PRODUCTIVITY OF RICE (*Oryza Sativa*) AS INFLUENCED BY WEATHER PARAMETERS IN KANO RIVER IRRIGATION PROJECT, KANO STATE, NIGERIA.

BY

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CHAPTER ONE: INTRODUCTION

1.1 Background to the Study

Agriculture is always vulnerable to unfavourable weather events and climate conditions. Despite technological advances such as improved crop varieties and irrigation systems, weather and climate are important factors, which plays a significant role to agricultural productivity (Tao, 2004). Apart from the socio-economic problems facing Nigerian farmers, weather parameters such as relative humidity, soil and atmospheric temperature constitute a major limiting factor in crop Production (Adefolalu, 1991).

Climatic factors such as temperature, rainfall, atmospheric carbon dioxide, solar radiation are closely linked with agricultural production. Reduction in rice productivity has been predicted to be a major concern in years to come due to changing climatic conditions. The noticeable climate change impacts are the increased global mean surface temperature; increased frequency and severity of drought, variations in precipitation characteristics such as onset, length of rainy season, cessation, seasonality index and hydrological ratio and heat waves. All these signs have a negative impact on agriculture. Among various sectors, agricultural sector is heavily influenced by the weather and climate especially rainfall and temperature. Agricultural sector reveals high sensitivity and resilience to the impact of rainfall and temperature (Yuji, 2009).

The influence of rainfall on agricultural food production is a global concern and in Nigeria, where must livelihood are dependent mainly on agriculture, is exposed to a great danger, as the country is one of the most vulnerable countries due to variability in rainfall and increased temperatures. Nigeria has a large agrarian base with 76 percent of total population living in the rural areas and 90 percent of the rural population directly relies on agriculture. Increasing food production and attaining food security in Nigeria requires sustainable growth of agricultural sector (Nigerian Economic Review 2008). The sector is already under pressure for increasing food demand, problems associated with agricultural land and water resource depletion. The issues of climate change make the pressure more acute for the sector (Nigerian Economic Review, 2008).

Nigeria faces a tremendous challenge for providing food security to the increasing population and it is imperative to increase rice production which is one of the important food crops in order to meet the growing demand for food emanating from population growth. Although, there have been ups and downs in the domestic production of food grain, the diverse climatic phenomena like drought, changing rainfall patterns and increase in temperature have led to a significant loss in food grain production over the recent years. The desiccation and siltation of large water bodies like the Lake Chad, River Kubanni, River Galma, River Rima, and Hadejia – Jama'are River in the northern part of the country has caused severe damage to agricultural production, especially the rice production. Therefore, the impact of climate parameters on the growth and yield of rice in Nigeria requires systematic integration of environmental and economic development measures for a sustainable agricultural growth (Odjugo, 2010).

With more than 146 million inhabitants in 1999 (NPC, 2006), Nigeria is by far the most populous country in Africa. The agricultural sector has been the backbone of the economy since independence, employing more than 70 percent of the country's population. Small farm holders dominate the sector and provide the bulk of the nation's domestic food supply. The Nigerian farm sector is characterized by low productivity that has persisted since the early 60s. World Bank reports put the growth rate in total food production at less than 1.5 percent in the 1990s, compared to an average annual population growth rate of about 3 percent during the same period.

This has placed tremendous pressure on the farm sector and the economy at large, as limited foreign reserves have to be allocated to food importation in order to meet consumption requirements (Odjugo, 2010).

Rice is an important cereal in Nigeria, with the share of rice in cereals consumed increasing from 15 percent in the 1970s to 26 percent in the early 1990s (Ana, 2010). Projections from the FAO indicate rice consumption growth rates of 4.5 percent per annum through the 2000s, this represented a 70 percent increase in total rice consumption by the end of the decade. Although total rice production has increased over the last two decades, the increases have not been sufficient to meet the increasing demand from the rapidly growing population. Mean annual paddy production increased from 332,800 metric tons during the period 1961-1975 to 3,189,833 metric tons during 1995-1999. However, most of this increase has been attributed to an expansion in the area under cultivation. During the same period, rice imports increased from 2036 to about 687,925 metric tons. The inability to meet rice consumption needs through local production has resulted in high cash outlays for importation. In 1998 for example, the value of rice imported into Nigeria was estimated at US$ 259 million. Recent policies have placed emphasis on increasing local rice production in order to reverse import trends and free up limited foreign reserves for use in other sectors (Maclean, 2002).

Global rice production was only 215 million tons in 1961, within the span of 45 years the global rice production rose to 644 million tons in 2006 or an increase of 429 million tons. During the first 15 years, 1961 to 1975, global rice production increased by 141 million tons or 9.4 million tons per year. Increases in both harvested area and yield were responsible for the increase of global rice production from 1961 to 1975 (UNDP 1999).

Nguyen (2008) was able to show that the global rice harvested area increased by 26 million hectares or 1.73 million hectares/year, hence global rice yield increased by 0.65 tons/ha, from 3.53 tons/ha in 1991 to 4.12 tons/ha in 2006 or an increase of 0.039 tons/year. The increase in global rice harvested area was substantially about 10 million hectares or 0.55 million hectares/year, but the expansion rate was much lower than that in the first 15 years, from 1961 to 1975. Although global rice production fluctuated now and then in 1961-1999, the production generally decreased, however. For the first time, global rice production decreased sharply and for a rather long period, from 1999 to 2000 (Nguyen, 2008).

The decrease in rice production during the period from 1999 to 2002 was caused by a sharp changes in precipitation effectiveness parameters such as onset, length of rainy season, cessation, seasonality index, hydrological ratio, etc. The sharp decrease of rice production from1999 to 2002 suggests that the rice production might become unstable in the future (Aggrawal, 2003). Food production in any country is directly related to the weather parameters. The changing patterns of weather parameter create the problem of droughts, floods, tropical cyclone, changing precipitation, heat waves which negatively affect the crop productivity, thus results in greater instability in food production and threat to livelihood security of the poor people (FAO, 2010).

As strategies to increase food production are being evolved, there is the need to assess the productivity of rice *(Oryza Sativa)* as influenced by weather parameters as resources affecting the yield of rice in the Kano River Irrigation Project (KRIP), Kano state, Nigeria.

1.2 Statement of the Research Problem

Globally, rice is the staple food of more than 3 billion people. However, production has become unstable after 1999 (Nguyen, 2010). The surge in the prices of rice since 1999 has affected food security in several developed and developing countries where rice is the staple food crop. The rate of growth of rice production is declining and water for rice production - especially in Africa and Asia - is becoming scarce (FAO, 2010). The food security of rice consumers depends on the weather and climatic favourability especially rainfall and temperature toward achieving sustainable production. Policy makers need information on the situation of rice production and on improved technologies that are available for sustainable intensification of rice production in order to formulate appropriate policies for supporting rice production.

(Karthick, 2013) carried out a research in India's agricultural sector and discovered that most of the rural population depends on agriculture, forest, livestock, fishery and other natural resources for their livelihood. These sectors are sensitive to changes in rainfall which also affects the socio-economic system. Globally, concerns are raised as regards the impact of changing climate on agriculture; much importance was given to assessing the impact of rise in temperature, drought and erratic rainfall on various crops. Field level research is also being carried out and it is reported that productivity of few crops could be affected due to rise in temperature, drought and changing pattern of rainfall (FAO, 2010).

As per the findings of a Model output based on future changes of rainfall scenario in Indonesian agricultural sector, Jinta & Srinkantha, (2011) indicated that a 0.5˚C rise in winter temperature will reduce rice yield by 0.45 tons/ha. A 2-5 percent yield reduction for rice for a temperature rise of 0.5-1.5°C in Indonesia was projected (Aggarwal, 2003). A 1.5˚C rise in temperature and

2mm increase in precipitation could result in a decline in rice yields by 3-15 percent (Senapati, 1998). It is estimated that a 5 percent decrease in rainfall results in 10 percent drop in the rice income and increase of 20˚C temperature and 7 percent rainfall reduces the rice net income to an extent of 8 percent (Carmer 2008).

Food and agricultural organisation of the United Nations (2010) describes the influence of the change in the pattern of rainfall and temperature as responsible for the great alteration of both the quality and quantity of food production through its adverse consequences such as flooding, desertification, drying up of water bodies and drought. The impact of changes in climate is greatly felt in the developing nations probably as a result of their low levels in technology and mechanisation of agricultural field.

IPCC (2001) reports that the consensus of atmospheric scientists is that climatic characteristic and pattern is changing base on the noticeable changes of its parameters such as onset, cessation, length of the rainy season and the hydrological ratio. Temperature can also influence evapo-transpiration rates, which impact on soil moisture, which in turn may influence infiltration and runoff amounts and rates. This generally, has led to a decreased in the productivity of most rain fed crops.

(Pruski and Nearing, 2002) examines the Changes in rainfall pattern on rice production in Argentina and they shows that, these are likely to be accompanied by changes in crop management, as farmers adapt their management practices to the new climate especially rainfall and temperature. Townsend (2009) studies the impact of climate in the Zimbabwe Paddy and shows that the changes in rainfall patterns and increasing temperature has decreased crop yield and has led the farmer to plant a new crop, or farmers may change planting dates of rice to take advantage of increased warmth or to avoid high temperatures and inadequate rainfall. Farmers may also plant crop varieties of different maturity periods, thus affecting the production of crops.

Townsend (2012) carried out a research on the changing rainfall on rice production in Pakistan. He discovered that the low productivity in rice is due to the change in some of the precipitation effectiveness indicators such as onset, length and cessation of the rainy periods; Jayanta, (2010) studied the upland rice farms in Sri Lanka and discovered that the 30 percent decline in rice productivity in areas such as Kalgum and Shama is as a result of the change in the length of the rainy season.

Depledge (2002) in the USA, carried out a research on the rain fed rice production and discovered that a sharp decrease is as a result of some of the climatic parameters such as high temperature and erratic rainfall and today most of rice production in the USA is under irrigation; Less attention is giving to the specific influence of weather parameters to rice production in Nigeria especially in the northern parts of the country where majority of the cereal crops are produced despite the sharp decrease in agricultural productivity over the recent years. A study of this nature was carried out by Nguyen, (2010) on a larger scale of Sub-Saharan Africa and the result shows that the recent changes in the pattern, duration, and quantity of rainfall over the recent years have greatly lead to a reduction in the quantity of rice produced in these areas.

Odjugo (2010) in Abakaliki, Ebonyi state, Nigeria discovered that the decline in rice production in the country is likely associated with the increase in the intensity and decreased in the length of the rainy season which leads to a severe flooding especially in the coastal areas, which leads to a submergences of rice farms and consequently affecting the produce.

Adebayo (2000) carried out a research on agro- climatic classification of Adamawa State for upland rice production. The study identified four critical climatic parameters influencing upland rice in AdamawaState. The parameters include hydrologic ratio, onset dates of rains, number of dry pendates during the growing season and rainfall amount. The researcher finds out that these parameters plays a significant role in the productivity of upland rice in the study area.

Adebayo and Adebayo (1996) carried out similar studies on precipitation effectiveness and upland rice yield in Adamawa state. The finding emphasised the importance of precipitation effectiveness indices as critical factors controlling crop yield in the state in particular and in the West African Savannah environment in general.

Abdulhamid and Giade (2007) carried out a research on the influence of precipitation effectiveness indices on the growth and yield of Sorghum in Katagum, Bauchi state of Nigeria. The study revealed that precipitation effectiveness parameters are most critical factors affecting the yield of Sorghum in the area.

Abaje (2010) carried out a research in Nigeria on the impact of change in rainfall on crops production, where the researcher focused on all the elements of climate, without really specifying the influence of each of the elements. Despite these studies however, not much attention has been given to the productivity of rice as influenced by weather parameters in the Kano State river irrigation project (KRIP). It is not the total amount of rainfall and temperature that matters but the influence of the weather parameters such as onset, length of the rainy season, cessation, hydrological ratio and temperature. To the best knowledge of the researcher, no work has been done covering the influence of the selected precipitation effectiveness indices (onset, cessation and length of the rainy season) and the minimum and maximum temperature, humidity and temperature. This study seeks to fill the existing gap, the research therefore seeks to deduce the influence of weather parameters on the productivity of rice. It therefore seeks to answer the following questions:

i. What is the pattern of weather parameters (temperature, humidity and rainfall) of the study area for the period 1994 - 2013?
ii. What is the relationship between maximum and minimum air temperature, relative humidity, rainfall and the productivity of rice?
iii. What is the relationship between precipitation effectiveness indices (Onset, Cessation and the Length of the rainy season) and productivity of rice?
iv. What are the combined effect of weather parameters in (ii & iii) above on rice productivity?

1.3 Aim and Objectives of the Study

The aim of this research is to analyze the productivity of rice *(Oryza Sativa) as* influenced by weather parameters in the Kano State River Irrigation Project, Kano State, Nigeria. To achieve the afore-mentioned aim, the specific objectives shall be to

i. examine the pattern of weather parameters (temperature, humidity and rainfall) of the study area between 1994 - 2013
ii. determine the relationship between maximum, minimum air temperature, relative humidity and rainfall on the productivity of rice
iii. determine the relationship between precipitation effectiveness indices (Onset, Cessation and the Length of the rainy season) and the productivity of rice

iv. assess the combined effect of the weather parameters in (ii & iii) above on rice productivity

1.4 Research Hypothesis

In order to verify the validity of the research, the following null (H_0) hypothesis was formulated. H_0 = There is no significant relationship between rice productivity and the maximum, minimum temperatures, relative humidity and rainfall.

1.5 Scope of the Study

The study focused on weather parameters; maximum and minimum air temperature, precipitation effectiveness indices such as onset, cessation and the length of the rainy season, all of which plays a very significant role in the growth and yield of rice.

The study centred on the Kano State River Irrigation Project (KRIP) located at Garun Mallam Local Government area of Kano State where data on the yield of rice is readily available; this is because this scheme provides local rice to most parts of the northern Nigeria since its inception. Both data of rice yield and weather parameters were collected for a period of 20 years from 1994 – 2013.

1.6 Significance of the Study

Reducing hunger and poverty are the key objectives of the United Nations Millennium Development Goals. This was the main reason for the UN declaration of the International Year of Rice 2004. In 2002, rice was the source of more than 500 calories per person per day for over 3 billion people (FAOSTAT, 2004). Furthermore, rice cultivation is the principal activity and source of income for more than 100 million households in developing countries of Asia, Africa and Latin America. The concerted and coordinated efforts to improve rice production through science, research and development in the 1970s and 1980s enabled global rice production to meet the demand of a growing population, created employment opportunities, increased the income of rice farmers, and enhanced access to rice of the poor populations living in urban centres across the world.

The gains made during the Green Revolution, however, have begun to show diminishing returns in recent years. Since 2000, world rice production has been less than rice consumption (FAO, 2004). The world population continues to grow steadily, while food supply, land and water resources are declining.

Townsend (2012) studies have demonstrated that the production and distribution of rice in different parts of the world might be affected greatly by the global changes in rainfall.

Nigeria, formally an exporter of large amount of rice, today imports more than 75 percent of the rice needed to carter for the growing population. A rapid increase in population, lack of governmental assistances to farmers, low mechanization of agricultural sector and high rate of rural- urban migration and above all a change in the pattern of rainfall such as onset, cessation, and length of the rainy season, hydrological ration and seasonality index can be attributed to the rice deficit. Not much is really understood as regards the influence of weather parameter on rice productivity in the study area. The research will go a long way in assessing the actual influence of weather parameter on the productivity of rice in the study area.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter contains the review of related literature on the influence of weather parameters on the growth and yield of rice. The first part deals with the biology and varieties, ecology, consumption. The second part focuses on the effect of weather parameters (rainfall, maximum, minimum temperature and relative humidity) on the productivity of rice. The third sub - division of the literature review focuses on the relationships between crops and weather parameters.

2.2 Rice Biology/Ecology/Consumption/Varieties/Processing

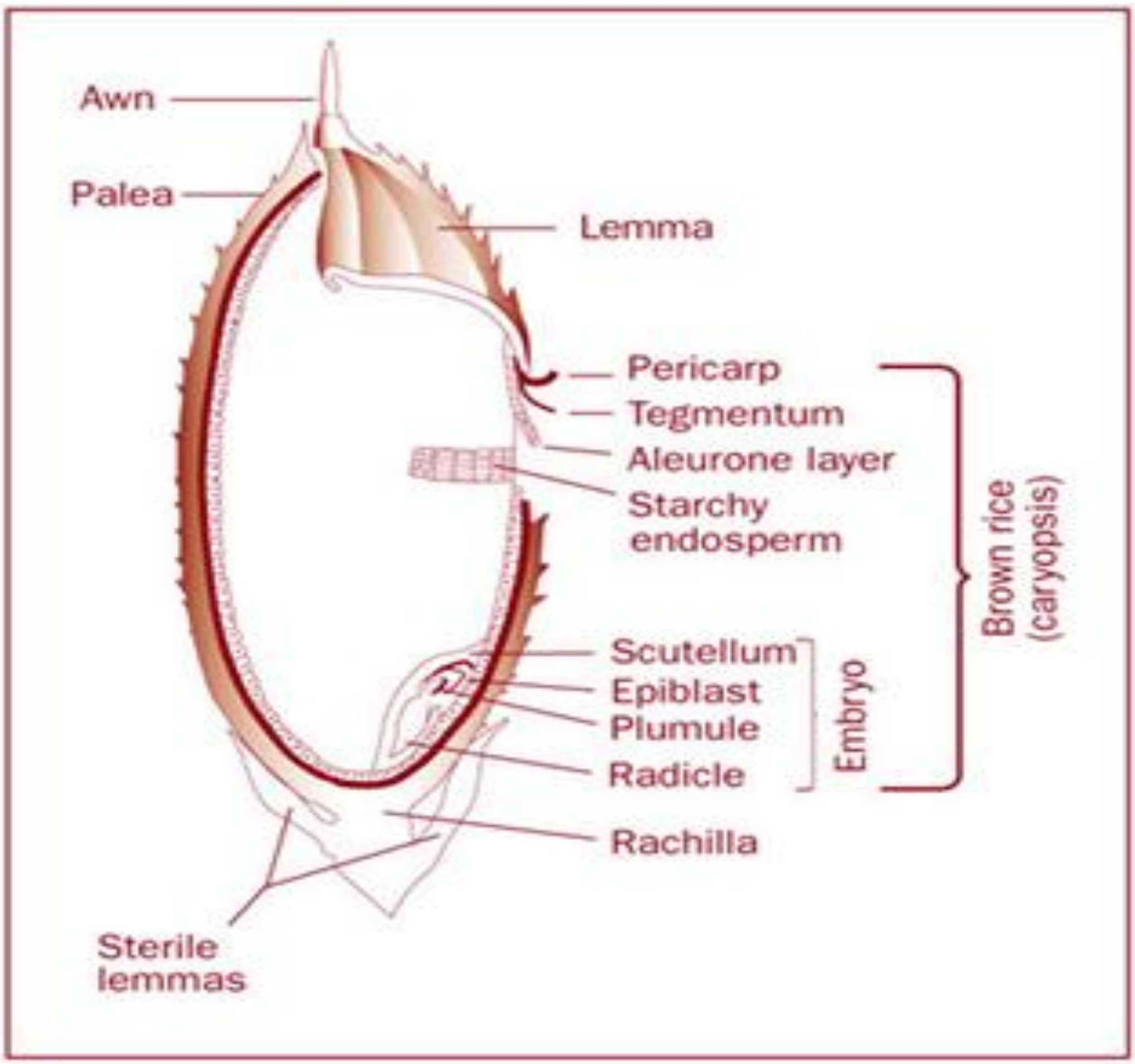
2.2.1 Rice Biology

Rice *Oryza sativa* (Asian rice) or *Oryza glaberrima* (African rice) is a monocot plant. As a cereal grain, it a member of the grass family, with high affinity for water (FAOSAT, 2008).

2.2.1.1 *Seed*

A rice seed consists of a husk (the inedible outer part) and the edible rice grain inside, Fig. 2.1. For the rice seed to be used to grow a new rice crop, the husk is retained and the whole seed is planted. To get to the edible rice grain inside the seed the husk has to be removed. Underneath the husk is the rice grain covered with a layer of bran. When rice has its bran intact it is called ‘brown’ rice. Some brown rice grains may even be viable if planted because the ‘germ’ part of the grain, which is the part of the seed that germinates into a new plant, may not have been damaged when the husk was removed. If the bran is also removed, you get ‘white’ rice.

FIG. 2.1 Physiology of a Rice Seed



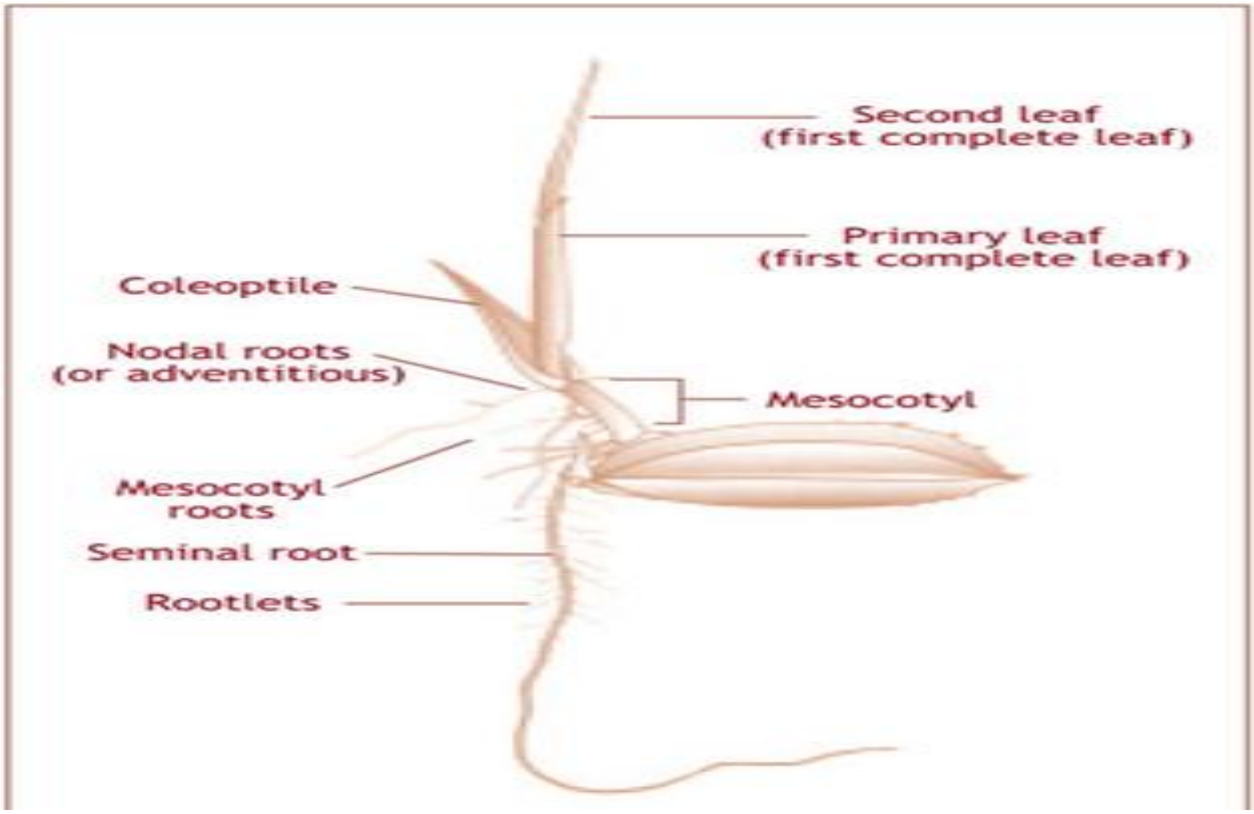
Source: Adapted from International Rice Research Institute

A single rice seed weighs 10 – 45 milligrams at 0% moisture content. Grain length, width, and thickness vary widely among varieties. Husk weight averages about 20% of total grain weight. Rice seed can be stored and remain viable from a few weeks if air moisture is below 14%, to as long as a year in drier conditions. Usually rice should be stored in paddy form rather than milled rice as the husk provides some protection against insects. In the International Rice Genebank where rice seed from more than 118,000 different types of rice is conserved, rice seed is kept in vacuum packed, freezers at -18 °C, where they can remain viable for 100 years.

2.2.1.2 *Seedling*

A rice seedling is the young plant that emerges from the rice seed after germination. A typical young seedling consists of three main parts: the first root (radicle), the first shoot (hypocotyl), and the first leaf (cotyledon).

Fig. 2.2 A Germinating Rice Seed



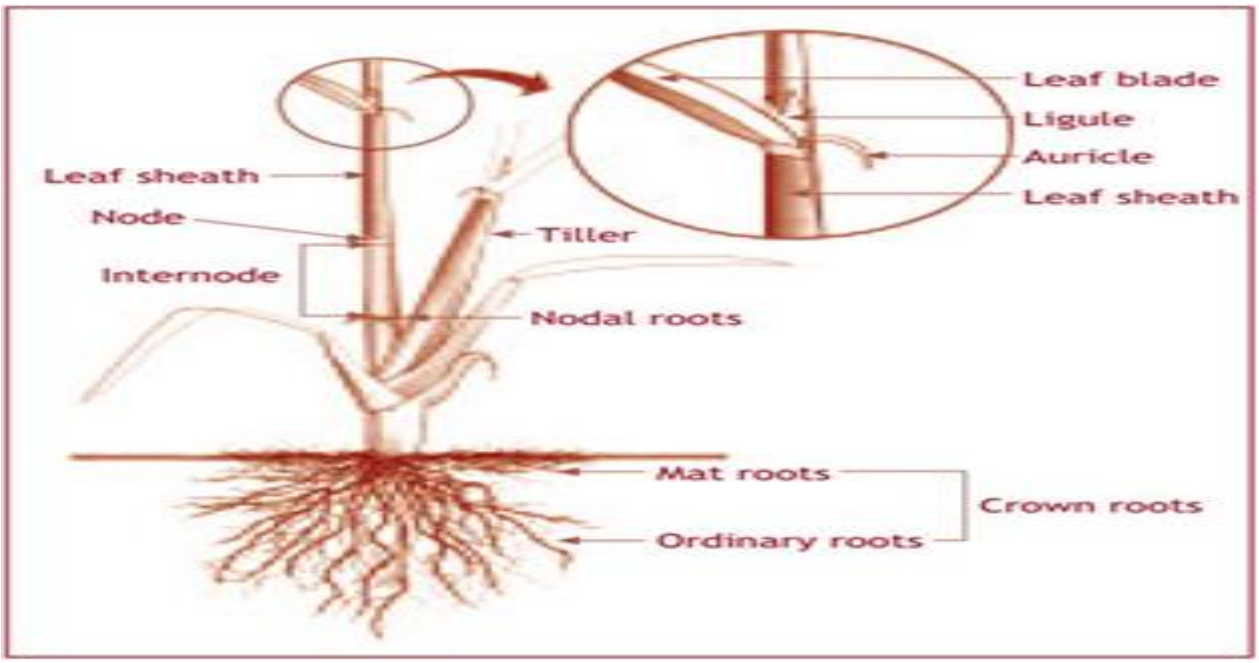
Source: Adapted from IRRI

If the seed develops in the dark – such as when seeds are sown beneath the soil surface – a short stem (mesocotyl) develops, which lifts the crown of the plant to just below the soil surface. After this shoot emerges, it splits and the primary leaf develops.

2.2.1.3 *Tiller*

Once the seedling has about five leaves, it is self-supporting and begins to develop into a more complex plant. This process is called tillering. More stems develop from the main stem – each is a called a new tiller. At the top of each of these new tillers are flatter leaves. Although the tillers remain attached to the plant, at later stages they produce their own roots and become independent. The amount of tillering depends on the variety of rice and environmental factors such as spacing, light, nutrient supply and cultural practices. Once fully developed, at the end of each tiller a flower cluster will develop, which will develop into grains when pollinated.

Fig. 2.3 Tillering in Rice Plant



Source: Adapted from IRRI

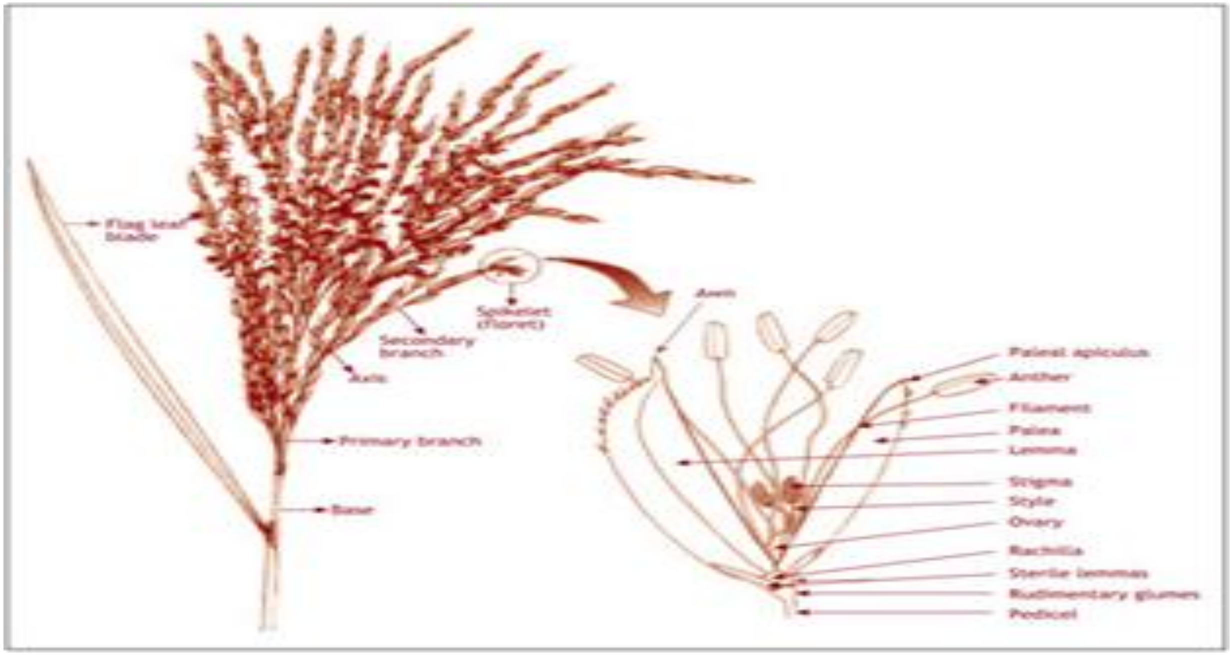
2.2.1.4 *Roots System of Rice Plant*

Once the rice plant has begun tillering, it needs to develop a more complex root system to anchor the developing plant. The initial small rootlets that sprang from the seedling develop into mature, fibrous roots, which in turn produce more rootlets (Fig. 2.3). The root system is shallow, with over 95 percent of the roots found in the top 8 inches of soil. All rice roots have root hairs to absorb moisture and nutrients. The rice root system consists of crown roots (including mat roots) and nodal roots. Both develop from nodes, but crown roots develop from nodes below the soil surface, while nodal roots develop above the soil surface. Nodal roots are often found in rice cultivars growing at water depths above 80 cm. Most rice varieties reach a maximum depth of 1 m or more in soft upland soils. In flooded soils, however, rice roots seldom grow deeper than 40 cm because there is not enough oxygen to supply the growing root tips.

2.2.1.5 Flowers

Although rice flower might not be obvious because they are not big or colorful, rice plants have flowers. The flowers of rice are more typically referred to by their scientific name – panicles – and they occur at the end of each tiller (Fig.2.4). Like most flowering plants, rice needs to be pollinated in order to produce seeds. Rice is mostly self-pollinating, which means that each rice plant can fertilize itself with its own pollen. Cross-pollination between different rice plants does happen, but if plants are separated by a short distance of a few feet or meters it is very rare. Pollination of rice occurs by wind alone – no insects are involved. Once the rice has been pollinated, the process of grain production begins and the panicles grow heavy with maturing rice grains (seeds).

Fig. 2.4: The Flowering System in Rice Plant



Source: Adapted from IRRI

2.2.2 Rice Ecology

Rice is grown in paddies or on upland fields, however, there is limited mangrove cultivation. Rice is grown on an estimated 1.77 million hectares of land area. The potential area for rice production in Nigeria is between 4.6 million and 4.9 million hectares (ha). This area includes five different rice environments or ecologies according to Imolehin, (1991).

i. ***The Upland Ecology*****:** In the upland ecology, the rice crop depends strictly on natural rainfalls for its growth and productivity. This ecology accounts for 55 to 60 percent of the rice cultivated land areas, and yielding an estimated 30 to 35 percent of total national rice production (Singh et.al 1997). Rice yields in the upland ecology are generally low in production and range from 0.8 to 2 tonnes/ha (IRRI, 2006). Hence, the upland ecology accounts for 32 percent of the total rice area in Nigeria (Singh et al, 1997).

ii. ***Inland or Shallow Swamp Ecology****:* This type of rice is strictly dependent on rainfall. An estimated 25 percent of Nigeria's rice area is under inland swamp rice production. The rice yield in this ecology is generally high and ranges from 2 to 8 tonnes/ha. It is estimated that this ecology contributes between 43 and 45 percent of national rice production (Singh et. al, 1997).

iii. ***Irrigated Rice Ecology:*** This irrigated rice ecology is one of the most recent developed rice ecology. It is of great importance in terms of the issues of the environmentally related strategy in the rice industry in Nigeria. Irrigation is supplied from aquatic resources (water) from rivers, creeks, streams, wells, boreholes and other sources to supplement rainfall for full rice crop growth (Imolehin, 1991). This ecology strategy accounts for about 18 percent of cultivated rice land, and yields are estimated to range from 2 to 4 tonnes/ha. It contributes 10 to 12 percent of the national rice supply (Singh, et.al. 1997).

iv. ***Deep Water or Floating Rice Ecology*****:** The floating rice ecology constitutes 5 to 12 percent of the national rice production area. The yields in this ecology are very low owing to the predominant use of unimproved rice varieties which yield less than 1 tonne/ha. The ecology does, however, contribute 10 to 14 percent of the national rice output (Singh, et. al.1997).

V. ***Tidal (mangrove) Swamp Ecology*****:** The Nigerian tidal (mangrove) swamp ecology lies between the coastline and the freshwater swamps. It covers a potential 1 million ha of land that would be cultivable for rice, but at present less than 100 ha of this ecology is being developed. The ecology contributes less than 2 percent to national rice production, and has low yields of only about 1 tonne/ha. The development of appropriate technology for expanding and increasing rice production in this ecology is the most urgent issue for attention (Singh, et. al., 1997).

2.2.3 Rice Consumption

Rice is the most important grain with regard to human nutrition and caloric intake, providing more than one fifth of the calories consumed worldwide by the human species (Smith, 1998).

Rice consumption in Nigeria has risen tremendously, at about 10 percent per annum due to changing consumer preferences (Akande, 2007). The demand for rice in Nigeria is growing faster than any other major staples, with consumption broadening across all socio-economic classes. Substitution of rice for coarse grains and traditional roots and tubers has fuelled growth in demand amongst other factors at an annual rate of 5.6 per cent between 1961 and 1992 (Osiname, 2002). According to Daramola (2005), Nigeria is the largest consuming nation in the west Africa, with the growing demand amounting to 4.1 million tons of rice in 2002, with only about half of that demand met by domestic production (USDA, 2003). Nigeria imported 1.9 million tons of rice in 2002 valued at approximately 500 million USA dollars (USDA, 2003). In 2010 alone, Nigeria spent N365 billions on imported rice (Daramola, 2005).

New varieties are produced and disseminated by research institutes, or are imported from Asia within the last twenty years. Some rice varieties like the Ofada has been reported through research results to have higher fibre content and better health consideration. Consequently, it now commands the highest market price given its scarcity relative to other rice varieties including the imported varieties.

2.2.4 Rice Processing

The paddies of the rice plant are first milled to remove the chaff /husk. This is subjected to steaming or parboiling. Raw untreated rice may be ground into flour for many uses - such as making of beverages (alcoholic or non-alcoholic), rice flour noodles and food items (*Tuwo*).

Processed rice seeds may be boiled, steamed or further fried in cooking oil before eating. When combined with milk, sugar, and honey, it is used to make rice desserts. Rice flour and starch are often used in batters and breading to increase crispiness (Akande, 2007).

2.2.5 Rice Varieties

Rice varieties can be categorized into two groups: the short duration varieties which mature in 105 – 120 days and the long-duration varieties which mature in 150 days. A 120 day variety, when planted in a tropical environment, spends about 60 days in the vegetative phase, 30 days in the reproductive phase, and 30 days in the ripening phase (Global Rice Science Partnership, 2014)

The productivity of rice plant are closely related to the seasonal patterns of some weather parameters notably rainfall and temperature, Longtau (2003).

2.3 The Effect of Weather Parameters on Rice Productivity.

2.3.1 Effect of Rainfall on the productivity of Rice

On average, 1.5 cubic meters of water is applied to produce 1 kilo of rice (FAO, 2010). Yuji (2009) Studies the relationship between different crops in different climatic region and rainfall the research discovered that the bulk of this water does not remain in the plant, but escapes to the atmosphere as vapour through the plant's leaves and stem after it has been sucked through the roots system of the crop. This process is called transpiration which occur mainly during the day time. Water from an open water surface escapes as vapour to the atmosphere during the day. The same happens to water on the soil surface and to water on the leaves and stem of a plant. This process is called evaporation. The water need of a crop thus depends on the rate of transpiration and evaporation. Collectively referred to as evapotranspiration. The water need of a crop is usually expressed in mm/day, mm/month or mm/season. Tao (2004), in his research on the variability in climatology and agricultural production in China emphasis that water intake by the roots system of plants aids nutrients circulation from the soil to other parts of the plant and hence aid the growth and yield of crops. Suppose a crop needs 10 mm of water, this means that this same amount is needed to properly aid nutrients circulation all over the crop.

The Crop water need mainly depends on the weather and climate, in a sunny and hot climate crops need more water per day than in a cloudy and cool climate; Crop type, crops like rice or sugarcane need more water than crops like beans and wheat; Growth stage, grown crops need more water than crops that have just been planted (FAO, 2010)

A certain crop grown in a sunny and hot weather needs more water per day than the same crop grown in a cloudy and cooler climate. When it is dry, the crop water needs are higher than when it is humid. Thus high temperature environment needs high amount of rainfall while low temperature places (cool) needs low rainfall and low humidity area needs high amount of rainfall and high humidity places thrives with low rainfall. The highest crop water needs are thus found in areas which are hot, dry, windy and sunny. The lowest values are found when it is cool, humid and cloudy with little or no wind. FAO (2010) studies proves that one crop grown in different climatic zones will have different water needs. The same rice variety grown in a cool climate will need less water per day than the same rice variety grown in a hotter climate.

2.3.2 The Influence of Rainfall on the Duration of the Growing Season of Rice.

Townsend (2012), studies the impact of climate change on rice yield he discovered that the duration of the total growing season has an enormous influence on the seasonal crop rainfall need. Many rice varieties, some with a short growing cycle (105 - 120days) and others with a long growing cycle (150 days). This has a strong influence on the seasonal rice water needs thus a rice crop which is in the field for 150 days will need in total much more water than a rice crop which is only in the field for 120 days. However, for the two rice crops the daily peak water need may still be the same, but the 150 days crop will need this daily amount for a longer period. The pre-sowing during which crops are grown is also very important.

2.3.3 Influence of the Phenological Stages of Rice on its Water Requirement

A fully grown crop will need more water than a crop which has just been planted. When the plants are fully grown the transpiration and water circulation is more important because there is a larger surface area of the plant to circulate. At planting and during the vegetative stage, the evaporation is more important than the transpiration and the evapotranspiration or crop water need during the initial stage is estimated at 50 percent of the crop water need during the flowering and grain filling stages, when the crop is fully developed. The maximum crop water need is reached at the end of the crop development stage (grain filling). With respect to the late season stage, which is the period during which the crop ripens and is harvested, a distinction can be made between two groups of crops (FAO, 2010):

i. ***Fresh harvested crops:***(such as sugarcane, cabbage). With these crops the crop water need remains the same during the late season stage as it was during the mid-season stage. The crops are harvested fresh and thus need water up to the last moment.

ii. ***Dry harvested crops:***(Such as rice, maize and sorghum). During the late season stage these crops are allowed to dry out and sometimes even die. Thus their water needs during the late season stage are minimal. If the crop is indeed allowed to die, the water needs are only some 25 percent of the crop water need during the vegetative or grain filling. No rainfall is needed by crops during the late season stage.

2.4 The Effect of Maximum and Minimum Temperature on productivity of rice.

2.4.1 Effects of Maximum Temperature (Tmax) on rice productivity

Global Rice Science Partners (2014), reports that plants can only survive within certain limit of temperature, each species and variety has not only optimal temperature limits, but also optimal temperature limits for different growth stages and functions as well as the upper and lower temperature limits. Temperature determines which plant species can survive in a particular region. Temperature affects the growth of plants directly and indirectly. Almost all the physiological processes of plant such as germination, photosynthesis, transpiration, absorption and osmosis are influenced by air and atmospheric temperature.

Jayanta (2010), examines the effect of maximum and minimum temperature on the growth and yield of crops in Bangladesh, the results of his research shows that maximum temperatures are directly related to the rate of photosynthesis and phenology. The optimum temperature for maximum photosynthesis range from 25 to 30˚C for rice under climatic conditions of Bangladesh. The model results show that the effect of maximum temperature would drastically reduce rice yield.

Maximum Temperature has significant negative impacts on rice yield that reduce about 2.6 to 13.5 percent due to increase 2˚C maximum temperature and 0.11 to 28.7 percent for 4˚C maximum temperature. The research shows that the maximum temperature has the most significant negative impact on Satkhira district for both 2˚C and 4˚C temperature increased and minimum impact on Sylhet district. From his analysis of daily average maximum temperature, it was found that the monthly average maximum temperature at Satkhira in January, February, March, April and May (growing season of rice) were 25.3˚C, 26.7˚C, 32.5˚C, 34.9˚C and 36.1˚C, respectively in 2008. Analyzing of monthly average maximum temperature over the last 30 years (1976-2005), it was also found that temperature increased 1.18˚C, 0.064˚C, 0.975˚C and 0.852˚C in February, March, April and May month, respectively which represented the most critical period for rice production in Bangladesh. These increasing trends are significantly higher compared to the IPCC assessment. Increased maximum temperature 2˚C above, the average value, yield reduction was above 13 percent and for 4˚C, it was above 28 percent at Satkhira. Similarly, the monthly average maximum temperature at Rajshahi in January, February, March, April and May were 23.7, 25.7, 33.0, 36.3 and 35.6˚C, respectively.

Increasing maximum temperature 2˚C and 4˚C above, the average value, yield reduction was 2.6 percent and 12.7 percent respectively. Similar results were also found for other locations in Bangladesh but the percentage changes of rice yields were different. Maximum temperature effect on rice production at Sylhet location is not so significant compared to the other locations in Bangladesh under those scenarios. The average value (average percentage change of rice yield for 6 locations) of yield reduction for maximum temperature was above 6 percent for 2˚C and above 16 percent for 4˚C

2.4.2 Effects of Minimum Temperature (Tmin) on Rice Production

In Bangladesh low temperature (cold) occurs during November to February when minimum temperature remains often below 20˚C. Sometimes minimum temperature occur below 20˚C in

March and April in some parts of the country. A crop encountering critical low temperature is appeared to suffer from cool injury. The extent of cool injury depends on the nature and duration of low temperature and diurnal change of low temperature and diurnal change of low (night) and high (day) temperature. Like that of maximum temperature, minimum temperature have also negative impact on rice yield that reduce about 0.40 to 13.1 percent due to increase 2˚C minimum temperature and 0.11 to 15.5 percent for 4˚C minimum temperature. The research shows that the negative impacts of minimum temperature at Satkhira district is more vulnerable compared to other five regions in Bangladesh. Calculated monthly average minimum temperature from daily average values were 12.5˚C, 14.5˚C, 22.0˚C, 24.1˚C and 24.9˚C in January, February, March, April and May, respectively in 2008 at Satkhira district. Analyzing of monthly average minimum temperature over the last 30 years (1976-2005), it has also found that temperature increased 1.21˚C, 0.50˚C, 0.695˚C and 0.831˚C in February, March, April and May month, respectively. Increased minimum temperature in 2˚C and 4˚C above those monthly average values, yield reductions were about 13 and 14 percent, respectively at Satkhira. Similarly, the monthly average maximum temperature at Comilla in January, February, March, April and May were 13.2˚C, 14.1˚C, 20.5˚C, 22.9˚C and 23.9˚C, respectively. Increasing maximum temperature 2˚C and 4˚C above those average values, yield reductions were 9.04 and 15.5 percent, respectively. Similar results were also found for other locations in Bangladesh but the percentage changes of rice yields are different. Minimum temperature effect on rice production at Sylhet location is not so significant compare to the other locations in Bangladesh under those scenarios. The average figure (average percentage change of rice yield for 6 locations) of yield reduction for minimum temperature was above 4 percent for 2˚C and above

8.5 percent for 4˚C. Therefore, maximum temperature is more vulnerable and negative impact on rice yield compared to the minimum temperature.

2.4.3 Combined Effects of Maximum and Minimum Temperature on Rice productivity

The combined effects of maximum and minimum temperatures are more significant compared to their individual effect on rice production in Bangladesh. Rice yield drastically reduce due to increase maximum and minimum temperature both 2˚C and 4˚C rice yield reduction was 3.2 to 18.7 percent and for 4˚C, it was about 5.33 to 36.0 percent. The most effective area is Comilla district where yield reductions were 18.7 percent and 36.0 percent for their combination effect of 2˚C and 4˚C, respectively. The average figure (average percentage change of rice yield for 6 locations) of yield reduction of the two temperature parameters was above 10.4 percent for 2˚C and above 22.87 percent for 4˚C.

2.5 Crop – Climate Relationship

Yuji (2009), Studies the impact assessment of climate change on rice production in Asia, his studies buttress the fact that the temperature sensitivity experiments have shown that for a negative decrease in temperature up to 5°C leads to a continuous decline in the yield. For every one degree increment the decline in yield is about 6 percent. Rainfall sensitivity experiments have shown that increase in rice yield due to increase in rainfall above the observed values. Hence decrease in rainfall results in yield loss at a constant rate of about 8 percent per 2 mm/day, up to about 16 mm/day (Yuji 2009).

Karthick (2013) in his research on the impact of climate on agriculture in Indian stream discovered that temperature variations had an observable effect on crop yield, he reported a significant reduction in summer crops. The production of rice is decreasing significantly with the increase of lowest minimum temperature but increasing with an increase in the maximum temperature. Maclean (2002) also reported in a studies carried out in Pakistan on crop climate relationships an increased global mean surface temperature increased frequency and severity of drought and variations in precipitation, all have negative impact on agriculture. The study is based mainly on secondary data of weather parameter such as maximum temperature, minimum temperature, rainfall and area, production, productivity of crops for the period of 20 years (from 1990-91 to 2009-10). The secondary data were collected from published sources of the season and crop report of Tamil Nadu during 1990 -91 to 2009- 10.

Nguyen (2008), studies the global climate change and rice production for food security and reported that Zimbabwe's core agricultural zone would be reduced by 67 percent with a 2°C temperature increase. Temperature regimes greatly influence not only the growth duration, but also the growth pattern and the productivity of rice crops. Extreme temperatures – whether low or high – cause injury to the rice plant. In tropical regions, extremely high temperature are a constraint to rice production. Various possible injuries to rice crops caused by extremely high temperatures. The most damaging effect is on grain sterility; just 1 - 2 hours of high temperature at anthesis (about 9 days before heading and at heading) result in a large percentage of grain sterility. Studies on rice productivity under global warming also suggest that the productivity of rice and other tropical crops will decrease as global temperature increases. IRRI (2006), using the Hadley-coupled model, predicted a yield decrease of 14.5 percent for summer rice crops across nine experiment stations in India in 2005. Peng (2004) reported that the yield of rain fed rice crops in the Philippines decreased by as much as 15 percent for each 1°C increase in the growing season mean temperature. Similarly, FAO (2010) estimated that by 2015, climate change in Niger could lower yields of millet by 13 percent, groundnut by between 11 and 25 percent and cowpea by 30 percent.

Tao (2004), conducted a research on the variability in climatology and agricultural production in China, his analysis confirmed that the yield of major crops were significantly related to climatic conditions notably rainfall and temperature.

2.6 Methods of Determining Crop-Climate relationships

According to Olaniran (1981), there are three main methods of determining Crop-Climate relationship.

i. Fundamental of the plant relationship.
ii. Agricultural data and climatic data.
iii. Plant-Climatic relationship under controlled environment.

The second method was adapted from Olaniran and Babatolu (1987), this also suggested the use of data on climatic variables influencing the productivity of crops rather than using the whole year, because plants pay more attention to the season rather than the calendar.

CHAPTER THREE: THE STUDY AREA AND METHODOLOGY

3.1 Introduction

This chapter contains the study area and the methods used in the collection and analysis of data. The first part deals with the study area while the second discusses the methodology.

3.2 The Study Area

3.2.1. Location

The Kano River Irrigation Project (KRIP), lies between latitude 11˚45′ and 12˚5′ north of the equator and longitude 8˚45′ and 9˚5′ east of the green wich meridian. The Kano River Irrigation Project is located at Garun Mallam Local Government Area of Kano State, Nigeria, it is popularly referred to the Kadawa farms because of the locality in which it is situated. The local government area is bounded by Madobi LGA to the north, Kura and Bunkure LGAs to the East and South East respectively, Rano to the South while Bebeji is to the West. Although the scheme was initiated by the Kano state government, the management of the water resources in the scheme was taken over by the Hadejia-Jamare River Basin Development Authority (HJRBDA) following the creation of several states within the former Kano state. The Authority has a total of 45000 km^2 arable land in its area of jurisdiction in Kano and Jigawa states. Two categories of land ownership exist at the scheme. At the onset of the scheme, farmers were allocated one-acre plots each, with a considerable portion of the land remaining state owned. There have been significant changes in land ownership over the years, and large numbers of farmers who were initially landowners now have to rent land from others. The Kano State Agricultural and Rural Development Authority (KNARDA) is responsible for providing extension services to farmers in the scheme.

FIG. 3.1 Kano, Study Area

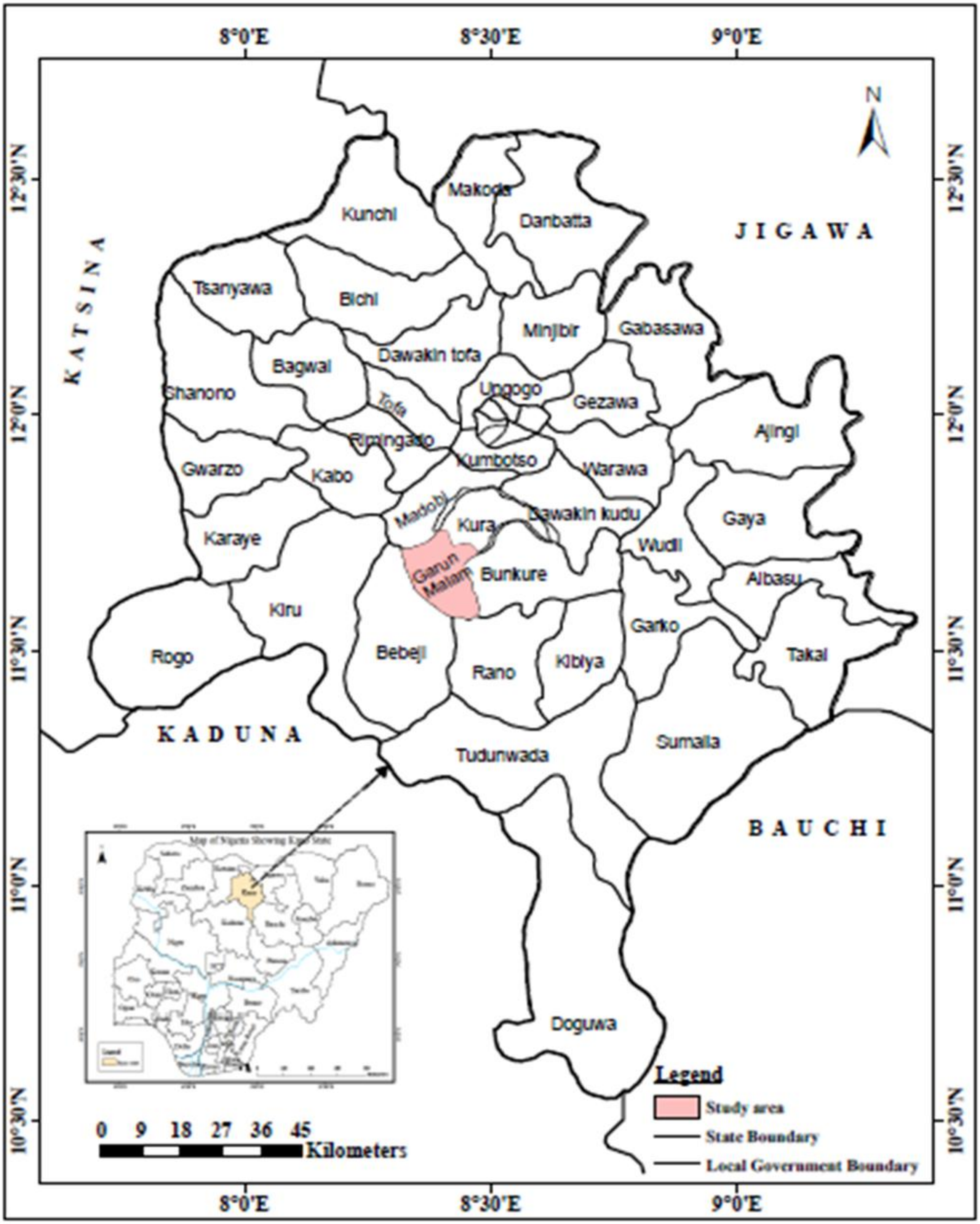


Figure 1: Map of Kano State Showing the Study Area
Source:Field Survey, 2014

3.2.2 Climate

3.2.2.1 Rainfall

The Kadawa scheme is situated in the Sudan Savanna agro-ecological zone, which is characterized by a mono-modal rainfall distribution averaging 600 to 1000 mm per annum. The length of the growing period is 90 to 165 days (for rain fed crops). The seasonal movement of the Inter tropical Convergence Zone (ITCZ), resulting in wet and dry seasons influences the climate of the region. Rainfall is strongly seasonal, and occurs between May and October, with the peak rainfall occurring in August - September. The dry season lasts between November and March. The area lies within the “wet and dry climate” with more dry than wet months (Olofin ,1987) which is categorized under Aw in Koppen’s classification it has a low mean annual rainfall of about 650mm in drought years, it could be lower than 450mm as in the case of 1972/73 drought. Recently between 1997- 1999 heavy down pours were recorded. In 1998 alone over 1000mm of rainfall was recorded (Abdulhamed, 2000). The area is characterized by four months of wet seasons and eight months of dry season, therefore water availability is very critical in the area.

3.2.2.2 Air Humidity

This refers to the amount of moisture in the atmosphere, air humidity is high during the wet season and very low during the dry season. Humidity is largely influenced by the movement of the Inter Tropical Discontinuity (ITD). Humidity is high under the influence of tropical maritime air mass (mT), during the rainy season. It can rise up to 90 percent and sometimes as low as 20 percent in the harmattan season between November and March (Olofin, 1987).

3.2.2.3 Temperature

Minimum temperatures occur from November to February, and highest temperatures occur in March and April. Daily temperature variation is high during the dry season and low in the wet season. Temperature is relatively warm to hot from March to October and cool from November to February, the mean annual temperature is 26° C, the hottest months(April and May) have the mean of 31°C and the coldest months (December and January) have the mean of 21°C. The mean monthly maximum and minimum temperature are 37.3˚C and 19.7˚C, respectively, and the hottest months are February, March and April. The vegetation lies within the Guinea savannah.

3.2.2.4 Evapotranspiration

Evapotranspiration (Et) is generally higher than precipitation. The evaporation data recorded and analyzed by standard class “A” pan and IAR 1974 (IAR, 1974) was estimated at 2214mm per annum using different data from various sources Olofin (1980) estimated the potential evaporation in Kano at 2538mm per annum. The vapour pressure (eP) is at its maximum point between May and August with the range of 25-28 hecto - pascal (Hp), with the lowest recorded in March which is 7Hp. The dew point is less than 1°C in March and rise up to 23 °C in August; this factor explains the water condition in the area. The potential evapo-transpiration exceeding rainfall changes in vapour pressure records and steady rise in dew point between April and August emphasized the dry condition of the area.

3.2.3 Geology, Relief, Drainage and Hydrology

3.2.3.1 *Geology*

The study area is characterised by two major geologic structures with minor intrusions of a third, the larger area of the region to the south and north underlain by rocks of the basement complex with intrusions of younger granite in the extreme southern parts. To the north-east unconsolidated sediments of the Chad formation, the two structures are separated by a transitional zone which constitutes the well-defined hydrologic divide of the region.

According to Olofin (1987), these rocks are of pre-cambrian origin and consist of metamorphic and igneous types common among these rocks are granite of different descriptions, granitised sand stones(as in Kazaure), migmatite, gneisses, phylittes and so on , on the granites dominate the structure hence it is common to refer to the rocks of the basement complex as the older granite, these rocks have being in existence for millions of years, they have been subjected to chemical and other forms of weathering to produce clay rich regolith.

The Jurassic intrusion that affected the Jos Plateaux occurred in the southern tips of the Kano region which consist of foot hills of the Jos Plateaux although younger granite have been subjected to some weathering their out crops dominate the area where the intrusion occur such as Riruwai, Rishi and Ningi, the younger granites are well jointed and occur in ring complexes. The important economic characteristic of the younger granites is their association with cassiterites, the ore of tin (Ma’aruf, 2012).

The chad formation is composed largely of unconsolidated sediments in the Kano region, these sediments are mainly of tertiary terrestrial origin on the surface, and they consist of vast tertiary accumulation of sand on plains and interfluves, recent alluvial accumulations in channel complexes. In some areas the vertical profile is an alternating bands of sand (aquifer) and clay (Impervious) layers (aquifer) (Olofin, 1987).

3.2.3.2 Relief

The relief of the study area can be described on three types, occupying three district zones, as the high land, the high plains and the low Chad plains. The first two types are part of the high plains of Hausa land and the third is a part of the Chad plains. The relief is greatly influenced by the geology. The highest elevation are associated with igneous structure and the lowest the Chad formation. The High lands occupy a relatively small area to the south and south-east of the region where they constitute part of the footsteps of the Jos Plateaux lying further south, the peaks of the high lands which are mostly outcrops of younger granite used more than 1100m above mean sea level. The elevation basins ranges 700m – 800m, the highest peak in the region is about 1240m above sea level (Ma'aruf, 2012).

Plains whose elevation ranges between 450m -700m occupy about 40 percent of the surface area of the Kano region and constitute the largest single relief unit. The areas of low relief are usually less than 30, except in sections where grouped hills occur in such sections, the hills may arise more than 100m above the plains(Olofin, 1987).

The lowest relief unit of this region consist of the plains developed essentially on the sedimentary structure known as Chad formation. The unit also includes the transition plains immediately west of the hydrological divide developed on the rocks of the basement complex lower than 450m above sea level and over which sands of the Chad formation occurs the relative relief is between 15 and 20m, except in sections occupied by sand dunes(Ma'aruf, 2012)

3.2.3.3 Drainage

The natural drainage of Kuta constitute two major rivers Kano and Chalawa and their major tributaries, the former from the extreme south and the latter from the south-west they make confluence and drained east wards to Hadejia, Nguru wetlands and ultimately to the lake Chad and Dambatta is characterized by one river which is River Thomas and got it's sources form Bichi local government area of Kano State and drained to Danbatta dam (Nemani, 2003)

3.2.3.4 Hydrology

The hydrology is predominantly surface water consisting of ponds and streams, which is the situation of all basement complex structures with limited ground water accumulation. On the other hand, gutters and drainage form the artificial hydrology of the area, making it a well-drained area where water drains into the ponds or stream (Olofin, 1987). There is considerable relation between the geology and drainage pattern with the highest network of rivers in the basement complex area. The small areas of Chad sediments in Danbatta and Gaya Local Governments Areas have groundwater potential with limited channel development. The drainage systems are the rivers Kano, Chalawa, Iggi and Gaya in the South while Rivers Gari, Thomas and Jakara are located in the north.

Ahmed (2011), further explained that; the rivers are dammed to store water in the surface reservoirs for multi-purpose use including irrigation, domestic supply, fisheries and recreation. Irrigation development is well advanced along the rivers Gari and Kano (Kano River Project-Phase 1). Also there are two other dams in the River Kano catchment area (Bagauda and Tiga dam reservoirs). Ground water potential is higher in the limited areas of sedimentary rocks and it occurs in perched aquifers as well as in confined and semi confined aquifers. The potential is low in the basement complex area and the success ratio of boreholes is lower because of the limited depth of the regolith, its clay content and localised occurrences of fractures and joints. However the basement area has higher surface runoff potential.

3.2.4 Soils and Vegetation

3.2.4.1 Soils

The factors of soil formation in the region are not different from the factors elsewhere however the role of parent material is very great in the region, parent rock appears to pull a greater influence than climate thus the variety of soils occurring in the basement complex is different from the variety occurring in the Chad formation zone, another factor of great significance is topography, climate has only a generalised influence rather parent rocks creates maculate spatial differences. The soils are generally matured on the plain but seriously altered due to human activities. The influence of topography, wind drift (materials from the desert) and climate are what shaped the aggregate of the soil, the matured soil are said to be latosols of the ferruginous origin (Olofin, 1987).The soil is however well drained brown to reddish in colour along the floodable areas of river channels hydromorphic soils are found, these are dark in colour and have high clay content. Intensive use of soils and addition of manure and chemical fertilizer have altered their character, profile, texture, structure and chemical characteristics (Olofin, 1987)

The soils are good for agriculture especially Fadama cultivation that is practiced in the area due to their clayey- loamy nature.

3.2.4.2 *Vegetation*

The natural vegetation of Kano region is the Savannah type, most of the region is contained within the Sudan Savannah variety, and the exceptions include the southernmost area which is characterised by the northern guinea savannah and the northern most section, which is characterised by the Sahel thorny shrubs. The study area lies within the Sudan Savannah zone and form part of the human settlement in which vegetation is seriously depleted through construction processes. It comprises of both tall and short grasses with scattered trees most of which are semi natural planted for shed and their economic value. The natural vegetation has been cleared especially for cultivation purpose. Very few natural vegetation species are often found and these do not exceed 20m in height consisting of trees like *Acacia, Tamarindus indicana, Butyospermum, Parkia Clappertonia* and handful of others, grasses are hardly found except in scanty patches, these hardly reach 1m high at maturity and tends to dry up during the dry season. Cultural vegetation has replaced the natural vegetation in the area where exotic species pre-dominate (Ma'aruf, 2012)

3.2.5 Land uses of the study area.

The major and most important land use in the study area is agriculture which can either be rain fed agriculture or irrigation agriculture, the farming system are mainly subsistence or commercial. The main crops that are grown in the study area are seasonal crops, the rainy season crops (rainfed) include rice, sorghum, millet, ground nut etc. While crops like wheat, rice, maize, tomatoes, onions etc., are also grown in the dry season using irrigation system. Other land use activities include the residential houses, markets and schools. Government offices for administration, motor parks, communication network, roads and forest reserved.

Although the study area are yet to be developed for industrial land use but only some small scale industries may be found for example rice processing mills and other small scale industries like black smith.

3.3 METHODOLOGY

3.3.1 *Reconnaissance Survey*

A reconnaissance survey was embarked upon by the researcher, this enabled the researcher to familiarize himself with the Kano State River Irrigation Project (KIRP) and the Institute for Agricultural Research (IAR), Kadawa Station Kano State and enable him to adopt the most appropriate means of data collection that satisfied the requirements of the research.

3.3.2 *Sources and Types of Data Required*

Data on weather parameters were collected from the Institute for Agricultural Research (IAR) Kadawa Station**.** The research used the secondary type of data; this is in view of the nature of the research. The data for this study are those of the basic weather parameters influencing rice productivity. These include: Observed climatic parameters namely: daily, monthly, annual rainfall and number of rain days and the maximum and minimum air temperature. Annual yield of rice in Kg/ha for a period of twenty years 1994 – 2013 was also collected.

3.3.3 Derivations of Precipitation Effectiveness Indices

The daily rainfall data were used in calculating the mean monthly and annual rainfall for the station, from the rainfall data collected, the following precipitation effectiveness indices were computed in accordance with the following methods

a. Onset of the rainy season (the day in which there is substantive amount of moisture in the soil to sustain plants growth and development)
b. Cessation (the day in which moisture is reduced to a level lower than it can sustain plant growth and development)
c. Length of the rainy season.

3.3.3.1 *Onset*

The onset refers to the time a place receives an accumulated amount of rainfall sufficient enough for plants growth, it is not necessarily the first day of rain. According to Walter (1967) the onset is computed using the formular

$$\text{The number of days in the month X } \frac{(51 - \text{Accumulated rainfall of the previous months})}{\text{Total rainfall for the month}}$$

3.3.3.2 *Cessation*

Cessation means the day in which the amount of water in the soil can no long support the development of plants. This does not necessarily mean the last day of the rainfall. This computed in the same way as the onset except that the computation is done back ward from December (Walter, 1967).

3.3.3.3 *Length of the rainy season*

The length of the rain season (LRS) is the difference between the onset and the cassation date of rainfall. The LRS can be computed using the simple formular:

Cessation – Onset (Adefolalu, 1991).

3.3.4 Methods of Data Analysis

Descriptive statistics (line graphs) were used to present some of the characteristic pattern of rainfall, humidity and the temperature while distribution graphs were used in order to show the relationships between the derived precipitation effectiveness indices (onset, cessation and length of the rainy season) and productivity of rainfall in the study area. Inferential statistical method were also used in order to test for the hypothesis, correlation analysis was used to test for the parameter's individual influence on rice productivity using the formular below

$$r = \frac{\Sigma(X - X)(Y - \bar{Y})}{\sqrt{\Sigma(X - X)^2 (Y - \bar{Y})}}$$

Multiple linear regression analysis was used in order to test for their combine influence on the productivity. The test were carried out on 0.01 and 0.05 significant levels.

3.3.5 Harmonization of data

Since the data collected were in different units, rainfall (mm), temperature (˚C), relative humidity (%), while derived onset and cessation were dates while the length of the rainy season (LRS) days. There is the need to harmonise the data to a common unit. Computer software Minitab (1994) version was used in order to harmonized the data to base 10

CHAPTER FOUR: RESULTS AND DISCUSSION

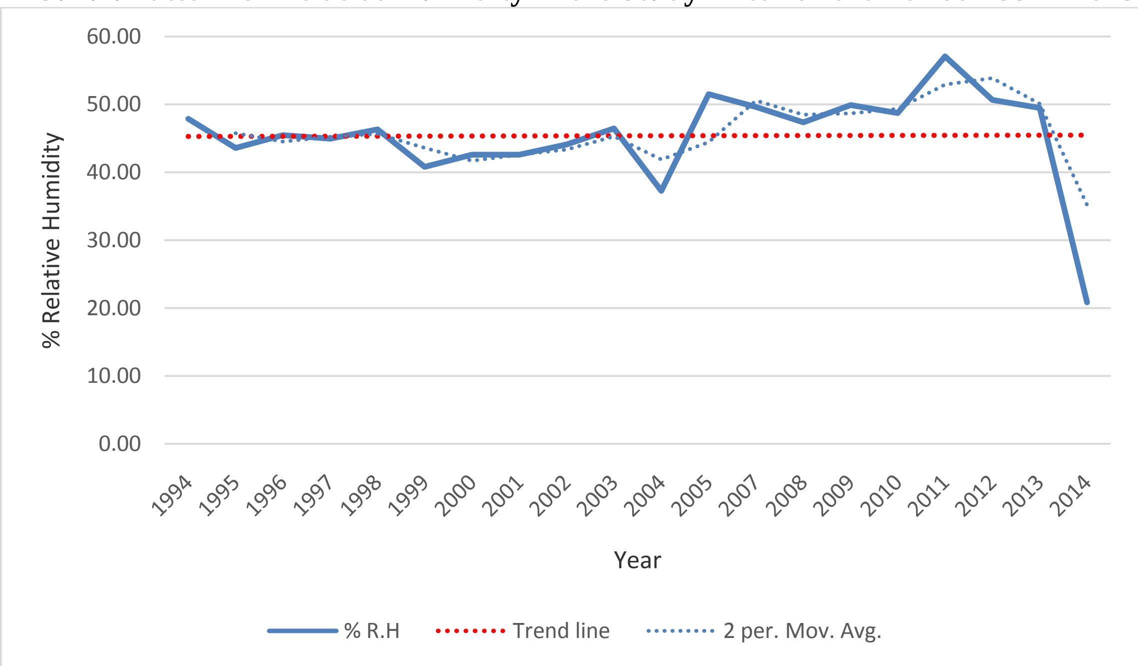
4.1 Introduction

In this chapter, an attempts were made to discuss the findings from the analysis carried out on the weather parameters (rainfall, maximum and minimum temperatures, relative humidity), precipitation effectiveness indices (onset, cessation, length of the rainy season) and rice yield data collected for the study area. The order of presentations of the results and discussions is guided by the earlier stated objectives, which will involves using line graphs to present the pattern of weather parameters, a careful examination of individual contribution of the weather parameters to rice productivity and also their combine effect on the productivity of the rice in the study area.

4.2 Pattern of Weather Parameters in the Study Area

4.2.1 Relative Humidity

FIG. 4.1. Pattern of Relative Humidity in the Study Area for the Period 1994 - 2013

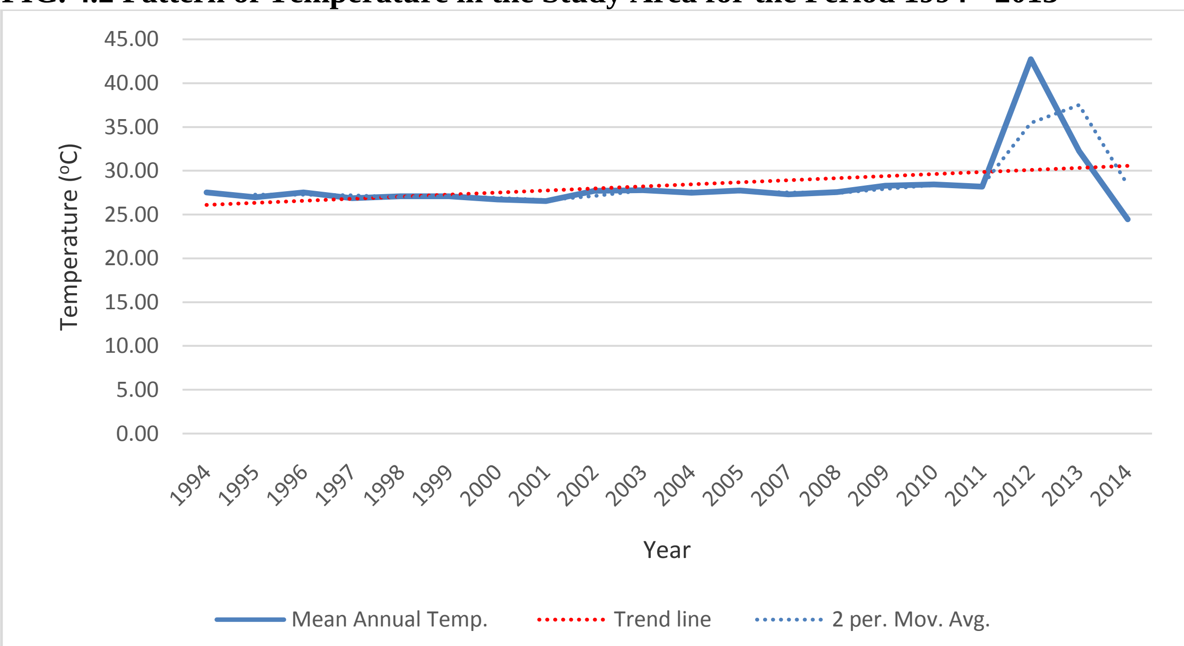


Source: Author's field Work, 2014

The trend in the relative humidity for the period 1994 - 2013 shows that humidity is relatively constant from 1994 till around 2004, usually rising and falling between 40 and 50 percent. It also show a sharp decrease below 40 percent in the year 2004 and subsequent rise above the 50 percent mark within the period 2004 – 2013 with its peak reaching about 57 percent in the year 2011 and later followed by a sharp decrease.

4.2.2 Temperature

FIG. 4.2 Pattern of Temperature in the Study Area for the Period 1994 - 2013



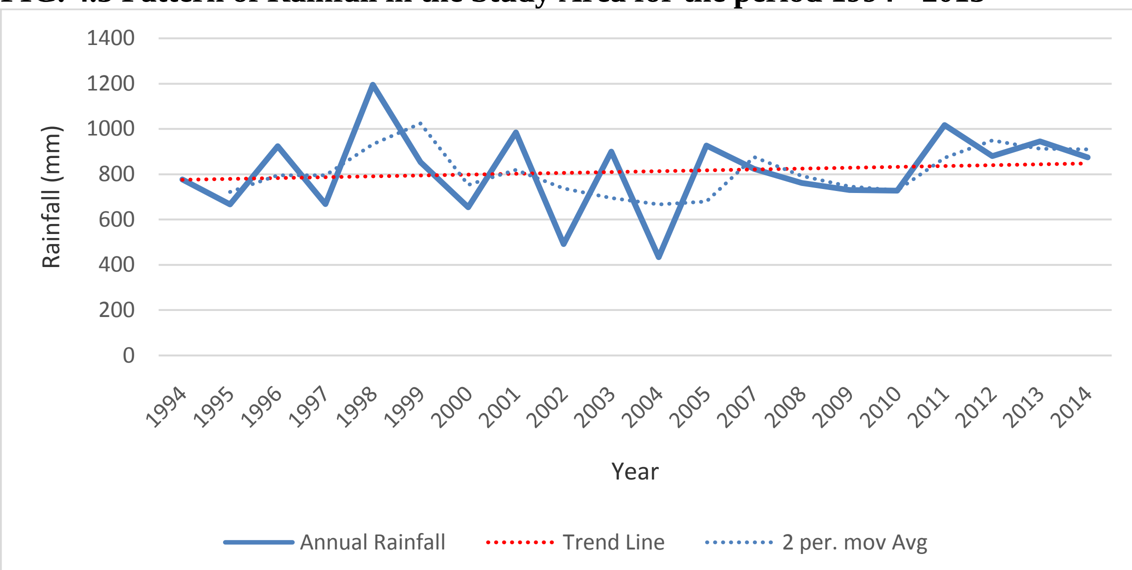
Source: Authors' Field Work, 2014

The mean annual temperature for the period shows a relatively constant temperature of between 26 – 29˚C for the period 1994 – 2011. But the years 2012 and 2013 shows a remarkable increase in the temperature with its peak reaching about 45˚C, this sharp rise in the temperature could partially be explain by the increase in human activities which might lead to increase atmospheric temperatures. Activities such as cutting down trees, bush burning and industrial emission although in a local scale, are in the increase in the study area.

Jayanta (2010), in his studies on the effect of temperature in Bangladesh reveals that temperature is directly related to the photosynthesis during the grain filling stage and so the higher the temperature, the higher is the final grain yield.

4.2.3 Rainfall

FIG. 4.3 Pattern of Rainfall in the Study Area for the period 1994 - 2013



Source: Authors' Field Work, 2014

The rainfall in the study area shows high rate of variability throughout the study period, but generally has a range of about 650 – 1000 mm per annum, this explained the fact that the Kano area falls within the guinea savannah agro- ecological zone (Olofin, 1987). The peak of the rainfall was observed in the year 1998 having an annual rainfall of about 1200mm per annum while the lowest was received in the year 2004 with an annual rainfall of about 450mm, this could be explained with respect to a major drought in that year. This emphasized earlier literatures that categorised that study area under the guinea savannah vegetation zone of annual range of temperature of about 650 – 1200mm of rainfall annually.

4.3 The data on the relative humidity, minimum and maximum temperature and the annual rainfall and the yield of rice for the period 1994 - 2013

Table: 4.1 Characteristics of the weather parameters

Year	R.H (%)	Tmax (˚C)	Tmin (˚C)	Annual Rainfall (mm)	Mean Annual Temp. (˚C)	Rice Yield (Kg/ha)	Rice Yield (Tonnes/ha)
1994	47.84	33.55	19.40	776.3	27.54	2980	2.98
1995	43.56	33.45	20.52	665.9	26.99	2820	2.82
1996	45.48	34.14	20.87	923.1	27.51	3020	3.02
1997	44.96	33.32	20.37	667.9	26.85	3100	3.10
1998	46.29	33.24	20.92	1195.1	27.08	3090	3.09
1999	40.79	33.97	20.18	852.7	27.08	2690	2.69
2000	42.56	33.67	19.81	653	26.74	2880	2.88
2001	42.60	33.56	19.54	984.2	26.55	3050	3.05
2002	44.08	34.44	21.00	490.7	27.72	3200	3.20
2003	46.44	34.51	21.04	900.3	27.77	3700	3.70
2004	37.28	34.49	20.48	433.1	27.49	3800	3.80
2005	51.50	35.33	20.17	926.7	27.75	3650	3.65
2006	49.60	34.85	19.78	823.4	27.31	3970	3.97
2007	47.36	35.33	19.80	760.8	27.57	3600	3.60
2008	49.90	35.25	21.33	729.9	28.29	3520	3.52
2009	48.71	35.36	21.52	727.4	28.44	4100	4.10
2010	57.05	34.84	21.50	1017.6	28.17	4200	4.20
2011	50.62	64.68	20.79	880.4	42.73	3800	3.80
2012	49.47	34.98	29.52	944.8	32.25	3920	3.92
2013	20.85	32.07	16.84	874.6	24.45	4100	4.10
Mean	**45.35**	**35.75**	**20.77**	**811.40**	**28.31**	**3459.50**	
STDV	**7.03**	**6.69**	**2.25**	**174.93**	**3.57**	**471.79**	
CV	**0.16**	**0.19**	**0.11**	**0.22**	**0.13**	**0.14**	

Source: IAR & HJRDBA

4.4 Derived Precipitation Effectiveness Indices

The derived agro- climatic parameters (onset, cessation and the length of the rainy season) are presented in the table 4.2.

Table: 4.2 Derived Precipitation Effectiveness Indices

Onset	Julian date	cessation	Julian date	L.R.S
2nd Jun	153	3rd Sept	246	93
6th Jun	157	8th Sept	251	94
22nd May	143	3rd Sept	247	104
18th May	138	7th Sept	250	112
14th May	134	6th Sept	249	115
13th May	133	6th Sept	249	116
4th Jun	156	31st Aug	244	88
4th Jun	155	11th Sept	254	99
19th Jun	170	8th Sept	251	81
19th May	139	7th Sept	250	111
12th May	133	14th Sept	258	125
8th Jun	159	31st Aug	243	84
23rd May	143	18th Sep	261	118
16th Jun	168	31st Jul	213	45
22nd May	142	16th Sept	259	117
11th May	131	11th Sept	254	123
6th Jun	157	2nd Sept	245	88
16th May	137	6th Sept	250	113
20th May	140	20th Sept	263	123
3rd May	123	15th Sept	258	135
Mean				**104.20**
STDV				**20.14**

CV				**0.19**

Source: Authors' Field Work, 2014

4.5 Relationships between Weather Parameters and P.E.I and Rice Productivity

Table: 4.3 Regression Analysis Weather Parameters and Rice Productivity

	Rice (Coefficient)
Onset	-0.262
Cessation	0.158
Length of rainy season	0.166
Relative Humidity	-0.009
Average Temperature	*0.413
Maximum Temperature	0.243
Minimum Temperature	0.172
Total Rainfall	0.095

***Regression is significant at the 0.05 level (2-tailed).**
Source: Authors' Field Work, 2014

4.5.1 Relationship between Onset date and the Productivity of Rice

Results from the regression analysis (Table: 4.3), indicates that the relationship between rice productivity and the onset dates of rainfall is given by -0.262. Although the relationship is not significant, Tao (2004); Abdulhamed and Gaide (2007) were able to show high positive relationships between the onset dates of crops and their total yield. It is therefore suggest that in order to boost their productivity in rice production farmers should take the advantage of planting their rice immediately the antecedence moisture status of the soil is established.

4.5.2 Relationship between Cessation date and productivity of Rice

The relationship although not significant at 0.158 (Table: 4.3). Abdulhamed and Gaide (2007), Ana (2010) also indicates negative relationships between crop yield and cessation dates of the rainy season but however suggest that farmers should harvest their produce immediately they ripped in order to avoid destruction by animals or hail storm.

4.5.3 Relationship between the LRS and Productivity of Rice

The result (Table: 4.3) shows that the LRS and rice productivity shows a relationship positive but in significant relationship at 0.166. This could be explain partly because of the gain that the HJRBDA and KNARDA usually provides farms with short duration high yielding varieties of rice (105 – 120 days).

4.5.4 Relationship between Relative Humidity and Rice Productivity

Although Abdulhamed and Gaide (2007) reported a high positive relationship between sorghum and relative humidity at Wailo farms, results from the regression analysis indicates a negative relationship between rice and relative humidity in the study area at -0.009 (Table:4.3). This probably could be explained by the fact that rice plant has higher affinity for water from its vegetative stage till it is ripped (IRRI 2006).

4.5.5 Relationship between Average Temperature and Rice Yield

By far the most significant of the weather parameters that indicates positive relationship with the productivity of rice is the average temperature at 0.413 (Table: 4.3). Jayanta (2010), in his studies on the effect of temperature in Bangladesh reveals that temperature is inversely related to photosynthesisand so the higher the higher the temperature, the higher the amount of food that will be produce by a crop to an optimum temperature of bout 39 - 45˚C.

4.5.6 Relationship between Maximum Temperature and Rice Productivity

The result of the regression analysis also indicates a positive but in significant relationship between maximum temperature and rice productivity in the kadawa farms. Placed at 0.243. This probably could be as a result the use of the three temperature variables in the computation (minimum temperature, maximum temperature and the average temperature. It could also be as a result of the short duration of the data. Generally rice plant can withstand an optimum temperature of not more than 45˚C.

4.5.7 Relationship between Minimum Temperature and Rice Productivity

The result from the analysis indicates that the relationship between the minimum temperature and the rice yield in the study area is placed at 0.172. Imolehin (1991) also reports a positive but in significant relationship between rice production and minimum temperature to about 15 – 10 ˚C in the Sudano - Sahelian region of Nigeria.

4.5.8 Relationship between Rainfall and Rice Productivity

The relationship is given by 0.095 which could be described as an in significant relationship, table: 4.3. This could be due to the fact that even during the rainy season and in the case of dry spells the irrigation water usually supply the agricultural farms with water needed to boost their farm produce.

4.6 Combined Effects of the Weather Parameters and Derived P. E. I

The combine effects of the various weather parameters on the yield of rice at the Kano river irrigation project was analysed using the Spearman's rho correlation statistical technique. The weather parameters are relative humidity, maximum temperature, minimum temperature,average temperature, rainfall, onset, cessation and length of the rainy season. Table. 4.4, shows the summary of the analysis.

The result of the combined effect of the selected weather parameters and the precipitation effectiveness indices indicates that the parameters exert a combine influence on the productivity in rice in the study area. From the analysis the R^2 equals 70 percent and the adjusted R^2 is given by 48.1 percent of the variation in the productivity of rice in the study area. It was deduced that the remaining 30 percent could be explained by other management practices in the study area such as the use of insecticides, pesticides, the application of fertilizer, the quantity of the fertilizer, weeding and the number of times weeding is done in the farms.

Table. 4.4: Relationship between weather parameters and Rice Yield

Weather Parameter	Rice Yield (Kg/ha)
Onset Date of the Rainy Season	.284
Cessation Date of the Rainy Season	.110
Length of the Rainy Season	.084
Relative Humidity	.047
Annual Rainfall	.408
Maximum Temperature	.507*
Minimum Temperature	.290
Average Temperature	.479*

s = 0.04430 R-square = 70.0% R-square (adjusted) = 48.1%
***. Correlation is significant at the 0.05 level (2-tailed).**
****. Correlation is significant at the 0.01 level (2-tailed).**
Source: Authors' Field work, 2014

Table: 4.4, shows that out of the five weather parameters and three precipitation effectiveness indices, only Maximum temperature and average temperature shows positive and significant correlation with the final grain yield at the Kano state river irrigation scheme at .507 and .479

respectively, while other indicates positive and yet insignificant correlation. Depledge (2002) was also able to show high positive correlation between temperature and the final grain yield at the Muda irrigation farms.

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 **Summary**

Weather parameters are very important resources in determining the productivity in crops, therefore the amount and distribution of these parameters are important factors in determining the ultimate yield in crop production. Rice is an important staple food worldwide, feeding about 3 billion people, in Nigeria importation of rice has been prioritized compared to our locally produced rice. Less attention has been given to the real influence of these weather parameters on the productivity of rice in the Kano State River Irrigation Project.

This research examined the influence of weather parameters on the productivity of rice in the Kano River Irrigation Project (Kadawa Farms Centre) in Garun Mallam Local Government Area of Kano State, Nigeria. The weather parameters considered were those of paramount importance in rice productivity, these include the rainfall, maximum and minimum temperature, relative humidity and precipitation effectiveness indices (onset, length of the rainy season, cessation).

The mean value of the weather parameters associated with the final yield of rice were computed and analyzed using regression analysis, while their combined effect was computed using spearman's' rho correlation statistical technique. The average temperature positively correlates with the total yield of rice at 0.05 level of significance. The multiple regression computed shows that relative humidity, maximum temperature, minimum temperature, rainfall and the precipitation effectiveness indices (onset, cessation and length of the rainy season), accounted for

70.0 percent of the variability of the rice productivity at the Kano State River Irrigation Scheme, while other management practices such as fertilizer application, weeding, application of insecticides and pesticides accounted for the rest of the 30 percent of the rice productivity in the study area.

The researcher looked at related previous studies on crop climate relationship, the study of fundamental of plants- climate relationships. Five sets of data were required for the purpose of this study, Daily rainfall records in millimetre (mm), relative humidity (%), minimum air temperature (˚C), maximum air temperature (˚C) and rice yield in kilogrammes per hectare (kg/h). The data on weather parameters were source from the Institute for Agricultural Research (IAR) Kano Station and rice yield from the Hadejia Jama'are River Basin Development Authority (HJRBDA). Both data were collected for a period of 20 years (1994 – 2013).

It was deduced that in order to achieve better rice output from the application of technological advances and modern extension practices, the beneficial effects of climate on rice yield must be optimized while the negative practices must be reduced to the barest level if not eliminated completely.

5.2 Conclusion

The conclusion drawn from the findings of the research is that the major weather parameters that influence the growth and the yield of rice in the Kano River Irrigation Scheme such as the relative humidity, rainfall and the mean annual temperature are the most important weather parameters that influence rice productivity in the study area.

Though, this study has not exhausted all the agro- climatological elements influencing crop yield. The findings of the study also reveals from the correlation matrix between the weather parameters (rainfall, relative humidity, Maximum and minimum temperatures) and the derived precipitation effectiveness indices (onset, cessation, Length of the rainy season and the seasonality index) that the mean annual temperature, minimum temperature and relative humidity are the most important during the growing season which also can explain the high yield in the rice production.

5.3 Recommendations

In view of the fact that, the issue of weather parameters and precipitation effectiveness indices are becoming a major treat in agricultural planning and productivity, the study strongly recommends the following:

1. Government at all levels should see that meteorological equipment are provided to all River basins development authorities, research and training institutions, departments of Geography and Agricultural Sciences and every other unit in order to facilitates and enhance the generation of climatic data nation-wide.
2. Farmers at all levels should acquaint themselves with information from meteorological agencies in order to have an idea of the predicted rainy season so as to know the likely onset, cessation dates, rainfall , relative humidity and others as they affect the performance and yield of crops.
3. This preliminary work on weather parameters – rice relationships is not exhaustive. More could still be achieved in further studies geared towards the understanding of the interplay of weather parameters and rice yield. There are about thirteen precipitation effectiveness indices others could be research on such as Hydrological ratio, Seasonality index, dry spell etc.

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APPENDIX

JULIAN DATE CALENDAR PERPETUAL

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Day
1	001	032	060	091	121	152	182	213	244	274	305	335	1
2	002	033	061	092	122	153	183	214	245	275	306	336	2
3	003	034	062	093	123	154	184	215	246	276	307	337	3
4	004	035	063	094	124	155	185	216	247	277	308	338	4
5	005	036	064	095	125	156	186	217	248	278	309	339	5
6	006	037	065	096	126	157	187	218	249	279	310	340	6
7	007	038	066	097	127	158	188	219	250	280	311	341	7
8	008	039	067	098	128	159	189	220	251	281	312	342	8
9	009	040	068	099	129	160	190	221	252	282	313	343	9
10	010	041	069	100	130	161	191	222	253	283	314	344	10
11	011	042	070	101	131	162	192	223	254	284	315	345	11
12	012	043	071	102	132	163	193	224	255	285	316	346	12
13	013	044	072	103	133	164	194	225	256	286	317	347	13
14	014	045	073	104	134	165	195	226	257	287	318	348	14
15	015	046	074	105	135	166	196	227	258	288	319	349	15
16	016	047	075	106	136	167	197	228	259	289	320	350	16
17	017	048	076	107	137	168	198	229	260	290	321	351	17
18	018	049	077	108	138	169	199	230	261	291	322	352	18
19	019	050	078	109	139	170	200	231	262	292	323	353	19
20	020	051	079	110	140	171	201	232	263	293	324	354	20
21	021	052	080	111	141	172	202	233	264	294	325	355	21
22	022	053	081	112	142	173	203	234	265	295	326	356	22
23	023	054	082	113	143	174	204	235	266	296	327	357	23
24	024	055	083	114	144	175	205	236	267	297	328	358	24
25	025	056	084	115	145	176	206	237	268	298	329	359	25
26	026	057	085	116	146	177	207	238	269	299	330	360	26

27	027	058	086	117	147	178	208	239	270	300	331	361	27
28	028	059	087	118	148	179	209	240	271	301	332	362	28
29	029		088	119	149	180	210	241	272	302	333	363	29
30	030		089	120	150	181	211	242	273	303	334	364	30
31	031		090		151		212	243		304		365	31

FOR LEAP YEAR USE THE NEXT JULIAN DATE CALENDAR

JULIAN DATE CALENDAR

FOR LEAP YEARS ONLY

Day	Jan	Feb	Mar	Apr	may	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Day
1	001	032	061	092	122	153	183	214	245	275	306	336	1
2	002	033	062	093	123	154	184	215	246	276	307	337	2
3	003	034	063	094	124	155	185	216	247	277	308	338	3
4	004	035	064	095	125	156	186	217	248	278	309	339	4
5	005	036	065	096	126	157	187	218	249	279	310	340	5
6	006	037	066	097	127	158	188	219	250	280	311	341	6
7	007	038	067	098	128	159	189	220	251	281	312	342	7
8	008	039	068	099	129	160	190	221	252	282	313	343	8
9	009	040	069	100	130	161	191	222	253	283	314	344	9
10	010	041	070	101	131	162	192	223	254	284	315	345	10
11	011	042	071	102	132	163	193	224	255	285	316	346	11
12	012	043	072	103	133	164	194	225	256	286	317	347	12
13	013	044	073	104	134	165	195	226	257	287	318	348	13
14	014	045	074	105	135	166	196	227	258	288	319	349	14
15	015	046	075	106	136	167	197	228	259	289	320	350	15
16	016	047	076	107	137	168	198	229	260	290	321	351	16
17	017	048	077	108	138	169	199	230	261	291	322	352	17
18	018	049	078	109	139	170	200	231	262	292	323	353	18
19	019	050	079	110	140	171	201	232	263	293	324	354	19
20	020	051	080	111	141	172	202	233	264	294	325	355	20
21	021	052	081	112	142	173	203	234	265	295	326	356	21
22	022	053	082	113	143	174	204	235	266	296	327	357	22
23	023	054	083	114	144	175	205	236	267	297	328	358	23
24	024	055	084	115	145	176	206	237	268	298	329	359	24
25	025	056	085	116	146	177	207	238	269	299	330	360	25
26	026	057	086	117	147	178	208	239	270	300	331	361	26
27	027	058	087	118	148	179	209	240	271	301	332	362	27
28	028	059	088	119	149	180	210	241	272	302	333	363	28

29	029	060	089	120	150	181	211	242	273	303	334	364	29
30	030		090	121	151	182	212	243	274	304	335	365	30
31	031		091		152		213	244		305		366	31

USE IN 1996, 2000, 2004, 2008, 2012, 2016

Regression Analysis (relationships between rice and weather parameters and the derived P.E.I

	Rice 1	Onset 2	Cessa 2	LRS 2	RH 2	Ave T 2	Max T 2	Min T 2
Onset 2	-0.262							
Cessa 2	0.158	-0.550						
LRS 2	0.166	-0.837	0.903					
RH 2	-0.009	0.455	-0.203	-0.301				
Ave T 2	0.413	0.141	-0.181	-0.156	0.254			
Max T 2	0.243	-0.092	-0.025	0.047	0.270	0.316		
Min T 2	0.172	0.028	0.232	0.125	0.536	-0.118	0.104	
Rainfal2	0.095	-0.164	-0.053	0.088	0.169	0.200	0.087	0.107

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Summary of RegressionAnalysis

Predictor	Coef	Stdev	t-ratio	p
Constant	-12.055	4.156	-2.90	0.014
Onset 2	-4.974	1.366	-3.64	0.004
Cessa 2	11.806	3.467	3.40	0.006
LRS 2	-3.2547	0.9310	-3.50	0.005
RH 2	0.2206	0.2156	1.02	0.328
Ave T 2	0.6728	0.2447	2.75	0.019
Max T 2	0.0496	0.1828	0.27	0.791
Min T 2	-0.0180	0.3586	-0.05	0.961
Rainfal2	0.0628	0.1099	0.57	0.579

s = 0.04430 R-sq = 70.0% R-sq(adj) = 48.1%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	8	0.050303	0.006288	3.20	0.039
Error	11	0.021587	0.001962		
Total	19	0.071890			

SOURCE	DF	SEQ SS
Onset 2	1	0.004937
Cessa 2	1	0.000021
LRS 2	1	0.015834
RH 2	1	0.009133
Ave T 2	1	0.019637
Max T 2	1	0.000098
Min T 2	1	0.000003
Rainfal2	1	0.000641

Unusual Observations

Obs.	Onset 2	Rice 1	Fit	Stdev.Fit	Residual	St.Resid
18	2.14	0.57978	0.58625	0.04413	-0.00646	-1.67 X

X denotes an obs. whose X value gives it large influence.

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The Descriptive Statistics (Characteristics of the Climate of the Study Area)

Parameter	*% R.H*	*Tmax*	*Tmin*	*Annual Rainfall*	*Mean Annual Temp.*	*Yield (Kg/ha)*
Mean	45.35	35.75	20.77	811.40	28.31	3459.50
Standard Error	1.61	1.54	0.52	40.13	0.82	108.24
Standard Deviation	7.21	6.87	2.30	179.47	3.67	484.05
Variance	52.01	47.13	5.31	32209.56	13.44	234299.74
Kurtosis	6.79	19.25	12.14	0.48	13.95	-1.47
Skewness	-2.04	4.35	2.88	-0.22	3.54	-0.01
Range	36.20	32.61	12.69	762.00	18.28	1510.00
Maximum	57.05	64.68	29.52	1195.10	42.73	4200.00
Minimum	20.85	32.07	16.84	433.10	24.45	2690.00

Summary of Rainfall data for the period 1994 - 2013

	1994	1995	1996	1997	1998	1999	2000	2001	2002
Jan	0	0	0	0.6	0	0	0	0	0
Feb	0	0	0	0	0	0	0	18.4	0
Mar	0	0	0	0	0	0	0	0	13.6
Apr	10.4	8.4	0.8	4.9	1.8	0	0	1	4.4
May	47.7	13.5	67.8	84.1	107.3	124.2	28.9	50.6	0
Jun	136.4	150.1	80.6	135.4	147.7	57	150.7	172.3	53.2
Jul	160.7	178.8	232	92.5	305.1	268.8	113.2	324	123
Aug	249.8	136.2	299.5	203.4	365.7	314.8	226.4	279	195
Sep	133.4	170.4	220.8	123.1	258.2	74.5	86	138.2	65.4
Oct	37.9	8.5	21.6	22.3	9.3	13.4	47.8	0.7	36.1
Nov	0	0	0	1.6	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
13.6	13.6	0	0	0	0	0	0	0	0	0
4.4	0	0	0	16.7	0	0	19.4	23.2	0	28.2
54.1	89.2	22.5	68.8	60.8	70.4	12.2	58.1	54.1	20.1	35.3
183.5	0	127.8	98.3	224.4	40.1	116.8	145.8	164.9	229.3	120.6
208.9	206.2	254.4	244.6	108.5	344	247.1	236	180.1	230	157.1
276.2	22.3	287.7	139.6	309.4	184	224.7	329.4	277.5	385.2	440.3
143	96.3	186.2	180.4	41	86.1	120.1	189.5	169.1	79.2	83.1
16.6	5.5	48.1	91.7	0	5.3	6.5	39.4	11.5	1	10
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0

Summary of data on Relative humidity and Temperature for the period 1994 - 2013

	2007				2008			
	R.H 10a.m	Temp Max	R.H Min		Temp 10a.m	R.H Max	Temp Min	
Jan	41.48	28.48	14.19	21.34	42.35	28.16	14.71	21.4
Feb	29.25	35.57	16.68	26.13	33.79	30.86	15	22.9
Mar	29.58	38.03	19.9	28.97	25.55	39.65	20.74	30.2
Apr	52.13	41.5	25.47	33.49	38.13	39.87	24.27	32.1
May	62	39.19	25.35	32.27	54.13	38.97	24.74	31.9
Jun	70.23	34	22.33	28.17	64.77	49.2	23.87	36.5
Jul	74.84	32.29	22.03	27.16	79.19	31.48	21.52	26.5
Aug	65.23	33.02	24.05	28.55	75.74	32.08	21.93	27.0
Sep	68.80	31.32	23.56	27.44	49.03	35.23	19.9	27.6
Oct	42.50	30.35	22.78	26.57	28.83	35	15.77	25.4
Nov	37.27	29.73	12.27	21.00	29.41	28.12	15.39	21.8
Dec	49.60	34.85	19.78	27.31	47.36	35.33	19.80	27.57

2009				2010			
R.H 10a.m	Temp Max	R.H Min		R.H 10a.m	Temp Max	Temp Min	
29.06	33.32	15.87	24.6	36.29	32.52	14.77	23.6
21.66	36.03	18.24	27.1	27.45	36.93	19.17	28.1
22.71	38.26	21.52	29.9	27.42	37.9	22.29	30.1
51.5	41.77	26	33.9	40.03	40.6	26.2	33.4
57.71	39.39	24.71	32.1	58.9	39.9	26.55	33.2
66.03	36.97	23.7	30.3	69.9	35.17	24.27	29.7
70.77	32.94	22.97	28.0	76.94	31.23	23	27.1
76.08	32.67	23.13	27.9	73.79	31.74	22.26	27.0
68.68	35.55	23.74	29.6	68.13	34.87	22.39	28.6
44.8	32.9	19.27	26.1	28.9	35.5	18.07	26.8
39.95	28	15.47	21.7	28.05	32.6	17.73	25.2
49.90	35.25	21.33	28.29	48.71	35.36	21.52	28.44

2011				2012			
R.H	Temp			R.H	Temp		
10a.m	Max	Min		10a.m	Max	Min	
				39.55	30.81	14.32	22.6
26.72	36.34	19.97	28.2	31.97	35.83	19.24	27.5
36.81	39.48	21.45	30.5	25.19	36.77	21.13	29.0
43.73	40.07	23.53	31.8	49.1	41.3	26.17	33.7
58.68	39.65	25.9	32.8	56.77	39.26	26.16	32.7
64.5	34.67	23.8	29.2	66.63	33.87	23.2	28.5
73.48	32.1	22.61	27.4	72.65	31.45	22.58	27.0
74.33	32	21.9	27.0	74.56	31.18	22.2	26.7
56.1	34.68	21.68	28.2	58.16	35.81	23.48	29.6
22.5	34.13	16.37	25.3	31.63	34.7	18.2	26.5
113.68	25.25	17.75	21.5	33.50	360.5	12	186.3
57.05	34.84	21.50	28.17	50.62	64.68	20.79	42.73

2013			
R.H	Temp		
	Max	Min	
36.84	30.71	16.29	23.5
24.83	34.66	18.03	26.3
41.48	40.03	21.45	30.7
61	39.37	25.13	32.3
70.94	39.03	27.29	33.2
66.43	35.47	24.37	29.9
72.06	31.94	22.87	27.4
72.56	31.24	22.52	26.9
43.39	34.68	21.03	27.9
25.17	35.53	17.37	26.5
29.43	32.13	108.37	70.3
49.47	34.98	29.52	32.25

2006

R.H	Temp		
10a.m	Max	Min	
27.74	33.42	15.19	24.3
30.79	37	18.36	27.7
	38.43	20.33	29.4
39	40.17	22.76	31.5
64.33	38.73	25.3	32.0
77.25	36.41	23.41	29.9
	34.47	22.3	28.4
79.3	32.12	21.37	26.7
70.73	34.47	22.23	28.4
40.79	33.72	17.93	25.8
33.53	29.66	12.71	21.2
51.50	35.33	20.17	27.75

2005

R.H	Temp		
10a.m	Max	Min	
32.48	29.35	13.94	21.6
27.86	37.86	20.46	29.2
29.33	39.73	22.77	31.3
38.28	41.03	23.97	32.5
56.6	39.33	25.57	32.5
70.52	35.69	23.48	29.6
80.63	31.63	21.7	26.7
80.56	31.76	21.56	26.7
81.32	33.83	22.13	28.0
69.57	33.75	21.38	27.6
28.32	32.39	13.77	23.1
49.40	35.12	20.98	28.05

2004

R.H	Temp		
10a.m	Max	Min	
25.39	31.19	13.71	22.5
24.07	32.46	15.79	24.1
17.43	35.57	19.7	27.6
39.62	41.34	24.1	32.7
59.43	39.6	24.63	32.1
68.5	35.52	23.1	29.3
	32.5	21.4	27.0
	32.12	21.86	27.0
	35.87	21	28.4
26.5	28.77	19.5	24.1
37.28	34.49	20.48	27.49

2003

R.H	Temp		
10a.m	Max	Min	
16.87	31.81	14.23	23.0
15.68	35.46	17.43	26.4
19.63	36.2	20.37	28.3
42.48	40.97	25.28	33.1
37.57	40.33	24.5	32.4
71.21	33.86	22.69	28.3
75.43	31.86	21.33	26.6
83.95	31.78	24.66	28.2
72.87	35.37	21.4	28.4
28.71	27.49	18.46	23.0
46.44	34.51	21.04	27.77

2002				2001			
R.H	Temp			R.H	Temp		
10a.m	Max	Min		10a.m	Max	Min	
22.84	25.97	13.19	19.6	17.61	29.45	11.97	20.7
19.75	31.54	15.39	23.5	17.04	30.64	14.68	22.7
20.6	37.67	21.07	29.4	13.7	36.63	19.43	28.0
39.31	40.69	25.45	33.1	33.45	39.28	24.28	31.8
45	40.83	25.9	33.4	56.23	38.03	24.37	31.2
55.86	37.07	24.14	30.6	65.41	33.59	22.97	28.3
67.63	33.7	23.13	28.4	74.3	31.5	20.73	26.1
75.39	31.85	22.85	27.4	78.14	30.53	21.42	26.0
64	33.14	23	28.1	50.4	34	21	27.5
30.4	31.9	15.87	23.9	19.7	31.97	14.5	23.2
44.08	34.44	21.00	27.72	42.60	33.56	19.54	26.55

2000				1999			
10a.m	Max	Min		10a.m	Max	Min	
22.81	31.87	14.84	23.4	21.26	30.03	13.19	21.6
17.14	29.43	14.32	21.9	15.04	33.75	16.71	25.2
14.77	33.87	18.1	26.0	22.83	38.47	20.6	29.5
27.79	40.43	23.72	32.1	30.9	38.69	23.97	31.3
42.13	39.7	24.93	32.3	46.83	38.27	25.17	31.7
63.93	34.83	23.24	29.0	54.24	37	24.59	30.8
71.17	32.13	22.1	27.1	76.23	30.67	21.13	25.9
76.37	31.02	21.05	26.0	79.72	29.97	21.27	25.6
65.5	33.4	21.57	27.5		31.83	20.83	26.3
24.03	29.97	14.2	22.1	20.07	31	14.38	22.7
42.56	33.67	19.81	26.74	40.79	33.97	20.18	27.08

1998

10a.m	Max	Min	
17	28.84	14.03	21.4
13.57	33.07	17.57	25.3
11.43	33.6	19.3	26.5
28.38	39.55	24.52	32.0
56.13	38.47	26.37	32.4
68.72	32.76	23.24	28.0
73.5	30.9	21.03	26.0
80.17	29.69	20.24	25.0
67.67	32.3	22	27.2
46.29	33.24	20.92	27.08

1997

10a.m	Max	Min	
17.19	31.55	14.29	22.9
13.5	27.79	14.86	21.3
16.37	34.6	20.77	27.7
34.52	37.97	24.34	31.2
54.07	36.37	23.17	29.8
62.66	33.62	22.34	28.0
68.6	31.97	21.1	26.5
73.86	31.58	20.41	26.0
63.83	34.47	22.07	28.3
44.96	33.32	20.37	26.85

1996

10a.m	Max	Min	
15.81	31.13	17.29	24.2
14.61	34.04	16.68	25.4
14.07	36.93	22.33	29.6
22.31	38.76	23.31	31.0
52.2	38.93	24.73	31.8
65.28	33.79	22.41	28.1
79.2	30.37	19.8	25.1
77.47	30.47	19.95	25.2
68.33	32.83	21.37	27.1
54.88	33.55	20.55	27.05
60.35	32.10	27.2	29.65
45.48	34.14	20.87	27.51

1995

10a.m	Max	Min	
18.23	26.74	11.97	19.4
16.24	30.83	14.76	22.8
16.45	37.06	20.74	28.9
33.43	38	30.37	34.2
50.1	38.03	24.35	31.2
59	34.83	21.77	28.3
70.65	31.32	20.48	25.9
75.49	30.69	19.72	25.2
52.45	33.58	20.55	27.1
54.88	33.55	20.55	27.05
60.35	32.10	27.2	29.65
43.56	33.45	20.52	26.99

1994

10a.m	Max	Max	Av. T
23.9	29.58	13.2922	21.4
12.72	31.66	15.6916	23.7
12	38.52	20.132	29.3
42.3	38.57	24.47	38.6
48.32	37.29	24.5549	30.9
73.17	31.9	20.1064	26.0
74.06	31.48	20.107	25.8
78.9	30.21	20.0076	25.1
65.23	32.74	21.2945	27.0
33.4	33.67	21.89	27.78
43.0	31.82	20.60	26.21
47.84	33.55	19.40	27.54

```
NONPAR CORR
  /VARIABLES=Rice Onset Cessatn LRS R.H Rainfall mT minT AveT
  /PRINT=SPEARMAN TWOTAIL NOSIG
  /MISSING=PAIRWISE.
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Nonparametric Correlations

Correlations

		Rice	Onset	Cessatn	LRS	R.H	Rainfall	mT	minT	AveT
		1.000	-.252	.369	.396	.449*	.196	.507*	.290	.479*
	Rice	.	.284	.110	.084	.047	.408	.022	.214	.033
		20	20	20	20	20	20	20	20	20
		-.252	1.000	-.438	-.882**	.262	-.045	.134	-.101	.056
	Onset	.284	.	.053	.000	.265	.850	.573	.672	.814
		20	20	20	20	20	20	20	20	20
		.369	-.438	1.000	.754**	-.119	-.149	.021	.203	.043
	Cessatn	.110	.053	.	.000	.617	.530	.930	.391	.857
		20	20	20	20	20	20	20	20	20
		.396	-.882**	.754**	1.000	-.166	.010	-.029	.147	-.002
	LRS	.084	.000	.000	.	.483	.967	.905	.537	.992
		20	20	20	20	20	20	20	20	20
		.449*	.262	-.119	-.166	1.000	.391	.700**	.405	.775**
Spearman's rho	R.H	.047	.265	.617	.483	.	.088	.001	.077	.000
		20	20	20	20	20	20	20	20	20
		.196	-.045	-.149	.010	.391	1.000	.033	.114	.153
	Rainfall	.408	.850	.530	.967	.088	.	.890	.631	.520
		20	20	20	20	20	20	20	20	20
		.507*	.134	.021	-.029	.700**	.033	1.000	.408	.834**
	mT	.022	.573	.930	.905	.001	.890	.	.074	.000
		20	20	20	20	20	20	20	20	20
		.290	-.101	.203	.147	.405	.114	.408	1.000	.692**
	minT	.214	.672	.391	.537	.077	.631	.074	.	.001
		20	20	20	20	20	20	20	20	20
		.479*	.056	.043	-.002	.775**	.153	.834**	.692**	1.000
	AveT	.033	.814	.857	.992	.000	.520	.000	.001	.
		20	20	20	20	20	20	20	20	20

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).