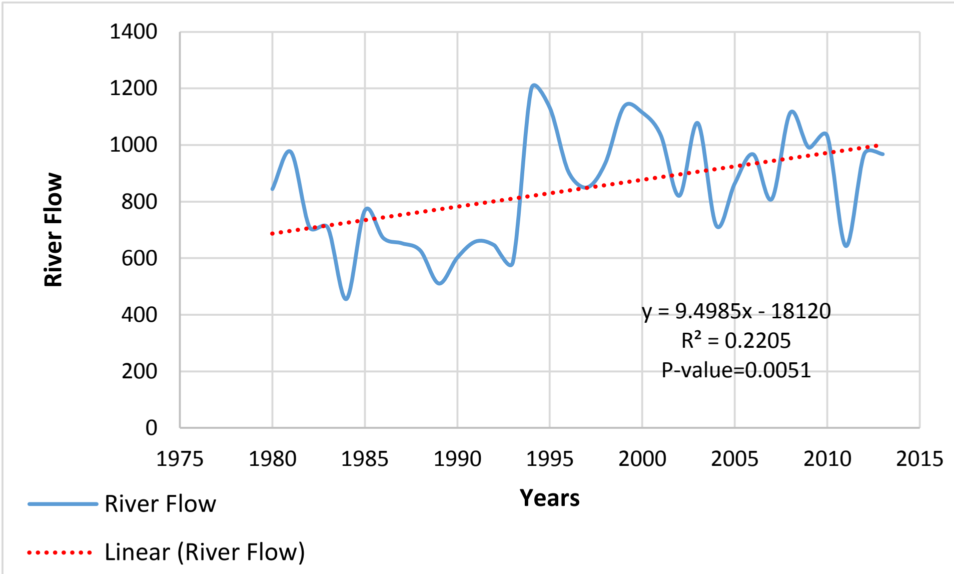


**Figure 4.8:** Inter-annual variability of river flow (1980-2013)

### 4.1.9. Anomaly in River Flow

The analysis of 34 years hydrological data shows a fluctuation in inter-annual anomaly of river flow. It has been identified in Figure 4.9 that the river flow was below the normal during the period of 1982 to 1993 and above the normal from 1994 to 2013 with the exceptional of 2002, 2004, 2007 and 2011. Therefore, the use of the moving average of 5 years times' interval demonstrated two (2) main changes in the trend of river flow. From 1984 to 1995, the trend of River flow is below the normal and above the normal from 1995 to 2013. This inter-annual variability of water in River Niger could be due to the fluctuation in rainfall. This finding concurs with the result of research conducted by Verburg *et al.* (2009) who found out that there are fluctuations in River Flow in Office du Niger.

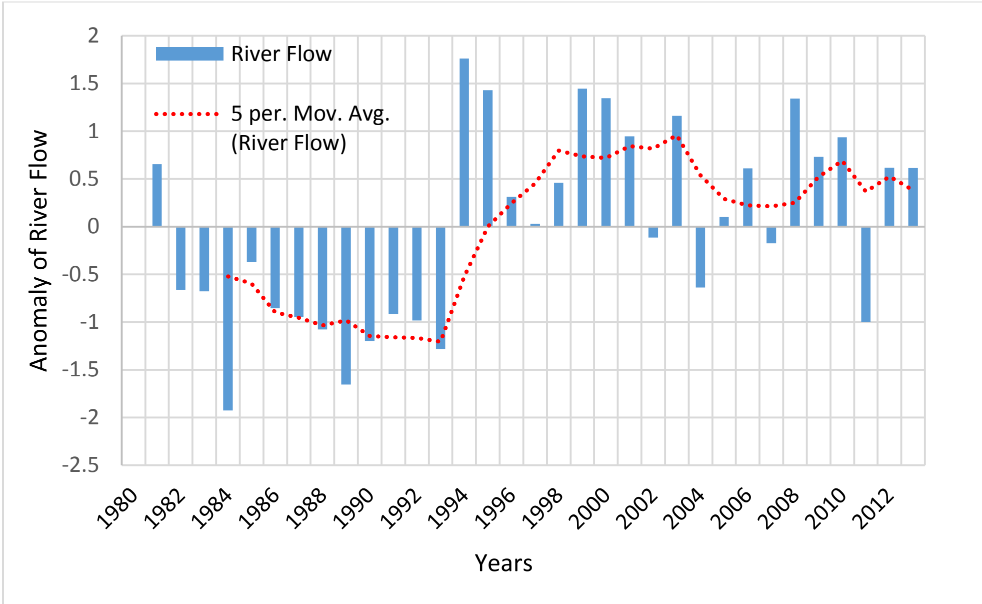


**Figure 4.9:** Anomaly of inter-annual mean river flow (1980-2013).

Table 4.1. Summary of the trend of hydro-climatic parameters indicating maximum, minimum, average, standard deviation and slope coefficients of the four factors.

**Table 4.1:** Summary of statistical trend analysis

| **Statistics** / **Hydro-climatic factors** | **Standard deviation** | **Slope coefficient** | **Range Min - max** | **Mean Value** |
|---|---|---|---|---|
| Rainfall | 237.6 | 3.75mm/year | 391.4 - 954.9mm | 636.18mm |
| Temperature | 0.56 | 0.03$^o$C/year | 28.40 - 30.45$^o$C | 29.40$^o$C |
| Humidity | 2.57 | 0.12%/year | 46 – 56% | 51% |
| River flow | 201.44 | 9.50$m^3s^{-1}$/year | 455.23 - 1198.82$m^3$/s | 843.85$m^3$/s |

**4.2. Inter-annual Variability of Rice production**

**4.2.1. Trend of Rice Production**

Figure 4.10 shows the analysis of rice production in Office Riz Ségou, explaining inter-annual variability of rice yield. This shows three (3) main peaks in 1998, 2002 and 2010 with 40,000, about 5,000 and more than 66,000 tons, respectively. This result shows that 2003 corresponds to a serious reduction in rice production, while 2010 witnesses there is an increase of rice production. However, rice production in ORS has an increasing trend in figure 4.10, with the co-efficient of determination ($R^2$=0.5882) and p-value equals to 0.00003 with insignificant increasing trend. The inter-annual variability of rice production in the study area can be explained by the variability of climatic parameters which may affect food availability in the study area and may adversely affect food and nutrition security in the country.

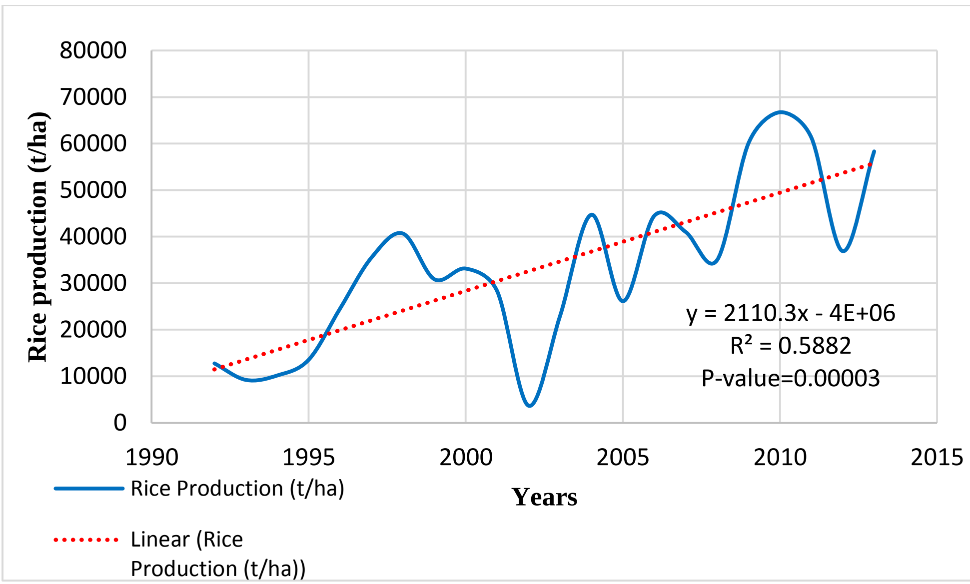


**Figure 4.10:** Inter-annual variation of rice production (1992-2013)

### 4.2.1. Rice Production Anomaly

Figure 4.11 illustrates three main variations, from 1992 to 2005 rice production is approximatively below the normal, while from 2006 to 2013 rice production is above the normal. By using the moving average of 5 years times' interval analysis of 22 years of rice production, two (2) main changes in the trend can be observed. From 1996 to 2006, the trend of rice production is below the normal except in 2001 where it equals to the normal; it is above the normal from 2007 to 2013. Also, from 1996 to 2001 and 2006 to 2013 there are increasing trends in rice production. This result is in line with the findings of Sarma *et al.* (2008), who also noticed the increasing trend of the moving average of rice yield. On the contrary, a decreasing trend was observed from 2001 to 2003.

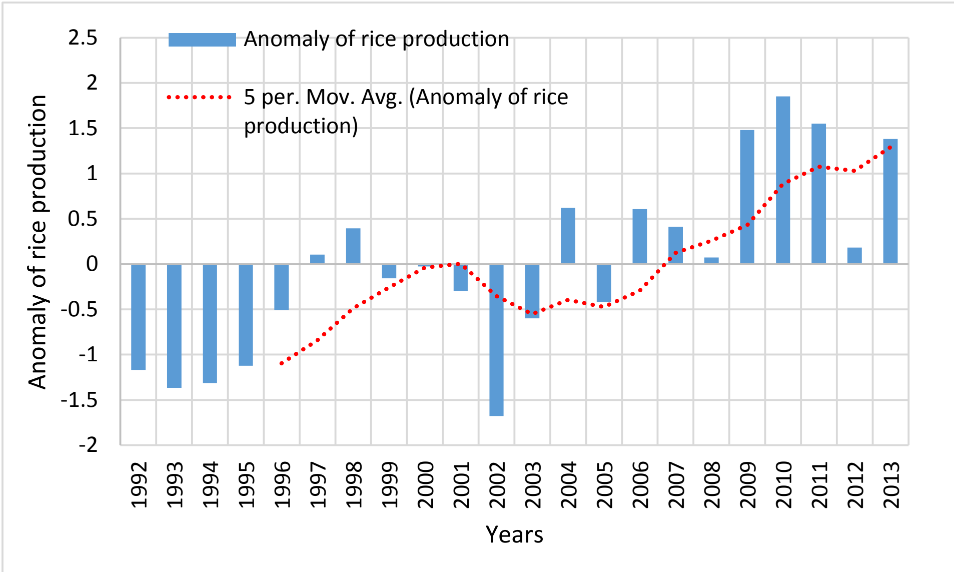


**Figure 4.11**: Inter-annual anomaly of rice production anomaly (1992-2013).

### 4.3. Relationship between Rice Production and Hydro-climatic Parameters

#### 4.3.1. Rainfall and Rice Production

Figure 4.12 below shows the relationship between rainfall and rice production. From 1992 to 1999 when rice production is increasing, rainfall is fluctuating indicating that, there is no relationship between them. However, an increase in rice production as a result of an increasing rainfall trend was recorded from 2000 to 2012. In this case, there is a relationship between rainfall and the production. While, in 2013, there is no correlation between rice production and rainfall in Office Riz Ségou. This concurs with the findings of Tanaka *et al.* (2012) who found out that, “the relationship between rainfall and rice production is not clear”. However, this result is contrary to the finding of Zakaria *et al.* (2014) who found a good relationship between rice production and rainfall in Bangladesh.

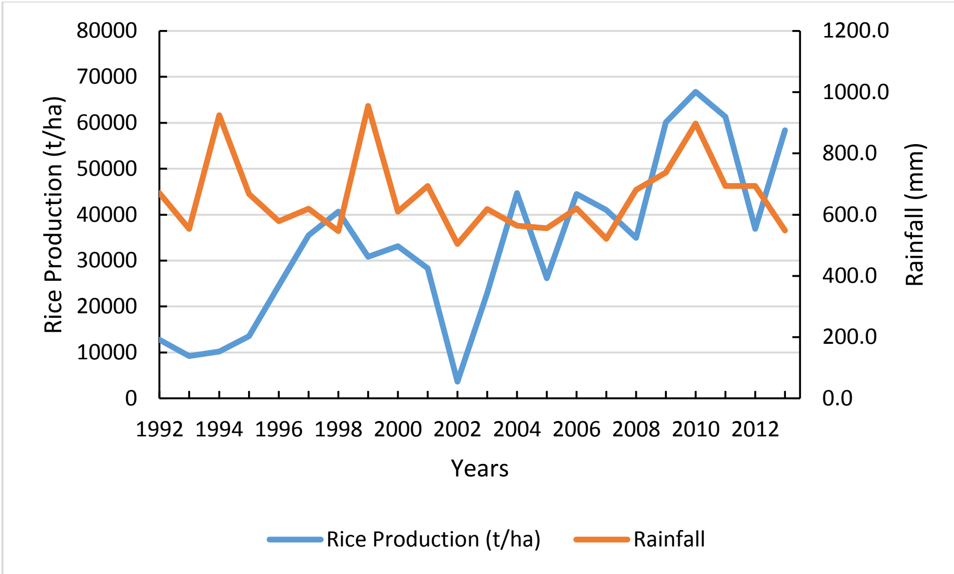


**Figure 4.12:** Relationship between rice production and rainfall

The correlation between rainfall and rice production is shown in Figure 4.13, which is not significant with p-value = 0.5488. Some researchers also have concluded that the correlation between rainfall and rice yield was 0.14 which is low and is an indicator of direct independence of rice yield on rainfall (Sarma *et al.*, 2008). It can be inferred from Figure 4.13 that there is no correlation between rainfall and rice production in ‘‘Office Riz Ségou”. Therefore, rice production in ‘‘Office Riz Ségou” is not dependent on the amount of rainfall in the locality. This can be explained by the fact that the farms are irrigated at certain period of the rainy season. Rice production may have a good correlation with river water, so it is necessary to do a correlation between the river water irrigation and rice production.

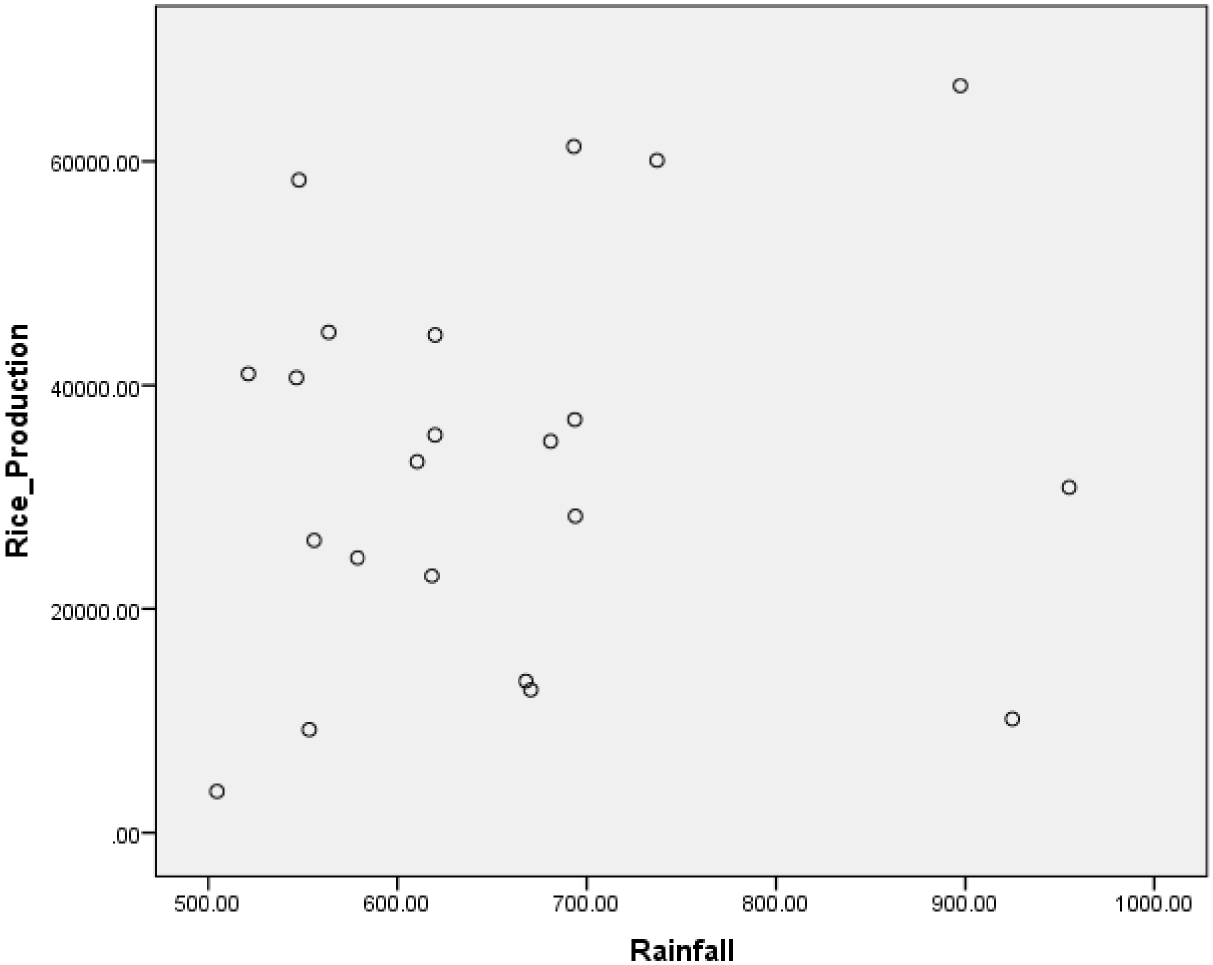


**Figure 4.13:** Correlation between rice production and rainfall

### 4.3.2. Temperature and Rice Production

The relationship between temperature and rice production as depicted by Figure 4.14 indicates increasing trends for both rice production and temperature from 1994 to 1998. From 1999 to 2013, as rice production is decreasing, temperature is increasing with some exceptional years (from 2010 to 2013). Similar result was found by Tanaka *et al.* (2012) who concluded that there is no relationship between rice production and temperature.

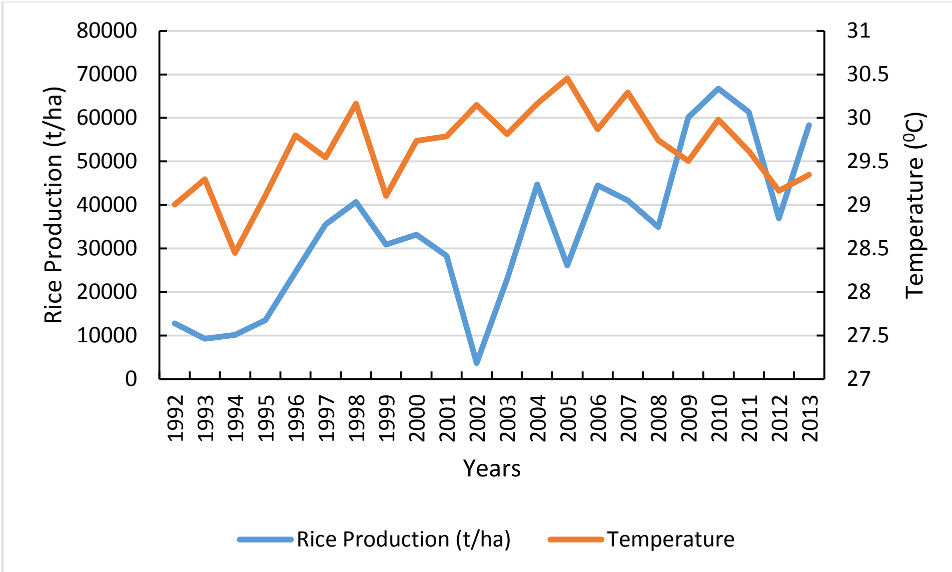


**Figure 4.14:** Relationship between temperature and rice production

The correlation between temperature and rice production is shown in the figure 4.15. This shows that the correlation between rice production and temperature is not significant with a p-value equals to 0.2074. According to Soungalo Sarra, the head of irrigated rice research program at Institut d'Economie Rurale (IER), temperature between 13 to 40ºC is good for rice production, while 1°C rise in average daily temperature reduces major crops production by 5-7% (Matthews *et al.*, 1997, cited in Wassmann and Dobermann 2007). The yield of non-irrigated crops such as wheat and rice shows a decrease and loss in farm-level net revenue by 9% and 25% for a temperature increase of 2–3.5°C (Wassmann and Dobermann 2007). In addition, it is observed that a 2°C increase results in a 15–17% decrease in grain yield of rice and wheat (Aggarwal and Mall, 2002, cited in Wassmann and Dobermann, 2007).

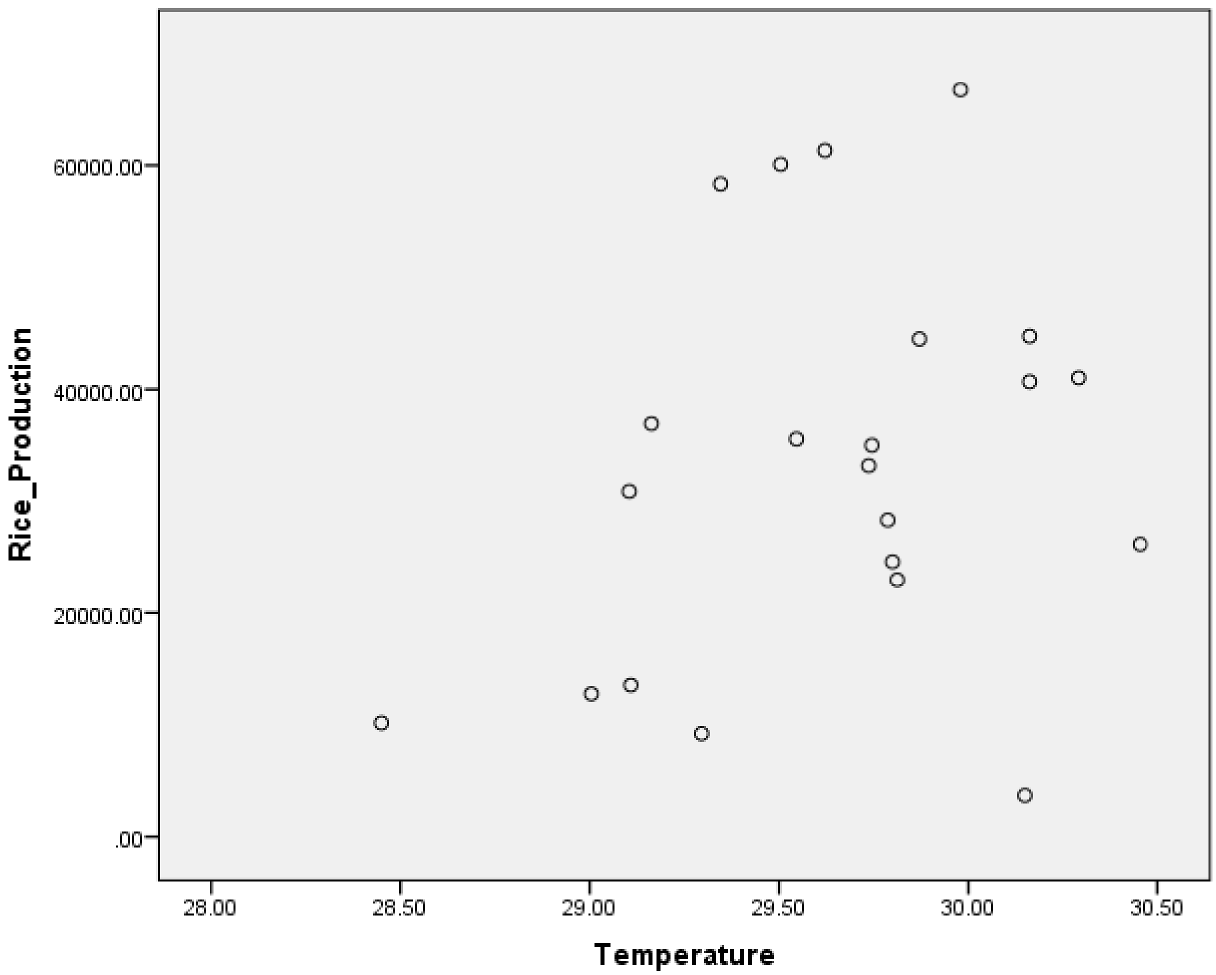


**Figure 4.15:** Correlation between rice production and temperature

### 4.3.3. Humidity and Rice Production

Figure 4.16 shows the relationship between humidity and rice production. From 1993 to 1998 rice production shows an increasing trend, while humidity shows both increasing and decreasing trends. However, from 1999 to 2013 when humidity is increasing, rice production is increasing and as humidity is decreasing, rice production is also decreasing with the exception of the last two years (2012 and 2013).

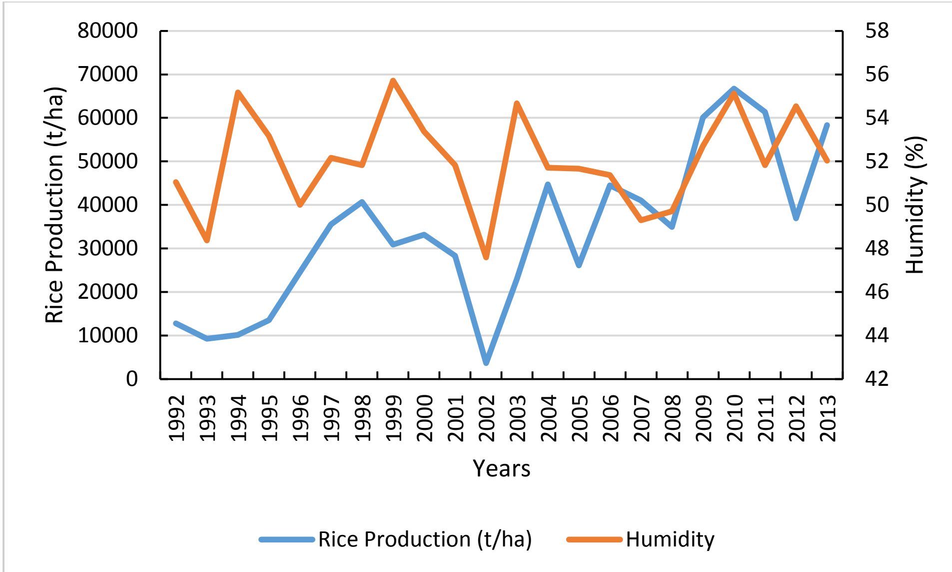


**Figure 4.16:** Relationship between humidity and rice production

The correlation between humidity and rice production is shown in figure 4.17 with p-value: 0.2349. The correlation between humidity and rice production is not significant. The finding of Ayinde *et al.* (2013) shows that an increase of 1% in humidity will cause 17.1% reduction in rice production in Niger State. From the results of correlation between rice production and climatic parameters (rainfall, temperature and humidity), it can be inferred that rice production does not directly depend on climatic factors.

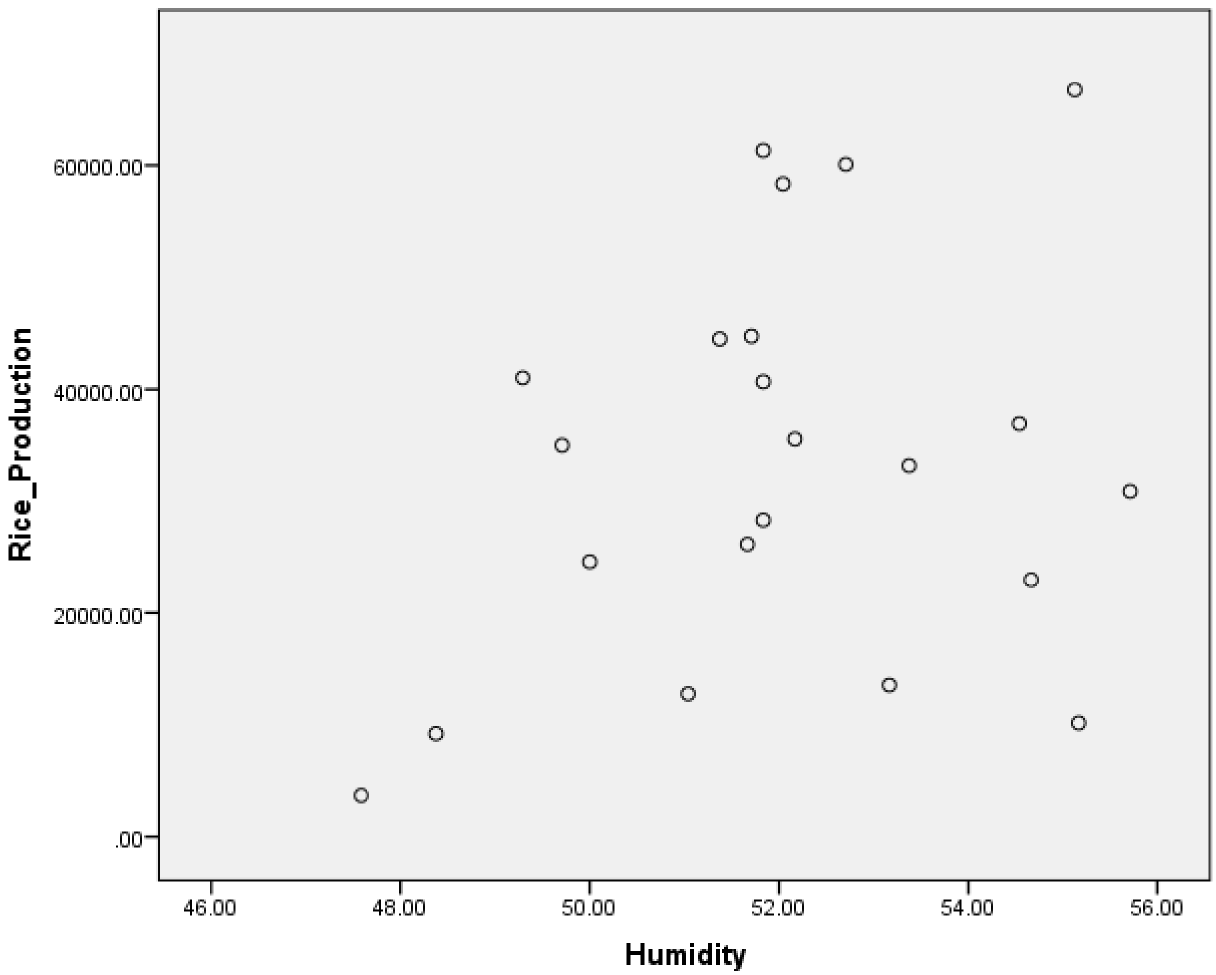


**Figure 4.17:** Correlation between rice production and humidity

### 4.3.4. River Flow and Rice Production

Figure 4.18 shows the relationship between rice production and river flow. From 1993 to 1998, rice production shows an increasing trend, while river flow was fluctuating. However, from 1999 to 2013, generally when river flow shows an increasing trend, rice production shows a decreasing trend except 2002 where the decrease of rice production corresponds to decrease of river flow. The Figure 4.18 below shows no significant relationship between rice productions and river flow.

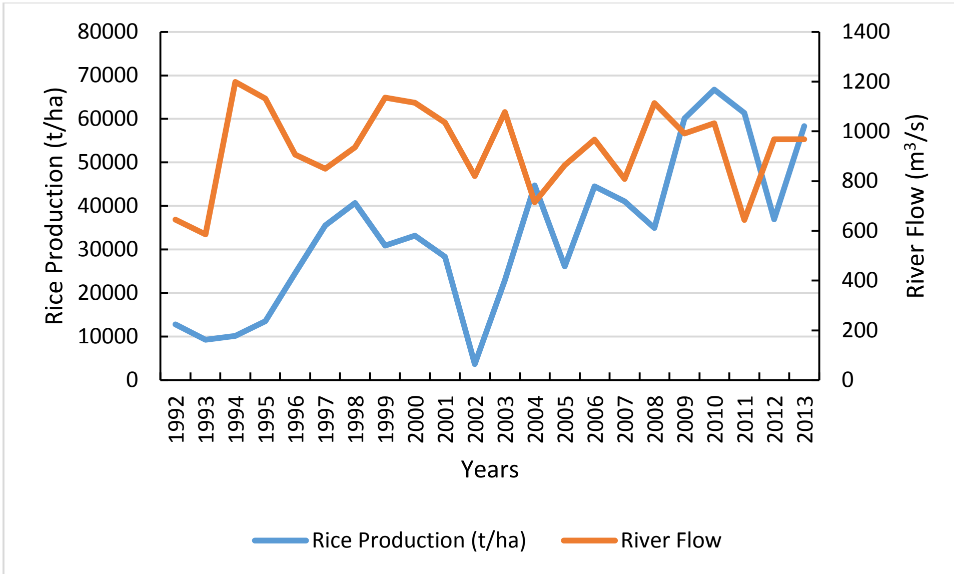


**Figure 4.18:** Relationship between river flow and rice production

Figure 4.19 below shows a correlation between rice production and river flow. The correlation is not significant with p-value: 0.9707, implying that rice production does not depend on river flow in the study area. This may be attributed to data location because results of Verburg *et al.* (2009) shows that rice production in Office du Niger depends on River Niger flow.

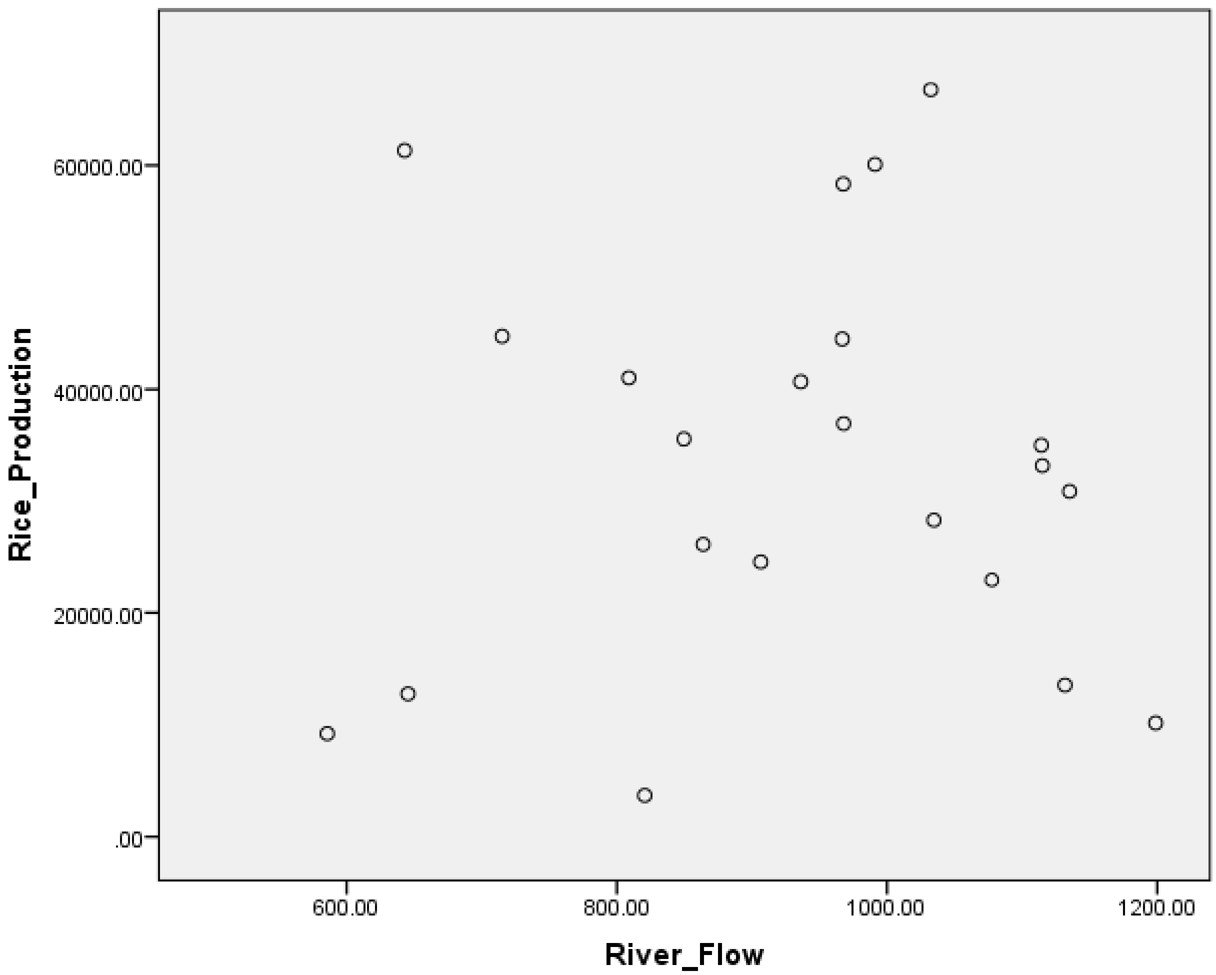


**Figure 4.19:** Correlation between rice production and river flow

In summary, the result shows no relationship between hydro-climatic parameters (i.e. rainfall, temperature, humidity and river flow) and rice production. Also, the correlation between rice production and hydro-climatic factors are not significant.

**4.4. Multiple Regression of Rice Production as a Function of Hydro-climatic Factors.**

To evaluate the effect of climate variability on rice production, the production in ORS is taken as dependent variable of rainfall, temperature, humidity and river flow for a period of 22 years (1992 to 2013). The multiple regression model for production is applied for the analysis, it helps us to know which of the hydro-climatic parameters influence rice production in the area.

The regression analysis for rice production and hydro-climatic parameters are described in Table 1. Regarding model validation, we used the Fisher-Snedecor test to validate the individual significance of each coefficient indicated in Table 1. Furthermore, the coefficient of determination ($R^2$) shows that the model explains 32% of the total variation in the rice production in ORS.

**Table 4.2:** Multiple regression of rice production as a function of hydro-climatic factors.

| **Variables** | **Coefficients** | **t-statistic** |
|---|---|---|
| Constant | -774382.86369 | -2.5534324 |
| Rainfall | 33.24448 | 0.7159896 |
| Temperature | 0297.24267 | 2.2574321** |
| Humidity | 4071.97037 | 1.5549172 |
| River Flow | -29.34251 | -1.1127224 |

**Note:** *1% and ** (5%) level of significance

The result of multiple regression analysis shows that temperature is the only variable which is significant at 5%. This result is similar to the findings of Rahman (2005) who found out that the minimum temperature has significance on rice production while, rainfall, relative humidity and river flow are not significant. Rahman's results clarify that weekly rainfall has huge significance on rice production while annual rainfall has no significance on rice production. On the contrary, Ogbuene (2010) found out that rainfall is significant to rice yields in Nigeria, while Sarker et al. (2012) found that rainfall has a statistically significant effect on Aus and Aman rice production in Bangladesh. Although temperature contributes positively to rice production in the study area (ORS), it does not have meaningful level of influence.

In sum, the correlation and multiple regression analysis between hydro-climatic parameters and rice production shows that rice production does not only depend on hydro-climatic factors; so, the first hypothesis is rejected.

### 4.5. Farmers' Perception on Climate Change

#### 4.5.1. Farmers' Perception on Rainfall

The local farmers have determined the change in rainfall by using the length of rainy season, the amount of rain, onset of the rainy season and cessation of rainy season. From the result of the analysis, 99.3% of the households perceive a change in seasonal rainfall, while 0.7 % perceive no changes in seasonal rainfall. Also, 32%, of the farmers show that rainfall starts late, while 23.3% of the farmers observe that rainfall ends early and the length of rainy season is becoming shorter, according to 37.3% of the farmers. All the respondents identify an increase in dry spell, while 7.3% of the farmers introduced the modification of seasonal rainfall (figure 4.21). Furthermore, in a similar research conducted in Burkina Faso, over 90% perceived a decline in the amount of rainfall during rainy season and 95% of the farmers confirm that rainfall starts late and ends early (Sanfo *et al.*, 2014). Figure (4.22) indicates that 76% of the farmers notice a decrease in rainfall, while 24% of respondents indicate that the rainfall has increased. Also, 24% perceived an increase in rainfall and 49% of the total respondents' perceived decrease in rainfall in Bawku, Ghana (Acquah, 2011). (See Annex A)

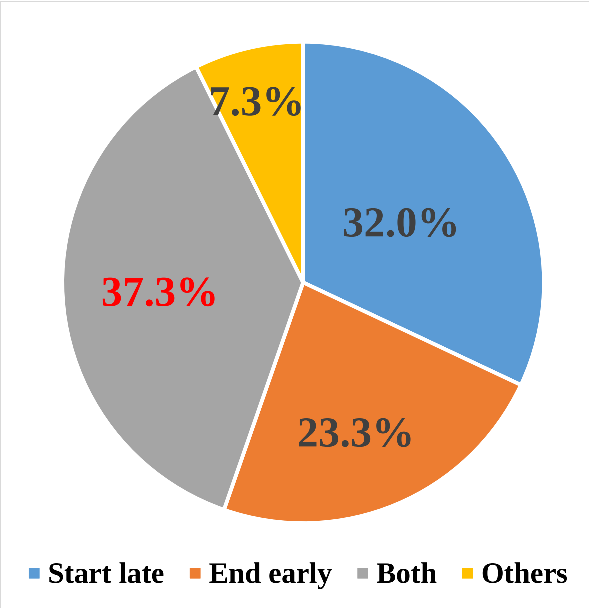


**Figure 4.20:** Farmers' perception on the timing of rainfall

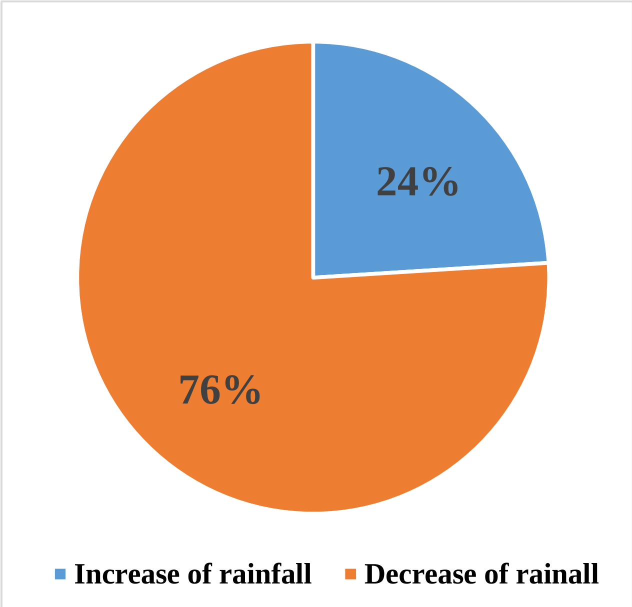


**Figure 4.21**: Farmers' perception on the nature of rainfall

### 4.5.2. Farmers' Perception on Temperature

Concerning the perception of farmers regarding temperature; 84.7% of the farmers observe the change in temperature, 6% see no change in temperature and 9.3% have no idea about the variability of temperature (see Annex A). Figure 4.23 below shows that 75% of respondents realize an increase in temperature, while 12% of respondents indicate a decrease in temperature. This result is similar to the findings of Acquah (2011) who showed that the majority constituting 60% of the total respondents perceived an increase in temperature in Ghana and that of Sanfo *et al.* (2014), where 95% of the farmers noticed changes in temperature in Burkina Faso.

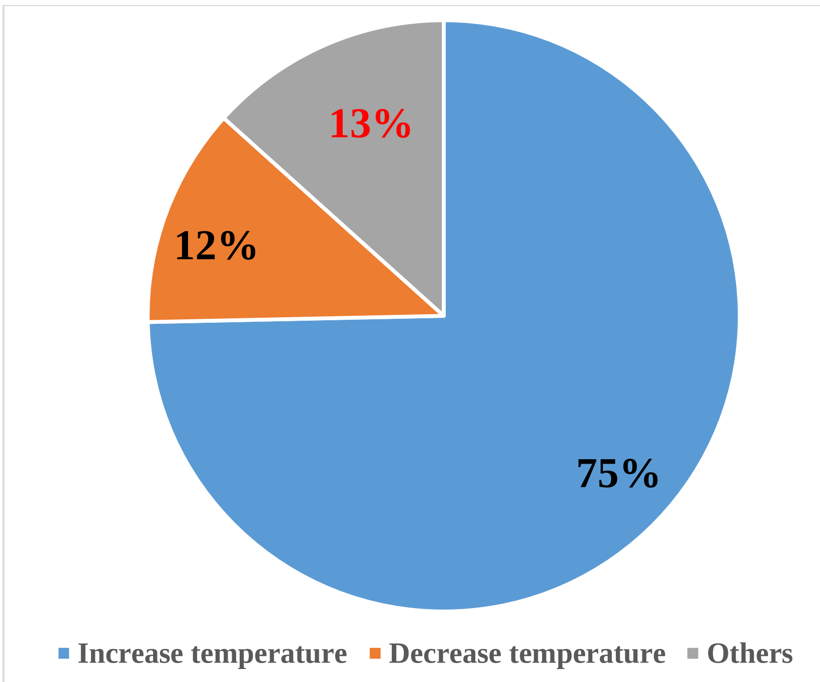


**Figure 4.22:** Farmers' perception on temperature

### 4.5.3. The Effect of Climate Hazard on Rice Production

Rice production is affected by many factors: climatic parameters or other hazards. From figure 4.24 below, 86% of the households considered drought as the main cause of decrease in rice production and 4% agree on the increase in rice production during dry spell. Again, 43.3% of the farmers have identified high temperature as an important factor that affects rice production. Figure 4.25 below shows that out of these 43.3 % of respondents who identified high temperature as an important factor that affects rice production, 11% of them realized that high temperature leads to increase in rice production, while 35% of them said high temperature can lead to decrease in rice production.

Furthermore, 68% of the farmers perceive that climate is changing. Concerning the causes of climate change, 55.3% considered deforestation as the main cause, while 10% of the farmers considered population growth as the main cause of climate change. According to Kalinda (2011), most of the farmers considered deforestation as the main cause of climate change in Zambia. Again, 79.3% considered climate change as bad, while 16.7 % of the farmers opposed it. The farmers who said it was good based their views on their religious beliefs. Equally, 98.7% of the household perceived climate has been changing since early 2000s. Drought was considered as the most climate hazard that affects households. It was also opined that climate change enormously affects food security. (See Annex A)

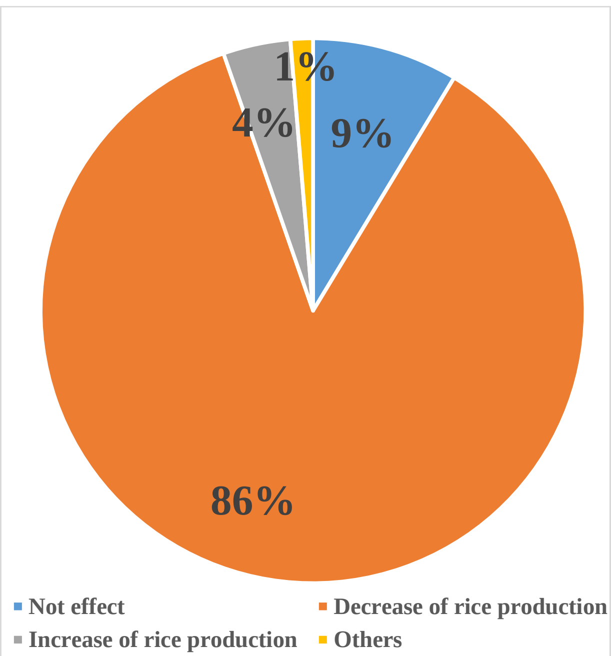


**Figure 4.23:** Farmers' perception on the effect of rainfall on rice production

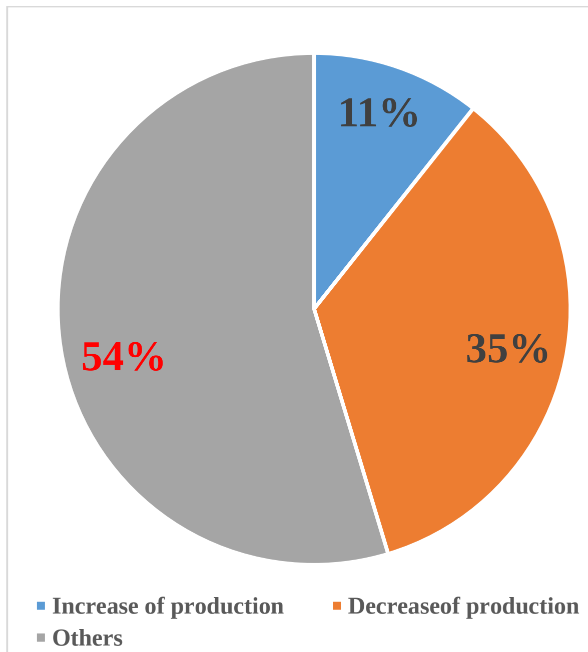


**Figure 4.24**: Farmers' perception on the effect of temperature on rice production

### 4.5.4. Adaptation Strategies

The result from statistical analysis shows that farmers were limited by drought and other hazard that affect rice production. It was discovered that 98% of the households did not have adaptation strategies to drought but 7.3% of the farmers created drainage systems, while 45.3% of them used improved seeds as the main adaptation strategies to flood in the study area, as Figure 4.26 below illustrates it. Also, 72.7% of the households affirmed that they lacked aid to face the effects of climate change on rice production, as opposed to 26% of the respondents who had aid in the area. (See Annex A)

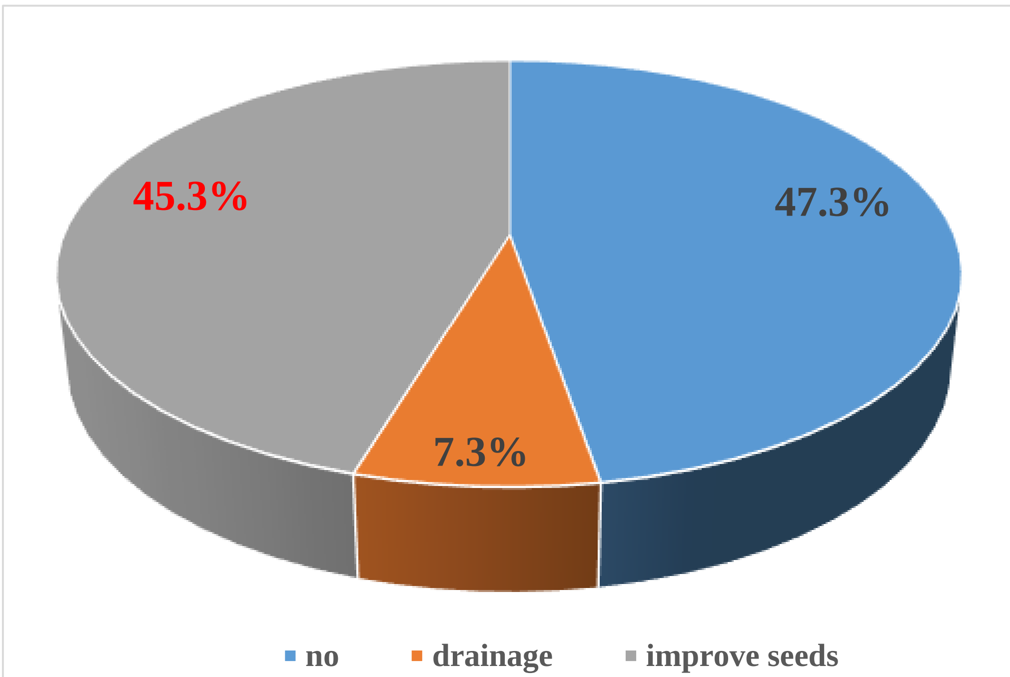


**Figure 4.25**: Farmers'adaptation strategies

In sum, the results of farmers' perception shows that the households are aware about climate variability/change and its effect on rice production in Office Riz Ségou: so, the second hypothesis is accepted.

# CHAPTER FIVE

## CONCLUSIONS AND RECOMMENDATIONS

The study focused on the influence of climate variability on rice production in "Office Riz Ségou" from 1980 to 2014. An increasing trend in hydro-climatic parameters (temperature, humidity and river flow) was observed; they are significant at 1%, while rainfall is not significant. In addition, using the moving average of 5 years the trend of hydro-climatic parameters show two main differences (above and below the normal), except rainfall which show a very high variability. The variability of the rainfall indicates that the rainfall is not regularly distributed during the period of the study. It is observed that rice production increases and the trend is significant at 1%.

There is no relationship between hydro-climatic factors and rice production. Also, correlation between hydro-climatic factors and rice production is not significant at 5% level. Furthermore, the correlation between rice production and hydro-climatic parameters (rainfall, temperature and humidity) indicates that rice production is not directly dependent on climatic factors. All the correlations were positive but they do not have significant influence on rice production within the study area.

The multiple regression analysis for rice production and hydro-climatic parameters shows that the correlation between temperature and rice production was significant at 5% while, rainfall, humidity and river flow are not significant.

Majority of the farmers do not have strategies to combat or cope with drought, while drought was considered as the main cause of decrease in rice production. Also, farmers considered deforestation as the main cause of climate change. While there is no adaptation strategies to address drought, the creation of drainage system and the use of improved seeds are considered as the main adaptation strategies to flood in the study area.

Finally, most farmers have identified a decrease in the amount of rainfall and increase in temperature in the study area. As a result, there is a similarity between time series analysis of temperature, rainfall and farmers' perception on these parameters (temperature and rainfall).

Considering the various effects of hydro-climatic parameters on rice production in the study area, it is necessary to apply the following recommendations:

- promote agro-meteorological advisory services which will be useful in farm planning and environmental resource sustainability through closer collaboration among meteorologists and agricultural scientists. This is needed to increase people's awareness of the existing data-base in the study area

- promote best rice production practices that are climate change resilient such as efficient irrigation system in ORS.
- improved seed and early maturing species should be adapted to increase rice production; and
- adapt and promote drought tolerant rice crops species to increase rice production

Limitation

- Hydro-climatic parameters are not the only parameters that influence rice production: farm practices and farm inputs are other factors. Thus, it is necessary to further examine such factors to increase rice production and food security in Office Riz Ségou.

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**Annex A:** Farmers' Perception on Climate Change

**Modification of Seasonal Rainfall**

| | | Frequency | Percent | Valid Percent | Cumulative % |
|---|---|---|---|---|---|
| Valid | yes | 149 | 99.3 | 99.3 | 99.3 |
| | no | 1 | .7 | .7 | 100.0 |
| | Total | 150 | 100.0 | 100.0 | |

**Get help from government or NGO**

| | | Frequency | Percent | Valid Percent | Cumulative % |
|---|---|---|---|---|---|
| Valid | | 2 | 1.3 | 1.3 | 1.3 |
| | yes | 39 | 26.0 | 26.0 | 27.3 |
| | no | 109 | 72.7 | 72.7 | 100.0 |
| | Total | 150 | 100.0 | 100.0 | |

**Adaptative strategies to drought**

| | | Frequency | Percent | Valid Percent | Cumulative % |
|---|---|---|---|---|---|
| Valid | no | 147 | 98.0 | 98.0 | 98.0 |
| | others | 3 | 2.0 | 2.0 | 100.0 |
| | Total | 150 | 100.0 | 100.0 | |

**The name of climate change**

| | | Frequency | Percent | Valid Percent | Cumulative % |
|---|---|---|---|---|---|
| Valid | yes | 102 | 68.0 | 68.0 | 68.0 |
| | no | 48 | 32.0 | 32.0 | 100.0 |
| | Total | 150 | 100.0 | 100.0 | |

**The main cause of climate change**

| | | Frequency | Percent | Valid Percent | Cumulative % |
|---|---|---|---|---|---|
| Valid | deforestation | 83 | 55.3 | 55.3 | 55.3 |
| | population growth | 15 | 10.0 | 10.0 | 65.3 |
| | transport | 5 | 3.3 | 3.3 | 68.7 |
| | land degradation | 1 | .7 | .7 | 69.3 |
| | others | 46 | 30.7 | 30.7 | 100.0 |
| | Total | 150 | 100.0 | 100.0 | |

**Climate change good or bad**

| | | Frequency | Percent | Valid Percent | Cumulative % |
|---|---|---|---|---|---|
| Valid | good | 25 | 16.7 | 16.7 | 16.7 |
| | bad | 119 | 79.3 | 79.3 | 96.0 |
| | 3 | 6 | 4.0 | 4.0 | 100.0 |
| | Total | 150 | 100.0 | 100.0 | |

**Effect of climate variability village**

| | | Frequency | Percent | Valid Percent | Cumulative % |
|---|---|---|---|---|---|
| Valid | yes | 148 | 98.7 | 98.7 | 98.7 |
| | no | 1 | .7 | .7 | 99.3 |
| | 3 | 1 | .7 | .7 | 100.0 |
| | Total | 150 | 100.0 | 100.0 | |

**Effect of temp on rice production**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | yes | 65 | 43.3 | 43.3 | 43.3 |
| | no | 57 | 38.0 | 38.0 | 81.3 |
| | others | 28 | 18.7 | 18.7 | 100.0 |
| | Total | 150 | 100.0 | 100.0 | |

**Changes of temperature**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | yes | 127 | 84.7 | 84.7 | 84.7 |
| | no | 9 | 6.0 | 6.0 | 90.7 |
| | Don't know | 14 | 9.3 | 9.3 | 100.0 |
| | Total | 150 | 100.0 | 100.0 | |

**Annex B: QUESTIONNAIRE**

**QUESTIONNAIRE OF CLIMATE CHANGE ON RICE PRODUCTION IN MALI: A CASE STUDY OFFICE RIZ SEGOU**

Region………………………. Circle……………………Extension service…………………….,..
Compartment……………………..… Name of Village……………………………………..

Work number: Date of Interview: / / 06 / 2015

| | **Questions** | **Answers** |
|---|---|---|
| **I** | **SOCIO-ECONOMIC CHARACTERISTICS** | |
| 1.1 | Age of household chief | 1.) 30-40 ☐ 2.) 40-50 ☐<br>3.) 50-60 ☐ 4.) more than 60 ☐ |
| 1.2 | Gender | 1.) Male ☐ 2.) Female ☐ |
| 1.3 | Ethnic | |
| 1.4 | Marital Status | 1.) Single ☐ 2.) Married ☐<br>3.) Widowed ☐ 4.) Divorced ☐<br>5.) Separated ☐ |
| 1.5 | Level of education of household chief | 1.) Primary ☐ 3.) High ☐<br>2.) Secondary ☐ 4.) University ☐<br>5.) Arabe ☐ 6.) Bambara ☐<br>7.) Others ☐ 8.) Never ☐ |
| 1.6 | How many people are in your family? | 1.) Men / / women / /<br>2.) Children: boys / / girls / / |
| 1.7 | How many people work in your farm? | 1.) Men ……….. 2.) Women…………<br>Children 3.) boys…………, 4.) Girls……………. |
| 1.8 | What is your main activity? | 1.) Crop production ☐ 2.) livestock ☐<br>3.) Trade ☐ 4.) Fishing/catch ☐ |
| 1.9 | If crop production, which type of crop are you producing adding to rice?<br><br>RS (rainy season)<br>DS (dry season) | (see table below) |

| | Area | | Product$^{O}$ | | yield | |
|---|---|---|---|---|---|---|
| Rank | RS | DS | RS | DS | RS | DR |
| Rice ☐ | | | | | | |
| Sorghun ☐ | | | | | | |
| Millet ☐ | | | | | | |
| Grandnut ☐ | | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| | | Others ☐ | | | |
| 1.10 | Are you rising animals? | | Rank | numbers | |
| | | Cows | | | |
| | | Sheep | | | |
| | | Goat | | | |
| | | Horse | | | |
| | | others | | | |
| 1.11 | Fishers | 1.) Fishing/catch ☐ 2.) Trader ☐<br>3.) Pisciculture ☐ 2.) Others ☐ | | | |
| 1.12 | What is/are the Source of land you use for rice farming? | Area<br>1. Purchased ☐ ☐<br>2. Inherited (family) ☐ ☐<br>3. Rented/hired ☐ ☐<br>4. Attributed ☐ ☐<br>5. Contract ☐ ☐ | | | |
| 1.13 | If your land is rented/attributed/ Purchased, how much do you pay per hectare? | Price/ha<br>1.) Rented ☐ ☐<br>2.) Attributed ☐ ☐<br>3.) Purchased ☐ ☐<br>4.) contract ☐ ☐ | | | |
| 1.14 | Input used for rice production per hectare. | Seeds (Kg/ha) ………… , Fertilizers(Kg/ha)……….<br>Others(kg/ha)……………… | | | |
| 1.15 | How many times did you produce rice per year? | 1.) One ☐ 2.) Two ☐ | | | |
| 1.16 | If one, why? | | | | |
| 1.17 | Are women allowed to inherit land in your village? | 1.) Yes ☐<br>2.) No ☐ | | | |
| 1.18 | If not, why? | | | | |

| II | FARMERS' PERCEPTION OF CLIMATE | | |
|---|---|---|---|
| 2.1 | Are there any modification in the seasonal rainfall during these last 10 years in your area? | | 1.) Yes ☐<br>2.) No ☐ |
| 2.2 | If yes, what are the modifications? Answer<br>………………………<br>…………………………<br>………… | How long is the rain season? | 1.) 1 to 3 months ☐ 3.) More than 5 months ☐<br>2.) 3 to 5 months ☐ |
| | | How long is the dry season? | 1.) 2 to 4 months ☐ 3.) More than 6 months ☐<br>2.) 4 to 6 months ☐ |
| 2.3 | Are there any changes of rainfall in your area? | | 1.) Yes ☐ 2.) No ☐ |
| 2.4 | If yes, how is occurring? | | 1.) Increase of rainfall ☐<br>2.) Decrease of rainfall ☐<br>3.) More rainfall causing flooding ☐<br>4.) Decrease of rainfall causing drought ☐ |
| 2.5 | What is the occurrence of daily rainfall in your area? | | 1.) Continuous ☐<br>1.) Intermittent ☐ |
| 2.6 | In case of intermittent rain what is the main duration in the day? | | 1.) An hour ☐<br>2.) More than hour ☐ |
| 2.7 | What is the duration between the rains in your area? | | 1.) 1-4days ☐ 2.) 4-7days ☐<br>2.) 2weeks ☐ 4.) 3weeks ☐<br>5.) A month ☐ 6.) More than a month ☐ |
| 2.8 | Are there any changes of temp in your area? | | 1.) Yes ☐ No ☐ |
| 2.9 | If yes how? | | 1.) Higher temperature ☐<br>2.) Lower temperature ☐ |
| 2.10 | Does the increase of temperature have an effect on rice production? | | 1.) Yes ☐<br>2.) No ☐ |
| 2.11 | If yes, what are they? | | 1.) Increase of prodt ☐ 2.) Decrease of prodt ☐ |
| 2.12 | Did you hear the name of climate change? | | 1.) Yes ☐ 2.) No ☐ |
| 2.13 | What are the main causes of climate change? | | 1.) Deforestation ☐ 4.) Land degradation ☐<br>2.) Population growth ☐ 5.) Industrialization ☐<br>3.) Transport ☐ 6.) Others ☐ |

| | | |
|---|---|---|
| 2.14 | Is-climate change good or bad thing? | 1.) Good ☐ 2.) Bad ☐ |
| 2.15 | Since when did you know the climate is changing? | |
| **III** | **EFFECT OF CLIMATE CHANGE** | |
| 3.1 | Did you think climate variability or change have an effect in your village? | 1.) Yes ☐<br>2.) No ☐ |
| 3.2 | If yes, what is the main climatic hazard in your village? | 1.) Drought ☐ 2.) Flood ☐<br>3.) Storm (wind) ☐ 4.) Bush fire ☐<br>5.) Others ☐ |
| 3.4 | What is the frequency of the hazard? | 1.) More ☐ 2.) Average ☐ 3.) Less ☐ |
| 3.5 | Is this hazard affecting rice production? | 1.) Yes ☐ 2.) No ☐ |
| 3.6 | If yes how? | 1.) Decrease of production ☐<br>2.) Increase of production ☐ 3.) Other ☐ |
| 3.7 | Did you change your activity because of it? | 1.) Yes ☐ 2.) No ☐ |
| 3.8 | If yes what are you doing now? | |
| 3.9 | Apart from climate, are there any other hazards which affect rice yield in your area? | 1.) Yes ☐<br>2.) No ☐ |
| 3.10 | If yes, what are they? | 1.) Insects ☐ 2.) Low nutrient ☐ 3.) Others ☐ |
| 3.11 | Does climate variability or change affect food availability in your village? | 1.) Yes ☐<br>2.) No ☐ |
| 3.12 | If yes, how (in which sense/way)? | |
| 3.13 | What are the most vulnerable people of climate change in your village? | 1.) Men ☐ 3.) Children ☐<br>2.) Women ☐ 4.) All ☐ |
| 3.14 | Why? | |

<table>
<tr><td>IV</td><td colspan="6">EDUCATION/INFORMATION</td></tr>
<tr><td>4.1</td><td>How often does agricultural extension services visit your farm?</td><td colspan="5">1.) Weekly ☐ 2.) Monthly ☐<br>3.) 1-6 months☐ 4.) Yearly ☐<br>4.) 1-4 years ☐ 6.) Not at all ☐</td></tr>
<tr><td>4.2</td><td>Do you receive any information about climate change, awareness program?</td><td colspan="5">1.) Yes ☐ From who......................<br>2.) No ☐</td></tr>
<tr><td></td><td>Do you continuous to receive information about it?</td><td colspan="5">1.) Yes ☐ From who……………..<br>2.) No ☐</td></tr>
<tr><td rowspan="6">4.3</td><td rowspan="6">If yes, what is the time interval?</td><td>CC</td><td>Hours</td><td>days</td><td>Weeks</td><td>Months</td></tr>
<tr><td>Radio</td><td></td><td></td><td></td><td></td></tr>
<tr><td>TV</td><td></td><td></td><td></td><td></td></tr>
<tr><td>ORS</td><td></td><td></td><td></td><td></td></tr>
<tr><td>others</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>V</td><td colspan="6">ADAPTATIVE STRATEGIES TO CLIMATE CHANGES</td></tr>
<tr><td>5.1</td><td>In case of drought, what are your adaptative or coping strategies?</td><td colspan="5"></td></tr>
<tr><td>5.2</td><td>What are your adaptative/coping strategies for rice production if flooding occurs in your area?</td><td colspan="5"></td></tr>
<tr><td>5.3</td><td>When flood/drought occurred, did you get help from government or NGOs?</td><td colspan="5"></td></tr>
</table>

**<u>Others Comments:</u>**