RAINFALL VARIABILITY IMPACTS ON RICE PRODUCTION: A CASE STUDY OF RICE YIELD IN THE ADMINISTRATIVE UNIT OF COLLINES IN BENIN, WEST AFRICA

BY

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DECLARATION

This research project is my original work and it has never been presented for examination in any other University or institution.

_____________ Date_____/_____/_____

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This research project has been submitted for examination with our approval as University supervisors.

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ABSTRACT

Rice is considered as key crop in the strategic planning to revitalize the agricultural sector to a level of self-sufficiency, reduce poverty as specified in the National Rice Strategic Plan. To place rice as a strategic crop in Benin, there is need to have information on both physical and human factors that influence production.

This study aims to determine the impact of inter-seasonal rainfall variability on rainfed rice yield in Collines. In order to achieve these purpose three objectives were considered; establishing the nature of spatial and temporal variation of inter-seasonal rainfall and rice yield, determining farmers' perception on agro-calendar and to determine the relationship between inter-seasonal rainfall and rainfed rice yield in districts of Collines. Different types of datasets were used; Secondary dataset - Tropical Rainfall Measuring Mission dataset calibrated (correlation coefficient r = 0.86) with in situ measurement of weather station of Save for the same period, data on annual yields and total rice growing acreage; Primary data of 100 rainfed rice farmers were randomly and purposively interviewed on rainfall season, rice growing season, constraints and factors affecting production. The primary and secondary data sets were transformed and subjected to descriptive statistics, correlation analysis and simple linear regression analysis to determine impacts of inter-seasonal rainfall over a time period 1998 to 2015.

The results shows inter-seasonal rainfall is decreasing (coefficient of determination, r^2 = 0.15) and rice yield is increasing (r^2 = 0.18) within the six districts with coefficients of rice yield variability are; Bantè (0.22), Dassa-Zoumè (0.24), Savalou (0.21), Ouèssè (0.32), Glazoué (0.35) and Savè (0.36). Rainfed rice farmers responses (68%) of three districts (Bantè, Savalou and Glazoué) indicate rainfall and rice yield are decreasing within the districts and 100% blame a shift in agro-calendar onset. Finally inter-seasonal rainfall variability impacts varies differently from district to another but statistically significant for Ouèssè where 29.6 % of inter-seasonal rainfall variability are explaining rice yield variability in a district of Ouèssè, 70.4% remaining are attributed to other unexplained factors such as soil, farming methods, planting date, weeds, seed varieties, pest and diseases.

The study concludes that the decreasing rate of inter-seasonal rainfall and impacts have not reached a critical level to induce significant impacts on the rice yields within districts of the Administrative Unit of Collines. The study recommends a need to invest in rainfed rice insurance scheme, rice farmers' capacity building on farming practices and the irrigation scheme for the Collines region in future.

LIST OF ACRONYMS

AUC	Administrative Unit of Collines
AMO	Atlantic Multi-decadal Oscillation
AO	Artic Oscillation
ARC	Africa Rainfall Estimate Climatology
ASECNA	Agency for Aerial Navigation Safety in Africa and Madagascar
BRGM	Beninese Office of Geological and Mining Research
CARD	African Coalition for Rice Development
CCFS	Climate Change and Food Security
CENATEL	National Centre for Tele detection
CHIRPS	Climate Hazards Group Infra-Red Precipitation with Stations
EMICoV	Integrated Household Living Conditions Survey
ENSO	El Nino Southern Oscillation
FAO	Food and Agricultural Organization
GES	Geological Earth Survey
HDI	Human Development Index
INSAE	National Institute of Statistic and Economic Analysis
IOD	Indian Ocean Dipole
IPCC	Intergovernmental Panel on Climate Change
ITF	Inter-Tropical Front
MAE	Mean Absolute Error
MALF	Ministry of Agriculture Livestock and Fisheries
NAO	North Oscillation Atlantic
NAPA	National Adaptation Plan Action
NASA	National Aeronautics Space Administration
NERICA	New Rice for Africa
NRDS	National Rice Development Strategy
OXFAM	Oxford Committee for Famine Relief
PDO	Pacific Decadal Oscillation
PERSIANN	Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks
PSRA	Strategic Plan to Revitalize the Agriculture Sector
RFE	African Rainfall Estimation
RMS	Root Mean Square
RMSE	Root Mean Square Error
SCRP	Growth Strategy for Poverty Reduction
TAMSAT	Tropical Applications of Meteorology using SATellite
TARCAT	African Rainfall Climatology and Time series
TMPA	TRMM Multi-satellite Precipitation Analysis
TRMM	Tropical Rainfall Measuring Mission
UNFCCC	United Nations Framework Convention on Climate Change
WARDA	West Africa Rice Development Association ex AFRICA Rice Center

TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF PLATES

LIST OF TABLES

CHAPTER ONE: INTRODUCTION

1.1. Background of the Study

Rainfall variability spatially and temporally is one of the common indicators of climate that has effects both socially and ecologically (IPCC 2007). Extreme rainfall variability triggers environmental challenges such as flood, erosion, drought and desertification, which have serious effect on crop yield(IPCC 2007). Today rainfall occurrences are becoming unpredictable and unreliable with projected significant decreasing trend for agriculture productivity (Parry et *al*, 2004).

According to the IPCC (2012) prediction on rainfall variability impacts projected by 2050 indicate the declining rate on the staple food in Sub-Saharan Africa, a rate counts for 14% of rice, 22% of wheat and 5% for maize pushing many people to depend on rainfed agriculture for subsistence in deeper poverty and vulnerable condition (IPCC, 2012). Some extends of rainfall variability is expected in many part of the world with extreme events; increasing frequencies of heat stress, drought and flooding events with potential adverse effects on agriculture system (Parry et *al*, 2004).

Sub-Saharan African as a region is more vulnerable to rainfall variability events due to increasing population and inadequate national production system (Spearman et *al*, 2012) and the West Africa which located within equatorial belt where rainfall is spread throughout the year have experienced rainfall deficits within many countries. Servat et *al* (1998) indicated that a serious deficit from 20 to 25% on rainfall variability since 1960 which had a starting point in 1970 across West Africa region brought about significant impacts on hydrological system, socioeconomic and environmental sectors.

Benin is located within the equatorial belt region of West Africa and Administrative Unit of Collines and relies on rainfed agriculture and is not exempted from the declining condition of rainfall impacts on livelihood and livelihood strategies (Eric Servat et *al*., 1998). Ogouwalé et *al* (2005) ; Vodounou et *al* (2011) indicated that at national level since the late 1960 the annual height of rainfall was decreasing with potential changes in hydrological system and therefore agricultural production over the country. Annual rainfall is ranging between 1000mm to 1300mm and differs from district to district and is progressing from southern part to the north part of the country.

The explorative studies in general perspective do not focus on the rate of these changes in space and time for crops varieties producing across an administrative unit of the country to anticipate the food crisis. Obviously the food crisis that occurred in 2008 at national level with significant impacts on increasing population accelerated some mitigation initiatives that made ways to development of policies to boost agricultural production through the intensification of farming systems with particular emphasis on rice sector development (Republic of Benin, 2011; 2007; MALF, 2010). National Rice Development Strategy therefore have been setting up with crucial objective of producing 385 000 tons of milled rice and reach a level of self-sufficient by 2020. Careful assessments on the strategic plan indicated a need of investigation of climate action on rice production within rice growing districts specifically rainfed but the key of strategic plan were based only on intensification of rice production through facilitation of suitable and timely credit (MALF, 2011) to small rice farmers.

Little information is known on the rice production and especially on rainfall variability impacts in space and time in central part of country. In addition, rice is considered a strategic crop there is a need to investigate the potential rainfall influences on rice production as critical information for rice development policy. The study covered the Administrative Unit of Collines with its six districts. As such inter-seasonal rainfall variation was considered for the period of 1998 to 2015 and assessed using proxy dataset after validating with the rain gauge dataset of the Administrative Unit of Collines. Panel data on the six districts of annual production of rice yield was also assessed from the 1998 to 2015.The studies have also considered farmers perception through a survey on rainfall seasons, growing season and rice production constraints and management strategies for in-depth understanding of rainfall influences on rice yield in the Administrative Unit of Collines.

1.2. Statement of the Problem

Rice production is an economic activity in Collines where farming is exclusively rainfed. Rainfall variability is therefore a threat to rice yield associated with uncertainties of the past and future climate condition in Collines. This study addressed the role of climate impacts measured in terms of rainfall variability on rainfed rice yields. Specifically the study addressed how inter-seasonal rainfall variability, impact on rice production in terms of changes and in the farmers perceptions on agro-calendar and constraint on rice production, and the nature of relationship between inter-seasonal rainfall variability and rice yields in the Collines area of Benin, all in spatial and temporal context.

Studies carried out at the various levels on rainfall variability regimes warned about possible consequences on agricultural production. In this regard, Le Barbé et *al* (2002) pointed out the declining rate of inter-annual rainfall variability in West Africa, and Ogouwalé et *al* (2005); Vodounou et *al* (2011) stressed the declining trend of annual rainfall height in Benin and trends of wet years in 1950 and dry conditions in 1960 that justified the changes observed in hydro-climatic conditions which would probably be a combination effects of food crisis observed in 2008. Little of those studies have focused on climate issue with emphasis on rainfed rice production in the Administrative Unit level where rainfed rice has been grown for decades.

The main goal of the study was to determine climate variability influence especially inter-seasonal rainfall impacts on rice yield in the Administrative Unit of Collines by providing background information for rice policy development and future agricultural planning. Understanding therefore the influence of rainfall variability and farmers perception could favour the potential rice productivity and profitability for the Administrative Unit of Collines which experiences a bimodal rainy season from March to July for the major rainfall season and minor rainfall season from October to November. The inter-seasonal rainfall in this study covered the two rainy seasons, roughly from March to November which is also the period of rice growing in the Administrative Unit of Collines.

The challenge is therefore to investigate the impacts of inter-seasonal rainfall fluctuations on the growth and yield of rice that depends entirely on rainfall in the districts of Bantè, Save, Savalou, Glazoué, Ouèssè and Dassa-Zoume under Administrative Unit of Collines. The results of this study are critical as they contribute to rice yield improvement, effective policy and program for National Rice Development Strategies.

1.2.1. Research Questions

1. Are there significant changes in the inter-seasonal rainfall and rice yields in Administrative Unit of Collines?
2. Are there significant changes in farmer perceptions on agro-calendar in Administrative Unit of Collines?
3. What is the relationship between inter-seasonal rainfall variability and variation of rainfed rice yields Administrative Unit of Collines?

1.3. Study Objectives

1.3.1. Main Objectives

To determine the impact of inter-seasonal rainfall fluctuations on rainfed rice production in Administrative Unit of Collines in Benin.

1.3.2. Specific Objectives

The main objective of this research outlines the following specific objectives:

1. To establish the nature of spatial and temporal variations of inter-seasonal rainfall and rice yield in Collines.
2. To determine farmers' perception on agro-calendar in Administrative Unit of Collines.
3. To determine the relationship between inter-seasonal rainfall variability and rainfed rice yield in Administrative Unit of Collines.

1.4. Study Hypotheses

1. There are no significant changes in the inter-seasonal rainfall and rice yields in Administrative Unit of Collines.

2. There are no significant changes in farmer perceptions on agro-calendar in Administrative Unit of Collines.

3. There is no relationship between inter-seasonal rainfall variability and variation of rainfed rice yields in Administrative Unit of Collines.

Significant tests in all cases were at α 0.05.

1.5. Study Justification

Rice is considered as staple food and part of daily consumption intake in many countries in Sub-Sahara Africa, where rice is considered a major food crop and commercial crop, for example in West Africa regions and beyond (Tshibaka and Klevor, 2002), it is given special attention as one of the strategic crops both for food security, opportunities in the Administrative Unit of Collines and mostly in the commercial agri-business activities done around the regional market of Glazoué.

In the view of the National Rice Development Strategy, it has been assigned a crucial goal to increase rice production and support the Growth Strategy for Poverty Reduction and mitigate potential future food crisis, investigation on all rice aspects becomes an urgent need to be fulfilled. In addition, regional prediction and few at national level warned about the declining trends of inter-annual rainfall with strong implication in agricultural system (Le Barbé et *al*, 2002; Ogouwalé et *al*, 2005 and Vodounou et *al*, 2011). Benin being predominantly rainfed with traditional agriculture system being practiced by farmers (Igué, 2000), the rainfall variability in the future might be challenge and constitute limited factors in the rice productivity if no clear understanding were made on climate variability.

The findings of the study are critical for policy makers such as the Ministry of Agricultural Livestock and Fisheries, especially the National Rice Development Strategy to understand and appreciate the inter-connections through rainfall variability on rice production at the Administrative level. The study findings would facilitate the improvements of development approaches; agenda and policies in agricultural sector through a creation of favourable condition for rice farmers in the sector and strengthen the National Rice Development Strategy, to achieve rice sufficiency and poverty alleviation. Finally the findings will also serve as background information on the rainfall variability on rainfed rice production.

1.6. Scope and Limitation

The study covered six districts of Administrative Units of Collines such as Bantè, Savè, Savalou, Glazoué and Ouéssè where farming has been rainfed rice production since more than two decades and organized in individual and small group of rice growers. The data covered 18 years due lack of historical and reliable dataset on rice yield within the six districts therefore the period from 1998 to 2015 was adopted during all analyses.

Climate data on rainfall was mainly on monthly basis acquired from the Tropical Rainfall Measuring Mission and calibrated with in situ monthly dataset at Savè weather station, which is one of the six reference ground station of the National Meteorological Direction. The rainfall data covered the same period of rice growing, since rainfall is key determinant factor in rainfed agriculture in the Administrative Unit of Collines. Rainfall was considered as independent variable and rice yield as dependent variable, farmers' perception on agro-calendar is considered as parameters to understand in space and time rainfall influence on rice yield. However primary data collections have needed field assistant to translate questionnaire to local media communication due to language barrier and high illiteracy amongst rice farmers and due to unpredictable event the sample size expected was not reached out.

The study restricted to those variables hasn't taken into account other factors like temperature, relative humidity, sunshine, soil moisture, pests and disease, management practices.

1.7. Operational Definitions

Agro-calendar: is a complex including rainfall onset, period of rice planting and harvesting within the districts of Collines.

Farmer perception: are an opinions or views of rice farmers at the level of the study in relation to their experiences with rainfall season and rice growing season both measured in term of relative frequencies within the districts of Collines.

Gridded data: is a format of data which is represented in form of regular or non-regular point usually in cell. In this study the gridded data used was monthly rainfall in form of raster images with a regular cell of 0.25 degree 0.25 degree.

Inter-seasonal rainfall: Total annual rainfall for each year extending from March to November within the districts of the Administrative Units of Collines.

Rainfall Impact: results of high and low rainfall on rice yield within the districts of Collines over the 18 years.

Rainfall Variability or Variation: is a degree to which rainfall amounts vary across an area over a specific period of time. In this study it is the amount of inter-seasonal rainfall variation within the districts of administrative unit of Collines measured over a period of 18 years.

Rainfed: practice that relies on seasonally rainfall water

Rice Yield: an estimated quantity of rice (e.g. value) obtained by farmer during the growing season measured in standard unit such as kg/ha, tons/ha, etc.

Time series: is a statistical term used to the set of numerical data points in time order. In this study, inter-seasonal rainfall, annual rice yield were organized as data point over the period of 18 years.

Trend: significant and temporal variation from a defined period 1998 to 2015, also general direction (increasing/decreasing) or pattern taking by rainfall or rainfed rice yield over this period of time.

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

The literature review is organized topically from global picture to local picture as guided by the topic, the problem, the hypotheses and the methodology. The topics on which the review has been based are: rainfall variability; rainfall variability and agriculture; rice production; rice crops and rainfall variability, TRMM data.

This literature review was meant to provide general information on rainfall variability and agriculture so that a better understanding of the subject in this study could be gained. The review also assisted in having some insight on current trends in rainfall variability and agriculture particularly in the tropics. Relevant research methods and associated analysis techniques have been highlighted in this review. Finally the review assisted in identifying the gaps in rainfall variability and agriculture especially in Benin.

2.1.1. Rainfall Variability

Rainfall variability is an extent to which rainfall amounts vary across an area over a period of time. The concept of rainfall variability was originated both from climatology and meteorology and entails two variation scale known as areal and temporal. As such rainfall constitutes one of a critical factors determining climate characteristic of the area. The study made the use of areal and temporal in determining rainfall variability within the districts of Collines over the time period of 18 years. Cabas et *al*(2009 consider it in terms of various time scales from daily to intra and inter-seasonal to decadal scales. Ebi et *al* (2005). The variation of rainfall however, can be much more difficult to predict than temperature due to various combinations both natural and human factors.

Davis, (2011) argued that the variability of rainfall can be induced through natural processes within the climate system, which are the additional influences of human activity. In the same point of view Shaviv and Veizer, (2003) clarified that the variations of earth climate system alternate between cold conditions and warm at astronomical time scale. Shaviv and Veizer, (2003) explained that these variation were consequences of continuos shifts in the earths as it orbits around the sun and it rotational axis. Rainfall regime is therefore linked with seasons that occurred at different times of the year (Davis, 2011). Some of the manifestations are resulting in El Nino effects and as such major types of the El Nino were causing internal variations in the climate system, as declared by Diaz *and* Cabido (2001); Wanner *et al.* (2001) that include the El Niño-Southern Oscillation (ENSO), the Arctic Oscillation/North Atlantic Oscillation (AO/NAO), the Atlantic Multi-decadal Oscillation referred to as AMO, as well as the Pacific Decadal Oscillation known as PDO.

Nonetheless, among the above mentioned causes, Li *et al.* (2011) pointed out ENSO as the strongest natural fluctuations of climate on inter annual timescales, which lead to different global weather consequences on the human food system. Aside ENSO, it is well known that volcanic eruptions have numerous impacts on the climate system (Church *et al,* 2005).

According to the IPCC (2012), there is evidence that alterations in climatic extremes are most correlated with anthropogenic influences. Stott *et al.* (2011) also attributed the significant increase in the observed trends in temperatures experienced in many areas where human action affect environmental resources. The evidence provided by the IPCC (2012) and Stott *et al.* (2011) give a clear perspective on how human activities have a greater impact on the climate system and therefore on the food system. Most scholars have credited the influence of human activities on the climate system to the industrial development which provides most capabilities to control the forces of nature and manage their own environment (FAO, 2008). Humans have created artificial microclimates, in which plants are grown and breeding new race of animals with desired characteristics, improved soil quality through toxic fertilizers, and controlled the flow of water through development of irrigation schemes to further enhance man's activities on earth (FAO, 2008). These human activities have greatly affected climate variables due to land degradation, deforestation and biomass burning which fuel the intensity of rainfall event and other associated extreme events (Vermeulen *et al.,* 2012).

Vermeulen *et al.* (2012) explains that anthropogenic aerosol emissions are another important influence on climate, particularly on the intensity of rainfall event. For example, Li *et al.* (2011) research findings indicated a strong association between atmospheric aerosols loading on extreme rainfall events for the United States Great Plains.

In contrast Sub-Saharan Africa particularly West Africa regions, have not yet elucidated the declining rainfall factors in rainfall regimes but the deficit was attributed to rainfall variability observed since 1960 (Le Barbé et *al.,* 2002). Odekunle (2007) had shown the relationship between rainfall variability on crop yield in Guinea Savannah part of Nigeria. Barry et *al*, (2018) assessed the causes of variability through rainfall and temperature indices and came up with a conclusion that West Africa climate variability is due to a combination effects of human activities, land use and increasing of greenhouse gas over a region.

Like Wossen et *al*, (2018), Adamgbe et *al*, (2013) and Akpan *et al., (*2013) from West Africa have demonstrated the important role of climates variability on food security. Benin publication in that way, counts little background information at administrative level on climate variability impacts on food system despite a potential threats on hydrological and agricultural system warned by Ogouwalé et *al* (2005), Vodounou et *al* (2011).The authors attempted to justify declining trend of rainfall height but the study lack to highlight some potential crops in view of threats under the scenario of rainfall variability. As such climate variability especially rainfall variability impacts is therefore needed to understand rainfall variation to further anticipate mitigation plans within farming districts dominated by traditional agricultural system.

2.1.2. Rainfall Variability and Agriculture

Rainfall variability effects is likely to impact many development sectors according to IPCC, (2012) but the most obvious was predicting adverse effects on agriculture and therefore on human system livelihoods and livelihoods strategies (Cooper et *al.,* 2008).

Rudolf and Hermann (2009), Molua and Lambi, (2007) added that physical factors variation could impact agriculture and become detrimental to crop production, for example soil fertility and moisture could be affected directly by rainfall variability. Sub-Sahara Africa agricultural production system which is rainfed was found likely to feel more impacts of rainfall variability (Cooper et *al.,* 2008). West African, and

Administrative unit of Collines as well were not exempted from the variability in rainfall regimes with probable effects on it rice production system.

Ayoade (1993) explaining a need to considered main factors of climate variables as limiting agriculture productivity, most are known as abiotic factors such as rainfalls, solar radiation, wind, temperature, relative humidity and other factors known as biotic factors causing also adverse impacts on crop distribution and productivity. Rainfall and Temperature however are predominant variables controlling agriculture system with significant variation impacts at any stage of crop growth, influencing farming output from cultivation up to harvesting stage.

Acquaah (2010) illustrated that abiotic environmental stresses are responsible and counted about 70% of yield reduction of crops in production. In addition De La Pena et *al*, (2007) argued that the potential threat of climatic changes added to the severity of environmental stress imposed on crops productivity, and concluded that rainfall patterns and temperature trends are important factors and determinant for crop management. Lobell et *al*. (2007) used a model based approach integrated climatic variable with five most growing crops such as wheat, maize, barley and rice, concluded that recent warming have produced the negative response of climate on those crops yield. Thus authors came up with the need to combine climate response with changes in economy and other conditions like crop management to improve a model performance. However Aziz et *al.*(2014) found through their study in the South- Eastern region of Bangladesh that temperature has less effect on crop production which indicate other variables like salinity and soil condition effect are prominent on *Aman* rice production. Through all these empirical studies, it important to conclude the rainfall variability impacts differs from region to region (IPCC, 2007).

Furthermore Verón et *al*. (2015) pointed out a need to considered some other aspects of temperature while attempting to study the relationship between climate and crop yield. The authors therefore considered rainfall and diurnal temperature relative for three crops all in temporal context. According to the results, the median yield loss estimated over forty year period was amounted to 5.4% for maize, 5.1% for wheat and 2.6% for soy.

IPCC 2007 report have long predicted those changes in Africa continent whose was more exposed to global warming effects than other continent .Besides White et *al* (1994) and Rosenzweig et *al.* (2000) have demonstrated that both rainfall and temperature plays a significant role in crops production, controlling developmental stages from sprouting of seeds through vegetative growth, flowering and reproductive growth.

In addition Sivakumar et *al* (2005) have used model based approach, by combining rainfall and temperature through multi-linear regression analysis, discovered a contrasting relationship. Both rainfall and temperature indicate contrasting direction meaning that while temperature is rising rainfall is decreasing which lead to more severe impact on agricultural production system. In this regards Ceccarelli et *al.* (2010) predicted not only an effects of climate variability on the past livelihood system but also the current negative impact on food production and food quality on the poorest farmers in developing countries with high risk food insecurity.

Duku et *al.*(2015) , in contrast warn weaknesses to integrate only abiotic factors as limited factors in a model of agricultural production. Therefore the author recommends a consideration of biotic factors which were also strongly corroborated by Okafor and Fernandes, (1989). Okafor and Fernandes, (1989) suggest an integrating environmental hazards with anthropogenic component such as soil degradation (e.g. for Nigeria case) also need to be considered, proliferating insect pests and weeds as determinant factors in reducing rice productivity and therefore lowering yield.

Some empirical studies tend to link climate variability with human perception which could also influence the productivity of agriculture, farmers specifically on climate have not changed over the time in which rainfed farmers hold the climate as key in the crop productivity as indicated in the work of Moyo *et al* (2012). Farmers, in the semi-arid zone of Zimbabwe considered climate variability as the main cause of reduction in their agricultural productivity. Moyo et *al* (2012) findings contrasted the perception of farmers where no evidence could corroborate farmers' perceptions although a majority of respondent (75%) had identified climate variability as major agricultural productivity reducing factor. From Moyo et *al* (2012) it was evident that decline in agricultural productivity in Zimbabwe could have been due to other factors apart from rainfall variability. Res and Meze-hausken (2004)apportioned blame on crop failure to farmers not adopting suitable agricultural practices for better crop yields.

West Africa have seen many scholars researching on economic indicator of climate variability; Wossen et *al* (2018) among others have demonstrated a close link between climate variability and food price volatility and its effect on householders' food security. Climate variability impacts are therefore perceptible not only at environmental context but also at socio-economical context where keys points were indicators explaining potential impacts on livelihood and livelihoods strategies.

2.1.3. Rice Production

Rice is only crop that can be grown in various conditions of environment, from the sea-level area to highest altitude landscape (De Datta, 1981). Soils and water conditions are determinant in rice cultivation and depended on the environment and a cultivar. The most growing cultivar worldwide belongs to the genus *Oriza* with O. *sativa* most species cultivated under a wide range of climatic conditions Vaughan *et al* (2008). According to FAO many range of soils are suitable for rice cultivation namely Vertisols, alfisols and ultisols, luvisols and ferralsols.

Globally two broad rice cropping systems all over the world are known, lowland or wetland and upland or dry land (De Datta, 1981). Andriesse and Fresco (1991) explained some differences rainfed system between permanent, wet rice cropping systems (lowland type) and shifting rainfed rice cropping systems (upland type). Administrative Unit of Collines practice two systems are used but upland system is the most dominated within the three districts investigated and *Nerica* (New Rice for Africa) is most cultivar grown (Researcher, Field survey, August 2017).

Rice is most grown crops all over the world, and rank second after wheat in term of area harvested (De Datta, 1981). According to Palacpac (1980), the largest area of rice growing is located at to India followed by China with respectively 39.6%, 36.0%. FAO (2003) indicated Africa produce substantial amount of paddy rice about 15.08 million tons in an area of 10.23 million acre which represented approximately a third percent of the world's total rice production. West Africa was accounted for 70.4 percent which is roughly 8.74 million acre of rice area. Rice is grown not only for it richness calories but also for the socio-economic role it plays in rural areas as employment opportunities (FAO, 2003). But today rice consumption figures were changing and rice is being adopted as staple food in many traditional communities mainly in major cities in West Africa. Since decades rice is major source of calories intake in West Africa and comes third after maize and cassava for the continent as whole according to Bamba et *al* (2010). Annual rice consumption for West Africa increased by 6.5% according to WARDA (2008) which raise the demand faster than anywhere in the World, fuelling by population growth (2.6% per year) and increasing diet rate to 1.1% per year (Diagne and Demont ,2013). Moreover West Africa rice consumption per capita consumption have increased from 14 kg in the 1970s to 22 kg per person per year in the 1980s, and passed almost to 32 kg per person per in 2005. This high demand for rice in West Africa outpaced the production capacity and annually imported averaged to 8% since 1997 (WARDA, 2002).

In Benin, food consumption has changed and rice is not considered as special treat on feast days, but as daily intake both rural and urban areas. As a result, rice consumption per head has risen from 25 to 30 kg/year, or in total from 175 000 to 210 000 tons per year (MALF, 2011). Rice activities are spread all over the districts under different system and involve different communities (Researcher, Field survey, August 2017).

Rice cropping system involved both men and women at different stages, however Minnow (1977) reported through their survey that, the rice production was gender based and women are more involved at all stage of rice production mostly involved in seedling, applied fertilizers and participated in harvesting whereas men were mainly engaged in land preparation such as ploughing, harrowing and weeding in order to increase the productivity of rice outputs.

2.1.4 Rice Crops and Rainfall Variability

Rice production in Africa is influenced by many challenges from the weather vagaries to the inputs of the production. Misari (2002) and OXFAM (2005) reported a decreasing trends in rice production as a result of pests, weeds and diseases, drought and insufficient water control, weakness in seed management, soil fertility management, and low availability of credit facilities, farm inputs and equipment used in the farm. In addition Misari (2002) emphasized other constraints which could be explaining the decreasing productivity such as; delay in planting, harvesting, post-harvest management, marketing, inadequate extension service, inadequate rural infrastructures and ineffective farmers' organization.

Several abiotic factors such as drought, submergence, extreme temperatures, salinity and low soil fertility and add to biotic constraints such as weeds and diseases limit the continent's rice production (Duku et *al*., 2015). Climate variability induces many variations like increasing incidence of drought, extreme temperatures, flooding, and increasing levels of salt stress which impact rice yields (Duku et *al*., 2015). However, the extent of losses in production due to climate change will differ between the five rice production systems practicing in Sub-Sahara Africa; rainfed upland, rainfed lowland, irrigated lowland, mangrove swamp and deep water (Duku et *al*., 2015). Among these, the greatest threats to rice production due to climate change are anticipated in the rainfed rice production systems and total dependence on rainfall as a source of water (Ball et *al*., 1997).

2.1.5. Research with Tropical Rainfall Measuring Mission

The Tropical Rainfall Measuring Mission satellite, TRMM-3B43-v7 is a partnership between NASA (National Aeronautics and Space Administration) and Japan's Aerospace Exploration Agency (JAXA), which estimates rainfall data for the tropics region (NASA,2014).The use of TRMM dataset is a reliable precipitation data with good spatial coverage (Louzada et *al*, 2018).

According to Louzada et *al* (2018), the Climatic Water Balance variable generated with 3B43 showed a good correlation with the gauges data. Louzada et *al* (2018) concluded that the use of the TRMM- 3B43 rainfall data allow a consistent characterization of the regional water availability which contributing to the agricultural planning and management, mainly fill the gaps left due to the absence of rain gauges and to possible failures in the rain gauges data series.

In the opinion of Fensterseifer and Paz, (2016) both daily and monthly comparison of the rainfall shows a good reproduction with the observed rain gauges, which over estimates some peak values. Thus, V7 is an excellent tool that complements the available ground rainfall data as drought conditions are perfectly simulated. Flood conditions as well are simulated, with some reasonable overestimations. Fensterseifer and Paz, (2016) acknowledges that TRMM 3B43 data could thus be used to improve hydrologic studies needed to better manage water resources in reducing the extreme effects of climate conditions which particularly have damaged the south region of Brazil.

A.Rahman Assyakur et *al,* (2014) compared the spatial temporal relationship of rainfall with ENSO (El Nino-Southern Oscillation) and IOD (Indian Ocean Dipole) between land and sea using linear correlation on the basis of 13 years dataset of TRMM Multi-satellite Precipitation Analysis. The results showed an interesting relationship between IOD and ENSO with rainfall in Indonesia, where the influence of ENSO and IOD started during June, July and August especially in July in the southwest of Indonesia and ended in the December, January and February period especially in January in the northeast of Indonesia.

In West Africa, M. Dembélé and S. J. Zwart (2016) has compared satellite products the Burkina-Faso using continuous statistics to evaluate the performance of seven operational high-resolution satellite based rainfall products, Africa Rainfall Estimate Climatology (ARC 2.0), Climate Hazards Group Infra-Red Precipitation with Stations (CHIRPS), Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN), African Rainfall Estimation (RFE 2.0), Tropical Applications of Meteorology using SATellite (TAMSAT), African Rainfall Climatology and Time series (TARCAT), and Tropical Rainfall Measuring Mission (TRMM) daily and monthly estimate. These previous products were compared to ground data from 2001 to 2014 on a point to-pixel basis at daily to annual time steps, and then M. Dembélé and S. J. Zwart (2016) concluded that TRMM product was good for monitoring flood condition for Burkina –Faso. Based on these empirical studies, TRMM must be found capturing the rainfall variability in Benin since specific study has been carried out and specifically in the Administrative Unit of Collines.

2.2. Theoretical and Conceptual Framework

2.2.1. The Theoretical Framework

FAO, (2008) have developed the theoretical framework which took a broader view on understanding the impacts of the seasonal variation or climate change on food security. The theoretical framework is known as the Climate Change and Food Security (CCFS) framework. This conceptual framework provided information on the interrelationships between climate change and food security (food availability, food accessibility, food utilization). Most of the variables considered in the framework are: increased of greenhouse gas concentrations (CO2 fertilization effects), increased of mean temperatures, precipitation gradual changes, and increased of weather events in frequency and intensity.

Globally, the goal of the FAO‘s climate change framework is to inform and promote both regional and local dialogue about what the impacts of climate change are likely to be and what options exist for reducing vulnerability, and to provide local communities with site-specific solutions to prevent any future predicament of climate change (FAO, 2008).The theoretical framework depicted by Figure 2.1 was modified as a key point of reference for the purpose of this study. The modified version figure 2.2 is used in determining the impacts of rainfall variability on rice production in Administrative Unit of Collines at spatial context.

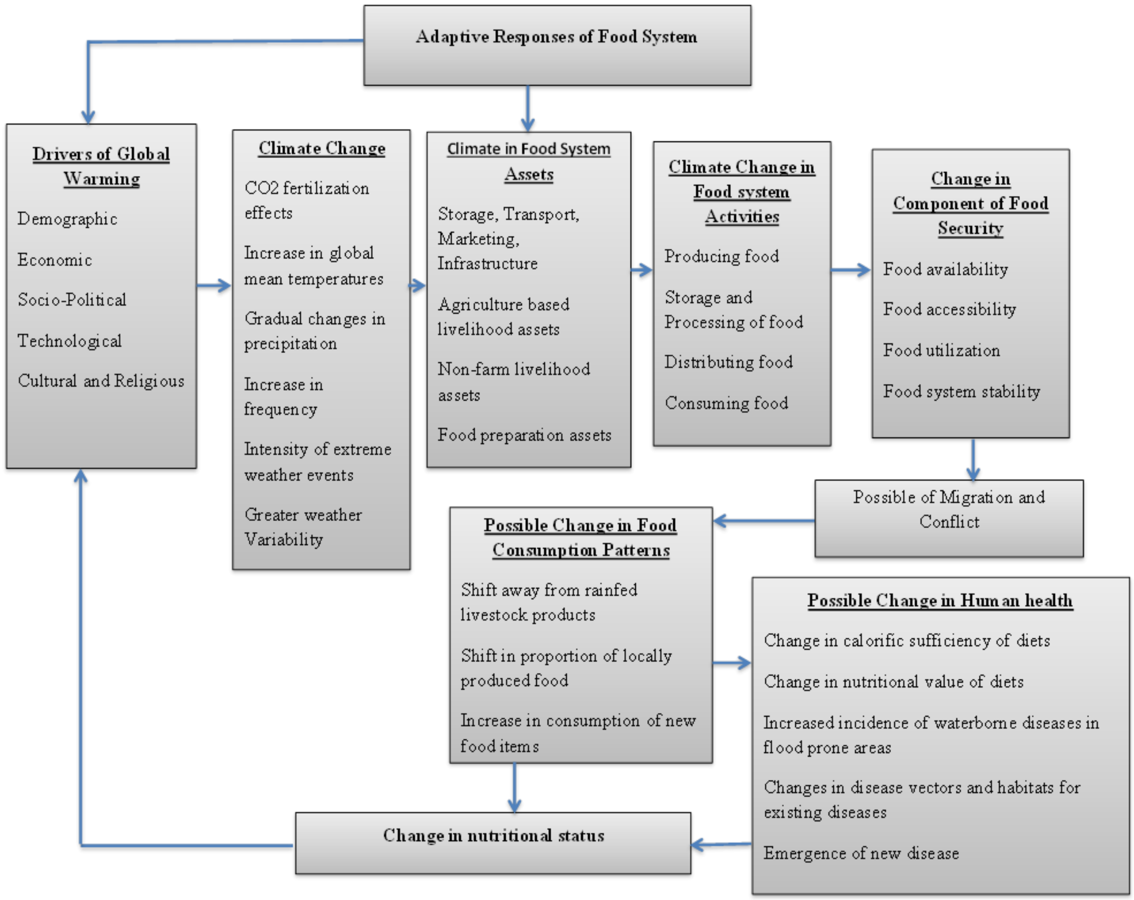

Figure 2.1: Theoretical Framework of Climate Change and Food Security

*(**Source**: FAO, 2008)*

2.2.2. The Conceptual Framework of study

The study used a modified version Figure 2.2 as conceptual framework which shows the factors that result in rainfall variability taking into consideration both natural factors and anthropogenic factors and how they could influence rice production in Administrative Unit of Collines. The framework highlights seven interacting elements: that is, drivers of climate variability, rainfall variability, impacts on rainfed rice production, positive effects, and negative effects.

The doubled-edged arrows which link some of the components indicate the dynamic and interactive nature of climate variability and on rice production. Thus, these components affect and are also affected by the components. The framework is limited to the study not exhaustive but dependent on rainfall variability on rice production which constitutes the source of livelihoods of farmers at Administrative Unit of Collines. The framework explains the rainfall variability conditions with associated impacts whether there are positive or negative and its implication for rainfed rice farmers. These factors are grouped and displayed under seven elements. These are not meant to be completely exhaustive sets of all possible elements; rather these represent those that were considered in the study. The conceptual element attempt to describe graphically the linkages flowing from left drivers of rainfall variability as an independent variables to a middle rainfed rice production as (dependent variables) and at right with some probable impacts of rainfall variability. These impacts lead to some implication at rainfed rice farmer's level. These linkages or relationships are represented by arrows connecting to impacts whether positive or negative.

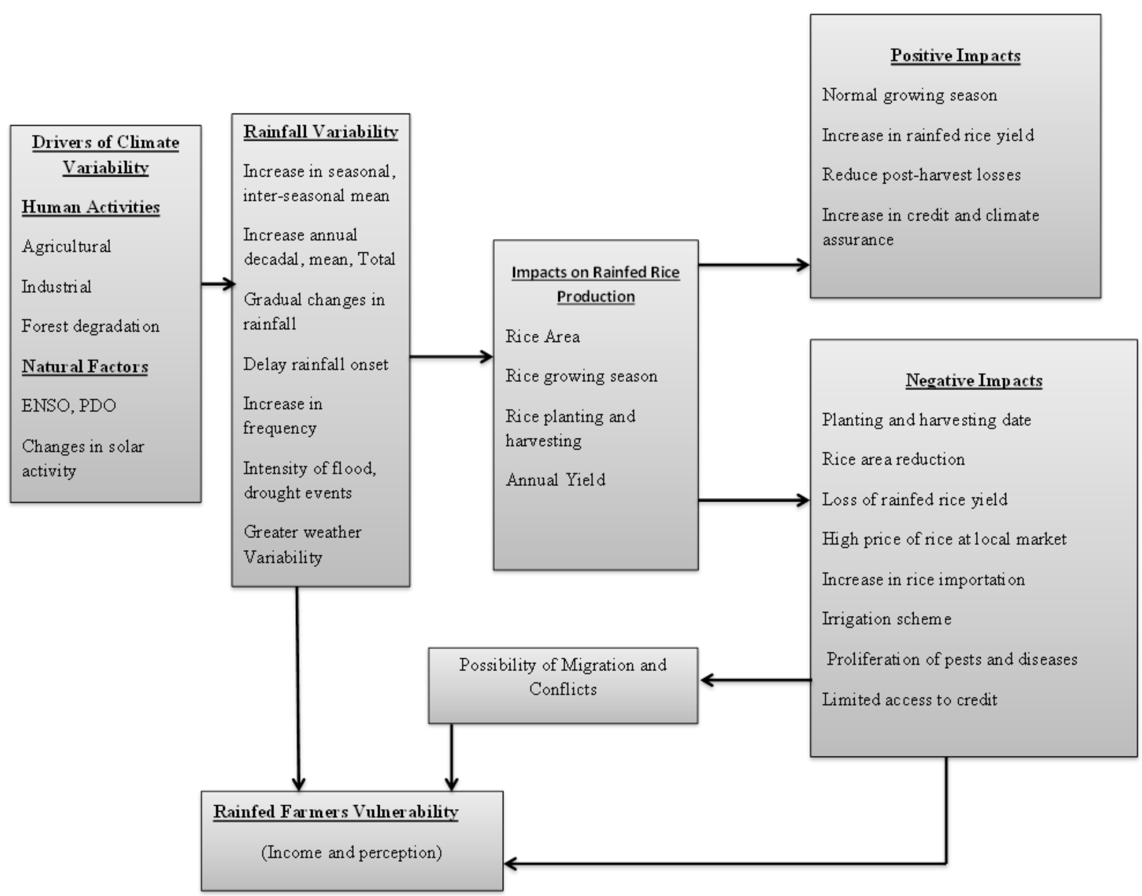

Figure 2.2: Conceptual framework of Rainfall Variability Impact on Crops Yield

(**Source**: modified from FAO, 2008)

CHAPTER THREE: STUDY AREA

3.1. Location and Size

The study area is in Benin and particularly the Collines Administrative unit geographically located within latitudes 6°30’N, 12°30’N and longitudes 1°E, 3°40’E, covered 13931 Km sq with six districts including Bantè, Dassa-Zoumé, Glazoué, Ouèssè, Savalou and Savè and a total of 297 villages. Collines is bordered to the South by the Administrative unit of Zou, Dong to the North West, to the North East is Borgou and to the East by the Republic of Nigeria and in West Togo Republic.

Figure 3.1 depicts the Administrative unit of Collines and districts location with the survey districts.

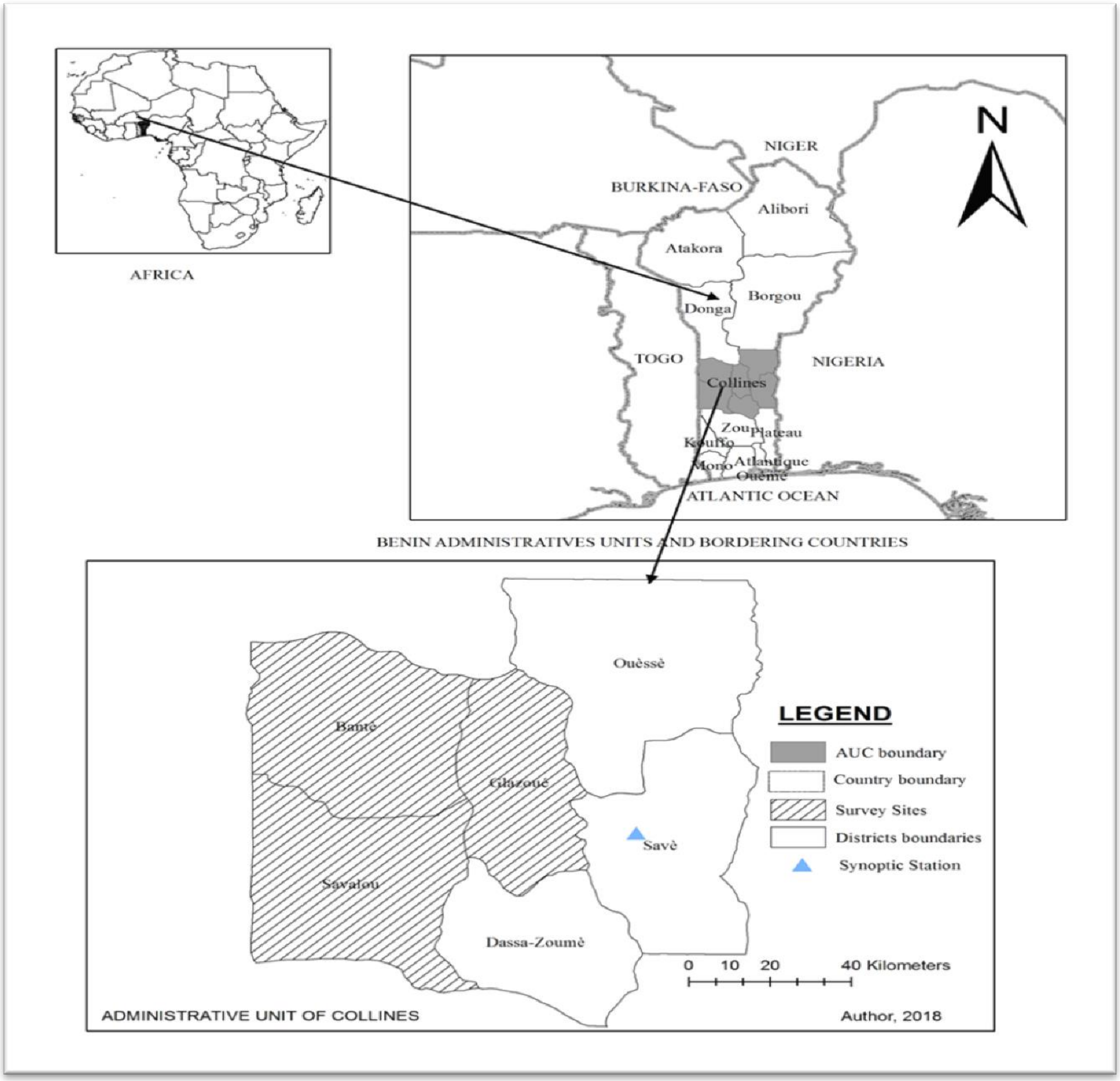

Figure 3. 1: Administrative Unit of Collines location

(**Source**: modified from IGN, 1997)

3.2. Geology and Soil

Collines has varied geological Precambrian meta-sedimentary to unconsolidated sedimentary. The soil components includes tropical ferruginous laying on crystalline basis with variable characteristics ferric luvisols and gleyic luvisols favourable for crop production, black and hydromorphic soils are also found in the valleys of the rivers and streams that cross the Central Benin.

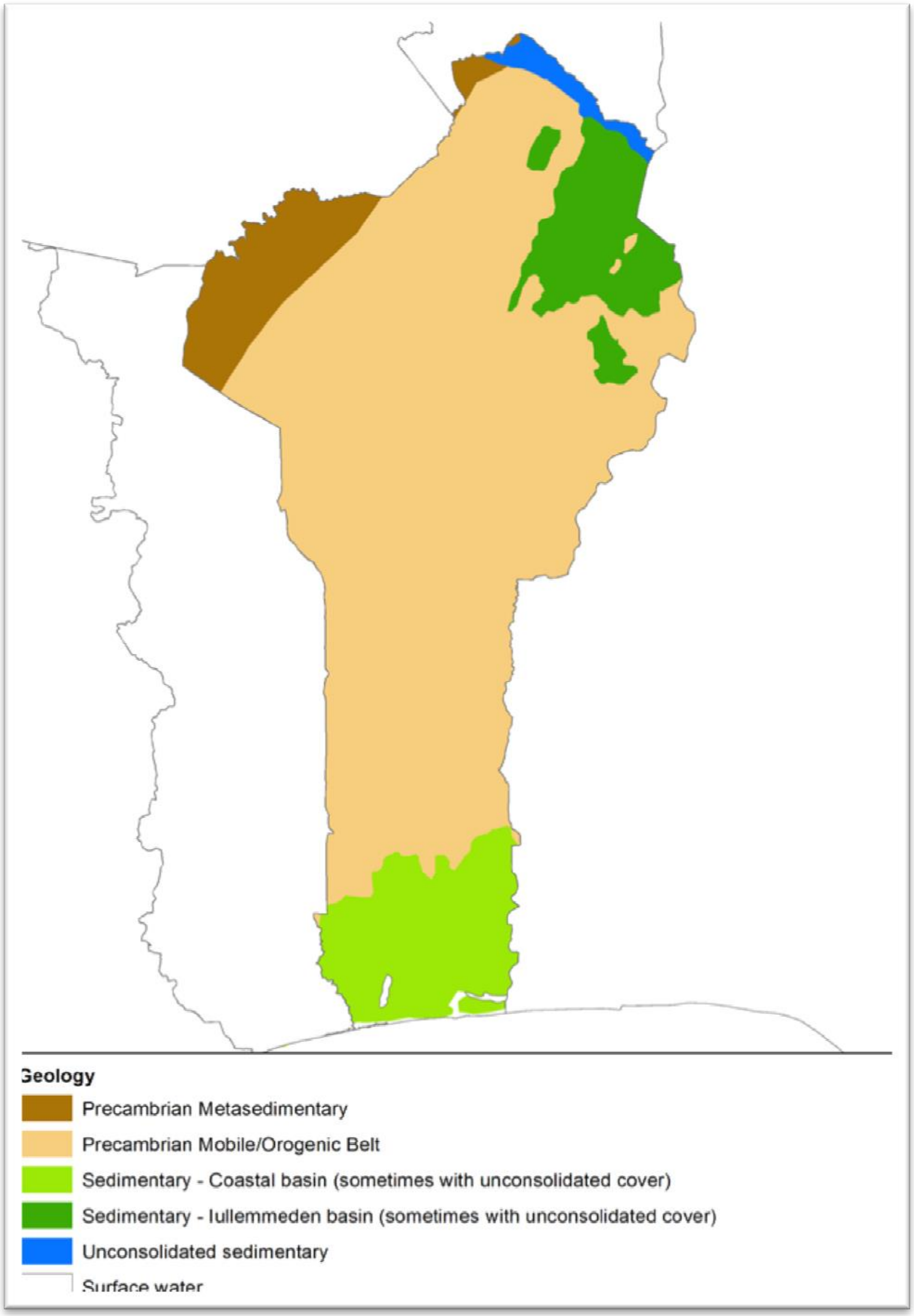

Figure 3. 2: Geology of Benin

(**Source:** BRGM, 1978)

3.3 Climate and Drainage

3.3.1 Climate

The Climate of Collines is of equatorial rain belt that is characterized by warm temperatures and rainfall throughout the year and one should therefore expect the climate of Benin to reflect the same with some modifications due to unique local conditions.

Collines is within the inter-tropical zone experiencing typical West African climate, which with a shift between the Monsoon (from the ocean) during the warm and rainy season, and increasing intensity of the Harmattan wind that blows daily during the dry season from the Sahara .The Monsoon and the Harmattan reduces and alternates towards North and South. The Inter-Tropical Front (ITF) is the central point of precipitation that causes such alterations. Temperatures experienced annually are 26.9°C (Bantè), 27.9°C (Dassa-Zoumè), 27.°C (Glazoué), 27.1°C (Ouèssè) 27.4°C (Savalou), and 27.4°C (Savè). The temperature rises as one moves towards the northern region across the savannah and plateau into the zones.

Harmattan winds have no moisture and blows from the Sahara during December to March. Causing wilting of vegetation and a veil of fine dust hangs over the country leading to the skies to be overcast. This is the duration of time when farmers practice burning land in preparation for rice production. Collines has two climatic zones; a dry savannah zone experienced within 80° and 90°N and an average rainfall fluctuation trends of 1000 mm/year and 1200mm/year and the period of continuous vegetation growth of 200 days. A subequatorial zone covers from the Atlantic Coast through Savè (7°30'N) with rainfall totals of 950 to 1400mm per annum and a period of vegetative growth of approximately 240 days.

Administrative unit of Collines is a bimodal rainfall pattern with short and long rain season. The long rainfall extends from April to June whereby the short rainfall expands from September to October. This bi-modal regime is an emerging issue and has resulted a uni-modal season with uncertainty in the rainfall regime in this region especially with regard to non-perennial crops. Moreover the annual rainfalls respectively 1116 mm (Bantè), 1173 mm (Dassa-Zoumè), 1131mm (Glazoué), 1019 mm (Ouèssè), 1140 mm

(Savalou), and1108mm (Savè) which are enough in improving production level for crops such as oil palm, rice, cocoa and coffee but rainfall within those districts are unevenly distributed therefore the Collines districts agriculture system might be suffering from climate variability impacts for crops production.

From district of Savè up to North, a uni-modal rainfall pattern emerges within a period of May- October which is suitable for a variety of crops and for cotton growth as well. The Administrative Unit of Collines falls within two agro ecosystems which are characterized by two rainfall peak periods; the long rains in the period March-July and; short rains in the period October to November. The normal total number of rainy days in the year varies between 80 and 110 with the hilly regions protecting from the maritime influence.

3.3.2 Drainage

Three main drainage pattern exist on the basement complex; rivers run downstream from the south to the Atlantic Ocean, which discharge into the Niger in the North and into the Pendjari in the Northwest, the larger rivers like Niger, Mono and southern parts of Ouémé until Zangnando discharge water the annually whereas other rivers run seasonally during the dry season

The figure 3.3 depicts the hydrography network across Benin. Some networks are still unknown but the Majors Rivers are Ouémé and Couffo at the southern, Mono which forms part of the border with Togo, drains the southwest .The main rivers of northern Benin are the Niger, which forms part of the boundary with the republic of Niger and its tributaries with the Sota, Mékrou and Alibori rivers. On the coast some are estuaries Lakes Ahémé and Nokoué.

The Collines is crossing by a small hydro-graphic network and lowlands spread within the districts. Most of these networks are composed of rivers such as Zou, Agbado, Aporou and Opkpara. Nevertheless, this network with some rivers provides partial coverage of people's water needs. The Administrative Unit of Collines is well supplied in terms of water availability and therefore could not be suffering from water scarcity for the food production. However, the insalubrity of these waters exposes the population to many diseases including the *Guinea worm* or Dracunculiasis which handicaps agricultural workers over a long period of the year.

Figure 3. 3: Hydro-graphic Network of Benin

(**Source:** BRGM, 2011)

3.4. Vegetation

Three vegetation zones in Collines are influenced by the rainfall patterns and the climatic zones namely; Guinea, Sudan and Sahel are .Along the Coastal or Littoral Zone exist a small stretch of coastal swamps and mangroves. Further north, within the Guinea-Congolian zone is a semi-deciduous forests and savannas. A small extent of rain forest is as a result of low rainfall amounts within the Dahomey further north, in the Southern Guinea Zone are found woodland and savannas which are dominant.

In the drier Northern Guinea Zone exists trees, shrubs and savannah type of vegetation with abundant Isoberlinia doka being domirnant. There are the grass layers of the savannas which are not very tall due to regular annual bush fires. In both Guinea Zones, inselbergs with their typical vegetation characterized the landscape features. The transition from the Southern to the Northern Guinea Zone corresponds with the northern boundary of bimodal rainfall.

The Southern Sudanian Zone covers nearly the complete northern Benin. In this zone woodlands and tree savannas coexist. Furthermore, different types of gallery forests occur along rivers. Westwards from the town of Bassila, a hydrophyte enclave, between the Northern Guinean and the Southern Sudanian Zone is found. There are vegetation of the Guinea-Congolian Zone found in dry deciduous forest, forests in valleys and forms of woodland on hilltops. Northern Sudanian Zone is characterized by annual precipitation of 600 to 900 mm, savannas and woodlands are found all over.

These are covering some Administrative Unit of Collines and Zou. The dominant vegetation of the area is the wooded savannah with Daniella oliveiri vegetation. This vegetation is more pronounced towards the north path of the administrative Unit. The most common species today are shea trees (Vittelaria paradoxa), néré (Parkia Biglobosa*)* and the caïlédrat (Khaya senegalensis*).* The iroko (Milicia excels*)* (Chlorophora excels*)* has almost disappeared. The Administrative Unit of Collines is home to some classified forests, which are highly threatened by human’s activities through searching fertile land; harvesting wooding fire and charcoal. The Government has launched the manmade plantation programme such as cashew (Anacardium occidentale*)*, and teak wood

(Tectona grandis*)* to contribute the enhancement of agriculture and safeguarding of the forest heritage by plantations.

3.5 Socio-Economic Activities

3.5.1 Population

According to the final Report results of the third General Census of Population and Housing (RGPH4, 2013), the population of this Administrative Unit of Collines was 717.477 inhabitants. The gender distribution of this population reflects the trend observed at the national level. In fact, 50.7% are recorded for females compared to 49.3% for males with average density of 52 inhabitants per km². This density of the population varies according to the districts. It is weak in Ouèssè and Bantè: between 10 to 20 inhabitants per km ² and relatively dense on the remaining part of the Administrative Unit of Collines (superior to 20 inhabitants per km ²). The sex ratio is 92.2 men per 100 women. In rural areas live 78.0% of the populations against 22.0% in urban areas. The Administrative is made up of two main ethnic groups: Yoruba and related (46.8%), Fon and related (39.2%). On a religious level, Hill populations are mostly protestant Methodists (20.7%), and other Protestants (12.3%), catholic are 11.5% and 10.6% of people without any religion.

3.5.2. Agriculture

Collines agriculture has an elementary socio- economic meaning and gives work and income for the majority (around 80%) of the population (Igué, 2000). Cotton is most important cash crop but others common cash crops are oil palm, groundnuts, cashew and pineapple. Traditional agriculture systems are a main source of income in many districts and the yields depends strongly on the available biophysical condition as farmers lack the capital to compensate for natural constraints. The traditional farming systems are still dominant with little mechanization and these traditional systems constitute subsistence drivers for smallholders which generate the majority of agricultural products In the central Benin, crops like rice, mango, groundnuts or cashew are generally grown for marketing purposes and accounts for at least 60% of the total cropland.

The practice in these districts is slash-and-burn agriculture which is originated from the districts of Ouèssè, Savè and is now giving way to a cropping system based on alternating fallow-crops with the majors' crops grown like sugar cane, tobacco, maize, rice, cassava, yams, okra and vegetables, observed that in the districts of Dassa-Zoume and Glazoué, due to the nature and the importance of the hills, the demographics pressure, the cropping system is somewhat limited and giving place to the practice of fallow-crops. But the burial system of herbs during ridging is widespread in some districts (Savè, Dassa-Zoume, Glazoué and Ouèssè) and contributed significantly to the organic fertilizer. The agro-calendar is established with the rainfall season where the farm activities start in March and crop planting by April pursuing through the short rainfall season. Agro-calendar in Collines is made up of four rainfall features namely long rainy season from March to July, a short dry season from August to September, a short rainy season from October to November; and a long dry season from December to March. The inter-seasonal rainfall used in this study covered the entire period of rainfall in order to capture the variability within the districts of Collines.

3.5.2 Other Economic Activities

INSAE reported in 2003 different economic activities in the Administrative Unit of Collines, essentially agriculture is 68% followed by trade 15%. Retail trader relies mainly on the distribution of food, manufactured goods and export products such as mahogany seeds, rice and chili. Industry development is very modest and essentially based on the ginning of cotton, the main export product. There were also few emerging consumption factories. There are the following units; Glazoué ginning plant, ginning plant of Savalou, Kpanhouingnan ginning factory; Sugar Company of Savè; Rice Factory of Glazoué.

Tourism activities are not well developed and organized but the Administrative Unit of Collines is home of the Hills which has a major tourist attraction that turns around the "Savè Mamelles", the "41 hills" of Dassa-Zoumè without forgetting the cultural folklores of the communities of Maxi, Tchabè and Idatcha. There is a potential of tourism activities that could generate fund and enhance the community welfare.

CHAPTER FOUR: METHODOLOGY

4.1 Study Design

This study was based on a descriptive survey to obtain information about large group of individual rice farmers in order to determine the status of agro-calendar and constraints of rice production in Collines in relation to rainfall variability impact on rice yield. Random sampling method was used to gather information from every rice farmers and the data complimented information obtained from secondary sources. Time series analysis was established the nature of inter-seasonal rainfall variation on rice production in Collines.

4.2. Data Types and Sources

To achieve the stated objectives, different data sets from various sources including primary and secondary data were used. Secondary datasets included; Simulated rainfall data downloaded from the TRMM(2011) for a period of eighteen years (18) in each district of Collines obtained from Goddard Earth Science website, observed rainfall data from a representative weather station of Collines obtained from the National Direction of Meteorology (ASECNA), annual total rice yield and cultivated area for some districts of Collines obtained from the Direction of Agriculture Statistic of (MALF) in the Ministry of Agriculture, Livestock and Fisheries of Benin.

The Simulated monthly total TRMM rainfall data was in in millimetre for each year and district for a temporal period 1998-01-01 to 2016-03-31. The observed daily rainfall data of Savè Weather Station was in millimeters for the period of 1995 to 2015.Annual Crop yield data was in Kilograms per hectare for each district per growing season for the period of 1995 to 2015.

Primary data was gathered from rice farmers using questionnaires, interviews, focus group discussion and field observation. The self-administered questionnaires were for each rainfed rice growing site of the districts sampled while the focus group discussion was made up of leaders from rice farmer’s association. Data collected from the rice farmers were; agro-calendar situation, rice production constraints and rainfall variability and strategies to improve rice yield, field observation was made by capturing the relevant pictures. Table 4.1 recapitulates data type and source

Table 4.1: Summary of data used and their characteristics

Data	Types	Temporal Coverage	Source
TRMM (Proxy)	Monthly Rainfall	1998 to 2016	NASA, EARTH DATA GES
Weather Station (In situ)	Daily Rainfall	1995 to 2015	ASECNA-BENIN
Crops Data	Annual Rice Yield	1995 to 2015	DSA/ MALF-BENIN
Field Work	Qualitative and quantitative	2 weeks	COLLINES SURVEY

(Source: Researcher, 2017)

From Table 4.1, shows that only18 years was found reliable as time period for analysis of inter-seasonal rainfall variability impacts on rainfed rice yield within districts of Collines.

4.3. Data Collection

4.3.1. Pilot Survey

A preliminary survey was purposively done to familiarize with the study area, administrative officers and the geographical location. It was also necessary to cross check existing information both on climate and crops through agriculture offices, agencies, online searches and documentation. These included all relevant documents reviewed, informal conversation, study areas, potential target population, and full coverage of rainfall. Then on the basis of that preliminary survey with technical assistance of Agricultural Officers, Administrative Unit of Collines was found suitable with a given data frame of 232 rice site which is potentially 232 rainfed rice farmers by the Planning and Forecasting Office of the Ministry of Agriculture, Livestock and Fisheries of Benin..

4.3.2 Target Population and Sample Size

Proxy data: The target population of collecting data from Tropical Rainfall Measuring Mission was Benin and at Collines districts level in particular including raster images (gridded). For this particular location 15 gridded data in which 219 granules were available for the product 3B43 monthly rainfall total in NetCDF format with a size of 3.8MB. The temporal coverage available was 1998-01-01 to 2016-03-31.

Crop data: Rice yield data obtained was for 77 potential rice growing district including both irrigated rice and rainfed rice. The data was in form of annual total yield in Kilogram per hectare per district covered the period of 1995 to 2015. Then the Administrative Unit of Collines with its 6 potential rice growing districts data on rice yield was drawn considering the location of Collines.

Field data: The target population for collecting field data was rice farmers of Administrative Unit of Collines as a given data frame (appendices III). The data frame entailed three districts grouped per village and by names of each rice growing field which was itself numbered. The calculated sample size was one hundred and thirty one rainfed rice framers using the Nasuirma (2000) model in determining the sample size. The sample size was determined using the equation:

$$n = \frac{N * C^2_V}{C^2_V + (N-1)e^2} \tag{4.1}$$

Where N = is the target population, C_V is coefficient of variation, e = derived level of confidence. The sample frame for this study consisted of the total of 232 potential rice farmers (appendence III) for the three districts Bantè, Savalou and Glazoué as released by the Planning and Forecasting Office of MALF. The coefficient of variation is 0.5 and the level of confidence is 0.05.

Therefore: $n = \frac{232 * (0.5)^2}{(0.5)^2 + (232-1)(0.05)^2} = 131.5642$

The sample size of each district is presented in Table 4.2

Table 4.2: Potential Sample size in each district

Districts	Total numbers of rice farmers	Sample size
Bantè	78	44
Glazoué	76	43
Savalou	78	44
Total	**232**	**131**

(Source: Researcher, 2017)

In addition, to complete some of uncovered information two (2) focus group discussions were purposively made from rice farmers, leaders; and sub agricultural officers of the districts of Bantè and Glazoué. The sampling size was limited at some aspect considering many reasons such as literacy of some rice farmers, fears of strangers, accessibility and identification of rice fields, abandoned selected rice field, multiple fields belonging to same farmers and multiple same names of the rice field. Therefore the effective sampling size is depicted in Table 4.3;

Table 4.3: Sample distribution in each district

Districts	Total numbers of rice farmers	Sample size per district	Sampled
Bantè	78	44	34
Glazoué	76	43	32
Savalou	78	44	34
Total	**232**	**131**	**100**

(Source: Researcher, 2017)

4.3.3. Data Collection Instruments

The study used various instruments in collecting both primary and secondary data including;

Proxy data: Considering the shape file of Benin, with districts coordinates the corresponding data were retrieved using raster to point method under ArcGIS toolbox

(NASA, 2011). Email: The email was useful both in registration as NASA GES data user and also receiving climatic and crops yield dataset.

TRMM Earth Data platform was used for NASA GES data query and retrieving and data preparation for the study area. ArcGIS Raster to point tools was useful in converting raster file into desirable format and also for TRMM outputs. Flash disc, this device was used for information store, data storing.

Field data: Sample frame, the structure of sample frame was used for physical randomization and rice growing site identification within each district of Collines. Questionnaires were used to collect some information related to the topic. Field note books were used for recording information and to uncover information in the questionnaire that could be explaining the outcome of the field survey using pens and pencils, rubber. A digital Camera was used in capturing relevant field images in related with the topic.

4.3.4. Sampling Procedure

Proxy Data Acquisition: TRMM is gridded data in form of granules that was acquired using incorporated algorithm involving the adjusted TRMM merge with microwave infrared precipitation rate (in mm/hr) and Root Mean Square (RMS) precipitation error estimation. The successful procedure entailed sub-setting, re-projecting and resampling performed combining ArcGIS tool and R programming language.

Then for the six districts of Collines the monthly rainfall were retrieved for each year for a period of 1998 to 2015.The use of point pixel approach needed a recalibration process since the satellite estimation is fundamentally smoother in space and time. Furthermore there are systematic differences between point observation value pixel estimation.

Rain Gauge Data Acquisition: Savè weather station data was made available by National Direction of Meteorology (ASECNA-Benin) through email. There was daily rainfall for the period of 1995 to 2015.Thus this daily rainfall data were converted into total inter-seasonal rainfall for the purpose of calibration with proxy data.

Field data acquisition: The study made use of the simple random and purposive sampling techniques to select the rainfed rice farmers. This was by using the data frame, and then before sampling was done in each district, physical randomization was applied to data frame. This method entails writing on a piece of paper, fold and mixed thoroughly on box container then pick without checking the desired number of samples without replacement. The selected site was then cycled on data frame until the size of the district exhausted. Then followed a plan to sample the selected field whether on farm or at home which was made available through assistants of each district and sub agriculture officers. Table 4.4 below indicates farmer perception and measurable indicators.

Table 4.4: Farmers perception measurable indicators

Variables	Indicators	Type	Measurement
Rainfall season	Starting months, ending months	Nominal	Conversation
Rice growing season	Starting months, ending months	Nominal	Conversation
Perception about current rainfall amount	Normal, increasing, decreasing, no idea	Nominal	Option items
Perception about rainfall (5yrs, 10 yrs, 20yrs ago)	Normal, increasing, decreasing, no idea	Nominal	Option items
Perception about current rice yield	Normal, increasing, decreasing, no idea	Nominal	Option items
Perception about rice yield (5yrs, 10 yrs, 20yrs ago)	Normal, increasing, decreasing, no idea	Nominal	Option items
Rice constraints	Flood, drought, pest and diseases, weeds	Nominal	Option items
Main factors affecting rice production	Lack of fertilizer, poor equipment, water scarcity, seed quality	Nominal	Option items
Strategies for rainfall management in rice production	Improved lowland, irrigation scheme, training, funding	Nominal	Option items

(Source: Researcher, 2017)

Plate 4.1: Interview of Rice farmer at Savalou

(Source: Researcher, 2017)

Plate 4.2: Interview with field assistant at Glazoué

(Source: Researcher, 2017)

The questionnaires were administered only to the rice farmers by face to face interactions. The rice farmers were briefed on the purpose and relevance of the study before the administration of the questionnaires. Two focus group discussions were carried out in Bantè and Glazoué to generate conversations that uncovered individual opinions regarding the effects of rainfall variability on rice production. The focus group discussions explored the same questions as in questionnaire for in depth information on the agro-calendar, constraints in rice production, and strategies of rice yield improvement. Each focus group was made up purposively with a minimum of eight participants and a maximum of ten. The participants were purposively selected from the rice growers' communities with the help of rice farmer association leaders, and agriculture sub officers guided from each district. The purpose of the discussion was to help determine the perceptions of the rice farmers on agro-calendar expressed by the participants of the selected rice grower's communities. The researcher facilitated the discussions using a checklist prepared for this purpose assisted by field assistant. Field observation was employed to capture the social setting of respondents and the influence of the physical environment on the activities of the respondents. This was to provide insight into the interaction between respondents and their physical environment and also ascertain the realities on the ground.

Plate 4 3: Focus group discussion at Bantè

(Source: Researcher, 2017)

4.4. Data Processing and Analysis

4.4.1. Data Processing

Rainfall data preparation: Savè weather station dataset was converted to monthly total rainfall to calibrate with a proxy dataset (TRMM, TMPA/3B43) which was already in form of monthly total through a comparison of statistics. The performance of the satellite products for the Collines was evaluated in estimating the total inter-seasonal rainfall during the period of 1998 to 2015 on the basis of categorical statistics to assess rain detection capabilities. Four statistical indictors were used, computed the Mean Absolute Error (MAE) estimates the average estimate error; a positive MAE shows that the estimated rainfall is generally overestimated, while a negative sign shows it is generally underestimated; the Bias reflects the degree to which the measured value is over- or underestimated (Duan, Bastiaanssen, and Liu 2012).The Root Mean Square Error (RMSE) is a frequently used as a measure of differences between two variables; it gives the average magnitude of the estimate errors: lower RMSE values indicate greater central tendencies and generally smaller extreme errors. Following are the mathematical formulae used for the proxy calibration (Appendices II):

The Mean Absolute Error (MAE) $$MAE = \frac{1}{n}\sum_{i=1}^{n}\left(| E_i - O_i |\right) \quad (4.2)$$

The root mean square error (RMSE) $$RMSE = \frac{1}{N}\left[\sum_{i=1}^{n}\left(E_i - O_i\right)^2\right]^{0.5} \quad (4.3)$$

Rice yield data preparation: Rice yield data obtained was in form of annual total yield for 77 potential rice growing district including both irrigated rice and rainfed rice. This dataset covered the period of 1995 to 2015, starting the growing season 1995-1996. In order to adjust with 18 years period of study, three growing season were removed from the data considering exclusively for the six potential rainfed districts for Collines location. Then the starting growing season for the analysis was 1998-1999 up to 2014 to 2015 growing season. The rainfed rice yield for this particular period was considered for all computations.

Field data preparation: The farmer's perception on agro-calendar was structured and coded as per the main variables as rainfall season, rice growing season, constraints and strategies of rainfed rice production which was discussed with farmers profile in order to capture the nature of rainfall variability impacts on rice yield within the districts of

Collines. The qualitative data obtained were subjected to descriptive statistic using (SPSS) version 20. The table 4.5below summarize the variables and mode of analysis.

Table 4.5: Variable and Modes of Analysis

Variables	**Indicators and code value under SPSS**	**Analysis**
Rainfall season	Starting months, ending months (1=January; 2=February; 3=March; 4=April; 5= May; 6= June; 7=July; 8=August; 9= September; 10=October; 11=November; 12=December)	Descriptive statistic Frequency tables
Rice growing season	Starting months, ending months (1=January; 2=February; 3=March; 4=April; 5= May; 6= June; 7=July; 8=August; 9= September; 10=October; 11=November; 12=December)	Descriptive statistic Frequency tables
Perception about current rainfall amount	0=Normal;1=increasing; 2=decreasing; 3=no idea	Descriptive Frequency tables
Perception about rainfall (5yrs, 10 yrs, 20yrs ago)	0=Normal; 1=increasing; 2=decreasing; 3=no idea	Descriptive Frequency tables
Perception about current rice yield	0=Normal; 1=increasing; 2=decreasing; 3=no idea	Descriptive Frequency tables
Perception about rice yield (5yrs, 10 yrs, 20yrs ago)	0=Normal; 1=increasing; 2=decreasing; 3=no idea	Descriptive Frequency tables
Rice constraints	1=Flood; 2= drought; 3= pest and diseases; 4= weeds	Descriptive Frequency tables
Main factors affecting rice production	1=Lack of fertilizer; 2= poor equipment; 3= water scarcity; 4=seed quality	Descriptive Frequency tables
Strategies for rainfall management in rice production	1=Improved lowland;2=irrigation scheme;3=training;4=funding	Descriptive Frequency tables

(Source: Researcher, 2017)

4.4.2. Data Analysis Techniques

4.4.2.1 Inter-Seasonal Rainfall and Rice Yield Variation

In order to achieve the stated objectives, descriptive statistic, trend analyses methods were applied to analyse the trends in both inter-seasonal rainfall and rice yield datasets transformed.

Time series plots: Time series analysis entails the use of time series graphical plots, in this study monthly total rainfall, total inter-seasonal rainfalls, and annual rice yield were plotted against 18 years from 1998 to 2015. This method is however too subjective when the variability within dataset is large. Then to minimize this variability, the Least Square Fit method was applied to data. The computation was made for each district considering rainfall season covering March to November of each year with three uncovered month for a growing season and rainfall namely December, January and February.

4.4.2.2 Agro-calendar in Collines

The farmer's perception on rainfall variability and rice yield as earlier described in the 4.1.5 were coded and submitted to descriptive statistic under *SPSS version 20*. Then the output was in form of table of frequencies with each item for the surveyed districts to facilitate easy understanding and interpretations.

4.4.2.3 Rainfall Variability and Rainfed Rice Yields

Simple correlation and linear regression techniques were applied to establish the relationship and effect of rainfall variability on rice yield in Administrative Unit of Collines. This approach has been widely used by many authors in analysing the impacts of climate variability or climate change and on food crop production (Adamgbe et al, 2013; Tunde, 2011, Rowhani et al., 2011). For example Odekunle et al (2007), has applied this approach to assess rainfall variability impacts on crops yield in Guinea savannah part of Nigeria. The variability of inter-seasonal rainfall on rice yield was determined through the use of coefficient of variation;

$$\text{CVp} = \frac{StDev}{\bar{X}} * 100 \tag{4.4}$$

Where CVp coefficient of variation is' $StDev$ is Standard deviation and $\bar{X}$ is the mean over 1998-2015.

The Pearson's correlation analysis (r) was performed in order to measure the strength of the linear association between rainfed rice yield, and inter-seasonal rainfall using following the Equation, in which x represents the independent variable and y represents the dependent variable

$$r = \frac{\sum_{i=1}^{n}(xj - \bar{\mathbf{x}})(yj - \bar{\mathbf{y}})}{\sqrt{\sum_{i=1}^{n}(xj - \bar{\mathbf{x}})^2 (yj - \bar{\mathbf{y}})^2}} \tag{4.5}$$

Where r is the correlation coefficient xj and yj are the j^{th} observations for the two variables, $\bar{x}$ and $\bar{y}$ are arithmetic means of the observations of the two variables and n is the number of observations. The coefficient of correlation varies between +1 to -1, and complete dependency is expressed by either +1 or -1, 0 represents the complete independency of the two variables.

For this study, the regression factors used were, total inter-seasonal rainfall, and coefficient of variation for the period from 1998 to 2015, in millimeters respectively. The regression model used was simplified from Adamgbe et *al* (2013) and Rowhani *et al* (2011) model with slight modifications in terms of inputs. Simple linear regression model was used as follow:

(5) $Y(t) = a + b_1X_1(t) + b_2X_2(t) + b_3X_3(t) + b_4X_4(t) \ldots + b_nX_n(t) + e$ (4.6)

Where $Y(t)$ is rice yield as depend; a= intercept; b_1, b_2,b_3, b_4, $\cdots$ b_n= is a slope of the regression line and each b represents the amount of change in Y(Rice yield) for one unit of change in the corresponding x value when the other x values are held constant; X_1(t), X_2(t), X_3(t), X_4(t), $\cdots$ $X_n(t)$ = the independent variables (inter-seasonal rainfall, Mean inter-seasonal rainfall, Coefficient of Variation and Growing Year respectively); and e = the error terms.

In order to reduce the potential heterogeneity and stabilize the variance of error term, Natural logarithms transformations have been applied to the model. The equation is therefore:

$$Ln\,(Y\,(t)) = a + Lnb_1X_1\,(t) + Lnb_2X_2\,(t) + Lnb_3X_3\,(t) + Lnb_4X_4\,(t) \qquad (4.7)$$

The Datasets obtained after transformation (appendices III) were used for Pearson correlation analysis and simple linear regression analysis under SPSS in order to establish the nature of inter-seasonal rainfall variability effect on rice yield within the districts of Collines.

To test whether the correlation and regression coefficients within those districts were statistically significant, the student's T-statistic test was applied in testing the significance coefficients of correlation and the slope of regression equations. This hypothesis testing was done at 0.05.The t-test statistic used in testing hypotheses through correlation coefficient and slopes are given in equation (4.6).

CHAPTER FIVE: RESULTS AND DISCUSSIONS

Chapter five is organized in three sections. Section one discusses the inter-seasonal rainfall and rice yield variation. The second section details farmers' perception on agro-calendar with on rainfall season, rice growing season, constraints and strategies for rice yield improvement on the study. The third section presents the influence of rainfall on rainfed rice production which provides a basis for understanding the impacts of inter-seasonal rainfall variability on rice yield in the Administrative Unit of Collines. Under these sections, results and discussions on inter-seasonal rainfall variation, rice yield variation and regression and correlation analyses of rainfall are presented.

5.1. Inter-Seasonal Rainfall Variation in Collines

5.1.1. Monthly Variations of Rainfall

Figure 5.1 shows Monthly total rainfall, inter-seasonal rainfall from 1998 to 2015.

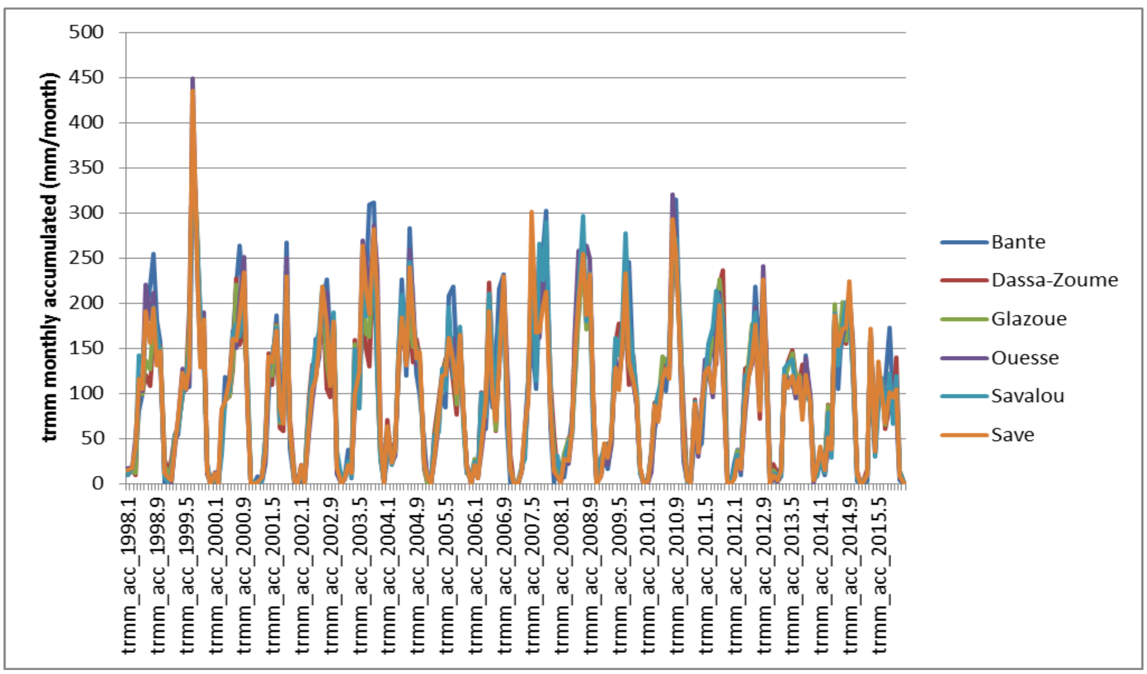

Figure 5. 1: Monthly Accumulated rainfall within district of Administrative Unit of Collines

(**Source**: Researcher, 2017)

Figure 5.1 indicates temporal variability in rainfall within six districts of Collines over 18 years. The upward trend shows increased rainfall for such district and downward trend decline in rainfall. Each of the six districts depicts two cycles of the rainfall period which are clearly identified throughout the rainfall season. The first period started from March with a peak of 120mm/month in May followed by decreasing trend in July. The second period in mid-July had an increase in rainfall to the highest peak 250mm/month in September then followed by decreasing trend from September to November. In view of most scholars, as **transiting ecological zone**, the Collines region has a uni-modal rainfall regime but the results for 18 years indicated a **bi-modal trend regime**. The highest record of monthly rainfall occurred in 1999 with a rate of 450mm/month, and almost 350mm/month in 2010 followed by monthly decreasing trend.

5.1.2 Inter-Seasonal Rainfall Variation

The amount of rainfall is critical in rice production; Figure 5.2 shows the inter-seasonal rainfall variability for each district of Collines due to variable climatic conditions. The Administrative Unit of Collines (AUC) had a decreasing trend of rainfall over the 18 years, the line of best fit is defined by an equation *-11.74x +1231* with a negative coefficient meaning that the rainfall amount is decreasing for all the six districts.

The results corroborates Le Barbé et *al* 2002 who demonstrated the decreasing trend of West Africa rainfall regime. The figure 5.2 indicates an occurrences of climatic events during the past 18 years, it is then suspected that some climatic event have occurred during the rainy season of 2001, 2005, 2009. In 2013 inter-seasonal rainfall rate was lowest but had stayed above a mean for all the six districts. The mean, maximum and minimum for each district are indicated in Table 5.1, from which all the Collines district were found to be wettest with Ouèssè recording the highest rate 1500 mm over the 18 year period time. This situation could be explained by the climatic situation of the districts which was variable within two characteristic agro-ecological zones, Northern and Southern Guinea zones with prevalence of forested areas.

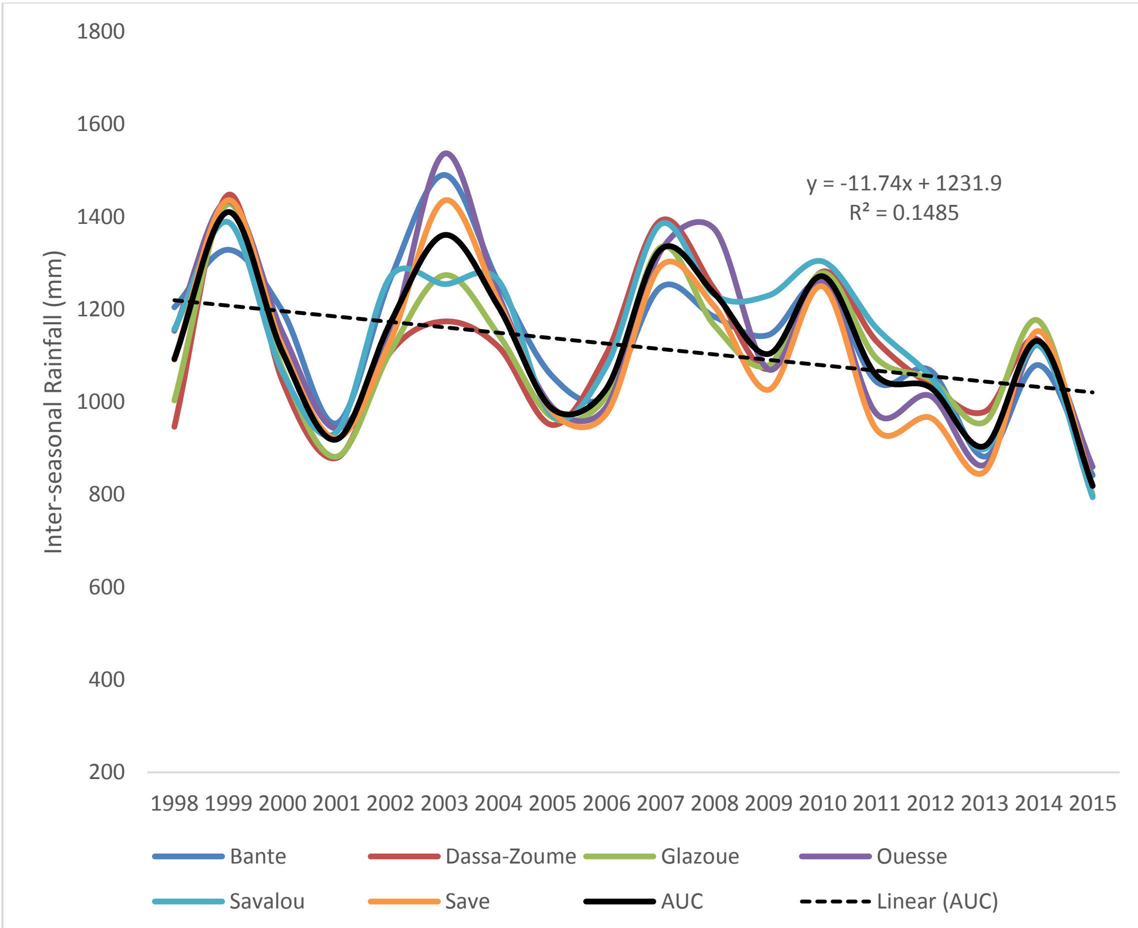

Figure 5. 2: Inter-seasonal rainfall in the Administrative Unit of Collines

(**Source**: Researcher, 2017)

Table 5. 1: Summary statistic of inter-seasonal rainfall in Collines over the 1998–2015 time periods.

	Bantè	**Dassa-Zoumè**	**Glazoué**	**Ouèssè**	**Savalou**	**Savè**
Mean (mm/yr)	647	626	625	645	649	625
Standard Error (mm/yr)	89	86	86	90	89	87
Standard Deviation (mm/yr)	527	511	510	531	529	513
Minimum (mm/yr)	94	89	89	96	88	91
Maximum (mm/yr)	1491	1448	1428	1537	1389	1436

(**Source**: Researcher, 2017)

5.2.3 Temporal Variations of Rainfed Rice Yields

The temporal variations in annual total rice yield could be explained as a consequence of inter-seasonal rainfall variation within each district. Figure 5.3 indicates the temporal trend of rice yield over the 18 years in the districts of Collines. The upward trend corresponds to more rice yield for the respective rice growing year and downward trend show less rice yield for the corresponding rice growing year. The variety of rice grown is *Nerica* which is drought and flood resistant. The overall pattern of rice yield in the Administrative Unit of Collines showed an increasing trend by the line of best fit with an equation *29.399x +2408*. This equation has a positive coefficient meaning that the rice yield is increasing for all the six districts.

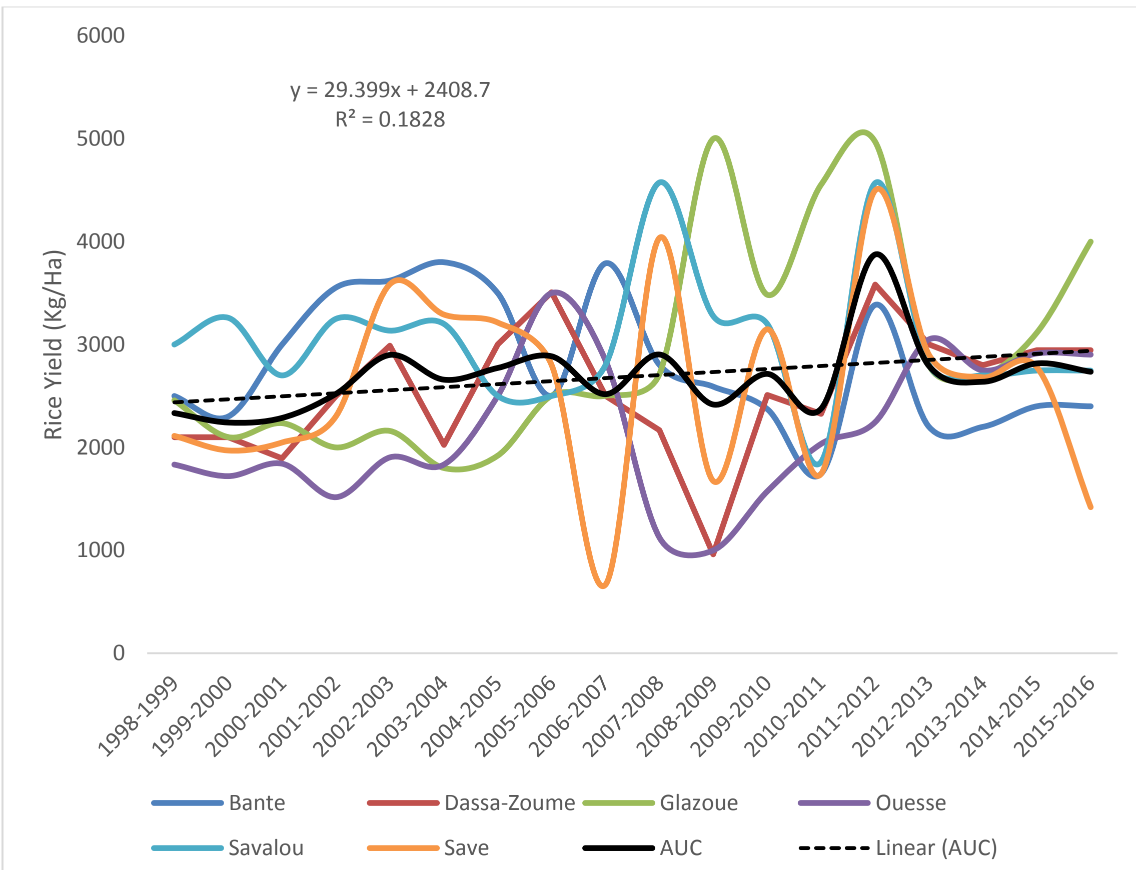

Figure 5. 3: Temporal Variation of rice yield in the Administrative Unit of Collines

(**Source**: Researcher, 2017)

Figure 5.3 indicates very little variations occurred during the past 18 year period where a most noticeable trend was recorded in 2011-2012 growing season most of the districts yielded highest rate of rice; Bantè, Dassa-Zoumè, Save, Savalou and Glazoué were found to have high yielding rates above the mean. The mean, maximum and minimum of rice yield as depicted in Table 5.2, a coefficient of variation is fairly weak for Bantè (0.22), Dassa-Zoumè (0.24), and Savalou (0.21) and quite moderate for Ouéssè (0.32), Glazoué (0.35) and Savè (0.36) for a period of 18 years. This little temporal variation observed in rice yield within those districts could be explained by the variety grown and other factors such as soil, planting date, farming methods, weeds, pests and diseases.

Table 5. 2: Summary statistic of rice yield in Collines over the 1998–2015 time periods.

	Bantè	**Dassa-Zoumè**	**Glazoué**	**Ouèssè**	**Savalou**	**Savè**
Mean(Kg/Ha)	2815	2547	2945	2171	3045	2604
Standard Error(Kg/Ha)	150	149	244	166	155	227
Standard Deviation(Kg/Ha)	637	632	1035	703	659	961
Minimum(Kg/Ha)	1744	962	1800	1000	1860	667
Maximum(Kg/Ha)	3800	3582	5000	3500	4575	4497
Coefficient of Variation	0.22	0.24	0.35	0.32	0.21	0.36

(**Source**: Researcher, 2017)

5.2. Farmers' Perception on Agro-calendar

5.2.1. Rice farmers Profile in the Administrative Unit of Collines (AUC)

Understanding the influence of rainfall variation on rice yield necessitate a clear knowledge about the socio-demographic features of rice farmers. Table 5.3, indicates the majority of the rice farmers within the surveyed districts were females (62.0%) and the remaining 38.0% were males.

Table 5. 3: Distribution of rice farmers by sex in Collines

Sex	Districts						Total	Percentage
	Bantè		Glazoué		Savalou			
	Freq	%	Freq	%	Freq	%		
Male	15	15.0	10	10.0	13	13.0	38	**38.0**
Female	19	19.0	22	22.0	21	21.0	62	**62.0**
Total	34	34.0	32	32.0	34	34.0	100	100

(**Source**: Researcher, 2017)

The disparity observed can be explained by a period of the season where women apply fertilizer to rice crops on farms which is already late according to agro-calendar in the district (plate 5.1). This high number of women on the farm doesn't suggest that women are controlling land administration within those districts but it simply indicating that women accessed land for farming in these districts but are most interested in rice farming activities that men. According Minnow (1977) survey, the rice production was gender based and women are more involved at all stage of rice production especially in sowing seed, applying fertilizer and harvesting than men engaged mostly in land clearing, ploughing, harrowing and weeding.

These results indicate a socio-economic role of the rice production in many parts of the world specially the developing country. At some point these results were likely to be confirmed with the survey in Administrative Unit of Collines, where most of rice farmers interviewed on a rice field were women. The assumption is women are accessible to land for farming than other districts mainly in north Benin where land is exclusively subjected to cotton cultivation. Therefore women would likely be vulnerable to rainfall variability on rice production in these districts of Collines.

Plate 5. 1: Women applying fertilizer to rice crop in District of Bantè

(**Source**: Researcher, 2017)

Table 5.4 presents the distribution of rice farmers by their age groups where the majority of rainfed rice farmers are in the range of 31-40 years count for 55.0% and 41-50 years count for 39.0%. This categorization shows that the age group from 31-50 year old are more experienced in rice farming within these districts and therefore are likely to give their views on rainfall variability impacts on rice production.

Table 5. 4: Distribution of rice farmers by their age groups in Collines

Age groups	**Districts**						**Total**	**Percentage**
	Bantè		Glazoué		Savalou			
	Freq	%	Freq	%	Freq	%		
31- 40 yrs	16	16.0	19	19.0	20	20.0	55	**55.0**
41- 50 yrs	14	14.0	13	13.0	12	12.0	39	**39.0**
51 yrs>	4	4.0	0	0.0	2	2.0	6	6.0
Total	34	34.0	32	32.0	34	34.0	100	100.0

(**Source**: Researcher, 2017)

Table 5. 5: Distribution of rainfed rice farm size by the districts surveyed

Districts	Farm size								Total	Percentage
	1-5 ha		**5-10 ha**		**11-20 ha**		**21 ha>**			
	Freq	%	Freq	%	Freq	%	Freq	%		
Bantè	26	**26.0**	8	8.0	0	0.0	0	0.0	34	34.0
Glazoué	17	17.0	**13**	13.0	**2**	2.0	0	0.0	32	32.0
Savalou	23	**23.0**	10	10.0	1	1.0	0	0.0	34.0	34.0
Total	66	66.0	31	31.0	4	3.0	0.0	0.0	100.0	100.0

(**Source**: Researcher, 2017)

From Table 5.5 it is important to distinguish that most of farmers within the three districts are likely to grow their rice on the area of 1-5 ha, with the highest records in Bantè (26.0%) and Savalou (23.0%). Glazoué hold the record of larger size of rice cultivation with 13% for 5-10 ha 2.0% for 11-20 ha, this trend might be linked with some motivating conditions in this area where there is a big storage of rice and initiative of rice transformation is setting down. Overall results on cultivated rice areas denotes a limited agricultural technologies applied in the districts which have an impacts on rice yields ; added the effects of biophysical condition, as farmers lacking a minimum capital to compensate natural constraints (Igué et *al*, 2004; Nonvidé et *al*, 2017).

The Agricultural practice in these districts is slash-and-burn which originated from the districts of Ouèssè, Savè and is now giving way to a cropping system based on alternating fallow-crops with the major crops grown like sugar cane, tobacco, maize, rice, cassava, yams, okra and vegetables (Igué, 2000). Further Igué (2000) observed other reasons in the districts of Bantè and Savalou, likely linked with the nature of complex basement in those districts, the demographic pressure and the cropping system.

5.2.2 Rainfall and Rice Growing Season

The field investigation conference in Table 5.6 indicates that 68% of rice farmers within the three districts agreed on a slight shift in rainfall season which normally started in March, 29% of rice farmers said April and 3% in May. Whereas 88% of rice farmers declared that the rainfall season ended in July and for 12 % in November. This variability observed in farmers' response about the rainfall season occurrences could be explained by their experiences of rainfall patterns in their district. Observation during a survey showed that rice farming was delayed in many districts of Collines. Overally, rice farmers of Savalou and Glazoué supported an idea that rainfall season is shifting from March to April and later May that led to most variability observed in space and time during the planting rice. The plate 5.1 below showed the impacts of onset in rainfall season within the same districts.

Table 5. 6: Farmers perception on rainfall season and rice growing season in Collines

Response (%)	Bantè	Glazoué	Savalou	Overall
Rainfall season starting	100	55.9	58.5	68.0
Rainfall season ending	64	100	97	88.0
Rice growing season starting	100	100	100	100
Rice growing season ending	100	100	100	100

(**Source**: Researcher, 2017)

In details, the onset of rainfall situation have not changed in Bantè and most farmer's plant the rice in July and harvested in November. Whereby rice farmers in Glazoué, declared the rainfall onset varies from March to May but the rice growing season have not changed. Some farmers' planted rice in July and harvested in November. The same perception is shared at Savalou, where the rainfall onset varies from March to May later but the rice growing season have not changed and some farmers' starts planting rice in July and harvested in November.

Table 5. 7: Farmers perception on rainfall variation in time in Collines

Response (%)	Bantè	Glazoué	Savalou	Overall
Current rainfall	100	100	100	100
Perception about rainfall 5yrs, ago	100	100	94	98
Perception about rainfall 10 years ago	100	100	94	98
Perception about rainfall 20yrs ago	100	100	79	93

(**Source**: Researcher, 2017)

The Table 5.7 indicates that the majority of rice farmers agreed that current rainfall amount is changing, 98% percent also have indicated that the rainfall amount was decreasing since 5 years and 10 years ago, 93% rice farmers recognized that the rainfall amount was normal this 20 years ago whereas 7 % said they have no idea about the rainfall for the past 20 years. These result shows that farmers are much more concerned about rainfall variation in their districts and identifies each variation in space and in time.

Table 5. 8: Farmers perception rice yield variation in time in Collines

Response (%)	Bantè	Glazoué	Savalou	Overall
Current rice yield	100	100	97.0	99
Perception about rice yield 5yrs, ago	100	100	94.0	98
Perception about rice yield 10 years ago	97.1	100	88.0	95
Perception about rice yield 20yrs ago	37.3	65.0	61.0	54

(**Source**: Researcher, 2017)

The Table 5.8 indicates 99% of farmers within the three districts had an opinion that the current rice yield is decreasing, 98% supported that this trend began 5years ago, 95% assumed that the rate yield had been increasing for 10 years at 54%, the amount of paddy rice was increasing for the past 20 years. These opinions indicated that variability had occurred in rice yield and might probably be related to some potential factors whether biotic or abiotic. This result of survey is in line at some point with the previous temporal trend of rice yield in the Administrative Unit of Collines which shows increasing trend within the districts over the period of study. The finding indicates that the amount of changes produced by inter-seasonal variability is minimal and not detrimental for rainfed rice within these districts. Since the rainfall season have slightly changed, according to a survey, it was obvious to note that 100 percent of farmers agreed that the rice production season started in July when the rainfall was well distributed, and ended in November.

5.1a 5.1b

Plate 5. 2: Variability of rice planting in Bantè (5.1a in May) and (5.1b in mid-July).

(**Source**: Researcher, 2017)

Picture 5.1a shows the rice at earlier ripening stage of maturity (booting or heading, milky or dough) whereas the picture 5.1b depicts rice at tillering stage due to delaying in rainfall season. In this regard some farmers avoid planting the rice on field until the rainfalls well felt within the districts.

5.2.3 Rice Constraints and Strategies of management

The rice yield constraints within the three district as illustrated in the survey was mainly due to occurrences of short drought during the rice growing season. Table 5.9 shows 96.96% of farmers' responses support idea of short drought during a planting period. This result could be explained by the delay in rainfall season and occurrences of short drought within rainy days. Then main factors affecting rice production within these districts are; 97 % poor equipment, weeds and water scarcity in certain districts; district of Bantè, and Glazoué respectively, weeds for Savalou. Rice farmers 82% therefore suggested some strategies in order to improve rice production. Most of those suggestions were development of irrigation system in relation to inter-seasonal rainfall variability to manage rainfall water, lowland improving and capacity building through training within the districts.

Table 5. 9: Farmer's perception on rice constraints and strategies of management

Response (%)	Bantè	Glazoué	Savalou	Overall
Rice constraints	97.0	100	93.9	96.96
Main factors affecting rice production	94.0	100	97	97
Strategies for rainfall management in rice production	76.5	85	87	82.83

(**Source**: Researcher, 2017)

5.3. Rainfall Variability and Rainfed Rice Yield

To examine the relationship between rice yield and rainfall variability, trend analysis, correlation analysis and linear regression analysis were carried out for the period of 1998 to 2015. The transformed variables for each district were used where inter-seasonal rainfall for each district was plotted against rice yield. This method helped to find out if inter-seasonal rainfall could explain the changes in rice yield in each district of Collines. Then the strength of potential relationship was checked through simple and linear regression analysis.

5.3.1. Trend Analysis between Rainfall Variability and Rainfed Rice Yield

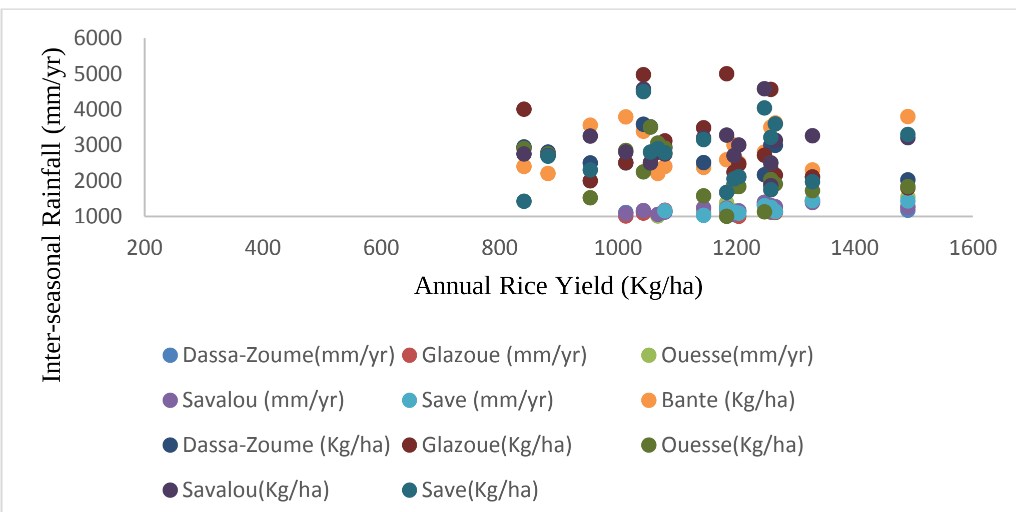

Figure 5. 4: Scatterplot analysis between rainfall variability and rainfed rice yield in Collines

(**Source**: Researcher, 2017)

Figure 5.4 indicate the possible linear relationship between inter-seasonal rainfall with rainfed rice yield in all the districts of Collines over the study period. This means inter-seasonal rainfall variability could be influencing at some extends rice yield within a six districts of Collines.

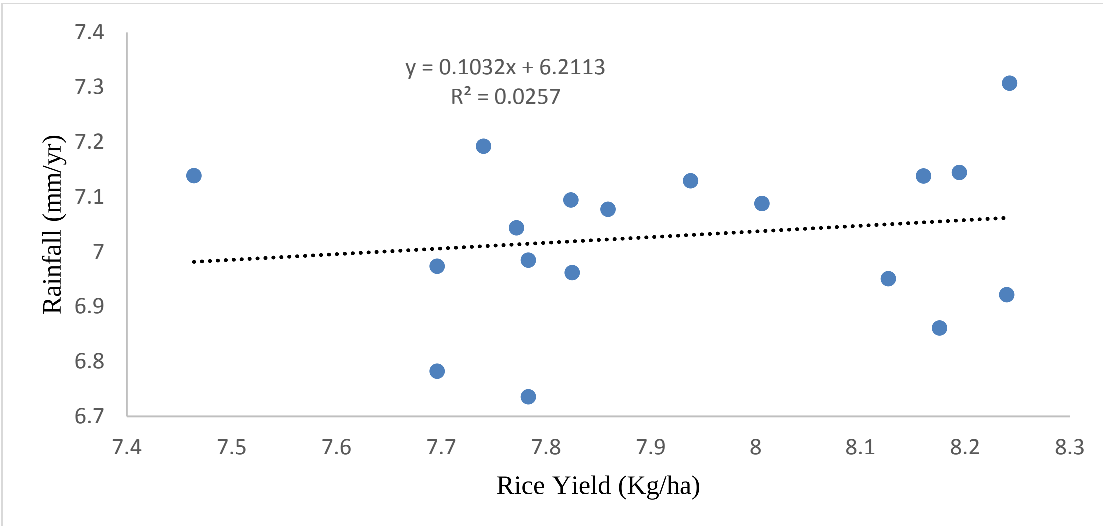

Figure 5. 5: Association between inter-seasonal rainfall and rice yield in Bantè

(**Source**: Researcher, 2017)

Figure 5.5 depicts the association between inter-seasonal rainfall which is positive and very weak in the district of Bantè, the line of best fit is defined by the equation $y = 0.1032x + 6.2113$. The coefficient of the equation is positive, inter-seasonal rainfall variation have an influence on rice yield in the district of Bantè. However this influence of inter-seasonal rainfall is very weak shown by the coefficient of determination $R^2 = 0.0257$.

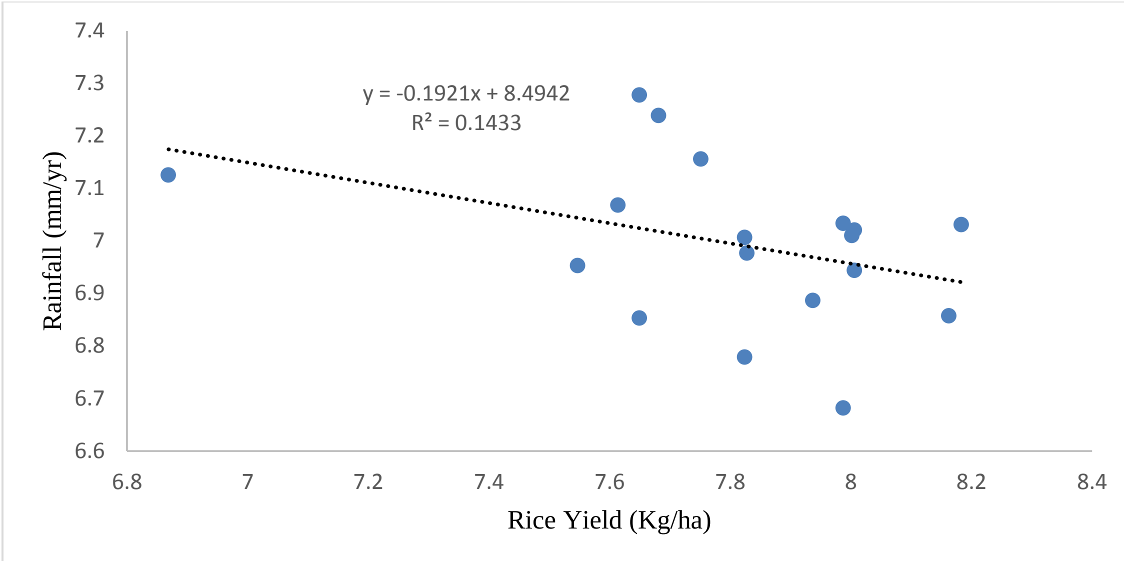

Figure 5. 6: Association between inter-seasonal rainfall and rice yield in Dassa-Zoumè

(**Source**: Researcher, 2017)

Figure 5.6 indicates the relationship between inter-seasonal rainfall is negative and weak in the district of Dassa, the line of best fit is defined by the equation $y = -0.1921x + 8.4942$. The coefficient of the equation is negative which means inter-seasonal rainfall variation seem to have less influence on rice yield in the district of Dassa-Zoumè, which is indicated by weakness of coefficient of determination $R^2 = 0.1433$.

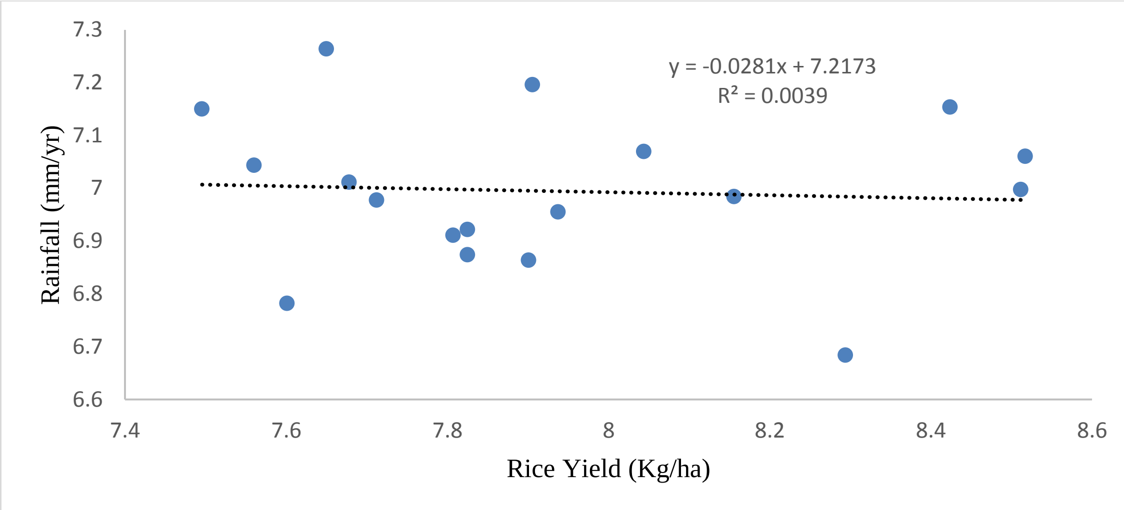

Figure 5. 7: Association between inter-seasonal rainfall and rice yield in Glazoué

(**Source**: Researcher, 2017)

Figure 5.7 indicates that the association between inter-seasonal rainfall is negative and very weak in the district of Glazoué, the line of best fit is defined by the equation $y = -0.0281x + 7.2173$. The coefficient of the equation is negative showing inter-seasonal rainfall variation seem to have less influence on rice yield in the district of Glazoué. This impact is very weak ,the coefficient of determination is $R^2 = 0.0039$

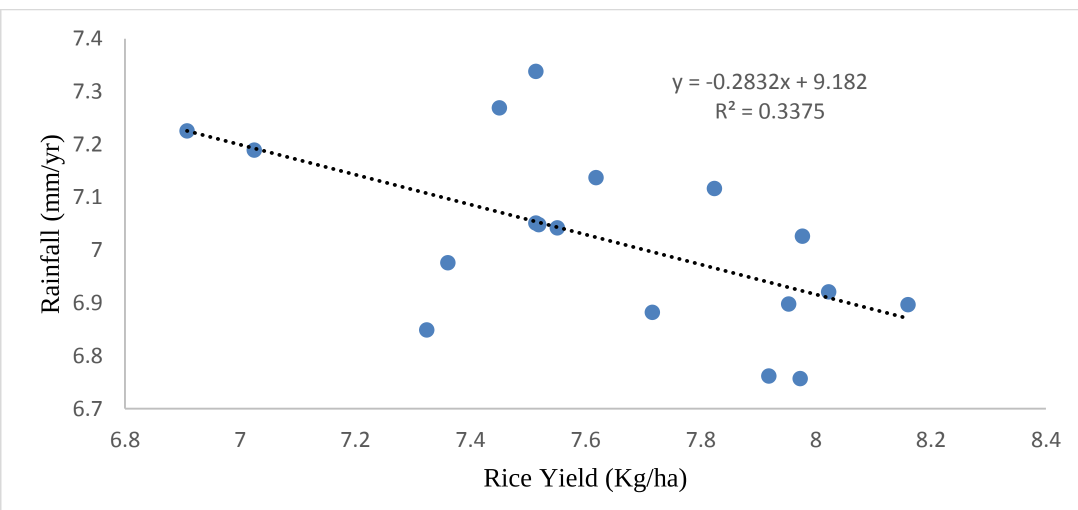

Figure 5. 8: Association between inter-seasonal rainfall and rice yield in Ouèssè

(**Source**: Researcher, 2017)

Figure 5.8 indicates that the relationship between inter-seasonal rainfall is negative and moderate in the district of Ouèssè, the line of best fit is defined by the equation $y = -0.2832x + 9.182$. The coefficient of the equation is negative which means inter-seasonal rainfall variation has a moderate influence on rice yield in the district of Ouèssè. This impact on rice yield is high in a view of coefficient of determination $R^2 = 0.3375$.

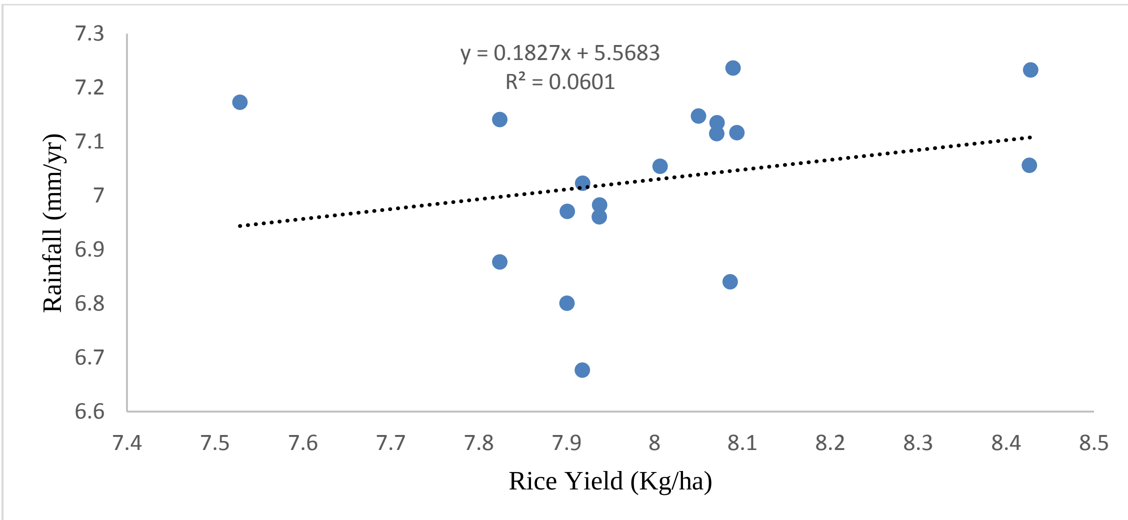

Figure 5. 9: Association between inter-seasonal rainfall and rice yield in Savalou

(**Source**: Researcher, 2017)

Figure 5.9 shows that the relationship between inter-seasonal rainfall is positive and weak in the district of Savalou, the line of best fit is defined by the equation $y = 0.1827x + 5.563$. The coefficient of the equation is positive and inter-seasonal rainfall variation have an influence on rice yield in the district of Savalou. However this influence of inter-seasonal rainfall is very weak according to the coefficient of determination $R^2 = 0.0601$.

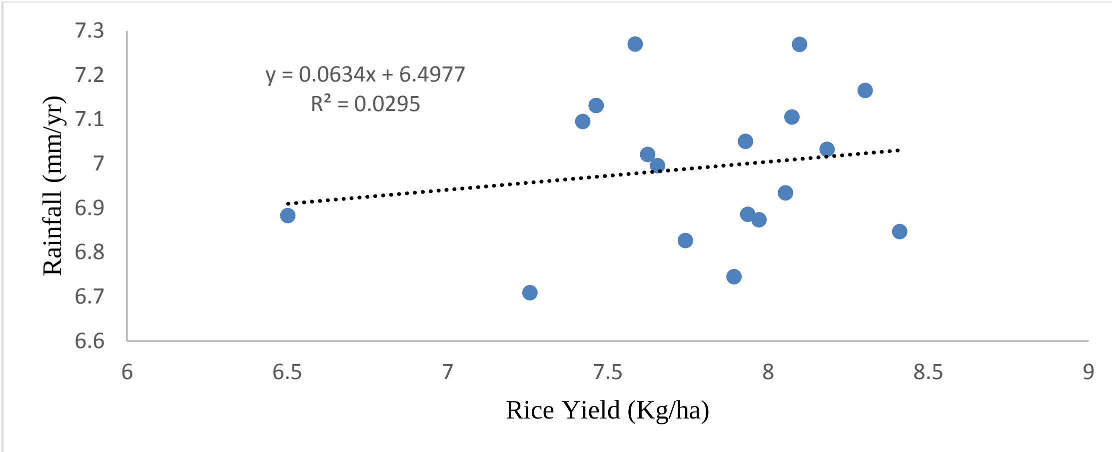

Figure 5. 10: Association between inter-seasonal rainfall and rice yield in Savè

(**Source**: Researcher, 2017)

Figure 5.10 indicates that the relationship between inter-seasonal rainfall is positive and weak in the district of Savè, the line of best fit is defined by the equation $y = 0.0634x + 6.4977$. The coefficient of the equation is positive which mean inter-seasonal rainfall variation have an influence on rice yield in the district of Savè. However this influence of inter-seasonal rainfall is very weak with the coefficient of determination $R^2 = 0.0295$.

5.3.2. Rainfall Variability and Rainfed Rice Yield

To examine the strength between inter-seasonal rainfall and rainfed rice yield, correlation analysis and linear regression were used in the study. Specifically Pearson correlation analysis was carried out between inter-seasonal rainfall and rainfed rice yield to test whether there is relationship between inter-seasonal rainfall variation and rainfed rice yield in each district. The results of correlation analyses are presented in Table 5.10.

Table 5. 10: Correlation Coefficients between inter-seasonal rainfall and rainfed rice yield

Districts	Correlation Coefficient	Significance
Bantè	0.16	NS
Dassa-Zoume	-0.38	NS
Glazoué	-0.06	NS
Ouèssè	-0.58	S
Savalou	0.24	NS
Savè	0.17	NS

NS= Non-Significance at 0.05, S= Significance at 0.05
(**Source**: Researcher, 2017)

The significance was tested using 2 tailed tests at the 0.05 level. From the table 5.10 it is noticeable that there is positive and weak relationship between inter-seasonal rainfall and rainfed rice for the districts of Save, Savalou and Bantè but the strength is not statistically significant. Dassa-Zoume, Glazoué indicated a negative and weak relationship but not statistically significant. That means the inter-seasonal rainfall variability impacts could be negligible in these districts which is also corroborated by increasing trend observed with rice yield within those districts. However the district of Ouèssè indicates a negative and moderate impact of the inter-seasonal rainfall on rainfed rice yield. The extent and significance of inter-seasonal impact on rice yield is tested for each district through a linear regression.

The linear regression analysis determines the extent and significance of inter-seasonal rainfall on rainfed rice yield in Administrative Unit of Collines over 18 years growing period. The regression statistics are shown in Table 5.11 for each district.

Table 5. 11: Regression statistics of inter-seasonal rainfall and rainfed rice yield

Districts	Multiple R	R Square	Adjusted Square	Significance
Bantè	0.16	0.026	-0.035	0.52*
Dassa-Zoume	0.38	0.0143	0.09	0.12*
Glazoué	0.06	0.04	0.58	0.80*
Ouèssè	0.58	0.337	0.296	0.01**
Savalou	0.24	0.06	0.001	0.33*
Savè	0.17	0.03	-0.031	0.49*

*Non-significant at 0.05; **Significant at 0.05.
(**Source**: Researcher, 2017)

Table 5.11 indicates that in the district of Ouèssè 29.6% of the inter-seasonal rainfall variability could be explained by the rainfed rice yield. The decreasing trend of the inter-seasonal rainfall could be affecting the rainfed rice yield in the district of Ouéssè, and other remaining percentage might be due to the combination of others climatic variable, management practices and potential effects of biotic factors.

These results findings are in line with Adamgbe et *al* (2013) who have statistically demonstrated a significant relationship between annual number of rain days and annual rainfall accumulated, and positively correlated with maize yield; duration and date of rainfall cessation also showed weak correlation with maize; while the starting date of rainfall indicated negative correlation with maize. In contrast, comparing the effects of rainfall variability in the district of Gboko Nigeria estimated to 67.7% for the past 30 year in this area higher than the rate obtained in the district of Ouèssè for the past 18 years which is 29.6% on rice yield. Simply this mean, the rainfall variability is explaining at 29.6. % the rate of rice yield in Ouesse although the rice yield show increasing trend due to potential of *Nerica* to resist climate effects; and the remaining percentage is due to unexplained factors such as weeds, pest and diseases, soil, management practice.

Tunde et *al*, (2011) examining the effects of climatic variables on different crops in Kwara State indicated that rainfall is negatively correlated with rice, sweet potato and groundnut yield. However this association was positive for maize, millet and sorghum in the same State. These findings are contrasting with Odekunle et *al*, (2011) who indicates in their conclusion that for the same geographical region the impacts of rainfall variability on crops are the same for the maize crop. These disparities within the districts explained the complexes' effects of rainfall variability on crops food system.

CHAPTER SIX: SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1. Summary

6.1.1. Inter-seasonal Rainfall and Rice Yield Variation.

The results of analyses produced show that inter-seasonal rainfall in Collines is decreasing in all the districts whereas rice yield is increasing over the periods of 18 years.

The decreasing trend of inter-seasonal rainfall within some districts was not statistically significant at 95% and not influencing the rate of rice yield in Bantè, Savalou and Glazoué, Dassa-Zoumè and Savè. However this rate was statistically significant in the district of Ouèssè where inter-seasonal rainfall was found explaining rice yield at 29.6 %.

The temporal results show substantial changes of rice yield with increasing trends both at Collines level and at districts level. The coefficient of variation indicated Bantè, Savalou, Dassa-Zoumè have low variation respectively 0.22, 0.25 and 0.24. Ouèssè, Glazoue and Savè have moderate variation respectively 0.32, 0.35 and 0.36 over the 18 years. But these variations are not statistically significant at 95% for five districts out of six which could probably be related to other combination factors.

6.1.2. Farmers' Perception on Agro-calendar.

The majority of rice farmers agreed the shift in the rainfall season onset, and 99% indicated that the rainfall amount was decreasing these past 5 and 10 years, 89% recognized that the rainfall amount was normal the past 20 years which was the result depicted by temporal trend analysis.

Rice yield is decreasing in a view of majority of rice farmers, that the current decreasing rate of rice yield is blamed by a delay in rainfall season, 99% of rice farmers situated the decreasing trend since 5years, 95% of respondents assumed that this yield was increasing 10 years ago but for the rainfall situation in Collines 54%, assume the rainfall season trend was normal past 20 years ago which is contrasting with rice yield trend analysis indicating increasing trend in Collines.

6.1.3. Rainfall Variability and Rainfed Rice Yield.

The Pearson correlation between rice yield and inter-seasonal rainfall variability is negative for Dassa-Zoumè (-0.38), Glazoué (-0.06), Ouesse (-0.58) and positive for Bantè (0.16) Savalou (0.24) and Savè (0.17) but only was found statistically significant for Ouesse at 95% over the period of 18 years.

The strength of these associations was found only statistically significant for the district of Ouéssè where inter-seasonal rainfall is explaining rice yield at 29.6 %. The inter-seasonal rainfall variability has no direct effect on rice yield within Dassa-Zoumè , Glazoué, Bantè , Savalou , Savè districts in Collines others factors could be influencing rice yield.

6.2. Conclusion

The study has revealed that inter-seasonal rainfall has been decreasing and the relationship between rainfed rice yields differs within the districts. The variability within the districts is not statistically significant at 95 % level for the majority of districts despite there is evidence of potential relationship of rice yield with inter-seasonal rainfall. Annual rice yield increasing apparently in rate indicate that the decreasing trend of inter-seasonal rainfall is not detrimental for rice producing in most of district but it is at optimum level of rainfed rice production. Precautionary principle need to be applied despite inter-seasonal rainfall showed an optimum condition of rice production in Collines in order to reach a target of rice self-sufficient and poverty reduction thus highlighted in National Rice Strategic Plan. In addition there is a need to identify local high-quality rice varieties that are suitable with different ecologies, and therefore promote their production by smallholder farmers to supply local demand and national needs. TRMM product 3B43 could therefore be considered as good as data source with potential capabilities to capture in the future the rainfall condition in Collines and beyond.

6.3. Recommendations

6.3.1. Policy Recommendations

The study recommends for policy makers to consider the decreasing rate of inter-seasonal rainfall within the districts of Collines as potential warning of future challenge of water scarcity. As precautionary principle needs to be applied, the study recommends;

- Rainfed rice insurance scheme in order to anticipate some adaptive strategies,
- Rice policies reviewing to preserve rice crops like development of irrigation scheme within the districts of Administrative Unit of Collines
- Promoting smart valleys rice production, within the districts of Administrative Unit of Collines

6.3.2. Research

The futures researchers need to expand by replicating the same approach to others Administrative Unit of Benin where farmers are dependent on rainfall for crop production.

- Consideration should be made on staple food production to understand not only the resilience capacity of each crop to weather vagaries but the inter-relationship between those crops yield
- Modelling variables by integrating farmers perception as moderating variables in combination with others variable like temperature, humidity, soil moisture, drought assessment for a same period of study.
- Climatic time series dataset should not be the barrier for any upcoming climatic studies. Consideration should be made to the TRMM NASA product 3B43 as potential source of data which could be well assessing and capturing the climatic impacts on crop production.

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APPENDICES

APPENDIX I: TYPES OF QUESTIONNAIRES

Agnontcheme, Abiola Innocent

Master Student at Department of Geography and Environmental Studies

P.O Box 30197 Nairobi
Field Questionnaire for a Master of Arts in Environmental Planning and Management

Dear Sir/Madam

RE: Field Data Collection

I am Masters Student at University of Nairobi, Department of Geography and Environmental Studies and my address is above. My field work seeks to investigate on Rainfall Variability Impacts on Rice Production: an Assessment on Rice Potential Yield in Benin, West Africa.

In this regards, I would like to kindly request you to assist by answering the following questions

Note that your views and opinion in this interview will be treated confidentially and strictly but will only be using for the purpose of academic research work.

APPENDIX Ia: RICE FARMERS QUESTIONNAIRE
BIO-DATA

1. Name of lowland:
2. Administrative Unit:
3. District:
4. Village:
5. Number of member:
    1. Gender: Male; Female;
    2. Age:
    3. Rice growing experiences:
    4. Varieties:
    5. Education status: Educated; Primary , Secondary, University Semi-educated; alp Never educated
    6. Type of field: Individual; Association;
6. Estimated Rice Area:
7. Area cultivated:

1. Rainfall and rice production season
    1. When the rainfall season is starting and ending? Please give the months
    2. When the rice production season is starting and ending? Please give the months
    3. For which purpose do you grow rice? Choose below the appropriate

Income

Family consumption

    4. What are others crops do you grow during?
        1. During the season? Choose below the appropriate

Maize

Vegetables

Bean

Okra

Millet

Soja

Other

2. After the season? Choose below the appropriate

Maize

Vegetables

Bean

Okra

Millet

Soja

Other

2. Rice production constraints in time and space

1. Rice production

2.1.1. What are the main constraints do you experience? Choose below the appropriate

Flood

Drought

Pest and disease

Weeds

2.1.2. What are the main factors affecting of rice production in the district? Choose among below

Lack of fertilizer

Poor equipment

Water scarcity

Seed quality

2.1.3. What is your perception about rice yield five year ago?

Normal

Increasing

Decreasing

No idea

2.1.4. What is your perception about rice yield 10 year ago?

Normal

Increasing

Decreasing

No idea

2.1.5. What is your perception about rice yield 20 year ago?

Normal

Increasing

Decreasing

No idea

2. Rainfall season in time and space

2.2.1 What do you think about rainfall season? Choose below the appropriate

Normal

Short

Long

Delay

No idea

2.2.2. What do you think about the current amount of rainfall?

Normal

Increasing

Decreasing

No idea

2.2.3. What is your perception about the rainfall season five years ago?

Normal

Increasing

Decreasing

No idea

2.2.4. What is your perception about the rainfall season 10 year ago?

Normal

Increasing

Decreasing

No idea

2.2.5. What is your perception about the rainfall season 20 year ago?

Normal

Increasing

Decreasing

No idea

2.2.6. What do you think better strategies for rain water management in rice production or other crops for the district? Choose the appropriate answers

Improve lowlands

Irrigation scheme

Training

Funding

Thank you

APPENDIX Ib: INTERVIEW QUESTIONNAIRE

1. Administrative Unit:

2 District:

3. Village:

4. Gender: Male; Female;

5. Rice production constraints in time and space

5.1 Rice production; Varieties:

5.1.1. What are the main constraints do you experience? Choose below the appropriate

Flood

Drought

Pest and disease

Weeds

5.1.2. What are the main factors affecting of rice production in the district? Choose among below

Lack of fertilizer

Poor equipment

Water scarcity

Seed quality

5.1.3. What is your perception about rice yield five year ago?

Normal

Increasing

Decreasing

No idea

5.1.4. What is your perception about rice yield 10 year ago?

Normal

Increasing

Decreasing

No idea

5.1.5. What is your perception about rice yield 20 year ago?

Normal

Increasing

Decreasing

No idea

5.2 Rainfall season in time and space

5.2.1 What do you think about rainfall season? Choose below the appropriate

Normal

Short

Long

Delay

No idea

5.2.2. What do you think about the current amount of rainfall?

Normal

Increasing

Decreasing

No idea

5.2.3. What is your perception about the rainfall season five years ago?

Normal

Increasing

Decreasing

No idea

5.2.4. What is your perception about the rainfall season 10 year ago?

Normal

Increasing

Decreasing

No idea

5.2.5. What is your perception about the rainfall season 20 year ago?

Normal

Increasing

Decreasing

No idea

5.2.6. What do you think better strategies for rain water management in rice production or other crops for the district? Choose the appropriate answers

Improve lowlands

Irrigation scheme

Training

Funding

Thank you

APPENDIXI c: GUIDE OF FOCUS GROUP DISCUSSION

1. Administrative Unit:

2 District:

6. Village:

7. Gender: Male; Female;

8. Number of rice farmers in discussion;

9. Rice production constraints in time and space

5.1 Rice production; Varieties:

5.1.1. What are the main constraints do you experience? Choose below the appropriate

Flood

Drought

Pest and disease

Weeds

5.1.2. What are the main factors affecting of rice production in the district? Choose among below

Lack of fertilizer

Poor equipment

Water scarcity

Seed quality

5.1.3. What is your perception about rice yield five year ago?

Normal

Increasing

Decreasing

No idea

5.1.4. What is your perception about rice yield 10 year ago?

Normal

Increasing

Decreasing

No idea

5.1.5. What is your perception about rice yield 20 year ago?

Normal

Increasing

Decreasing

No idea

5.2 Rainfall season in time and space

5.2.1 What do you think about rainfall season? Choose below the appropriate

Normal

Short

Long

Delay

No idea

5.2.2. What do you think about the current amount of rainfall?

Normal

Increasing

Decreasing

No idea

5.2.3. What is your perception about the rainfall season five years ago?

Normal

Increasing

Decreasing

No idea

5.2.4. What is your perception about the rainfall season 10 year ago?

Normal

Increasing

Decreasing

No idea

5.2.5. What is your perception about the rainfall season 20 year ago?

Normal

Increasing

Decreasing

No idea

5.2.6. What do you think better strategies for rain water management in rice production or other crops for the district? Choose the appropriate answers

Improve lowlands

Irrigation scheme

Training

Funding

Thank you

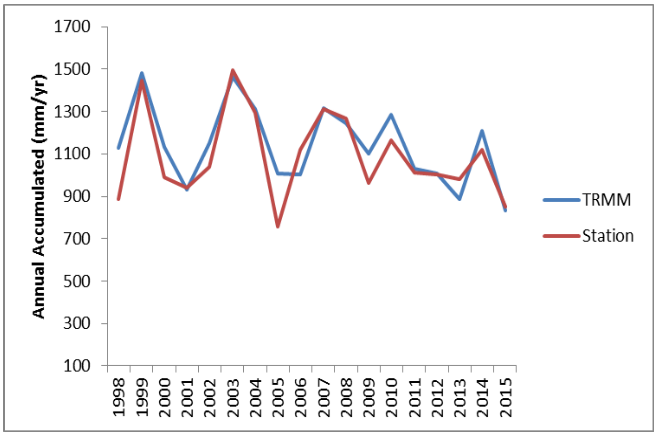
APPENDIX IIa: TRMM DATA CHARACTERISTIC

SHORTNAME	TRMM_3B43
LONGNAME	TRMM (TMPA/3B43) Rainfall Estimate L3 1 month 0.25 degree x 0.25 degree V7
DOI	10.5067/TRMM/TMPA/MONTH/7 Version: 7
FORMAT	HDF/ Net CDF
SPATIAL COVERAGE	-180.0,-50.0,180.0,50.0
TEMPORAL COVERAGE	1998-01-01 to 2016-03-31
FILE SIZE	4.9 MB per file
DATA RESOLUTIONSPATIAL	0.25 ° x 0.25 °
TEMPORAL	MONTH

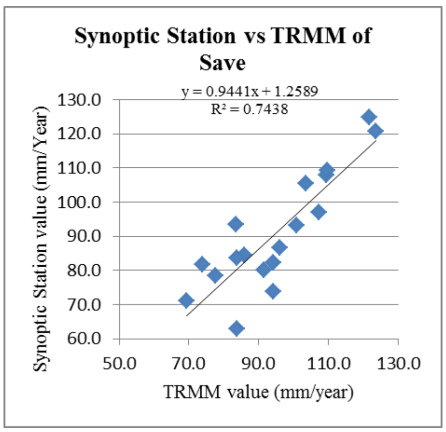
APPENDIX IIb: TRMM DATA CALIBRATION WITH IN SITU DATA AND CATEGORICAL STATISTIC

	Mean Bias (mm)	MAE (mm)	RMSE (mm)	Corr. Coef (r)
Annual accumulation Precipitation	49	83	112	0.86

Inter-comparison of inter-seasonal accumulation with observed, errors of satellite estimates



TRMM overestimation with in situ rainfall in Collines



Scatterplots analysis of rainfall between TRMM and in situ measurement in Collines

APPENDIX III: DATA TRANSFORMATION

Year	ln(Bante (mm/yr))	ln(Dassa-Zoume(mm/yr))	ln(Glazoue (mm/yr))	ln(Ouesse(mm/yr))	ln(Savalou (mm/yr))	ln(Save (mm/yr))	ln(Bante (Kg/ha))	ln(Dassa-Zoume (Kg/ha))	ln(Glazoue(Kg/ha))	ln(Ouesse(Kg/ha))	ln(Savalou(Kg/ha))	ln(Save(Kg/ha))
1998	7.093868	6.852741	6.911132	7.050909	7.053985	6.995148	7.824046	7.649693	7.807108	7.513891	8.006368	7.655507
1999	7.192176	7.277785	7.263972	7.268594	7.236033	7.269767	7.740664	7.649755	7.649799	7.45062	8.089518	7.585977
2000	7.087424	6.952633	6.977652	7.047882	6.970717	7.020502	8.006368	7.547017	7.712328	7.518664	7.901007	7.624739
2001	6.860572	6.778802	6.782053	6.848879	6.840287	6.82626	8.175829	7.824225	7.600902	7.324055	8.08641	7.742216
2002	7.143947	7.010073	7.011257	7.041903	7.147444	7.032162	8.194677	8.002085	7.67798	7.551454	8.050347	8.184923
2003	7.306994	7.068252	7.149961	7.33747	7.134719	7.269173	8.242756	7.613806	7.495499	7.513891	8.071205	8.099026
2004	7.137945	7.020506	7.043641	7.116273	7.140794	7.105101	8.160518	8.006368	7.560141	7.824046	7.824046	8.075111
2005	6.961605	6.856918	6.873865	6.896403	6.877265	6.885821	7.825319	8.162473	7.825127	8.160518	7.824046	7.937375
2006	6.921159	7.006702	6.921739	6.897949	6.982521	6.882832	8.239982	7.824046	7.824986	7.953343	7.937769	6.50229
2007	7.129212	7.238409	7.196215	7.189167	7.23276	7.165206	7.938205	7.681532	7.905647	7.02462	8.428293	8.303018
2008	7.076777	7.125462	7.060656	7.225146	7.11623	7.095192	7.859553	6.868599	8.517193	6.907755	8.094073	7.422211
2009	7.043148	6.976625	6.984225	6.975884	7.114799	6.933814	7.771924	7.827847	8.155854	7.360825	8.070906	8.054679
2010	7.138106	7.156021	7.153765	7.136747	7.173	7.130758	7.464126	7.751544	8.423926	7.618212	7.528453	7.463771
2011	6.950464	7.031006	6.997757	6.881833	7.05577	6.846243	8.12707	8.183585	8.511541	7.716495	8.426852	8.411077
2012	6.973528	6.943656	6.954882	6.920804	6.960668	6.873142	7.696213	8.006368	7.937375	8.022897	7.937375	7.972466
2013	6.78226	6.886512	6.86349	6.761661	6.800471	6.744537	7.696213	7.937375	7.901007	7.918598	7.900701	7.894132
2014	6.984566	7.033359	7.069302	7.026226	7.022669	7.050386	7.783224	7.98744	8.043755	7.97701	7.918331	7.93015
2015	6.735228	6.6815	6.684162	6.757	6.677186	6.70849	7.783224	7.98744	8.29405	7.97314	7.918092	7.257946

APPENDIX IV: SAMPLE FRAME OF COLLINES

N°	Name of rice field	Localisation administrative			Spéculation développée
		Commune	Arrondissement	Village	
1	Itchountchon	Bantè		Mayamon	Maïs, Riz
2	Ilagbo	Bantè		Ilagbo	-
3	Otounfou-Zankou -Madon	Bantè		Zongo	-
4	Koutadjaba	Bantè		Koutadjaba	Riz
5	Idiogou	Bantè		Idiogou	-
6	Attokolibé	Bantè		Attokolibé	-
7	Bouboula	Bantè		Koutadjaba	Riz
9	Lakpa	Bantè		Owodé (Ferme)	Riz, maraîchage
10	Kpô-Ôwo	Bantè		Owodé (Ferme)	Riz
11	Filia	Bantè		Owodé (Ferme)	Maraîchage
12	Koto-Olou	Bantè		Owodé (Ferme)	-
13	Gadja II	Bantè	Akpassi	Illagbo	Riz
14	Gadja I	Bantè		Illagbo	-
15	Idina	Bantè		Illagbo	-
16	Boro	Bantè		Illagbo	Riz, maraîchage
17	Otchéré	Bantè		Illagbo	Riz
18	Bouro	Bantè	Akpasi	Ilaré	Riz
19	veroirou	Bantè	bante	adjante	
20	tchallo	Bantè	bante	adjante	
21	beete	Bantè	bante	illelakoun	
22	djolodjo	Bantè	bante	illelakoun	
23	ferolakoun	Bantè	bante	basson	
24	gbelebia 1	Bantè	bante	illelakoun	
25	koubete	Bantè	bante	basson	
26	odooko	Bantè	bante	gbegamey	
27	odonla 1	Bantè	bante	illelakoun	
28	odonla 2	Bantè	bante	illelakoun	
29	owouko 1	Bantè	bante	illelakoun	
30	owouko 2	Bantè	bante	illelakoun	
31	idioke	Bantè	bante	basson	
32	ohuisessou	Bantè	bante	gbegamey	
33	adjoule	Bantè	bante	gbegamey	
34	agoue	Bantè	pira	adjigo	
35	aguehe	Bantè	bante	gbegamey	
36	odoboukou	Bantè	pira	adjigo	
37	omudonagbo	Bantè	pira	idiogou	
38	alladji	Bantè	pira	okoutaosse	
39	kagoure	Bantè	pira	adjigo	

40	kpamiokpe	Bantè	akpassi	ilare	
41	golofo	Bantè	akpassi	okoto	
42	okeowo	Bantè	akpassi	illagbo	
43	katakata	Bantè	akpassi	illare	
44	omioyi	Bantè	lougba	kotakpa	
45	dodokpako	Bantè	lougba	gotcha	
46	binonon	Bantè	akpassi	kouradjou	
47	koukpatcho	Bantè	bante	konta	
48	owo	Bantè	lougba	agongni	
49	ogouroro	Bantè	lougba	alletan	
50	adjimon	Bantè	akpassi	ilare	
51	odookere	Bantè	koko	itchocobo	
52	akatakou	Bantè	koko	itchocobo	
53	ketou	Bantè	atokolibe	malomi	
54	odokoto	Bantè	atokolibe	atokolite	
55	afofo	Bantè	atokolibe	malomi	
56	ateron	Bantè	atokolibe	atokolite	
57	idjoukou	Bantè	atokolibe	atokolite	
58	allou	Bantè	koko	itchocobo	
59	temidire 1	Bantè	bobe	assaba	
60	ifekpadjo	Bantè	koko	itchocobo	
61	temidire 2	Bantè	bobe	assaba	
62	kassonhoun 1	Bantè	bobe	assaba	
63	otoumbou	Bantè	bobe	assaba	
64	konoukou	Bantè	gouka	mayamon	
65	imorookpesse	Bantè	gouka	mamatchoke	
66	okoutara	Bantè	gouka	gouka	
67	donko	Bantè	gouka	gouka	
68	zankoumadon	Bantè	gouka	gouka	
69	imoro	Bantè	gouka	mamatchoke	
70	abebi	Bantè	gouka	gouka	
71	kpoba	Bantè	gouka	gouka	
72	sawere	Bantè	gouka	gouka	
73	okoutalakoun	Bantè	gouka	gouka	
74	kpipatcho	Bantè	gouka	galata	
75	odohilamon	Bantè	gouka	gouka	
76	gbangbaloke	Bantè	gouka	gouka	
77	koutokounon	Bantè	agoua	n'tchon	
78	konguinon	Bantè	agoua	n'tchon	
1	Adjakété	Glazoué		Sowé	Riz
2	Béthel	Glazoué		Béthel	Riz

3	Assanté	Glazoué		Assanté	Riz – légume
4	Akplassouté	Glazoué		Sowé II	-
5	Adjima	Glazoué		Boubou	Riz
6	Oguirin	Glazoué		Oguirin	Riz – maïs
7	Ararômi	Glazoué		kpakpada	Riz
8	Aklassouté	Glazoué		kpakpada	-
9	Kpoto	Glazoué		kpakpada	-
10	Ayédjoko	Glazoué		Yawa	Riz – igname
11	Awalayé	Glazoué		Yawa	-
12	Arigbokoto	Glazoué		Yawa	Riz –igname
13	Toga	Glazoué		kpakpada	Riz
14	Mèdahotonou	Glazoué		Atéguédji	Riz
15	Gbègbèlè	Glazoué	Aklankpa	Affizoungo	
16	Kpolé	Glazoué		kpakpada	Riz
17	Médékpo	Glazoué		kpakpada	Riz
18	Kpesseman	Glazoué		Oké-Okounou	Riz
19	Dagbéto	Glazoué		Oké-Okounou	-
20	Idjè	Glazoué		Oké-Okounou	-
21	Balé	Glazoué		Oké-Okounou	-
22	Akouégba	Glazoué	Sokponta	Akouégba	
23	Alawénonsa	Glazoué	Aklampa	Alawénonsa	Riz
24	Okéowo	Glazoué	Thio	Okéowo	Riz
25	Atenguédji	Glazoué		Yagbo	Riz
26	Offe	Glazoué	zaffe	zaffe	
27	kpele	Glazoué	zaffe	egbessi	
28	egbessan1	Glazoué	zaffe	egbessi	
29	zaffe 2	Glazoué	zaffe	zaffe	
30	okowassan	Glazoué	sokponta	akpikpi	
31	itchedjiro	Glazoué	glazoue	affecia	
32	kaloufe	Glazoué	kpakpaza	sowe	
33	kassowokpo	Glazoué	kpakpaza	sowe	
34	ifedoun	Glazoué	kpakpaza	sowe	
35	abedoun	Glazoué	kpakpaza	yawa	
36	Toba	Glazoué	kpakpaza	yawa	
37	trantran 1	Glazoué	kpakpaza	kpakpaza	
38	trantran 2	Glazoué	kpakpaza	kpakpaza	
39	americain	Glazoué	kpakpaza	attogbo	
40	Abia	Glazoué	kpakpaza	attogbo	
41	attogbo 1	Glazoué	kpakpaza	attogbo	
42	attogbo 2	Glazoué	kpakpaza	attogbo	
43	orokoto	Glazoué	glazoue	orokoto	

44	kotobo	Glazoué	gome	gome	
45	essinou	Glazoué	gome	gome	
46	gome 1	Glazoué	gome	gome	
47	xassagbaka	Glazoué	aklampa	allawenonsa	
48	lantadji	Glazoué	aklampa	affissoungo	
49	logozodohoui	Glazoué	aklampa	lagbo	
50	yenanwassetego	Glazoué	assante	yenanwassetego	
51	wesse	Glazoué	aklampa	wesse	
52	kolowo	Glazoué	aklampa	sowiandji	
53	adonoutche	Glazoué	aklampa	allawenonsa	
54	tognon	Glazoué	aklampa	sowiandji	
55	babato	Glazoué	aklampa	sowiandji	
56	xovi	Glazoué	aklampa	affissoungo	
57	lanta	Glazoué	aklampa	affissoungo	
58	dandohoue	Glazoué	aklampa	sowiandji	
59	manmonhoue	Glazoué	aklampa	lagbo	
60	batte 1 - 2	Glazoué	sokponta	sokponta	
61	Abia	Glazoué	sokponta	akwegba	
62	towe	Glazoué	sokponta	kpaco	
63	kakountonou	Glazoué	ouedeme	ouedeme et goto	
64	sofan	Glazoué	ouedeme	ouedemecentre	
65	sogoedjrosse	Glazoué	ouedeme	ouedemecentre	
66	godonou 1	Glazoué	ouedeme	ouedemecentre	
67	kolime	Glazoué	ouedeme	goto	
68	some	Glazoué	ouedeme	kpota	
69	Klou	Glazoué	ouedeme	yagbo	
70	abiya	Glazoué	ouedeme	yagbo	
71	dogbote	Glazoué	thio	hlasoe	
72	abori	Glazoué	thio	gbogbogni	
73	katchitche	Glazoué	thio	riffokpota	
74	ayewa	Glazoué	thio	riffokpota	
75	wokpa	Glazoué	thio	masse	
76	houala	Glazoué	magoumi	houala	
77	egbeko	Glazoué	magoumi	monso	
78	aboro	Glazoué	magoumi	aidjesso	
1	Lahadjô	Savalou		Mangoessi	Riz
2	Bahassè	Savalou		Mangoessi	Igname
3	Lahawô	Savalou		Carrefour	Riz
4	Lahanin	Savalou		Carrefour	-
5	Ganfan	Savalou		Klougo	Riz-arac-niébé
6	Kpakpa-Aïzin	Savalou		Klougo	Courge-crin-crin

7	Klan-Sowo	Savalou		Klougo	-
8	Sando	Savalou		kpakpavissa	Riz
9	Fifadji	Savalou		kpakpavissa	Riz – igname
10	Dah-Sinto	Savalou		kpakpavissa	Riz –igname
11	Sozoun	Savalou	Logozohè	Sozounmè	Riz
12	Gbodjèvè	Savalou		Adjahossou-Doho	Riz – igname
13	Logozo-Dowin	Savalou		Adjahossou-Doho	Riz – maraîchage
14	Sohé	Savalou		Adjahossou-Doho	-
15	Agonkpato	Savalou		Ferme	-
16	Djodagoin	Savalou		Ferme	Riz
17	Monro	Savalou		Ekpa	Riz
18	Létou	Savalou		Ekpa	-
19	Kiti	Savalou		Ekpa	Riz
20	Godé	Savalou		Lahotan	-
21	Kinnoussissadji	Savalou		Covedji	Maraîchage
22	Sandomè	Savalou		Kpakpavissa	Riz
23	Zounzonkanmey	Savalou		Zounzonkanmey	-
24	Kpakavissa (Sandomè)	Savalou		Kpakpavissa	Riz
25	Djalloukou	Savalou		Djalloukou	Riz
26	Toffadji	Savalou	Agbado	Toffadji	Riz – maraîchage
27	Lahotan	Savalou		Lahotan	Riz
28	nadjakpa	Savalou	ouesse	ouesse	
29	toganou	Savalou	logozohe	naoudji	
30	avounsawa	Savalou	agah	dagadoho	
31	alanmilan	Savalou	kpataba	codji	
32	monroakitikli	Savalou	kpataba	ekpa	
33	tchatcha	Savalou	tchetti	ottele	
34	assankon dago dago	Savalou	kpataba	miniki	
35	gogoedji	Savalou	gobada	lama	
36	zatedji	Savalou	gobada	lama	
37	kpakodji	Savalou	gobada	gobada	
38	okpitchoukouladjou	Savalou	tchetti	monsafou	
39	attan	Savalou	tchetti	adjoya	
40	kozodji	Savalou	kpataba	mondji	
41	dave	Savalou	logozohe	logozohe	
42	ahoho	Savalou	gobada	govi	
43	ahossouto	Savalou	ouesse	agbodranfo	
44	vete	Savalou	ouesse	akete	
45	mandogbo	Savalou	ouesse	aglamidjodji	
46	akpakpo	Savalou	ouesse	aglamidjodji	
47	tchoudoudouin	Savalou	ouesse	aglamidjodji	

48	kiosego	Savalou	ouesse	lowozoungo	
49	eninfekamoura	Savalou	ottola	ottolaigberi	
50	batikpo	Savalou	doume	coffeagballa	
51	kpako	Savalou	doume	ekpatiko	
52	agbanin	Savalou	doume	affezongo	
53	odi	Savalou	doume	affezongo	
54	n'gbodo	Savalou	doume	abeokouta	
55	laguidan	Savalou	ottola	akpaki	
56	odele	Savalou	ottola	akpaki	
57	logbo	Savalou	ottola	ottolaigberi	
58	alloudikadjehoun	Savalou	ottola	alloudi	
59	enefe	Savalou	ottola	alloudi	
60	kongbonran	Savalou	ottola	alloudi	
61	okoutagninni	Savalou	doume	bebiani	
62	odoatto	Savalou	doume	irroukou	
63	kodjovi	Savalou	doume	affezongo	
64	togba	Savalou	doume	affezongo	
65	kpako	Savalou	doume	agan	
66	odouagban	Savalou	doume	abeokouta	
67	obotchinse	Savalou	doume	abeokouta	
68	adjitche	Savalou	doume	affezongo	
69	gbogui	Savalou	doume	abeokouta	
70	otchoumare	Savalou	doume	abeokouta	
71	bayedje	Savalou	doume	abeokouta	
72	lodonou	Savalou	doume	n'gbehan	
73	aklajlo	Savalou	agbado	zounzonkanme	
74	agokoedji	Savalou	monkpa	monkpa	
75	satego	Savalou	monkpa	monkpa	
76	agbkin	Savalou	ouesse	ouesse	

(**Source**: Planning and Forecasting Office, 2016)

APPENDIX VI: RESEARCH PERMIT

MINISTERE DE LA DECENTRALISATION
ET DE LA GOUVERNANCE LOCALE

REPUBLIQUE DU BENIN

Contact

PREFECTURE DES COLLINES

BP: 01-882 : Tel: (+229) 21 30 40 30

info@decentralisation-benin.org

2017 N°05/016/PDC/SG-D/AR

Collines, 11th July, 2017

TO WHOM IT MAY CONCERN

AGNONTCHEME ABIOLA INNOCENT:

This is to introduce you that the above named person is a student of University of Nairobi, who is required to conduct a survey and gather information for academic purposes on " ***Rainfall variability impacts on rice production: a case study of rice yield in Administrative Unit of Collines, West Africa, Benin.***"

Please accord him the necessary assistance required for his academic award.

Faithfully Yours

A.R.

Firmin Aimé KOUTON (Interim Prefect)

FOR PREFECTURE OF COLLINES

Copies: All Mayors of Districts of Collines

Agnontcheme Abiola Innocent

APPENDIX VII: DECLARATION OF ORIGINALITY FORM

Declaration Form for Students

UNIVERSITY OF NAIROBI

Declaration of Originality Form

This form must be completed and signed for all works submitted to the University for examination.

Name of Student:	AGNONTCHEME ABIOLA INNOCENT
Registration No:	C50/82154/2015
College:	OF HUMANITIES AND SOCIAL SCIENCES
Faculty/~~School~~/~~Institute~~:	OF ARTS
Department:	OF GEOGRAPHY AND ENVIRONMENTAL STUDIES
Course Name:	CGP 598 MA PROJECT
Title of the work:	RAINFALL VARIABILITY IMPACTS ON RICE PRODUCTION: A CASE STUDY OF RICE YIELD IN COLLINES

DECLARATION

1. I understand what Plagiarism is and I am aware of the University's policy in this regard.
2. I declare that this ......project...............(Thesis , project, essay, assignment, paper, report etc) is my original work and has not been submitted elsewhere for examination, award of a degree or publication. Where other people's work, or my own work has been used, this has properly been acknowledged and referenced in accordance with the University of Nairobi's requirements.
3. I have not sought or used the services of any professional agencies to produce this work.
4. I have not allowed, and shall not allow anyone to copy my work with the intention of passing it off as his/her own.
5. I understand that any false claim in respect of this work shall result in disciplinary action in accordance with University Plagiarism Policy.

Signature: ....[signature]..........

Date: ....15/10/2018..........

APPENDIX VIII: PLAGIARISM REPORT

RAINFALL VARIABILITY IMPACTS ON RICE PRODUCTION: A CASE STUDY OF RICE YIELD IN THE ADMINISTRATIVE UNIT OF COLLINES IN BENIN, WEST AFRICA

by Agnontcheme Abiola I

Submission date: 31-Oct-2018 12:32PM (UTC+0300)
Submission ID: 1030279087
File name: TURNITRIN.docx (5M)
Word count: 17248
Character count: 106854

RAINFALL VARIABILITY IMPACTS ON RICE PRODUCTION: A CASE STUDY OF RICE YIELD IN THE ADMINISTRATIVE UNIT OF COLLINES IN BENIN, WEST AFRICA

ORIGINALITY REPORT

11%	9%	6%	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

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4	Franciane L. R. de O. Louzada, Alexandre C. Xavier, José E. M. Pezzopane. "CLIMATOLOGICAL WATER BALANCE WITH DATA ESTIMATED BY TROPICAL RAINFALL MEASURING MISSION FOR THE DOCE RIVER BASIN", Engenharia Agrícola, 2018 Publication	<1%
5	www.scirp.org Internet Source	<1%
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APPENDIX IX: PROOF OF REGISTRATION

9/4/2018 Students Management Information System (SMIS)

UNIVERSITY OF NAIROBI

COLLEGE OF HUMANITIES AND SOCIAL SCIENCES

STATEMENT OF FEES ACCOUNT **Date :** 04-Sep-2018

Name : ABIOLA INNOCENT AGNONTCHEME (KENYAN) **Reg. Number :** C50/82154/2015

Overall Status : CURRENT **ACADEMIC YEAR STATUS:** CURRENT

Academic Year : 2015/2016 **Billing Currency :** KES

Transaction Id	Date	Description	Debits DR	Credits CR	Balance	Cur.Rate
218978920	22-SEP-15	FEES PAYMENTS	0.00	214,744.00	-214,744.00	KES=1
C50/82154/2015-2015/2016-SEM1	02-OCT-15	FEES PAYABLE FOR SEM1	79,500.00	0.00	-135,244.00	KES=1
C50/82154/2015-2015/2016-SEM2	10-FEB-16	FEES PAYABLE FOR SEM2	62,000.00	0.00	-73,244.00	KES=1
C50/82154/2015-2015/2016-SEM3	19-JUL-16	FEES PAYABLE FOR SEM3	62,000.00	0.00	-11,244.00	KES=1
		Academic Year Totals :	**203,500.00**	**214,744.00**	**-11,244.00**	
Closing Balance : -11,244.00						
Academic Year : 2016/2017	**ACADEMIC YEAR STATUS:**CURRENT					
Opening Balance			0.00	11,244.00		**-11,244.00**
2180245744	09-MAR-18	FEES PAYMENTS	0.00	208,254.00	-219,498.00	KES=1
		Academic Year Totals :	**0.00**	**219,498.00**	**-219,498.00**	
Closing Balance : -219,498.00						
Academic Year : 2017/2018	**ACADEMIC YEAR STATUS:**CURRENT					
Opening Balance			0.00	219,498.00		**-219,498.00**
C50/82154/2015-2017/2018-SEM3	25-JUN-18	FEES PAYABLE FOR SEM5	0.00	0.00	-219,498.00	KES=1
C50/82154/2015-2017/2018-SEM2	25-JUN-18	FEES PAYABLE FOR SEM4	74,500.00	0.00	-144,998.00	KES=1
C50/82154/2015-2017/2018-RF	31-AUG-18	FEES PAYABLE	144,998.00	0.00	0.00	KES=1
		Academic Year Totals :	**219,498.00**	**219,498.00**	**0.00**	
		GRAND TOTALS :	**422,998.00**	**422,998.00**	**0.00**	
Closing Balance : 0.00						

Checked By :..

Sign

Approved By :..

BURSAR

CENTER FOR SELF SPONSORED PROGRAMMES (CESSP) ACCOUNTANT P.O. Box 30197-00100 G.P.O., NAIROBI UNIVERSITY OF NAIROBI

11/9/2018.

NB: Valid with an Official University of Nairobi Stamp
Any fee balance disqualify one for sitting for examination

http://umis.uonbi.ac.ke/smis/feestatement.php 1/