ASSESSMENT OF RAIN-FED AND IRRIGATED FARMING SYSTEMS OF SUGARCANE PRODUCTION IN BAUCHI STATE, NIGERIA

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ABSTRACT

The study assessed rain-fed and irrigated farming systems of sugarcane production in Bauchi State, Nigeria. The specific objectives were to describe the socio-economic characteristics; determine the productivity, determine the costs and returns, determine the level of improved technologies utilized and to examine constrains of sugarcane. A three – stage purposive sampling procedure was used to select 123 and 108 sugarcane farmers under rain-fed and irrigated farming systems respectively. This gave a total of 231 respondents. Structured questionnaire was employed to collect primary data which were analysed using descriptive statistics (means, percentages counts and frequency distribution), productivity index, farm budgetary techniques and Kendall's coefficient of concordance as well as attitudinal measuring scale such as Likert type scale. The result of analysis revealed that the farmers were within the age group of 26 – 55 years with mean age of 44 and 42 years, respectively, while 96.7% and 97.2% under rain-fed and irrigated farming system respectively were married. The mean years spent in formal education by the respondents under rain-fed and irrigated farming system was 6 and 8 years, respectively, while mean farming experience was 10 and 12 years, respectively. Few respondents under rain-fed (17.1%) and irrigated (12.0%) farming system had access to credit facilities, while 48.8% and 21.3% of the farmers had contact with extension agents, respectively. The result of sugarcane productivity revealed that 60.2% of the respondents under rain-fed farming system had sugarcane productivity ranges of 261 – 1000 kg/ha with an average productivity of 382 kg/ha, while 58.3% of the respondents under irrigated farming system had sugarcane productivity greater than 1000 kg/ha with an average productivity of 1824 kg/ha. The costs and returns analysis result revealed that the gross margin realized from sugarcane production under rain-fed and irrigated farming systems was ₦430,038.82 and ₦947,697.23, respectively, while the net farm income was ₦414,342.25 and ₦926,638.339, respectively. Thus, profitability ratio of 1.14 and 1.85 implies that for every ₦1 invested in sugarcane production under rain-fed and irrigated farming system, ₦1.14 kobo and ₦1.85 kobo were realized, respectively. The results on improved technologies utilized by the respondents under rain-fed farming system revealed that 56.1% of the respondents utilized light texture soil with good drainage, 69.9% raised sugarcane nursery during land preparation, 71.5% utilized Autum planting of sugarcane (i.e. September to October), 76.4% utilized weeding by hoe; 31.7% applied NPK fertilizer at112kg(N), 25kg(P), 48kg(K) rate/acre; and 64.2% utilized manual harvesting; while improved technologies utilized by the respondents under irrigated farming system revealed 62.0% of the respondents utilized ploughing depth of 30cm during land preparation, 65.7% utilized sowing depth of 30cm, 59.3% utilized combination of cultural and chemical methods during weeding, 74.8% utilized application of water once at every 7 days during growing phase of sugarcane, 31.7% applies inorganic fertilizer and 54.6% utilized early harvesting (10 – 11 months) of sugarcane plantation. The major constraints associated with sugarcane production under rain-fed farming system was inadequate capital and access to credit facilities ($\bar{X}$= 2.74) ranked 1st for rain—fed, irrigated and pooled. Kendall *W* value of 0.201 for rain-fed, 0.166 for irrigated and 0.155 for pooled revealed consensus agreement on the constraints to sugarcane production. Meanwhile, the t-test value of 9.579 at 1% level of probability implied significant difference in sugarcane productivity. The study concluded that sugarcane production is profitable, however, irrigated farming system gave higher profitability ratio when compare to rain-fed farming system. It was, therefore, recommended that agricultural extension agencies should intensify efforts in educating and sensitizing sugarcane farmers on how to appropriately and optimally utilise available resources to maximise sugarcane productivity in the study area.

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1.0 INTRODUCTION

1.1 Background to the Study

Sugarcane (*Saccharum officinarum*) is one of the most important crops in the world because of its immense usage in the daily life of man and or any nation for industrial uses aimed at nutritional and economic sustenance. Sugarcane contributes about 60% of the total world sugar requirement while the remaining 40%, is from beet (Girei and Giroh, 2012). It is a tropical crop that usually takes between 8 to 12 months to reach its maturity. Mature cane may be green, yellow, and purplish or reddish and considered ripen when sugar content is at maximum.

The main driver behind the expansion of land under sugarcane farming and increasing sugarcane monoculture is the rise in the world's demand for sugar. Furthermore, industrialization has led to more investments in sugarcane farming for production of clean fuels, such as ethanol and biogas. According to Murthy (2010), Sugarcane provides the cheapest form of energy giving food with the lowest unit of land area per unit produced to man. Although sucrose alone is not a diet on which man live, it represents almost 1/7 of total energy intake of human food for a normal person under non restricted condition of supply.

It has been stated that an average man's annual food composition is approximately one million calories. The consideration of other numerous direct and indirect products derived from sugarcane gives an even more impressive conception, because apart from its varied uses as food and sweetening agent, it is equally used prominently as a raw material for the production of important chemicals such as refrigerants and drugs (Murthy,2010). It was revealed that sugarcane is cultivated either under irrigation or rain-fed farming systems in the tropical areas with ample rainfall. Land productivity in area suitable for its rain-fed production is typically much higher than cultivated land in cooler regions or arid sub-tropical and tropical agriculture, and the crop is found throughout the tropics and sub-tropics (Forum for Agricultural Research in Africa (FARA), 2008).

However, large part of the world cannot grow it for climatic reasons and its impact in this suitable area is, therefore, more significant. Hence, climatic changes threaten the sustainability of the most rain-fed sugar farming systems (Aina *et al*., 2015). According to Oni (2016), certain climate change scenarios may harm sugarcane growth and yield without the introduction of appropriate irrigation facilities. Therefore, rain-fed sugarcane farming system is gradually being replaced by irrigated farming system whenever such transition is possible. In addition, low efficiency irrigation systems are being replaced by high efficiency systems to make sugarcane farming more economically sustainable. However, irrigation is one of the most expensive of sugarcane farming systems and can account for more than 25% of the production cost (Aina *et al*., 2015). Therefore, the dimensions of sugarcane irrigation systems need to be adjusted for water conservation while simultaneously reducing operational costs. Like most major tropical crops, sugarcane growth, yield and quality respond markedly to variation in moisture present in the soil; Therefore, availability of water is an important factor causing variation in sugarcane yield and juicy quality.

Although sugarcane can tolerate some moisture stress, it still has a high water requirement in range of 1500 to 2500mm per season to have high yields. Although sugarcane requires high water supply, it is affected by water logging, which reduces plant growth, encourages fungi growth and eventually reduces yield. Therefore maintenance of optimum soil moisture throughout the growing period and achievement of close to maximum or expected yields in sugarcane fields, both appropriate effective irrigation and drainage facilities are vital. Water is a key to sugarcane growth and development, as well as subsequent conversion of recoverable sugar to sucrose. Amount of water utilized by cane plant had a linear relationship with total dry matter produced; they equally said that favorable soil moisture condition during cane growth also had significant effects on overall sugarcane productivity (Aina *et al*., 2015).

There are other identified problems associated with the growing of sugarcane in Nigeria with respect to both rain-fed and irrigated farming systems, although the overall environmental impact can be said to be much larger than any other problems. Some of these specific and general production problems of sugarcane in Nigeria include inconsistent policy measures, poor market access, inefficient extension delivery system with high transportation costs, others are abiotic factors (the environmental issues), infrastructural inadequacy, pests and diseases, shortage of planting material or improved varieties, and low skill acquisition as well as lack or inadequate access to improved technologies development transfer among others Therefore, there is reduction in the supply of sugar in both local and global markets (Makinde *et al*., 2009).

1.2 Statement of the Research Problem

Sugar is a very essential commodity consumed by majority of the Nigerians. The production of sugarcane through the conventional methods cannot meet up with the demand of the people. The demand for sugar in Nigeria is put at between 2.5 and 3.0 million tonnes (Lyocks, 2016). Therefore, this contribute to shortage of sugarcane production to feed our industries locally and commercially export to other countries, to boost our economy, as a result of inadequate use of improved varieties, extension services and technologies for sugarcane production. Various attempts have been made in the past to increase sugar production in Nigeria which led to establishment of large-scale sugar processing factories in four strategic locations; Bacita, Numan, Sunti and

Lafiagi (Tiamiyu *et al*., 2013). However, Bacita and Numan which went through transformation from public to private ownership are out of production presently. For sugarcane production to make a positive impact in the lives of the Nigerians, several of these mini plants will be required to produce sugar raw materials that will feed the larger factories for rapid growth and sustainable development in the sector.

With growing population, the human demand for sugar consumption is on increase in Nigeria. The trends in sugarcane industrial activities suggest that the demand for sugar will continue to rise to the point that demand for sugar in Nigeria will outstrip supply thereby causing a deficit in supply (Lyocks, 2016). It is in this light that this study, seeks to assess sugarcane production under rain-fed and irrigated farming systems in Bauchi State, Nigeria. Hence, the study provided answers to the following research questions:

i. What are the socio-economic characteristics of sugarcane farmers under rain-fed and irrigated farming systems in the study area?
ii. What is the productivity of sugarcane production under rain-fed and farming systems in the study area?
iii. What are the costs and returns of sugarcane production under rain-fed and irrigated farming systems in the study area?
iv. What is the level of improved technologies utilized under rain-fed and irrigated farming systems in the study area?
v. What are the constraints of sugarcane production under rain-fed and irrigated farming systems in the study area?

1.3 Aim and Objectives of the Study

The main objective of this study was to assess the rain-fed and irrigated farming systems of sugarcane production in Bauchi State, Nigeria. The specific objectives were to:

i. describe the socio-economic characteristics of sugarcane farmers under rain-fed and irrigated farming systems in the study area;
ii. determine the productivity of sugarcane production under rain-fed and irrigated farming systems in the study area;
iii. determine the costs and returns of sugarcane production under rain-fed and irrigated farming systems in the study area;
iv. determine the level of improved technologies utilized under rain-fed and irrigated farming systems in the study area, and
v. examine the constraints hindering sugarcane production under rain-fed and irrigated farming systems in the study area.

1.4 Hypotheses of the Study

Two null hypotheses were tested in this research; they are as follows:

HO_1: There is no significant difference between the productivity of sugarcane under rain-fed and irrigated farming systems in the study area.

HO_2: There is no significant difference between the income of sugarcane farmers under rain-fed and farming systems in the study area.

1.5 Justification of the Study

Nigeria's farming practice is largely rain-fed. However, considerable investment has also been made in irrigation infrastructure which is yet to make the desired impact on food security in the country. Both irrigated and rain-fed farming systems are dominated by small scale farmers who majorly cultivate less than five hectares. Rainfall in most northern parts of Nigeria is neither sufficient in amount nor dependable in distribution. Consequently, sugarcane frequently suffers from water inadequacy for the growth and development to have expected sugarcane yield, and they are endowed with abundant water resources that could be utilized for irrigation. Utilization of the extensive low land areas through irrigation is among the viable options to increase sugarcane production in this country.

Accordingly, expansion of irrigated agriculture is considered for playing a pivotal role in reaching the broader development vision of achieving sustainable economic growth, ensuring food security and reducing poverty level of numerous farmers. In addition, there is a growing understanding that climate change poses serious challenges to agricultural development in Nigeria, reason for this is, not far-fetched from the agricultural practice in Nigeria which is majorly rain-fed system, which is highly sensitive to climate change and variability (Lyocks, 2016).

In view of this, an effective use of agricultural technologies; the use of viable irrigation techniques and also given adequate information about good cultural practices and about factors hindering production of sugarcane and then provide adequate ways or methods to resolve these problems in the study area. The findings of this study will be of immense benefits to both small and medium scale sugarcane farmers in the study area because it will increase their productivity and income level as against total dependence on rain-fed farming system. It will also assist the government and other stakeholders in the agricultural sector in formulating relevant policies that will help achieve national food security. The findings of this study will also serve as a frame of reference to other researchers by providing a basis upon which further studies can be conducted and as such contributing to the existing knowledge of the subject matter, sugarcane production in Nigeria.

CHA PTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and Distribution of Sugarcane

From its origin, the sugarcane plant has been widely dispersed as it followed human migrations. Sugarcane originated in prehistory and is among the oldest cultivated plants. In Nigeria, sugarcane can be cultivated almost all the states locally but commercially it is produced in; Kastina, Kwara, Niger,Taraba, Kano, Adamawa, Jigawa, Kaduna, Kebbi, Bauchi, and Sokoto States. Nigeria is one of the most important producers of the crop with a land potential of over 500,000 hectares of suitable sugarcane field capable of producing over 3.0 million metric tons of sugar if processed (Dimelu *et al*., 2017).

Nigeria has vast human and natural resources, in terms of land and water, to produce enough sugarcane, not only to satisfy the country's requirement for sugar consumption and bio-fuel, but also as an industrial export crop. Sugarcane for domestic consumption is produced more than that produced for industrial use. Thus, chewing cane accounts for between 55 – 65% of the total cane production. The bulk of these are consumed raw for its sweetness of the juice but some of it is processed into a variety of products such as sugar, molasses, bagasse, sweets and left-over leaves/stalks (Busari and Misari, 2007).

Although there is vast potential for the commercial production of this crop, its processing industries did not come into existence in Nigeria until the early 1960s. Commercial cultivation of sugarcane did not start until 1950 while industrial production of refined sugar started in the early 1960s with the establishment of the Nigeria Sugar Company (NISUCO), at Bacita, Kwara State in 1964. Since then another mill, the Savannah Sugar Company (SSCL) has taken off at Numan, Adamawa State in 1980 and smaller one in Lafiagi in 1983. Similarly, National Sugar Development Council, Abuja, installed a medium-size 250 tonnes cane-day Mini sugar plant at Sunti, Niger State. The combined installed capacities of these mills are about 120,000 metric tonnes of processed granulated white sugar per annum. However, total domestic production fluctuated between 16,000 and 50,000 tonnes annually, which are able to satisfy only about 5% of the total national demand for sugar (Busari and Misari, 2007).

2.2 Names and Varieties of Sugarcane

Sugarcane is a sensitive crop and its yield dependent on climate, soil type, irrigation, varieties, and the harvest period and even the planting time. The stalk consists of 14%, 68%, 15%, and 3% or less of fibre, water, soluble sugar and non-sugar respectively. Types of sugarcane could be crystal canes, syrup canes, non-crystallized, largely commercial but high concentrations of sucrose and the common eaten able or chewing canes found almost every states of Nigeria is known as chewing sugarcane and or bush cane, botanically name, *Sacharum officinarum*. Locally called 'Ireke' in Yoruba language, 'Reke' in Hausa language and known as 'Ukhuere-oha' in Benin, 'Okpete' or 'Okpoto' among the Ikwere and Igboid speaking tribes of the south-south and south-east region of Nigeria.

Nigerian Seed Portal Initiative (2017). Among sugarcane varieties includes many improved sugarcane varieties released and published by Nigeria Cereal Research Institute, Badeggi (NCRI) and Nigeria Sugarcane Development Council (NSDC). The sugarcane varieties that are soft, with fibrous center which are good for chewing are more than 150 varieties however, some are mentioned below.

CoC671 which are obtained by crossing 063 and Co775

CoC85061 which early matured (in 11 months, NR12) with yield potential of 187.5 MT

CoM7114 of medium duration and good for planting after November.

Co-S.I.776; Co7219 (Sanjeevani) released 1982; Co.419 released 1936, matured early; Co.740 released 1956 from double crosses between Co421 & Co440 and Co464 & Co440 the leaves are erect and broad. Mary Ellen-Ellis (2021). Some common sugarcane varieties identified among are,

ILS-002 (USRI 86/04) released 1984 and registered 1997 vigorous rationing ability, tolerant to moisture stress; NCS001 (BD83-019) released 1984 and registered 1997.

ILR-001 (USRI 85/46) released 1984 and registered 1997.

B63349 (B63349) released 1984 and registered 1996 is a broad spreading, non-hairy leaves, good juice quality.

NCS-005 (BD94-017) released 1999 and registered 2001.

NCS-003 (BD-93-030) released 1999 and registered 2001 high yield, heavy tillering, vigorous growth at early stage, early maturity and high tolerant to drought (90t/ha-plant crop; 80t/ha ratoon crop); NCS002 (BD83-025) released 1984 and registered 1997.

NCS-007 (KRS-8) released 2000 and registered 2001 high resistant to smut, high tillering with good canopy, good juice quality, also have good quality and high yielding(100t/ha-plant crop; 90t/ha-ratoon crop); NCS-006 (KRS-01) released 2000 and registered 2001.

NCS-008 (BD96-016) released and registered in 2006, is a high yielding, high tillering and good ratoon ability, early maturity and moderate resistant to smut (90 t/ha-plant crop and86t/ha-ratoon crop). According to publication updated by Indian Agronet.com (2021). There are numerous varieties of sugarcane, Co0238 (Kara 4) released in 2009 in India, is a high yielding and high sugar content variety from the cross Co LK 8102 and Co775

NCS-009(DTS-51) released and registered 2012, is a high cane and sugar yield, tolerant to smut (188.1t/ha).

2.3 Importance of Sugarcane

Sugarcane is a versatile crop in term of usage, since is a rich source of food (sucrose, jaggery and syrups), fiber (cellulose), fodder (green leaves and tops of cane plant), fuel and chemicals (bagasse, molasses and alcohol) (Dotaniya and Datta, 2014). Sugarcane is an important cash and or industrial crop and an important source of income and employment for the agricultural communities which produces it. More so, sugar is one of the essential items of daily consumption of Nigerian because of its ability to store high concentrations of sucrose or simple sugar in the stem. The bulk of these is of course consumed raw for its sweetness of the juice but some of it also is processed into a variety of products such as sugar granules, molasses, baggasse “Jaggery” (Mazarkwaila), sweets (Alewa) and left – over leaves/stalks (Dotaniya and Datta, 2014).And also as an industrial crop, because of its valuable source of raw material for production of bio-ethanol and bio-electricity. It serves as a raw material for a variety of products for brewing beer, soft drinks, confectionaries, pharmaceuticals and the plant is the most efficient converter to solar energy, carbon dioxide and water; as an energy giving food and the first food sweetening material of our ancestors (Godheja*et al*., 2014). Other than raw sugar products derived from sugarcane, other by-products derived include falernum, molasses, rum, cachaça (a traditional spirit from Brazil), bagasse and ethanol (Godheja*et al*., 2014). Basically, sugarcane has three main products namely: Sugar, Bagasse and Molasses. The sugar industries are responsible for the manufacture of raw of refined granulated brown or cubed sugar from sugarcane which is consumed as a basic food item. Nevertheless, sugarcane is grown for chewing, drinking juice, raw sugar and centrifugal sugar; thick noble canes, which are relatively soft with a high sugar and juice content and low fiber, are best for chewing; By boiling the juice over an open fire until it is almost dry, a form of sugar is prepared (Godheja*et al*., 2014).

With further improvement in sugar production, all insoluble materials and all impurities are separated from the juice of sugarcane and this resulting to a product, a fine-grained, pale yellow sugar which is further refined to produce white sugar which has become an important item of human diet today. The dark brown viscous liquid separated from the crystalline sugar in the last stage of juice processing is called molasses, containing 35% sucrose and 15% reducing sugars. It is an important industrial raw material crop used to produce rum, gin, vodka, ethyl alcohol, acetone and butanol, likewise also bakers and brewer's yeast are produced from it. It is widely used as a livestock feeds and use in preparing animals' silage additives and also partly used in constructing roads. The modern sugar estates use this by-product as fuel for power generation; and it has a great potential in a fodder crop in animal husbandry (Godheja*et al*., 2014).

To date, producing bioethanol from the sugar in sugarcane (first-generation biofuels) has been one of the world's most commercially successful biofuel production systems. The residue obtained after the pressing of sugarcane stalks to extract juice at sugar factories is called 'bagasse'. Bagasse is typically used to produce heat and electricity, but it is currently underutilized in Africa. Sugarcane bagasse has potential as a source of carbohydrate for the production of second-generation biofuels. Ethanol produced in this way is seen as a viable option for decreasing any perceived competition between food production and bioenergy (Godheja*et al*., 2014).

2.4 Production of Sugarcane under Rain-fed Farming System

Farming system in Nigeria can still be regarded as subsistence-based and it is predominantly rain-fed, which makes it overly dependent on weather fluctuations. Agriculture is highly dependent on climate variability and that is why the threat of climate change is particularly require urgent attention in Africa (Boko *et al.*, 2007). The climatic condition in Nigeria is characterized by relatively high temperature and variations in the amount of precipitation throughout the year with alternating two seasons (rainy and dry) (Ibe and Nymphas, 2010). The dry season persists from late October to early March. This period witness' dusty north-east winds (Chineke *et al*., 2010). However, the Northern Nigeria which experiences short wet season, and longer dry season is usually from October to mid-May. Annually, the average temperature ranges from 21 to 32°C in the south while the north has a temperature range of 13 to 41°C. According to Ikpi (2010), climate change in Nigeria is making some land to uninhabitable to certain crops and also affecting water supplies, threatening people's basic needs and this triggering displacement of the farmers.

Sugarcane requires an ample supply of water (1,200–1,500 mm) for effective development of stems annually, not only as the total water supply during rainfall but stretch more than ten months during production season. This water requirement may be higher than those for rice production which usually mature in three to four months. Therefore, sugarcane production takes place either in areas with abundant rainfall like northern Brazil or in areas with full-control irrigation systems like India (Müller *et al*., 2008). The humid tropics like Brazil and Democratic Republic of the Congo have sufficient potential for rain-fed sugarcane (Müller *et al*., 2008). However, outside these areas, substantial irrigation investments may be needed for sugarcane production to give expected productivity.

2.5 Irrigated Farming System

Irrigated agriculture only accounts for one percent of the cultivated area in Nigeria (FAOSTAT, 2017). Many farmers are out of jobs during the dry season and local food prices are on the rise as a result of food scarcity during this period. However, the green revolution agricultural policy by the government requires all-year round farming. The role of irrigation cannot be ignored as it is the only way to achieve the mandate of "Green Alternative" of the present administration. More so, water supplied could be sourced from groundwater through pumping to the surface or surface water diversion from one landscape position to another in sugarcane is very necessary. The traditional application of water to land for dry season farming was first conceived in northern Nigeria in form of gravity, using bucket/calabash and pump methods by farmers and without any financial assistance from the government and this practice lead to poor yield of irrigated sugarcane production in Nigeria. According to Kundell (2008), irrigation practice across the world is vital to successful green revolution all year round to achieving sustainable development goals in food security, socio-economic and rural development. However, irrigation practice in Nigeria has not achieved the set goals despite the huge investment involved. Moreover, the level of investment and abundant water resources ought to have expedited the goals of food self-sufficiency and socio-economic development in this country. Food and Agriculture Organization of the United Nations (FAO) classified irrigation scheme into three, based on land mass size, the large irrigation scheme has over 10,000 ha, between 100 –10000 ha is classified as medium-scale scheme while the small-scale scheme has less than 100 ha. In Nigeria, irrigation schemes and projects consist of three categories; the public irrigation schemes, which are government-executed schemes, the farmer-owned irrigation scheme, and the floodplains called fadama irrigation scheme, this classifications or groupings limiting the sugarcane production. Kundell (2008) compared the irrigated and rain-fed yields of selected crops including onions, sugarcane, and wheat in his study, the results showed that there was an appreciable increase in the yields of agricultural production in irrigated agriculture as compared to rain-fed agriculture, which will equally give the same outputs in sugarcane production.

2.6 Prospects of Irrigation Development

Currently, Nigeria has a total arable land estimated at about 34.6 million ha, however, only 40% is under cultivation out of which less than 5% is irrigated (Lowder *et al*., 2016; Omorogbe *et al*., 2014). Notwithstanding the abundant land and water resources, the availability of land for crop production is under threat due to recently increased conflict of the resource among the farmers and the herders in some selected agro-ecological zones of the country (Dimelu *et al*., 2017). It was revealed that, productivity of the available land can be enhanced through irrigation systems and other cheap, available agricultural inputs including fertilizers, herbicides, insecticides to mention a few (Takeshima and Adesugba, 2015). Furthermore, Cosmas *et al*. (2010) and Xie *et al*. (2017) are of the opinion that more land can be cultivated by engaging in small-scale irrigation scheme to our rural farmers.

Ugalahi *et al*. (2016) reported that about 2-million-hectare irrigated land is required to produce 11 million tonnes of rice demand by 2025 to feed the Nigerian population. Nevertheless, the available resources for agricultural and irrigation development are still underutilized, this including land, water resources, and other agricultural inputs (Mallam *et al*., 2014). The agricultural sector has been projected as an alternative to the future economic sustainability of the country (Omorogbe *et al*., 2014). Therefore, the essential needs, however, is the sustainable irrigation development to meet the future demand for food production (NINCID, 2015). Since agriculture and irrigation are intertwined, especially in a country like Nigeria where there is a wide spatial-temporal variation of rainfall across the country (Akande *et al*., 2017), every plan towards agricultural development must also be extended to irrigation system development. In addition, water resources development for irrigation plays a vital key role in agricultural and economic growth (Mugagga and Nabaasa, 2016).

With the unabated population growth, the dire need to meet the growing food demand and the nutritional requirement of the population require bringing more land under cultivation. Consequently, the opportunities of water development for future irrigation as the rain-fed agriculture only, cannot sustain the production of growing food demand (Cosmas *et al*., 2010; Olayide *et al*., 2016). This implies that there will be more pressure on the food demand and also an expansion of irrigated agriculture in the nearest future(NINCID, 2015). However, its developmental plan cannot be achieved without addressing the challenges being faced by the irrigation systems. On this account, the recent government policy towards increased importation tariff and an outright ban on importation of some staple food like rice has started bringing development to the country's irrigation system as more stakeholders including private sectors and youths are now interested in irrigated agriculture (Arigor *et al*., 2015).

Apart from the provision of irrigation infrastructures, the Nigerian farmers have also recently benefitted financial supports of US$495.3 million under the Transformation Irrigation Management in Nigeria (TRIMING) project from the World Bank (World Bank, 2014). This is to enhance improvement of the existing irrigation on 27,000 hectare and more than 140,000 farmers benefited while this mobilizes some private sector investment. The project aims to expand food production and spawn economic growth in rural areas through large-scale public irrigation improvement (World Bank, 2014).

2.7 Trend in Sugarcane Production in Nigeria

Among 92 countries that belong to the international sugar organization, Nigeria is the only one that belongs to the category of sugar importers and ranked fourth. Evidence showed that when compared to some selected West African Sugar producing countries, Nigeria is the least food secured in terms of sugar (National Sugar Development Council, 2012). Arising from the overdependence on sugar importation, cultivation of sugarcane for industrial purpose has suffered a serious setback due to poor performance of government established and owned sugar companies in Nigeria. Development in the Nigerian sugar industry has been very slow for the past three decades while the domestic supply of sugar had lagged behind the demand for the product, in spite of the country's comparative advantages for sugarcane production. The desired productivity improvements and competitiveness in Nigerian sugarcanes enterprises have been difficult to achieve over the years due to weaknesses in the commodity marketing system; the lack of attention to develop the commodity chain, producing value added products (value-chain) and enhance market access (FAOSTAT, 2015).

Sugar industries in Nigeria rely more on improved cultivars brought in from overseas rather than those developed in Nigerian Research Institutes, for reason not beyond inadequate information about the performance of these local cultivars that were bred in this country. The country's sugar industry only supplies about 3% of the nation's requirement. (NSDC, 2012). In Nigeria, according to the Food and Agriculture Organization Statistics (FAOSTAT), (2017), the trend of sugarcane production in Nigeria can be deduced to have being increasing. The production trend between 1992 and 2001 increased between 1% and 9.7% but decreased more for up to 30% in 1994. In the last decade, the production increased more than ever, that is between 3.4% and 52.5%, especially in 2009 where the significant expansion has occurred. This was as a result of double and more increase in the area of harvest. The trend in the first half of this period is an upward one before it then fluctuated. This could be despite the increases in the area harvested, asa result of inefficiency in the production and climatic changes in the area. This trend of sugarcane production in Nigeria from 1992 – 2016 is presented in Table 2.1.

Table 2.1: Trend of Sugarcane Production in Nigeria from 1992 – 2016

Year	Area Harvested (Ha)	Yield (Tonnes/Ha)	Production (Tonnes)
1992	22400	40.00	896000
1993	23800	38.03	905000
1994	18750	33.76	633000
1995	19270	30.57	589000
1996	21053	29.21	615000
1997	21900	30.82	675000
1998	23000	29.35	675000
1999	24000	28.42	682000
2000	24000	28.96	695000
2001	23000	30.65	705000
2002	40000	18.75	750000
2003	42000	19.00	798000
2004	43000	19.86	854000
2005	44000	20.77	914000
2006	47000	21.00	987000
2007	63000	23.90	1506000
2008	71890	19.64	1412070
2009	73060	19.19	1401680
2010	73060	19.16	1400000
2011	74000	19.59	1450000
2012	74000	19.59	1450000
2013	74000	19.59	1450000
2014	75000	19.73	1480000
2015	75050	20.12	1510000
2016	77000	20.06	1545000

Source: FAOSTAT, (2017).

According to result of digital data collected knoema.com in 2019, sugarcane yield for Nigeria was 166,728kg per ha. Though Nigeria sugarcane yield fluctuated substantially in recent years, there were tended to decrease through 2008-2019 period, as represented in table 2.2

Table 2.2 Sugarcane Production in Nigeria from 2008 – 2019

DATE	VALUE (Kg)	CHANGE, (%)
2019	166,728	-1.08
2018	168,549	-1.08
2017	170,369	1.30
2016	168,179	-0.57
2015	169,151	-2.03
2014	172,649	-1.34
2013	174,997	-2.53
2012	179,538	-2.46
2011	184,069	-1.07
2010	186,055	-3.02
2009	191,853	-2.33
2008	196,421	

Source:knoema.com (2019)

2.8 Socio-economic Characteristics of Sugarcane Farmers

Aina *et al*. (2015) examined the socioeconomic characteristics of farmers on economic analysis of sugarcane (*saccharum officinarum*) production in Moro Local Government Area of Kwara State, Nigeria and found that majority of the farmers were male (65%). The dominant age group of the respondents was 31 – 40 years (70%) and 75% of the farmers had more than 10 years of farming experience. Girei and Giroh (2012) conducted a study on analysis of factors affecting sugarcane production under the out-growers scheme in Adamawa State, and reported that majority of the respondents (60%) were males who engaged in sugarcane production in the study area while 40% were found to be females. This could be attributed to the fact that sugarcane production is strenuous, labour intensive and hence more males are found in sugarcane production than females.

The results of socio-economic characteristics of farmers in Mubi North Area of Adamawa State according to Anaryu (2017) shows that majority (97.5%) of the farmers were male and fall within the age of 41 years and above. About 25% of them had no formal education; while 75% have one form of education or the other. They cultivate average farm size of 1 – 2ha.Tashikalma *et al*. (2014) examined the socioeconomic characteristics of farmers under irrigation and rain-fed farming system in Adamawa State, Nigeria and found that 54.29% of the farmers under rain-fed and 69.02% under irrigation were in their productive years of 31-50 year of age. Also, 74.28% and 53.33% of the farmers attended one level of formal education or the other. Similarly, 58% of rain-fed and 78.11% of irrigated farmers cultivated less than 2 hectares of land while 92.38% and 89.48% had more than 10 years farming experience respectively.

The result of socio-economic characteristics of farmers in Yola North and South of Adamawa State, Nigeria were examined by Abdul *et al*., (2016) and the result results revealed that the respondents had a mean age of 39 years and have large household size of family (8-15 member). The sampled farmers are experienced and with farm size on average two hectares of land. Also the respondents acquired one form of formal education or with primary school at least. Babalola *et al.,* (2013) in a study carried out under assessment of the influence of government intervention programme on sugarcane production in Nigeria: evidence from Jigawa State, reported that farmer’s year of experience in farming is expected to increase quality and quantity of output by reducing pre-harvest and post-harvest losses and increase efficiency of the farmers.

Giroh (2012) conducted a study on the efficiency of latex production and labour productivity in rubber plantation in Edo and Delta States, Nigeria. The result revealed that age, extension contact and farm distance enhance the allocated efficiency of rubber farmers in the study area. Zalkuwi *et al.* (2014) analyzed the determinants of cost efficiency in cowpea production in Adamawa State, Nigeria using stochastic cost frontier. The inefficiency models used revealed that socio economic variables, namely: family size, farming experience, gender and extension contact had significantly reduced cost inefficiency among the farmers in the study area.

2.9 Productivity of Sugarcane Production under Rain-fed and Irrigated Farming Systems

Mbuyazwe and Barnabas (2012), studied the relationship between the amount of sugarcane harvested in relation to farm size in Swaziland and observed that large scale farmers get the highest level of yields, with the medium and small-scale farmers coming second and third respectively. They found out that sugarcane productivities were influenced by three variables: distance from the farm to the mill, hand application fertilizer man days and strength of labour. Distance from the mill had a significant effect on the productivity as they found out that yield reduced by 0.44 ton per hectare for every 1 kilometre change in distance between the mill and the farm. Management practice and farming inputs such as fertilizer, pesticides, etc. were also important determinants of the level of sugarcane productivity in their study area as they concluded.

Ikeme (2009) reported that Nigeria is currently experiencing increasing in incidence of disease and this bring declining in agricultural productivity. Many disease epidemics related to red rot, smut, wilt, yellow leaf disease, grassy shoot disease along with leaf scald occur at timely intervals and affect the crop badly at its severity. In a year, around 30–40% yield losses are estimated due to the several diseases associated with the sugarcane crop in sub-tropical zone (Viswanathan and Rao, 2011).

According to Viswanathan and Rao 2011, development of new biotechnological and molecular diagnostic protocols contributed significantly for authentic diagnosis of fungal, bacterial and virus diseases of sugarcane at different stages of growth and development. Breeders always attempt to evolve varieties resistant to the diseases especially red rot, wilt and smut to avoid the losses caused by them. Early detection of incipient pathogen through serological and molecular techniques would help to check the spread of the disease at early stage of infection. Selection of healthy certified seed materials and seed treatments with fungicide before planting also helpful in preventing fungal diseases. Hot-water treatment at 50 °C for 2 hours would help to prevent sett-borne disease like sugarcane mosaic virus, grassy shoot disease and ratoon stunting. Also, use of disease-resistant varieties along with healthy seed nursery programmes would form the basis to successful managing the diseases/pests in sugarcane and this eventually helps to check the losses caused by the diseases/pests.

2.10 Costs and Returns of Sugarcane Production under Rain-fed and Irrigated Farming Systems

Sulaiman *et al*. (2017) conducted a study on profitability of sugarcane production and its contribution to farm income of farmers in Kaduna State, Nigeria. The result showed that the net farm income of sugarcane farmers in the study area per hectare was₦78,036.05k.The result also revealed that the average return on investment was ₦1.83k; meaning that for every ₦1 invested in sugarcane production in the study area, a profit of ₦1.83 k was realized by the farmers. There was an indication that sugarcane production in the study area is profitable and contributed averagely to about 19.55% of the farmers' annual farm income.

In a study conducted by Aina *et al*. (2015) on economic analysis of sugarcane (*saccharum officinarum*) production in Moro Local Government Area of Kwara State, Nigeria. They found out that sugarcane production in the study area was profitable as the farmers realized an average net farm income of ₦27,100.21/ha with a return of

₦1.88 per every naira invested. The study also showed that the most important determinants of sugarcane production in the study area were farm size and sugarcane sett, which were significant ($P < 0.05$ and $P < 0.01$) respectively. In the same vein, Masuku (2011), the profitability of cane farming is determined by yield per hectare, sucrose content in the sugarcane, the farmer's experience in farming and the distance between the farm and the mill.

Yusuf *et al*. (2018) assessed the profitability of Egusi (melon) under sole and intercropping system in Okene Local Government area of Kogi State, Nigeria and found out that the average net farm income per hectare for sole melon and two, three and four crop mixtures were ₦1,328.68, ₦915.77, ₦887.27 and ₦414.57 respectively; the total gross return per hectare for melon (pooled data) averaged N12,638.61 while the total cost of production was ₦8,838.74 on average and the total net farm income per hectare for both sole and mixed (pooled data) melon was ₦3,799.00 on the average, implying that Egusi production was profitable in the study area.

The results of farm budgeting analysis from the study of Tashikalma *et al*. (2014) revealed an average gross margin of ₦45,448.63 per hectare under rain-fed production while under irrigated farm an average gross margin of ₦53,904.68 per hectare was obtained, the results of the profit function analysis under rain-fed condition shows that labour was significant at 1% level and inversely related with profit. However, farm size, seed, and fertilizer were positively related to profit and significant at 1%. Similarly, under irrigated condition labour was significant and inversely related to the profit. Land, fertilizer and agrochemicals were significant at varying levels and positively related to profit.

Anaryu (2017) conducted a study on cost and return analysis of sugarcane production in Mubi North Local Government Area of Adamawa State, Nigeria and found that the average total revenue/ha, average variables cost/ha, gross margin, average gross margin/ha, average total fixed cost/ha and the net from income for sugarcane production in the study area were ₦500,762.50, ₦222,156.06, ₦65,828,933.94, ₦168,852.44, ₦909.10 and ₦26,915.44, respectively. Ayinde *et al*. (2011) examined the profitability of fluted pumpkin and found that the net farm income to be N116, 891.39 per hectare in their study area, thereby showing how profitable the crop was.

In a study on the Economic Evaluation of Chewing Sugarcane in the Central Zone of Nigeria carried out by Wayagari *et al.* (2013) showed that the gross revenue on chewing (soft) sugarcane production in Benue state is ₦103,578/ha at a market price of ₦3000/tonne. The average output is 35.5 tonnes per hectare. The total cost of production is ₦46,667/ha. The resultant net return is ₦56,909/ha. The net return per each Naira invested in chewing sugarcane production is ₦1.22. Labour cost had the highest operating expenses and that constituted 68% of the total production cost. Ramarao *et al*. (2011) conducted a study on the costs and returns on value added products of sugarcane in order to suggest to how profitable and how to sustained it. The result revealed that cost of cultivation of sugarcane is the prime factor in the various value-added products.

Abdulrahman *et al*. (2015) examined profit efficiency of cocoyam production in Kaduna State. The result of their finding revealed that the total revenue (TR) was ₦290,076.7 while the total cost (TVC + TFC) was ₦171,760. The net farm income was therefore ₦118,316.7; the average rate of return on investment (return per naira invested) was 1.69, indicating that for every ₦1 invested in cocoyam production in Kaduna state, a profit of 69 kobo was made. Thus, it could be concluded that cocoyam production in the study area though on a small scale, was economically viable. Ramarao *et al*. (2011), estimated in their study that TVC of sugarcane cultivation in North Coastal districts was Rs.0.95 lakhs with Benefit-cost Ratio of 1.49. Thus, there was an increase of Rs.10000 per hectare in TVC in a span of a year in the study area.

Girei and Giroh (2012) also conducted a study on profitability analysis of sugarcane (*saccharum officinarum*) production in Numan Local Government Area Adamawa State, Nigeria. They found that the gross farm income was ₦38,625.83 while the NFI was ₦l7,666.83/ha. Similarly, the return/naira invested in the production of sugarcane by the out-grower farmers was ₦0.84 implying a positive return of 84 Kobo on every ₦1 invested, showing that production is profitable in the short run. Sunibabu *et al.* (2011)in their study estimated that the TC of sugarcane per hectare in irrigated conditions was Rs.1.72 lakhs with TVC is Rs.1.05 lakhs for plant crop. In case of ratoon crop the TC of production was Rs.1.08 with TVC Rs.0.64. In TVC labour cost constitute 30 to 33 percent and this shows the intensive nature of labour in sugarcane cultivation.

2.11 Concept of Agricultural Technologies

This is use of technology in agriculture, horticulture, and aquaculture with the aim of improving or increasing yield, efficiency and profitability. Agricultural technology (abbreviated agtech, agritech, Agri Tech or agrotech) can be products such tractors, ridgers, harvesters, sprayers etc. or the applications derived from agricultural knowledge that improve various input or output processes. In general, to create more sustainability in agriculture, farming practices requires adopting a new technology for crop management, pest control, quality control and integrated diseases management. The new technologies like smart farming automation among others, which involving automating the production cycle of crops and livestock allow current and future generations of farmers to grow without compromising the needs of the earth such as increase of global population, farm labour shortages and changing in consumer preferences. The advance in agricultural science, agronomy and agricultural engineering have led to development of agricultural technologies by the scientists or technologists. Some of these new technologies in agriculture include, sensors to monitor temperature, humidity, water content, plant moisture, light and carbon iv oxide (CO_2) levels others are equipment to control irrigation, shade, heating, cooling, humidifying, lighting, and even harvesting. Others are remote management of scheduling, plant growth, supplier pricing and energy consumption to mention a few. Scientists saw future agriculture and then began to use more sophisticated technologies such as robots, aerial images, and global positioning system (GPS) technology in farming and rearing activities.

These advanced technologies, precision agriculture and robotic systems will allow agriculture to be more profitable, increase efficiency, safe and manage costs and environmentally friendly. Through soil DNA technology, the farmers can test microbiomes and organic matter to analyze health metrics of their soil and take better care of them to predict and prevent crop damage. Other identified new agricultural technologies are precision agriculture that is developed to help farmers to maximize yield by controlling moisture level, pest stress, and soil condition and other micro-climate.it enable the farmers to increase efficiency and manage costs.

Smart sensor, this is one of the most successful agricultural technologies across the globe. The remote sensor satellite and UAVs can gather information 24 hours over an entire field. They monitor crop health, soil condition, temperature, humidity etc. They are cost effective and beneficial for agriculture, can scan a field from sky via drones to detect dry patches and nutrient deficient area of the field.

Al-enabled self-driving tractor: it is automated farming equipment that can work round the clock to bring higher yield in reduced time because the farmer can scale operations from a few thousand acres to ten thousand acres and it provides solution to labour shortages and time constraints.

Laser scarerows, this is an effective agricultural device that was invented by University of Rhode Island to keep pests away from the field such as starlings, blackbirds, crows etc. that can destroy up to 75% of crops if allow with 48 hours of harvest, leading to a huge loss of revenue.

The use of traditional scarerows or propane cannons did not prove effective to combat the bird pest issue. Many pest control companies have adopted this new technology and they claim the device can prevent up to 90% of crop losses.

Harvest Quality Vision (HQV) is one of recent agric.tech innovation/technology that simplified the harvest processes of fruits and vegetables. It uses computerized scanners to capture and determine the quality and quantity of crops. The software creates alerts whenever there is disease, defects and quality shortages of crops so that corrective measures can be taken in the harvest processes. Moreover, HQV helps farmers to produce more consistent crops of higher quality especially for apple grading and sorting through crop tracker.

Vertical Farming is one of the oldest and most bought-after agric.tech technologies. It is a vertical stacked layers production such as in a skyscraper, used warehouse or shopping container. This type of new farming method uses indoor farming technique and controlled environment agriculture (CEA) technology to control environmental factors (climatic factor). Vertical farming might be the salvaging solution with urbanization and industrial development of countries come a loss of arable land for farming activities.

According to Ibrahim, M (2018) Technological Change in Rural Societies, technology could also be defined as the translation of scientific law into machines, tools, mechanical devices. However, agricultural technology is viewed as representing much more than mechanization, it including: introduction of new farm inputs such as compounded fertilizers tailored to particular soil and crop, use of different insecticides and herbicides, new irrigation systems, and the introduction of new plants (seeds) varieties to mentioned a few, that are immune to fungi and other diseases, less sensitive to sunlight response, short stalk and earlier maturity that resulted to more yield and profits. Moreover, agricultural technology could be grouped into two: material technology which is made of material implements, equipment, hand tools, and machines like tractors, knap sac sprayer, harrows, etc. these are materials man can see with their naked eyes. The second agricultural technology is the knowledge based technologies which involve use of skills and knowledge application or technical-know-how such as mixing of inputs (herbicides, fertilizer).

2.12 Improved Technology Utilization in Sugarcane Production

Variable-rate technology (VRT):This allows fertilizer, chemicals, lime, gypsum, irrigated water and other farm inputs to be applied at different rates across a field, without manually changing rate setting on equipment or having to made multiple passes over an area, especially for spraying fertilizer and water irrigation. Sugarcane production is a common agricultural activity that can be completely automated with the correct implementation of variable-rate application technology. Venkatachalam and

Ilamurugu (2011). This is through: Firstly; zoning/management zones, by separating parts of a field with different material to be applied. To dictate which zones the machines should apply specific material to, otherwise you may be setting yourself up for a problem, therefore this is first step when applying fertilizer or irrigation water. With variable rate application technology is to set proper management zones. It is also important or crucial to make sure this information is properly inputted into VRT system itself. Secondly; map-based and sensor-based, this is where map is generated on the landscape and inputted into the system before the system goes about its activities. The sensor-based where the variable rate application technology integrates sensor that can automatically detect the data that will help it decide which chemical or water or fertilizer should be applied, it could also sense the crop health and made a decision based on that. And thirdly data and imagery devices- after selecting map-based and sensor-based, the next step is to determine what type of data the sensor should collecting or what short of imagery should be used in the mapping.

Many VRT utilizes drones or other imaging system to detect information about the landscape, others include sensors on the application hardware itself, examples of machinery-based sensor are, N-sensor from Yara, Isaria from Fritzmeier and Green Seeker from Trimble. Some of the information that is relevant for applying fertilizer for example would be things like soil quality and material (soil type); type of crop; climate information and speed at which the vehicle is travelling while applying the fertilizer for example. All of this information and more, is made available through the variable-rate application technologies that are being used. The benefits of VRT; it is used for many application or activities on the field or farms such as herbicides, lime and other chemicals, seeding, and the detection of weeds and diseased crop on the field. Overall, VRT is primary used for both detect information about a given landscape and to have a system make decision based on the information. The decisions that are made by the VRT system determine which material should be applied to the field or farm. The benefit of having a VRT system is that it can help automate this part of the agricultural process. The more automation and precision that a company or farmer introduces to their farms operations, the more money they saved through higher production and efficiency. Thus, saving on fertilizer and chemicals, based on a study at the University of Illinois, the farmers can save about 5USD per acre due to a VRT for nitrogen fertilization and also there is potential yield increase due to more efficient fertilization and spraying based on actual crop needs and variability of fields. There is also environmental protection from excess fertilization or spraying of chemicals.

Ratoon management: Ratooning is a method where the lower parts of the plants along with the roots are left uncut at the time of harvesting. This is one of improved agricultural technologies commonly followed and practice in sugarcane cultivation; there is a saving in cost of cultivation in terms of land preparation, seed canes, etc. and if ratoons are well maintained, they give greater high yields. Never the less, to get a better ratoon crop, a better planting seed is necessary. Generally, within a week after harvesting the plant crop (sugarcane); ratoon management practices like stubble shaving, off baring, gap filling etc., should be initiated. For a better ratoon crop, trash mulching/shredding should be done manually or mechanically after harvesting of plant crop and organo-decomposer (Tricoderma at 10–15 kg/ha) should be apply for decomposing of trash and improving organic carbon in the field. Application of chemical fertilizer (N-100Kg, P-80Kg, K-60 Kg) along with bio-agents (Azotobactor, PSB, Trichoderma at 10 kg/ha each) along with organic manure at 10 t/ha followed by hoeing at proper moisture and the remaining dose of nitrogen should be applied at the tillering phase for a better ratoon yield (Singh *et al*., 2018).

The crop raised from planting cane sett is called crop. After the harvest of plant crop, the stubble sprouts and give rise to succeeding crop called ratoon crop. The practice of taking up ratoon crop is called “ratooning”, examples of good ratooners are Co1148, Co 419, Co740. A better ratoon crop is an answer to improved recovery, reducing cost of production and increased productivity sustainability and these could be bringing more income to the farmers. Efforts to enhance ratoon yield (90 t/ha) through suitable agronomic packages and physiological interventions will surely help in increasing the income of farmers. One of the major reasons for adopting sugarcane crop production over the other crops among the farmers lies in taking 2–3 ratoon crop so as to augment the high cost of sugarcane seedlings; however, poor management practices of the field and ratoon crop could lead to substantially reduced yield of ratoon.

Advantages of ratooning are, it reduces cost of field preparation, planting material, operation cost and overall ratoon matures earlier than plant crop, thereby saved field duration, and it may give equal yield than that of plant crop. In ratoon management select suitable variety during plant crop and plant crop should harvested at right maturity phase or stage, delayed harvest should be strictly avoided. Harvest close to the ground with sharp cutting. Stubble shaving up to 4-6cm is recommended and there should be uniform cut at harvest. Remove the trash and do not burn it. Thereafter, irrigated the field properly and remove decayed stubbles and gap filling with sprouted setts or seedlings. Ratoon is less efficient in N utilization, hence, add N from 5-7 days after ratooning is very desirable, also P and K should be judiciously added. Spraying of $FeSo_4$ @ 2.5 Kg/ha in 150 litres on 15 days if chlorotic symptom is noted. If it persists repeat twice at 15 days’ interval, in the last spray add 12.5 Kg urea. Ratoon requires more plant protection from Glassy shoot disease and ratoon stunting,Venkatachalam and Ilamurugu (2011).

Pit or Ring Pit Method of Sugarcane Cultivation: In pit method the crops are raised in pits at a spacing of 180 between rows and 15cm between pits in a row. The pits are dug using specialized designed tractor draw power tillers. The pits are then filled with top soil, 5 Kg of farm-yard manure (FMY), 100gms gypsum and 125gms of superphospate and then water well before now planting. About 16 double or 32 single budded setts were used for the planting. The setts are collected from 8 month-old plant and are treated with 0.1 per cent carbendazim for 10 minutes before now planted. About 60,000 double budded setts required for planting one hectare. The pits are irrigated daily for an hour through drip fertigation. Detrashing should is done on fifth month after planting, the plants were tied without lodging by dried leaves. Due to the equal spacing maintained on all the sides, this gives stead growth and the supply of plant nutrients through fertigation reduced the crop duration on the field. The continuous supply of nutrition and spacing induces the early physiological maturity, and this is the major benefit. Also all the shoots are of the same age, so there is uniform growth and high accumulation in the canes. Sufficient spaces between the clumps and row to row allows sufficient light and air circulation which is very important for good growth of the crops. Generally, it is cost-effective and at the same time help the farmers to get high yield. Several farm trials have proved that adopting this method, the yield can be increased to two or three times compared to the normal row to row planting techniques. Under the conventional system or this special pit or ring pit method of sugarcane production, farmers in Tamil Nadu are presently harvesting 130 tonnes per hectare.

Measures to obtain higher germination, the farmer should use disease freed, healthy setts, and carefully prepare the setts without damaging the buds or the setts. Always plant freshly prepared and treated buds or setts with fungicides and trash mulching under moisture stress or hot weather or under late planted situation.

Other cultural improved technologies practice in sugarcane cultivation involved some operations that being carried out after planting of seedling, the setts, including; the detrashing, the propping, the earthing-up, fertilization and manuring, irrigation and flowering control.

Detrashing: On the average, a stalk may produce 30-50 leaves, all are not useful for effective photosynthesis, only 8-10 leaves are sufficient, most of the bottom leaves that are dried will not participate in photosynthesis and at the same time they are drain out the food materials which otherwise could be used for stalk growth. Therefore, it is important to remove the lower, dried leaves. This operation is known as detrashing. The detrashing helps in clean cultivation, easy movement of air within the crop canopy, it reduces certain pests like scales mealy bugs, white fly. It allows easy entry into the field. It disallows buds germination due to accumulation of water in the leaf sheath. Make harvest easy and clean cane is obtainable for milling. Detrashing leaves can be used for mulching in the furrows or used for composing and it enable the farmer to burnt out infested leaves by pests and disease.

Propping: This is tying the canes by using the lower bottom leaves to check lodging of cane. Propping can be either done for each row or two rows can be brought together and tied. The important of propping are: to prevent lodging, extensively in the coastal belt where cyclone effect is very severe, also as lodging commonly found in tall varieties of sugarcane, top growth is heavy where the growth habit is not erect type and or the variety with less fibre content.

Earthing-up: Usually practice on the furrows and always performed 2-3 times during crop life time on the field. The first earthing-up is known as “partial earthin-up” and this is done to cover the fertilizer; to provide anchorage for the root system. The second earthing-up is called “full earthing-up” and this is done after the second or final manuring, (about 90-120 days this usually coinciding with peak of tillering). The soil from the ridges is thrown on both sides toward the cane rows and then the farrow will then become the ridges and the ridges as farrows and the now formed farrows are now used for irrigation. Wet earthing-up, this is an operation is done around 6 months’ age of the crop, the furrows are irrigated and the wet soil from furrows is taken and plaster the ridges, it checks the tillering and watery shoots. Heavy earthing-up is useful during floods, when the flood water recedes, the excess water from earthing-up soil drains out quickly thus providing aeration, Venkatachalam and Ilamurugu (2011).

Fertilization and Manuring: Singh *et al.*(2018) reported that fertilizer recommendations based on the targeted yield need to be developed for sugarcane crop in different climatic zones. Soil health cards should also be prepared and made available to each and every farmer for balanced application of fertilizers for increased sugarcane and sugar productivity. Application of organic manures along with inorganic fertilizers plays a major role in boosting up the macro- and micronutrient content in the soil and this enhances the physio-chemical and biological properties of the soils at large. Always apply FYM or compost manure during field preparation and the following inorganic fertilizer are required as demanded by the soil and the crops:

For coastal or plain and flow irrigable areas: 270 :112.5: 60N: P_2O_5:K_2O Kg/ha. Note N and K should be applied in three equal quantities at 30, 60 and 90 DAG. The N may be coated with neem cake @ 20%.

For lift irrigated areas: 225: 112.5: 60N:P_2O_5: K_2O Kg/ha

For Jaggery producing areas: 175:112.5: 60N:P_2O_5: K_2O Kg/ha.

For those soils deficient in:

Iron :100 Kg Ferrous sulphate/ha

Zinc: 37.5 Kg Zinc sulphate.

Foliar application and drip fertigation can reduce N dose but increase cane yield and save ground water pollution by fertilizers. Azospirillum application enhance cane growth, so also band placement of fertilizer is another method by which losses can be minimized or reduced.

Irrigation: Sugarcane seedling or setts are best raised in nursery site, and water supply is necessity to support and sustain a vigorous growth of these nursery crop, any shortage in the irrigation practice both in the nursery and the field lead to poor yield, also moisture stress will pre-dispose the both the setts and crop to some attack pests and diseases.

Irrigation: This is doneat /W/CPE/ ratio of 1.0 is very ideal, although according to moisture depletion irrigating at 25% of available soil moisture(ASM) may be as well ideal. This in practical means once in every6-7 days in a loamy soil and also at about 10-12 days in a heavy clay soil.

Maturity and Harvest:According to Venkatachalam and Ilamurugu (2011), ripening of sugarcane refers to rapid synthesis and storage of storage of sucrose in the cane stalk. Accumulation of sucrose in the stalk starts soon after completion of elongation phase. Glucose produced during photosynthesis is not utilized for conversion but stored as sucrose. When the concentration exceeds 16% in the juice and 85% purity the cane is said to be matured. As the crop advances in maturity, the water content decreases and the sucrose content increases. Both organic and inorganic non-sugar also decrease and at peak of maturity sucrose content is at maximum and the non-sugar are at minimum. To assess sugarcane maturity, we can use hand refractometer (HR Meter). The brix reading, 18-25% indicates optimum maturity, when the reading between top and bottom is 1:1, it is right time to harvest, if delayed the sucrose content decreases and non-sugar and fibre content increased.

Ripening of Sugarcane: This is influenced by number of factors; the prevailing climate, soil nutrients and the variety of the sugarcane planted. Cool, dry weather is the key factors, bright sunshine with the day temperature of 28-30 ^{0}C and the night temperature of 12-14 ^{0}C. Some of the ripening agents are spraying of sodium metasilicate, 4 Kg in 750 l/ha six months after planting and should be repeated at 8th and 10th months and not at declining phase, or Polaris @ 5Kg in 600 l/ha

Control of flowering: In commercial sugarcane cultivation, flowering is not desirable. Once the plant flowered the cane growth stops and starts ripening. If not harvested immediately reversion of sugars, increase in fibre, pith formation, cane breaking etc. followed. The deterioration is much faster if it is summer. The solution of flowering or to inhibit flowering in sugarcane cultivation could be through the use of non-flowering or shy flowering varieties, where flowering is a severe problem, also controlled irrigation can be adopted, change of planting period, or use of growth regulating substances such as spraying of ethrel at 500ppm, twice or 1000ppm once at floral initiation. Venkatachalam and Ilamurugu (2011).

In India, Ramaiah (2011) highlighted that, there is need to save power as much as possible, in the present circumstances existing in the country. Indian sugar factories have adopted very significant and laudable technological innovations to save considerable amount of steam energy, and generated electrical energy by using saved bagasse, and exported the same to the grid. Selection of appropriate early and mid–late varieties can increase sugarcane production; the efficiency of the sugar industry mainly depends on availability of high-yielding and high-sugarcane varieties in adequate quantity.

Studies by Singh *et al.* (2017) emphasized that a proper balance of early and mid–late maturing sugarcane varieties is very important for longer crushing periods with higher sugar recovery. The cost of production of sugar and profitability of the sugar industry besides many other factors depends primarily on the availability of sufficient quantity of good-quality sugarcane. If early-maturing high sugared varieties are available with optimum sugar content during the 1st and 2nd months of crushing season, each ton of cane crushed would be worth for better production.

Murali and Balakrishnan (2011) stated that labour scarcity coupled with high labour wage rate has greatly affected the irrigation practice and harvesting of sugarcane crop in time. It has reduced sugarcane area from 3.91 lakh/ha to 3.14 lakh/ha in Tamil Nadu. Modern sugarcane machinery and labour-saving devices were introduced on a large scale to reduce dependency on labour, and finish different farm operations in time. The study has found the mechanical operations to be superior to manual operations in sugarcane cultivation and this have reduced cost of production and have enabled efficient utilization of resources with better work output.Mandla and Masuku (2012) observed that profitability in sugarcane was realized through good and proper crop husbandry practices like observing time in weeding, applying fertilizers and irrigating the crops. They observed that the size of the farm, costs of labour and fertilizers and experience in farming in terms of time the farmer had in farming have a critical role on the amount of harvest hence influencing the profitability to cane growers.

Maraddi *et al*. (2017) studies on analysis of farmer's knowledge about selected Sustainable Cultivation Practices (SCP) in sugarcane production in Belgaum and

Bagalkot District of Karnataka, revealed that, more than half of respondents (53.33%) had medium knowledge level of selected SCP. However, higher knowledge was observed in land preparation, planting related SCP, and use of FYM, mulching, inorganic manures (NPK) whereas least knowledge noticed in bio fertilizer. It was revealed that, the compost and micro nutrients, education, farming experience, risk orientation, attitude towards SCP, management orientation, achievement motivation, innovative proneness and extension contact of respondents had positive and significant relationship with the knowledge level of selected SCP.

On use of mechanical for harvesting, Yadav *et al*. (2018) studies revealed, that cultural operations for sugarcane production are very arduous especially planting, inter culture, plant protection and harvesting. Modern sugarcane machinery is labour-saving devices and reduce the cost of sugarcane production; help in completion of operation timely thereby reduce human drudgery and enable efficient utilization of resources with better quality work output. In general, it helps in increasing overall production and productivity. For example, in India, sugarcane planting requires about 350 man-hour and 30.6-bullock pair-hour/ha with the cost of operation of Rs3987 in conventional system of planting, as against mechanical planting requires Rs 2200/ha with the engagement of 20-man hours. Sugarcane cultivation requires high labor input right from the planting of the seed to harvesting of the crop. However, scarcity of labor is usually observed during pivotal cultural operations and the condition is severe nowadays. It has been calculated that sugarcane cultivation being a labour-intensive crop, almost 60–70% of cost of production of sugar lies in cost utilized in the production of sugarcane (Nagendran, 2014). However, utilization of machinery like, automatic cane planter, cultivator, harrow rotavator, hoeing machine, power sprayer and ratoon management device (RMD), one could save almost 40–50% of total cost of production. Conclusively, production cost could be significantly cut down by introduction of mechanism-based sugarcane farming. The non-use of machinery causes a lot of pressure on demand of labor in sugarcane growing areas which results in scarcity as well as high wage rates during peak seasons. Hence, there is a need to introduction of sugarcane de-thrasher-cum-harvester especially in the areas where harvesting is carried out by paid labors. And apart from reducing cost of production, mechanized harvesting will also ensure well-timed operations, better quality work, cutting of human drudgery, etc. This will also impart timely clearing of the field for next crop and increasing overall productivity (Singh *et al*., 2018).

Dharmawardene (2018) studied the trends in farm mechanization by sugarcane small land holders in Sri Lanka. He found that the mechanization of farm power is becoming extremely important day by day for the survival, efficiency and competitiveness of all field and plantation crops of the country. Also found that sugarcane crop grown in the dry zone is no exception. Although, these areas have low manpower due to low population densities and harsh climatic conditions and remoteness of locations from major cities. In addition, manual work gets easily tired while working in the dry zone with the hills due to higher temperatures, harder soils, insolation and dry desiccating winds. Thus, scarcity of labour is common in sugarcane areas for manual work. This reduction in cane quality due to delay in processing not only affects sugar industry but also the cane growers significantly. The delay in supply of harvested cane to sugar factory could result into major economic loss to cane farmers. The most efficient solution for the issue of post-harvest losses is proper, quick and efficient communication between the growers and the industry personnel which will reduce the cut-to-crush delay. For best results, the harvested cane must be processed within 24–48 hours of harvest.

Bio-technological techniques and genetic engineering can be a powerful tool to alter the physiological features and sugar content of the sugarcane. For example, introducing genes responsible for high sugar content, thick stem, shorter leaves and resistance to diseases etc. In the last two and a half decades, several biotechnological tools have been developed to improve various yield- and quality-related traits in sugarcane. Various molecular marker systems have been developed for diversity analysis, varietal identification and trait mapping studies (Swapna and Srivastava, 2012).Biotechnological tools augment the breeding process in two ways; first, by searching for desirable genes or alleles either from other genotypes or cultivars of sugarcane or from related genera with which sugarcane could not hybridize easily, and second, by placing such genes into sugarcane to confer adaptability to climatic changes and biotic stresses. Moisture stress including waterlogging and drought, along with salinity are the crucial environmental factors that adversely affect sugarcane productivity.

As sugarcane is among highly perishable crop, it must be processed into sugar as soon as it is harvested. The delay in processing causes many folds' reduction in cane tonnage as well as sugar recovery (Singh *et al*., 2018).

2.13 Irrigation Technology

2.13.1 What is irrigation?

According to Stephanie Obasanho (2017). Irrigation is the process of applying water to soil, primarily to meet the water needs of growing plants. Water from rivers, reservoirs, lakes, or aquifers is pumped or flows by gravity through pipes, canals, ditches or even natural streams. Irrigation could be an artificial process of applying controlled amount of water to land or field to assist in producing of crops. It is also to grow landscape plants and lawns, where it may be known as watering. It is a process of water supply to fields lacking moisture. Applying water to fields enhances the magnitude, quality and reliability of crop production. According to the Food and Agriculture Organization of the United Nations, irrigation contributes to about 40% of the world's food production on 20% of the world's crop production land. It increases water content in the root layer of soil in order to increase soil fertility.

Though it is necessary to bear in mind the fact that some plant prefer dry soil and some plant prefer dry soil and need moisture or water. Before applying an irrigation farming system in Nigeria, you have to study the peculiarities of plants you are going to produce. There are two types of irrigation systems: low flow and high flow. Both can be used in the same field or farm if needed. Low flow system refers to micro spray, drip emitters or drip lines. High flow systems are fixed spray, rotor, impact, bubbler, and soaker hose.

According to the International Commission on Irrigation and Drainage, surface irrigation is used on about 85% of the 299 Mha of irrigated crop land in the world. India and China each irrigate more than 60 Mha of crop land, accounting for almost half of the irrigated land in the world (FAO, 2014). India the top is country by surface irrigation in the world and has the largest network of irrigation canal. As of 2017, surface irrigation in India was 68,172.06 thousand hectares that account for 26.85% of worlds surface irrigation. In Africa, Algeria, ranks 52nd, Mali, ranks 61st, while Nigeria, ranks 69th in world ranking of surface irrigation system. Pakistan has the world's largest irrigation network with best canal irrigation system which serves 14.4million hectares of cultivated land. The canal is fed by water from Indus. The countries with largest extent of areas equipped for irrigation with ground water, in absolute terms, are India (39 million hectares), China (19 million hectares) and USA (17 million hectares).

2.13.2 Why irrigation is needed in sugarcane production

Irrigation is necessary for the absorption of nutrient by plants from the soil. Water is absorbed by the plant root. Along with water, minerals and fertilizers are also absorbed. Irrigation is necessary to provide moisture to germination of seeds because germination of seed, does not take place under dry condition.

2.13.3 Methods of irrigation systems

On types and methods of irrigation (Irrigation.com, 2018). Various irrigation methods have been developed over time to meet the irrigation needs of certain crops in specific areas. The three main methods of irrigation are surface, sprinkler and drip/micro. Sprinkler irrigation applies water to soil by sprinkling or spraying water droplets from fixed or moving systems. Micro-irrigation applies frequent, small applications by dripping, bubbling or spraying, and usually only wets a portion of the soil surface in the field. A fourth, but minor method of irrigation is sub-irrigation where the water table is raised to or held near the plant root zone using ditches or subsurface drains to supply the water.

2.13.4 Surface irrigation method

Surface irrigation entails water flowing by gravity over soil. Water is usually supplied by gravity from the water source through canals, pipes or ditches to the field. In some locations, however, water may need to be pumped from the source to a field at a higher elevation. Types of surface irrigation systems include furrow, basin and border irrigation. Surface irrigation systems are typically used for field crops, pastures and orchards. Water flows over the soil by gravity for surface irrigation. This method has three variations; border/bay strips, furrows and flooding.

Border/bay strip irrigation method - when using bay/border strip method, the water moves along parallel their ridges on the surface that are diagonal in a long strip and in the process of moving the water is absorbed into the soil. Basin and border irrigation systems are similar in that both involve a uniform sheet of water flowing over the soil. The general difference is that basin irrigation involves applying water to a nearly level field and may include ponding for extended time periods. With border irrigation, water flows between dikes that divide a sloping field into rectangular strips with free drainage at the end. The purpose of the dikes is to contain water as it flows across the field, unlike basin irrigation where the dikes pond the water. Furrow Irrigation is when furrow is irrigated with water, flows in evenly spaced furrows or corrugates that are typically 0.1–0.3 m wide on fields with slopes of 0.1–3%. Water commonly flows in furrows for 12–24 hours during irrigation, however, shorter or longer durations may be used depending on furrow length, soil properties, and water management considerations. When watering fields by furrows, running waters soaks into the soil through the bottom and sides of furrows in the process of moving. Such method is mainly used for growing maize and vegetables. Low inflow rates and long irrigation durations may be needed to apply the desired amount of water during irrigation on soils with low infiltration rate.

Conversely, higher inflow rates are often needed on fields with low slopes and/or high infiltration rate soils in order for the water to flow across the field and uniformly irrigate the upper and lower portions of the field. Flood irrigation: A small area is surrounded by soil ridges from all the sides; it is filled with a layer of water, which is then seep into the soil. The water comes from lakes and rivers, wells and boreholes. Surface Irrigation is characterized by the following features.

1. Water is carried out periodically, water reserves are accumulated in the upper soil layers, consumed in irrigation intervals

2. It is possible to reach different depths
3. Large fluctuations in the soil moisture between watering.
4. After watering the soil crust is formed on the entire wetted surface, which reduces aeration, nitrification and Increases evaporation from the soil surface
5. Crip crust prevents the appearance of weeds

Although such irrigation network system can relatively affect working conditions of agricultural machinery. This surface type of irrigation allows you to:

1. Get the only capillary hydration of the upper layers
2. Maintain a certain depth of moisture
3. Greatly reduce water evaporation from the soil surface
4. Provides a continuous supply of plants with water
5. Does not restrict the work of agricultural machinery.

2.13.5 Sprinkler system method

Sprinkler irrigation applies water to soil by spraying or sprinkling water through the air on to the soil surface. Water is pressurized and delivered to the irrigation system by a mainline pipe, which is often buried so it does not interfere with farming operations. Three main categories of sprinkler irrigation systems are solid-set, set-move and moving. Sprinkler irrigation is used for a wide variety of plants including field crops, vegetables, orchards, turf and pastures. Sprinkler systems are also installed for applying wastewater, protecting plants from frost, and dust control in confined animal operations in other countries.

Solid-set systems may be installed for a single season for certain field crops or permanently for turf, orchards or permanent crops. Solid-set sprinkler irrigation systems are typically designed to apply frequent, small amounts of water to meet plant water needs every 1 to 5 days. Water application rates can vary from about 4 to 6 mm h for field crops up to 5 to 30 mm h for turf applications. When properly designed, solid-set systems have high application uniformity. While solid-set systems are most commonly used with turf, landscape and permanent crops, these systems are also used for some high-value annual crops with low tolerance for water stress. Solid-set system designs are as varied as the applications; small sprinklers may irrigate 20 m2 or large, gun-type sprinklers may be spaced 50 m apart. Plastic pipe is frequently used for buried applications, but it is also used in some above ground applications. Aluminum pipe (50–100 mm diameter) is often used for field crops when the system is installed after planting and removed before harvest. Most systems are divided into zones so a portion of the area is irrigated at one time. Solid-set systems used for frost control, however, must be designed to simultaneously water the entire area.

Set-move systems are manually or mechanically moved to another part of the field after the irrigation. The common types of set-move irrigation systems are hand-move and side-roll systems. Hand-move systems can be a single sprinkler or a line of sprinklers. A line of hand-move sprinklers, sometimes called handlines, is typically 9 or 12m long pieces of 75- or 100-mm diameter aluminum pipe with a sprinkler mounted on one end or in the center. Individual pipes are connected to form an irrigation line, usually not more than 400m long. After an irrigation set is completed, the line is disconnected and each piece is moved by hand 10–20m to the next set. A slight variation to the handline is the dragline or end-pull system. These systems, which are less common, have special connections between sprinkler pipes that allow the irrigation line to be pulled by a tractor to the next set. Set-move sprinkler irrigation systems are designed to slowly apply water during the irrigation set (e.g. 4–6 mm h_1), which often lasts 8 to 24 hours. After completing the irrigation set, the sprinkler system is moved to an adjacent area for the next set. Adequate water should be applied during an irrigation set to meet crop water needs until the system is moved back to the area, often in 7 to 10 days. Side-roll systems, also called wheellines, are similar in principle to handlines except a large diameter wheel (1.5–3 m diameter), mounted in the center or on the end of each piece of aluminum pipe (100–125 mm diameter) to elevate the sprinkler. The sprinkler pipe is the axle for the side-roll. When an irrigation set is completed and the pipe has drained, the wheelline, powered by an engine, is rolled to the next position. Self-leveling sprinklers are used so the side-roll does not have to be exactly positioned for the sprinklers to operate correctly Moving Sprinkler Systems include center pivot, linear-move and traveling gun systems. A traveling gun has a large capacity sprinkler on a cart that is pulled across the field by a cable or by the water supply hose. These systems irrigate an area 50–100 m wide and up to 400 m long. A traveling gun can be considered a moving, set-move system because water is applied as the cart moves across the field and then the system is moved to another area in the field for the next irrigation set. For cable tow systems, a winch on the cart winds the cable, pulling the cart and a soft hose across the field. A hose reel system pulls the cart as a hard plastic hose (polyethylene) is wound around a reel on a trailer anchored at the end of the run. The reel or winch is powered by an engine or a water turbine. Smaller versions of traveling guns are available for irrigating athletic fields, small pastures or arenas. In some specialized situations, the single large sprinkler is replaced with a 20- to 60-m long irrigation boom containing multiple sprinklers that are similar to those on center pivot systems.

Center pivot and linear-move systems are similar in design and appearance. These systems consist of one or more spans of sprinkler pipe elevated by “A-frame” towers. Span length varies from 30 to 65 m. Towers, powered by hydraulic or electric motors, elevate the sprinkler pipe 2–4 m above the ground. The center pivot has a stationary pivot point so the towers move in a circle of a total length of about 400 m, and irrigates 50–60 ha. Center pivots are extremely popular because water is uniformly applied to a large area with little labor. Furthermore, once a circular field has been irrigated, the center pivot is in position to start the next irrigation. In 2008, center pivots were used on 45% of the irrigated land in the United States, which is an increase of 124% since 1988. Center pivots or traveling guns, apply water as the system slowly travels through the field. Sprinkler irrigation is often more efficient than surface irrigation because water application is more controlled. In hot and/or windy areas, however, sprinkler irrigation can have significant water losses to evaporation and wind drift. Maintenance is also important for efficient sprinkler irrigation; worn nozzles and leaking pipe connections reduce application uniformity and system efficiency.

In comparison with surface irrigation, this sprinkler irrigation is move expensive to implement, as the required equipment cost more. Overhead costs are greater for solid-set systems compared to other sprinkler systems because the entire irrigated area must be equipped with sprinklers and pipe. However, permanently installed systems can be automated to reduce labor and allow irrigation at any hour of the day, which reduces the opportunity for plants to be stressed. (Agric tech Wikipedia, 2021).Despise this, applying sprinkler irrigation, we may get better harvest or yield, and has the following advantages.

1. Irrigation is provided intermittently, the water accumulates in the upper soil layers.
2. It moisturize not only the soil but the plant itself, that activates its physiological processes
3. The depth of soil moisture is generally less than in a case of surface irrigation

4. You can apply frequent watering and small irrigation norms and thereby creates more uniform soil moisture regime.

A possible area of water delivery by centre-pivot hoses varies from 20 to 40 hectares. Travelling gun irrigation method delivers water on the top of plants, good for various fruits, and vegetables apart from tomatoes.

2.13.6 Drip irrigation method Is the process of lacing your field area with irrigation lines that feed into the root system of your plant, ”dripping” water into them gradually. Drip irrigation system is the most popular for several reasons, with drip irrigation water is continuously delivered to the soil and to the plant roots with the help of small drops. It was created with the aim of providing plants with constant moisturizing and nutritional supply. Its main benefit is in saving up to 50% of water and increasing the amount of harvest up to 40%. Other advantages of drip irrigation

1. Significantly reduction in labour costs for irrigation and processing
2. Improving the quantity of product
3. Effective consumption of fertilizers by plants (80%)
4. Ability to water plants at any time without risks to bring sunburns.

Drip irrigation is supposed to be quite expensive for installing, but its benefits may overweight the advantage

2.13.7 Aerosol irrigation method Water is supply to the field periodically in small doses in the form of very fine particulars. It moistens plant leaves and stem while reducing the temperature of the hot-air weather; it also increases photosynthesis of plant. This method of irrigation is usually used in combination with other irrigation methods.

2.13.8 Disadvantages of irrigation

Most common and unpleasant phenomenon in irrigating our farm land is soil salinity. Soil and underlying soil contain many readily soluble salts and in case of excess water on the field, the groundwater levels begin to rise. Owing to this fact, farmers can create salinity desert through incompetent irrigation methods. So, bear in mind this information in order to turn your irrigation system into a benefit one. Imprivatily, lack of irrigation network improves working conditions of agricultural machinery (FOA,2021)

2.14 Constraints Associated to Sugarcane Production under Rain-fed and Irrigated Farming Systems

Wada *et al*. (2017) conducted a study on Sugar cane production problems in Nigeria and part of Northern African countries and stated that sugarcane production in Nigeria and some Northern African countries is besieged with a number of problems ranging from biotic and abiotic to social and environmental. The common problems militating against increased sugarcane production and productivity in Nigeria and Northern African countries like requirement capital, lack of market outlay, abiotic stresses, high transport and production costs of hauling harvested sugar cane to the mills, low capacity building, lack of sugar cane growers and technologist associations, macro- and micro-environmental issues, lack of legal frameworks and lack of national and regional networking groups.

According to Ugalahi (2016), some of the most critical identified problems that hindered the growth and expansion of the sugarcane production is that, Nigeria irrigation development has been faced with inconsistent and unstable policies and inappropriate legal framework over the years by the government. Generally, sugarcane production is associated with a number of problems particularly from the production aspects and this resulted to low yield of cane, thereby translating to smaller earnings at the end of the day. Consequently, farm productivity is low and the cycle of low input, low yield, and low income and with a low level of productivity perpetuates poverty (Dayo *et al*., 2009).

Sugarcane farming, poverty and environmental management in Kenya and established that although sugarcane farming would raise farmers' income and help reduce the level of poverty. For example, Western and Nyanza provinces are still the poorest regions in Kenya; with 1.8 million and 2.4 million people considered poor in Western and Nyanza provinces respectively. These problems eating into farmers' income from cane farming, thereby farmers are poor despite coming from the rich Kenya sugar belt.

Futhermore, the sugarcane industry in Zimbabwe was declining despite its critical role in the country's economy. The low productivity levels were attributed to failures of the farmers to destroy old cane crop from the field and given a little or training to the farmers on good farming practices with unavailability of farm inputs (Clainos and Ledwin, 2011)

Funding towards irrigation systems is among critical hindrance according to Oravee (2015), who reported that the challenges of inadequate funding of the river basins can be traced back to 1989 which was instrumental to discontinuing of direct involvement in farming activities by some of the River Basins and Rural Development Authorities and consequently leading to the ineffectiveness of the scheme.

Oriola and Alabi (2014) reported that for a successful irrigation scheme, apart from the provision of irrigation infrastructures, there are other required inputs such as operating irrigation equipment, operation and maintenance of irrigation infrastructures, and technical expertise, which government has been responsible for their provision. But all these are either inadequately provided or are not provided at all. In addition, the government and its agencies in charge of the irrigation systems need to be proactive in discharging their duties and correspondingly provide a platform to encourage and sensitize the farmers on the need to engage in irrigation farming rather than on only rain-fed.

In the same view, Adekunle *et al*. (2015) found out in their studies that, poor knowledge of irrigation techniques among the farmers was one of the factors affecting their participation in large-scale irrigation scheme. Those that manage to participate are not equipped with the requisite knowledge for the operations and maintenance of the facilities. However, large parts of the world cannot grow it for climatic reasons and its impact in this suitable area is therefore more significant. Hence, climatic changes threaten the sustainability of the most rain-fed sugar farming systems (Aina *et al*., 2015).In Nigeria almost all sugarcane plantations are dependent on rainfall for its water requirement; hence the fertilizer application time is greatly affected and this resulted to poor yield.

The severity of diseases and pest infestation on sugarcane depends on variety, which resulted in withdrawal of many popular varieties from the sugarcane cultivation. YLD causes serious damage to cane production and up to 40% qualitative losses are reported (Iqbal *et al*. 2015). At the same time, severity and high incidence of grassy shoot disease has also become a major problem for sugarcane growers in most parts of India (Rao *et al*. 2014),and this may cause up to 40% yield losses (Tiwari *et al*. 2016) and in case of heavy incidence, losses may be up to 100%; the disease is spread by infected setts and vectors (Tiwari *et al*., 2017).

The major occupation of people in rural areas is agriculture with traditional ways of farming and usually crop production is under less fertile land. These farmers do not make adequate use of modern farming techniques, with a little or no capital and inputs, lack advisory services from extension services and poor market information; all these couple within adequate or poor social infrastructural facilities for maximizing agricultural production (Mgbenka *et al*., 2015). These majority of the sugarcane farmers, about 90% are considered small holder farmers who usually crop below 5 hectares, with income below the poverty level hence cannot afford to sustain the inputs requirement in sugar cane farming without outside financial support; right time and rate of fertilizers application and other farm inputs is hardly observed these poor sugarcane farmers. Fertilizer application is usually late and oftentimes, only one application is effected (Thorburn *et al*., 2007).

Sulaiman *et al*. (2015) identified low demand for sugarcane as the major constraint hindering sugarcane production in their study area, having the highest percentage, while inadequate capital, credit inaccessibility, as well as fertilizer at unaffordable price, and theft were identified as other constraints.

Chandrashila and Shweta (2017) studied the challenges faced by sugarcane mills and farmers in India and observed that low yield of sugarcane, short crushing season, fluctuating production trends, low rate of recovery, high cost of production, small and uneconomic size of mills, high support prices payable to farmers, lack of adequate working capital, partial decontrol and the uncertain export outlook, regional imbalances in distribution, old and obsolete machinery usage and low per capita consumption among others. But in recent times, the industry is faced with various grave problems like obsolete technology usage, short margin and policy hurdles; entry of private players, financial crisis as well as corruption among others.

Ramarao (2011), in his study titled efficiency, yield gap and constraints analysis in irrigated vis-à-vis rain fed sugarcane in North Coastal Zone of Andhra Pradesh. This finding reported that the most important constraint in sugarcane cultivation is shortage of labour during crucial farming operations.

Martina and Dilipsinh (2012) examined the constraints to sugar production and found that the main factors that hinder good and expected production and productivity are; inadequate farm size and late allocation of farms to the farmers, poor credit facility, unavailable or shortage of fertilizer and cane setts, prices paid by millers to sugarcane growers, recovery out of sugarcane, high returns from other alternative crops than sugarcane, shortage of rainfall and poor irrigation facility, bad government policies; others are high cost of sugarcane production which reduces the profits of the sugarcane farmers; soil type, planting time, varieties, inputs use and unavailability of irrigation water.

2.15 Theoretical framework

2.15.1 Theory of Diffusion – Adoption Process

This study adopted the theory of diffusion–adoption process which aimed at describing the interrelationship between improved technologies adoption and sugarcane production under rain-fed and irrigated farming systems in the study area. The adoption process is a socio- psychological decision making process that an individual goes through in accepting or rejecting a new farming practice. Also, Ajayi *et al.*(2016), opined that the socio-psychological decision making process has been recognized to occur over a period of time in at least five stages. These are:

i. awareness stage: An individual becomes aware of the existence of a new idea, practice or product. At this stage, the individual lacks details concerning the way it works, how to use it, and its benefits;

ii. interest stage: An individual develops an interest in the new practice and actively seeks additional facts on how it works, benefits and its potentialities;
iii. evaluation stage: An individual puts the new practice or product through a mental evaluation to determine its relevance to his own personal situations and then decides whether or not to try the new practice;
iv. trial stage: Based on the individual's judgment of worth of the innovation (results from self-evaluation), he actually tries it on a small scale to determine its relevance and usefulness or benefts;
v. adoption stage: Based on the individual's mental or practical evaluation, he makes a final decision whether to adopt or reject it. This is characterized by large scale and continued use of the new practice.

The five-stage adoption process model has, however, been criticized by Bandiera and Rasul (2006) because they viewed the process as always ending in adoption of the new practice whereas in reality rejection may be the final decision. It also gives the impression that the steps always occur in a sequential order whereas some of the stages may either be skipped or occur simultaneously. The adoption of farm technologies has been studied extensively in the past. However, the need for further study in the area of the diffusion of innovation still exists. This study tends to examine the adoption of recommended improved technologies in sugarcane production for enhanced productivity in the study area.

The diffusion-adoption process has also been conceptualized in terms of a macro-diffusion system framework involving three major sub-systems, namely: innovative, communicative and practitioner. The innovative subsystem is one from which most innovations emerge (scientists, engineers etc.). The communicative subsystem refers to the social organizations created to communicate new ideas, such as extension service, mass media and commercial companies, while the practitioner subsystem refers to the individuals (farmers) or social organizations that use the new idea.

The amount of time spent at certain adoption stages and for the complete adoption to take place is partly dependent upon the attributes of the practice. Generally, six attributes of innovations which are universally applicable are:

i. relative advantage: which refers to the degree to which an innovation is perceived as better than the idea it supersedes. This may be measured in economic terms such as profitability, time/energy saving, convenience and satisfaction etc.;
ii. compatibility: the degree to which an innovation is perceived as consistent with the existing values, past experiences and needs of the potential adopter;
iii. complexity: the degree to which an innovation is perceived as relatively difficult to use or understand;
iv. trial-ability: the degree to which an innovation may be experimented with on a limited scale;
v. divisibility: the degree to which an innovation may be experimented with in small units; and
vi. observability: the degree to which the results of an innovation are visible to the potential adopter and others. (Rogers, 1985; Rogers, 1995; Kavia *et al.*, 2007)

Three specific processes by which the diffusion-adoption process have consistently been identified by social theorists. These are invention, diffusion and change. Invention is the process by which the innovations are created or developed; diffusion is the process by which these innovations are communicated through various channels to members of a social system; and change (consequence) is the change that occurs within a social system as a result of the adoption of innovation. Consequently, the diffusion-adoption perspective is the theoretical framework chosen for this study.

Furthermore, Roger (1995), also presented four (4) additional adoption/ diffusion theories. Each of these theories can be considered in the context of either top-down or bottom-up, macro-level or micro-level dichotomy. Adoption studies have shown that the adoption-diffusion process of agricultural innovations, whether in Nigeria or elsewhere, is a function of a number of variables which can be grouped, as socio-economic, socio-psychological, socio-cultural (environmental), institutional and innovations factors. The socio-economic, institutional, and attributes of the innovations comprise the categories of factors considered in this study. Available studies both in Nigeria and elsewhere have demonstrated that knowledge of innovations and use are all influenced by socio-economic characteristic of the farmers, institutional factors, attributes of the innovations and so on.

2.15.2 Conceptual Framework of the Study

Conceptual framework is a confirmed idea about a phenomenon. It connects all aspects of inquiry in a research (e.g. problem definition, justification, literature review, methodology, data collection and analysis). It also provides the structure/content for the whole study based on literature and personal experience (Roger and Vaughan, 2008). The basic assumptions in this study are farmers' socio-economic characteristics, institutional and associated constraints as well as the production inputs which form the independent components will influence the production of sugarcane under both rain-fed and irrigated farming systems to bring about the expected changes in farmers' output, income and living standard; Therefore, the framework in Figure 2.1 is based on the premise that the dependent variable (sugarcane production under rain-fed and irrigated) also can be influenced by the government programmes and policies, technology adoption (utilization) and climatic factors (such as rainfall, temperature etc) which are the intervening variables. However, the intervening variables is usually a weak link as it does not cause direct change in the dependent variable as compared to the independent variables which have strong link. The over all interaction of these variables will influence sugarcane production under rain-fed and irrigated farming systems in the study area and this in turn determines the expected outcomes such as increased output, increased income, improved productivity and living standard of the farmers in the study area.

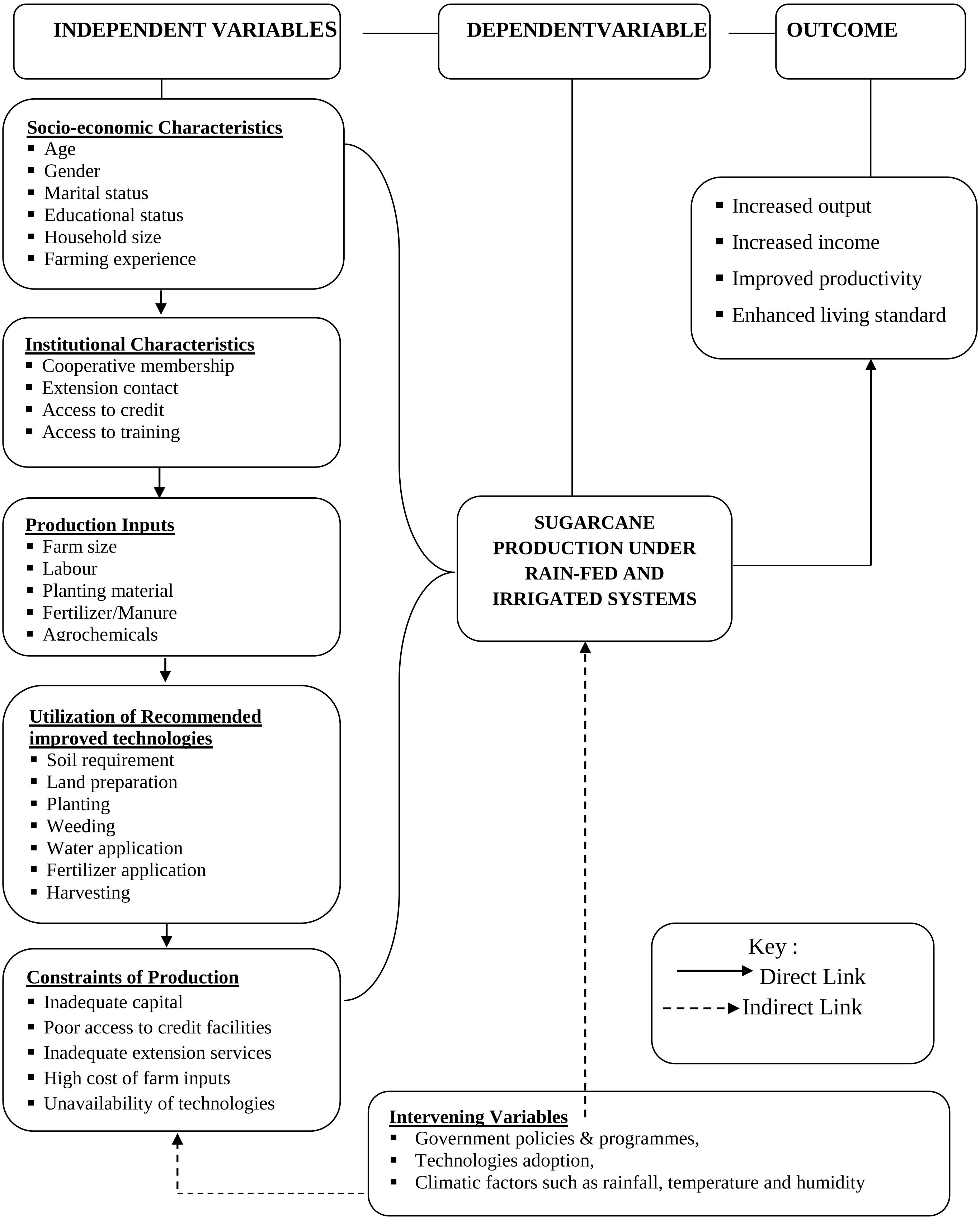


Figure 2.1: **Conceptual model on assessment of sugarcane production under rain-fed and irrigated systems**

Source : Author's Construct, 2021

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 The study Area

The study was conducted in Bauchi State, Nigeria. The state is located in the North-East agro ecological zone of Nigeria and was created in 1976 and located between Latitudes 9°30' and 12°30' North of the equator, and Longitudes 8°45' and 11°0' East of the Greenwich meridian. Bauchi stateis bounded in a clockwise direction by Yobe, Gombe, Taraba, Plateau, Kaduna, Kano and Jigawa states. The state comprised of 20 Local Government Areas (LGAs), namely; Alkaleri, Bauchi Bogoro, Dambam, Darazo, Dass, Gamawa, Ganjuwa, Giade, Itas Gadau, Katagum, Kirfi, Jama'are, Missau, Ningi,Shira, Tafawa-Balewa, Toro, Warji and Zaki. Bauchi State covers land area of about 49,259 Km^2 with a population of 4,653,066 people (National Population Commission (NPC), 2006) which was projected to be about 6,216,486 in 2018 at 2.8% growth rate per annum (National Bureau of Statistics (NBS), 2016).

Bauchi state is heterogeneous in terms of ethnicity, with predominant tribes like Hausa, Fulani, Jarawa, Tangale, Waja, Balewa, Sayawa and Tarewa with Hausa being the major language. The entire western and northern parts of the state are generally mountainous and rocky. The study area falls within the Sudan Savannah vegetation zone with an average annual rainfall of 1,300 to 1,600mm per annum which commences in April and ends in October. The residents of the area are engaged in agriculture with trading activities. Crops such as millet, sugarcane, maize, guinea corn, and groundnut are mostly grown in the area. Livestock rearing in the study area and this is greatly supported by the availability of a vast fertile land which provides suitable pastures for cattle, sheep and goat (Bauchi State Agricultural Development Project (BSADP), 2019.

3.2 Sampling Procedure and Sample Size

Three-stage sampling procedure was used for this study. The first stage involved the purposive selection of two (2) LGAs each from the three (3) agricultural Zones in the state to make a total of six (6) LGAs selected. The second stage involved purposive selection of two (2) villages from each of the selected LGAs to make up a total of twelve (12) villages considered for this study. In the final stage, Taro Yamane's formula at 5% precision level was used to select a sample size of farmers under irrigation and rain-fed farming system that are representative of the population of this study and this resulted to a total of 231 farmers. The sample outlay of the respondents is presented in Table 3.1. Taro Yamane's formula is given as:

$$n = \frac{N}{1 + N (e)^2}$$

(1)

Where

n = Sample size,

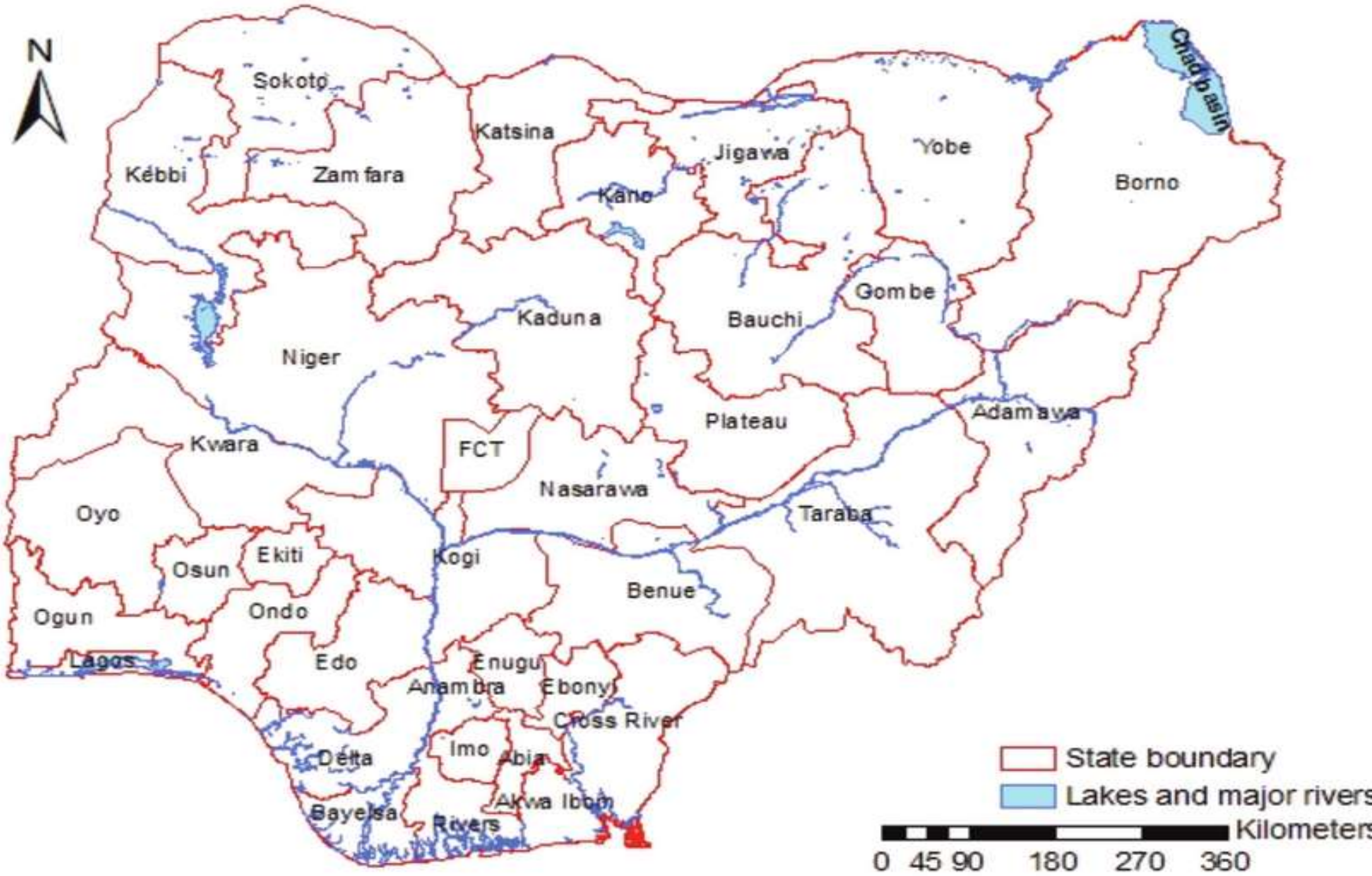
N = Finite population, and

e = limit of tolerable error (5% precision level).

Table 3.1: Sample outlay of the respondents in the study area

Agricultural zones	LGA's	Villages	Sample frame	Sample size
Farmers under rain-fed farming system				
Bauchi South	Bogoro	Badagari	21	14
		Bungu	11	8
	Dass	Wandi	12	8
		Baraza	13	10
Bauchi Central	Ningi	Kudu	16	11
		Yamma	14	10
	Dambam	Zaura	12	8
		Danbam	15	10
Bauchi North	Zaki	Maiwa	13	10
		Makawa	14	10
	Gamawa	Gadiya	19	12
		Tumbi	18	12
Sub-total	**6**	**12**	**178**	**123**
Farmers under irrigated farming system				
Bauchi South	Bogoro	Badagari	11	8
		Bungu	14	10
	Dass	Wandi	12	9
		Baraza	10	7
Bauchi Central	Ningi	Kudu	14	10
		Yamma	12	9
	Dambam	Zaura	11	8
		Danbam	13	10
Bauchi North	Zaki	Maiwa	14	10
		Makawa	12	9
	Gamawa	Gadiya	10	7
		Tumbi	15	11
Sub-total	**6**	**12**	**148**	**108**
Total	**12**	**24**	**326**	**231**

Source: Bauchi State Agricultural Development Project (BSADP), 2019



Map of Nigeria showing 36 states and FCT

The three agricultural zones and six local government areas of the study

3.3 Method of Data Collection

Primary data were used for this study collected through a structured questionnaire complemented with interview schedule; hence, necessary information from the respondents was elicited. Data were collected on the following: socio-economic characteristics of the respondents, the productivity and income levels of respondents under rain-fed and irrigated farming systems, profitability of sugarcane production, market price, sales revenue, cost incurred in sugarcane production under rain-fed and irrigated farming systems, improved technologies used in sugarcane production under rain-fed and irrigated farming systems as well the constraints associated with sugarcane production under rain-fed and irrigated farming system in the study area. Well trained enumerators were used to assist the researcher in the data collection.

3.4 Validation and Reliability of Data Collection

Validity of data collection instrument refers to the accuracy and correctness of data collection instrument that was used for the study. Both face and content validity was applied to the instruments; which means that the instruments for data collection were given to the supervisors and other experts in the field to ascertain its validity. They made their inputs before the instruments were taken to the field.

Reliability test is the degree with which data collection instrument yields consistent results over a repeated number of trials. This was established through the use of test-retest method. The test-retest method involves administering the same tools twice or more to the same group of respondents who have been identified for that purpose. A period of two weeks was allowed before the tools were retested. Sampled responses from the test-retest were analyzed using Pearson Product Moment Correlation (PPMC) and correlation coefficient of 0.83 was obtained.

3.5 Measurement of Variables

The variables measured in this study include the following:

(A) Dependent variables:

i. Output of the Sugarcane in the last cropping season was measured in Kilogramme.

ii. Income of the Sugarcane which is the total aggregate of revenue generated from the proceeds of Sugarcane harvested in the last cropping season measured in Naira (₦).

(B) Independent variables:

i. Net Farm Income (NFI) was measured as the difference between the Total Revenue (TR) and Total Cost (TC),

ii. Gross Margin (GM) was measured as the difference between Total Revenue (TR) and Total Variable Cost (TVC) of production,

iii. Total Revenue (TR) was measured as the product of price and quantity sold,

iv. Total Variable Cost (TVC) was measured as sum of the cost incurred on all variable assets,

v. Total Fixed Cost (TFC) was measured as sum of the cost incurred on all fixed assets,

vi. Total Cost (TC) was measured as sum of Total Fixed Cost (TFC) and Total Variable Cost (TVC),

vii. Return on Investment (ROI) was measured as Gross Margin (GM) divided by Total Cost (TC) of production,

viii. Age was measured in years and Sex: as dummy; Male = 1, Female = 2

ix. Educational status was measured by the number of years of schooling, as dummy: Non-formal = 1, Adult education = 2, Primary = 3, Secondary = 4, Tertiary = 5

x. Farming experience was measured in years,

xi. Farm income (on-farm income) was measured in naira,

xii. Non-farm income was also being measured in naira,

xiii. Farm size was measured in hectares,

xiv. Extension contact was measured based on the number of extension visit per year,

xv. Cooperative membership was measured as a dummy i.e. yes = 1 and otherwise = 0,

xvi. Access to credit was measured by the amount of credit accessed in naira.

3.6 Method of Data Analysis

Both descriptive and inferential statistics were used to analyse the data in line with the stated objectives of the study. The descriptive statistics includes mean, frequency distribution, percentages and the Likert type scale rating, while the inferential statistics were productivity index, farm budgetary techniques and Kendall's coefficient of concordance. Thus, objectives i and iv were achieved using descriptive statistics (mean, frequency distribution and percentages), objective ii was achieved using productivity index, objective iii was achieved using farm budgetary techniques, while objective v was achieved using descriptive statistics (mean, frequency distribution and percentages) as well as 3-point Likert type scale rating and Kendall's coefficient of concordance respectively. The hypotheses i and ii were achieved by using z-test.

3.7 Model Specification

3.7.1 Productivity index

Productivity index was used to ascertain the productivity level of sugarcane under irrigated and rain-fed farming system in the study area.

The productivity index model is specified as:

Productivity Index = $\frac{\mathrm{P}i}{\mathrm{A}i}$, in Kilogramme per Hectare (2)

Where

Pi = Output of the Farmer in Kilogramme

Ai = Area of Farm-land Cultivated in Hectares

3.7.2 Farm budgetary technique

Farm budgeting technique was used to estimate the profitability of sugarcane production under irrigated and rain-fed farming system as stated in objective three (iii). The profitability measures to be estimated includes: Net Farm Income (NFI), Gross Margin (GM) and Returns on Investment (ROI).

$$NFI = TR - TC \quad (3)$$

$$GM = TR - TVC \quad (4)$$

$$ROI = GM/TC \quad (5)$$

Where

NFI = Net Farm Income (₦/ha)

GM = Gross Margin (₦)

ROI = Returns on Investment (₦)

TR = Total Revenue (₦)

TC = Total Cost (₦)

TVC = Total variable cost (₦)

TFC = Total fixed cost (₦)

3.7.3 Likert type rating scale

The 3-point Likert type rating was used to examine the constraints associated with sugarcane production under rain-fed and irrigated farming systems in the study area. The model entails defining a scale of statement that mirrors the respondent's perception towards an underlying variable and establishing a score reflecting a quantitative measurement of the perception of each farmer. Their responses were Very Severe (VS), Severe (S) and Not Severe (NS) with the corresponding values of 3, 2 and 1, respectively. These values were added together to obtain an aggregate score of 6, which was then be divided by 3 to obtain 2.0 which taken as the cut off mean. The mean score value of less than 2.0 was taken as not severe constraint, while mean score value equal to 2.0 and or greater than 2.0 was taken as severe constraint to sugarcane production in the study area. Therefore, mean score for 3-point Likert scale is computed thus:

$$\text{Mean} = \frac{\Sigma fx}{n} \quad (6)$$

$$\frac{\Sigma fx}{n} = 3+2+1 = 6/3 = 2.00$$

3.7.4 Kendall's coefficient of concordance

The Kendall's coefficient was also used to examine the constraints hindering sugarcane production under irrigated and rain-fed farming system in the study area as stated in objective five (v). Kendall's coefficient (W) measures the extent of the agreement levels among several respondents who have common characteristics of suffering in a given set of challenges (Legendre, 2005). It is an index ratio of observed variance of the sum of ranks to the maximum possible variance of the ranks. The reason for the computation of the index is to find the ranks sum for each challenge being ranked. If there is a maximum agreement among the respondents` ranking, then the ranking is said to be perfect, otherwise, there is variability within or among the ranks sum (imperfect).

Kendall's coefficient of concordance (W) is given by the relation:

$$W = \frac{12S}{P^2\,(n^3 - n)} - P^T \quad (7)$$

Where

W = Kendall's coefficient of concordance;

P = number of respondents ranking the constraints,

n = number of quality perceptions.

T = correction factor for tied ranks,

S = sum of squares statistics over the row sum of ranks (Ri).

The sum of square statistics (S) is given as:

$$S = \sum_{i-1}^{n}(Ri - R)^2 \quad (8)$$

Where

Ri = row sums of rank;

R = mean of Ri

The correction factor for tied ranks (T) is given as:

$$T = \sum_{k-1}^{m}(t_k^3 - t_k) \quad (9)$$

The test of significance of Kendall's coefficient of concordance will be done using the chi-square statistic which is computed using the formula:

$$X^2 = P\ (n - 1)\ W \quad (10)$$

Where

n = number of constraints,

P = number of respondents, and

W = Kendall's coefficient of concordance.

The null hypothesis for Kendall's coefficient (W) is that, there is no agreement among respondents on the constraint hindering sugarcane production under irrigated and rain-fed farming system in the study area. If the computed or calculated chi-square is greater than the tabulated chi-square, then the null hypothesis will be rejected, otherwise it will be accepted.

3.7.5 Z-Statistics

Hypotheses i and ii was tested using the Z-test statistics. The Z-test statistics or model is mathematically given as:

$$Z = \frac{\overline{X_1} - \overline{X_2}}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \qquad (11)$$

Where

For hypothesis i,

Z = Calculated Z value

$\bar{x}_1$ = Mean productivity of farmers under irrigation farming system,

$\bar{x}_2$ = Mean productivity of farmers under rain fed farming system,

S_1^2 = Standard deviation of farmers under irrigation farming system

S_2^2 = Standard deviation of farmers under rain fed farming system

n_1 = Sample size of farmers under irrigation farming system

n_2 = Sample size of farmers under rain fed farming system

For hypothesis ii,

Z = Calculated Z value

$\bar{x}_1$ = Mean income of farmers under irrigation farming system,

$\bar{x}_2$ = Mean income of farmers under rain fed farming system,

S_1^2 = Standard deviation of farmers under irrigation farming system

S_2^2 = Standard deviation of farmers under rain fed farming system

n_1 = Sample size of farmers under irrigation farming system

n_2 = Sample size of farmers under rain fed farming system

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This chapter discussed the results of the data analysed based on the information provided by the respondents on socio-economic characteristics of the sugarcane farmers under rain-fed and irrigated farming systems, productivity level of sugarcane production, the costs and returns of sugarcane production, improved agricultural technology utilization as well as the constraints of sugarcane production under irrigated and rain-fed farming systems in the study area.

4.1 Socio-Economic Characteristics of the Respondents

The socio-economic variables examined were age, sex, marital status, educational status, household size, farming experience, farm size, farmland acquisition, access to credit, extension visits, membership of cooperatives and secondary occupation.

4.1.1 Age of the respondents

Table 4.1 revealed that majority (78.9%) of the respondents under rain-fed and irrigated (88.0%) farmers were within the age range of 26 – 55 years with a mean age of 44 and 42 years, respectively. The pooled results revealed that majority (83.1%) of the respondents were within the age range of 26 – 55 years with a mean age of 43 years. This implies that most of respondents were in their mid-age and most productive stage of life. So, they are capable of sugarcane production. The age of farmers is an important factor that determines the quality and quantity of work done in the farm, because at this age bracket they have ability and energy and are capable of performing most farm operations easily, thus, produce optimum or expected productivity. This finding agreed with the study of Tashikalma *et al*. (2014) who reported in their study the socio-economic characteristics of farmers under irrigation and rain-fed farming system in

Adamawa State, Nigeria. They found that most of the farmers in their study area under rain-fed and irrigation were in their productive years between 31 – 50 years.

4.1.2 Sex of the respondents

As revealed in Table 4.1, the pooled result showed on sex that majority (98.7%) of the respondents were males, while majority (97.6%) of the respondents under rain-fed and irrigated (100.0%) farming system were males. This implies that males are the dominant sex in sugarcane production in the study area, which could be due to its tedious nature of sugarcane cultivation. In most rural settings, especially in the northern area, roles are ascribed based on gender differences, as males are known to be engaged in strenuous agricultural production. This finding is in agreement with Girei and Giroh (2012) on analysis of factors affecting sugarcane production under the out-growers scheme in Adamawa State reported that majority of their respondents were males in sugarcane production.

4.1.3 Marital status of the respondents

Marital status is the act of being married or unmarried (such as single, divorced or widowed). As shown in Table 4.1, the pooled results revealed that majority (97.0%) of the respondents were married, while majority (96.7%) of the respondents under rain-fed and irrigated (97.2%) farming system was married. This implies that married individual farmer are more into sugarcane production in the study area which could have great moral and social means or attributes to provide basic needs of the family and this can promote the sugarcane cultivation in the study areas. This finding is in agreement with the work of Anaryu (2017) who reported that majority of the farmers in his study area were married and responsible.

4.1.4 Educational status of the respondents

The results in Table 4.1revealed that more than half (56.7%) of the respondents acquired formal education with a mean of 7 years. Also, 51.2% of the respondents under rain-fed farming system acquired formal education, while 62.1% of the respondents under irrigated farming system had formal education. The mean years spent in formal education by respondents under rain-fed and irrigated farming system was 6 and 8 years, respectively. This implies that most of the respondents had one form of formal education or the other with at least primary education been attained by farmers in the study area. Education is an important variable in agricultural development as it enhances farmers' decision-making process for adoption of new innovation in sugarcane production. This is in line with the findings of Abdul *et al*. (2016) who reported that most of their respondents acquired one form of formal education or the other with at least up to primary school level.

4.1.5 Farming experience of the respondents

The pooled result of the respondents on farming experience in Table 4.1 revealed that more than half (57. %) of the respondents had farming experience within the range of 6 – 20 years with a mean farming experience of 10 years. However, more than half of the respondents under rain-fed (51.2%) and irrigated (63.9%) farming system had farming experience within the range of 6 – 20 years with a mean farming experience of about 10 and 12 years, respectively. This implies that some of the respondents have been into sugarcane production over a relatively long period of time which could easily influence their decision making process. Farmers gain experiences when carrying out the same farming operations day in day out repeatedly, this resulted to farming expertise. This finding is also substantiate finding of Tashikalma *et al*. (2014) who posited that most of the farmers in their study area had more than 10 years of farming experience and their experiences catalysed or enhanced their farm operations or practices,

4.1.6 Household size of the respondents

Household size refers to the total number of people living together under the same roof and eating from the same pot. As revealed in Table 4.1, the result on household size revealed that most (65.0%) of the respondents had 6 – 20 people per household with mean of 11 people per household, while most of the respondents under rain-fed (65.8%) and irrigated (63.9%) farming system had household size within the range of 6 – 20 people with an average of 10 and 12 people, respectively. This implies that the respondents in the study area had large household size. Large household size is a good source of family labour that could enhance the capacity of the respondents to engage in sugarcane production. This also in agrees with the findings of Abdul *et al*. (2016) who stated that farmers with large household size is an important factor in agricultural production because they are all involve in the farm operations which can bring expected production or higher output.

4.1.7 Farm size of the respondents

Farm size is the total area of land that is put into agricultural production and an important fixed factor of production. As shown in Table 4.1, the pooled result of the respondents revealed that most (68. %) of the respondents had farm size of less than 3.1 hectares with a mean farm size of 3.1 hectares. Also, more than half (56.9%) of the respondents under rain-fed farming system had farm size of less than 3.1 hectares with a mean farm size of 3.9 hectares of farmland, while majority (80.5%) of the respondents under irrigated farming system had farm size of less than 3.1 hectares with mean farm size of 2.3 hectares. This revealed that most of the farmers in the study area were small to medium scale sugarcane farmers. The respondents under rain-fed sugarcane farming system had more farmland as compare to those under irrigated sugarcane farming system. This finding corroborate the work of Anaryu *et al.* (2017) who found some of the rain-fed farmers and most of the irrigated farmers in his studycultivated less than 3 hectares of sugarcane farmland and this could responsible to shortage of food in our society. Usually farmland acquired through family inheritance always small in sizes.

4.1.8 Method of farmland acquisition by the respondents

The pooled result of the respondents with respect to farmland acquisition revealed that majority (75.8%) of the respondents acquired their farmland through inheritance, followed by purchase (19.0%) and gift (11.7%). Also, majority of the respondents under rain-fed (78.9%) and irrigated (73.1%) farming system acquired their farmland through inheritance, followed by 21.1% and 16.7% who acquired their farmland through purchase respectively. This implies that access to farmland for sugarcane production in the study area is mostly through inheritance. Land ownership refers to situation where an individual has title to portion of land for farming through a tenure system. However, farmland acquired through inheritance usually lead to farmland fragmentation thereby limiting agricultural mechanization. Therefore, access to farmland determines the level of production by the sugarcane farmers and this could translate to high output and farmers' income in the study areas.

Table 4.1: Distribution of the Respondents based on Socio-Economic Characteristics

Variables	Rain-fed (n = 123)		Irrigated (n = 108)		Pooled (n = 231)	
	Freq	%	Freq	%	Freq	%
Age (years)						
< 26	8	6.5	5	4.6	13	5.6
26 – 35	19	15.5	25	23.2	44	19.0
36 – 45	38	30.9	38	35.2	76	32.9
46 – 55	40	32.5	32	29.6	72	31.2
> 55	18	14.6	8	7.4	26	11.3
Mean	**44**		**42**		**43**	
Sex						
Male	120	97.6	108	100.0	228	98.7
Female	3	2.4	0	0.0	3	1.3
Marital status						
Single	4	3.3	3	2.8	7	3.0
Married	119	96.7	105	97.2	224	97.0
Education (years)						
Non-formal	60	48.8	41	37.9	100	43.3
Primary	31	25.2	22	20.4	54	23.4
Secondary	25	20.3	30	27.8	55	23.8
Tertiary	7	5.7	15	13.9	22	9.5
Mean	**6**		**8**		**7**	
Experience (years)						
< 6	48	39.0	27	25.0	75	32.5
6 – 10	45	36.6	34	31.5	79	34.2
11 – 15	10	8.1	21	19.4	31	13.4
16 – 20	8	6.5	14	13.0	22	9.5
> 20	12	9.8	12	11.1	24	10.4
Mean	**9.8**		**11.6**		**10**	
Household size (number)						
< 6	33	26.8	21	19.4	54	23.4
6 – 10	39	31.7	36	33.3	75	32.5
11 – 15	32	26.0	20	18.5	52	22.5
16 – 20	10	8.1	13	12.1	23	10.0
> 20	9	7.3	18	16.7	27	11.7
Mean	**10**		**12**		**11**	
Farm size (hectares)						
< 3.1	70	56.9	87	80.5	157	68.0
3.1 – 5.0	33	26.8	11	10.2	44	19.0
> 5.0	20	16.3	10	9.3	30	13.0
Mean	**3.9**		**2.3**		**3.1**	
Farmland acquisition						
Inheritance	96	78.9	79	73.1	175	75.8
Purchase	26	21.1	18	16.7	44	19.0
Rent	6	4.9	13	12.1	19	8.2
Gift	14	11.4	13	12.1	27	11.7

Source: Field Survey, 2019

4.1.9 Distribution of the respondents according to Institutional variables

Institutional variables accessed by the respondents under rain-fed and irrigated farming system in the study area include; access to credit, extension services, cooperative membership, labour usage and secondary occupations as presented in Table 4.2. Credit is an important variable needed to acquire or develop farm enterprise. The pooled result of the respondents on access to credit revealed that only a few (14.7%) had access to credit, while the majority (85.3%) did not have access to credit. More so, a few of the respondents under rain-fed (17.1%) and irrigated (12.0%) farming system had access to credit facilities, while majority of the respondents under rain-fed (82.9%) and irrigated (88.0%) farming system had no access to credit facilities. However, the main source of credit facilities among the a few respondents that accessed credit facilities was family and friends as indicated by 8.9% and 7.4% of the respondents under rain-fed and irrigated farming systems respectively. The clear indicated that non access to credit facilities which limiting sugarcane production to majority farmers in the study area can be as a result of higher loan rate, unavailability of microfinance or bank of agriculture which support farming activities. This agreed with Sulaiman *et al*. (2015) study who identified low demand for sugarcane as the major constraint hindering sugarcane production in their study area, having the highest percentage, while inadequate capital, credit inaccessibility, as well as fertilizer at unaffordable price, and theft were identified as other constraints. In the same vein, Oravee (2015) sees lack of funding in the river basin and rural development lead to ineffectiveness of the scheme.

Moreso, the pooled result of the respondents on extension contact as presented in Table 4.2 revealed that 35.9% of the respondents had contact with extension agent while about half of the respondents under rain-fed (48.8%) and a few (21.3%) respondents under irrigated farming systems had contact with extension agents during sugarcane cultivation season. This implies that the respondents under rain-fed farming system had more contact with extension agents as compared to those under irrigated farming system which could be due to the fact that most extension service delivery are usually carried out during the raining season as oppose the irrigated farming system that being cultivated mostly during dry season. Agricultural extension services constitute the driving force for every successful agricultural development programmes of a nation, because this is where agricultural extension services and farmers interacted and most important information on new, improved technologies or innovation are acquired or communicated to farmers on farming practices. This is in line with Giroh (2012) who in his study on efficiency of latex production and labour productivity in rubber plantation in Edo and Delta States, Nigeria found that extension services among other factors that enhances the allocation efficiency of rubber production.

In addition, in term of number of extension agents' visitation to farmers, 22.8% and 10.6% indicated quarterly and annual contact with extension agents respectively under rain-fed farming system while 8.3% and 5.6% of respondents got visited monthly and quarterly with extension agents respectively, under irrigated farming system, and this poor or low visitation can influence their level of perception and adoption of new technology or access to inputs for sugarcane production in the study area. Dayo *et al.* (2009) identified low yield or productivity due to inadequate usage or non-usage of agricultural inputs such as fertilizer, herbicide and other agro-chemical in any farming system, this is supported by Adekunle *et al.* (2015) who found in their studies that poor knowledge of irrigation techniques among the farmers was one of the factors affecting their participation in large-scale irrigation scheme.

In terms of cooperative membership, the pooled result in Table 4.2 revealed that 39.8% of the respondents were members of cooperative societies, under rain-fed (50.4%) and a few (28.7%) respondents under irrigated farming systems were members of cooperative societies, while about half, 49.6% of the respondents under rain-fed and majority (71.3%) under irrigated farming systems were not members of cooperative societies respectively in the study area. The respondents under rain-fed farming systems were more into cooperative societies compare to farmers under irrigated farming system in the study area. Cooperative allows group of people with common interest come together to meet certain needs that could not be achieved through individual efforts. It helps in identifying economic opportunities, empower the disadvantaged members and provide financial security to farmers especially in the rural areas as well as marketing of their farm produce.

The distribution of the respondents based on their labour usage as presented in Table 4.2 revealed that more than half (53.7%) of the respondents under rain-fed farming system and half (50.0%) of the respondents under irrigated farming system used both family and hired labour during sugarcane production. The pooled result of the respondents also revealed that more than half (51.9%) of the respondents used both family and hires labour in sugarcane production in the study area. This implies that most of the respondents in the study area used both hired and family labour in their farming operations. The use of family labour in most rural farming households is to help minimize costs of production especially costs incurred through hired labour. However, the use of hired labour in agricultural production cannot be over-emphasized as most farmers with large hectares of land to cultivate will not be able to cope except those with large household size. Thus, availability of hired labour allows for better management for a larger area of farm investment. Farm labour availability for farming operations is a great constraint for household which members are mostly agricultural workers, hence, hired labour has been used to off-set these constraints in the study area.

This finding corroborate that of Langat *et al*. (2011) who posited that most farmers in their study area indicated heavy reliance on hired labour as major source of agricultural labour.

Also, the pooled result of secondary occupation as presented in Table 4.2 revealed that crop production (65.4%), trading (19.0%) and livestock production (13.4%) were the main secondary occupation of the respondents in the study area. However, majority (84.6%) of the respondents under rain-fed farming system were engaged in crops production, followed by 48.0% of the respondents who are engaged in trading, 30.9% of the respondents are into agro-processing and 29.3% of the respondents engaged in driving as secondary occupation. This implies that most of the respondents under rain-fed farming system were engaged in other crop production aside sugarcane with few proportions employed as civil servant in the study area. In the same vein, 45.4% of the respondents under irrigated farming system were engaged in agro-processing, followed by 43.5% of the respondents who were engaged in crop production, 38.9% were into driving and 23.1% of the respondents who were into trading as secondary occupation. This implies that some of the respondents under irrigated farming system were engaged in agro-processing and other crop production aside sugarcane in the study area.

Table 4.2: Distribution of the respondents according Institutional Variables

Variables	Rain-fed (n = 123)		Irrigated (n = 108)		Pooled (n = 231)	
	Freq	Percentage	Freq	Percentage	Freq	Percentage
Credit						
Access	21	17.1	13	12.0	34	14.7
No access	102	82.9	95	88.0	197	85.3
Credit sources						
BOA	2	1.6	0	0.0	1	0.4
Commercial banks	4	3.3	2	1.9	6	2.6
Family and friends	10	8.1	8	7.4	18	7.8
Cooperative	3	2.4	1	0.9	4	1.7
Microfinance	2	1.6	2	1.9	4	1.7
Extension contact						
Contact	60	48.8	23	21.3	83	35.9
No contact	63	51.2	85	78.7	148	64.1
Extension visits						
Weekly	0	0.0	1	0.9	1	0.4
Bi – weekly	8	6.5	4	3.7	13	5.6
Monthly	11	8.9	9	8.3	20	8.7
Quarterly	28	22.8	6	5.6	34	14.7
Annually	13	10.6	3	2.8	16	6.9
Cooperative						
Member	70	50.4	31	28.7	92	39.8
Not member	61	49.6	77	71.3	139	60.2
Labour usage						
Family	11	8.9	9	8.3	20	8.7
Hired	46	37.4	45	41.7	91	39.4
Both	66	53.7	54	50.0	120	51.9
Secondary occupation* **						
Crop production	104	84.6	47	43.5	151	65.4
Livestock production	18	14.6	13	12.0	31	13.4
Fish farming	7	5.7	3	2.8	10	4.3
Trading	59	48.0	25	23.1	44	19.0
Civil service	8	6.5	11	10.2	19	8.2
Artisan	18	14.6	3	2.8	21	9.1
Agro-processing	38	30.9	49	45.4	11	4.8
Driving	36	29.3	42	38.9	7	3.0
Tailoring	7	5.7	23	21.3	8	3.5

Source: Field Survey, 2019

*****implies multiple response cases**

4.2 Productivity of Sugarcane under Rain-fed and Irrigated Farming System

The results of the respondents' sugarcane productivity under rain-fed and irrigated farming systems are presented in Table 4.3. The pooled result of the respondents in terms of sugarcane productivity revealed that just above half (51.0%) recorded sugarcane productivity between the ranges of 261 – 1000 kilogramme with an average productivity of 1056 kilogramme per hectare. Moreso, more than half (60.2%) of the respondents under rain-fed farming system recorded sugarcane productivity between the ranges of 261 – 1000 kilogramme with minimum productivity of 55 kilogramme, maximum productivity of 928 kilogramme and an average productivity (mean) of 382 kilogramme per hectare. This implies that the sugarcane farmers under rain-fed farming system are producing below the optimum productivity as indicated by the mean productivity. However, given favourable environmental conditions and appropriate combination of available resources (inputs), the respondents could enhance their sugarcane productivity. An increase in productivity is usually associated with efficient use of some or all the factors of production, like land, labour and capital. Thus, productivity is the ability of a production system to produce more economically and efficiently as expected in agriculture.

Similarly, more than half (58.3%) of the respondents under irrigated farming system realised sugarcane productivity of more than 1000 kilogram per hectare with minimum productivity of 160 kilogramme per hectare, maximum productivity of 8000 per hectare kilogramme and an average productivity (mean) of 1824 kilogramme per hectare. This implies that the sugarcane farmers under irrigated farming system are also producing below the optimum productivity as indicated by the mean productivity. However, given favourable environmental conditions and appropriate combination of available resources (inputs), some of the respondents could increase their sugarcane productivity above the mean productivity. Sugarcane productivity signifies outputs in relation to less expended resources. This finding agreed with that of Onogwu *et al.* (2017) who posited that improvement in agricultural productivity is generally considered to be as a results of a more efficient use of the factors of production, the good combination of land, labour, capital and entrepreneurship.

Table 4.3: Distribution of the Respondents based on Sugarcane Productivity(kg/ha)

	Rain-fed		Irrigated		Pooled	
Productivity class (kg/ha)	**Freq**	**Percentage**	**Freq**	**Percentage**	**Freq**	**Percentage**
< 261	49	39.8	1	0.9	50	21.7
261 – 500	49	39.8	11	10.3	60	25.9
501 – 750	15	12.3	9	8.3	24	10.4
751 – 1000	10	8.1	24	22.2	34	14.7
> 1000	0	0.0	63	58.3	63	27.3
Total	123	100.0	108	100.0	231	100.0
Mean	**382**		**1824**			**1056**
Minimum value	**55**		**160**			**55**
Maximum value	**928**		**8000**			**8000**

Source: Field Survey, 2019

4.3 Costs and Returns of Sugarcane Production under Rain-fed and Irrigated farming

4.3.1 Mean sugarcane output of the respondents

Table 4.4 revealed the mean output of the respondents from sugarcane production. The pooled result of the respondents revealed minimum output of 100 kilogramme, maximum output of 10000 kilogramme and mean output of 1408.80 kilogramme. However, the minimum output of the respondents under rain-fed farming system was found to be 100 kilogramme, maximum output was 1100 kilogramme and mean output was 519.67 kilogramme, while the minimum output of the respondents under irrigated farming system was 160 kilogramme, maximum output was 10,000 kilogramme and mean output was 2,421.5 kilogramme. This implies that, respondents under irrigated farming system had higher output from sugarcane production as compared to the rain-fed farming system. This could be due to the fact that irrigation allows farmers to undergo two production cycle per season or in a year which is not possible under rain-fed.

Table 4.4: Mean sugarcane output of the respondents in kilogram

Output	Minimum (Kg)	Maximum (Kg)	Mean (Kg)
Rain-fed	100	1100	519.67
Irrigated	160	10000	2,421.5
Pooled	100	10000	1,408.8

Source: Field Survey, 2019

4.3.2 Mean income from sugarcane by the respondents

Table 4.5 revealed the mean income of the respondents from sugarcane production in the study area. The pooled result of the respondents revealed minimum income of ₦25,000, maximum income of ₦2,904,000and mean income of ₦1,081,356. However, the minimum income of the respondents under rain-fed farming system was found to be₦43,500, the maximum income was ₦2,500,000 and mean income was₦777,946, while the minimum income of the respondents under irrigated farming system was ₦25,000, the maximum income was ₦2,904,000 and mean income was₦1,426,906.94. This also implies that, respondents under irrigated farming system had higher income from sugarcane production as compared to the rain-fed farming system. Higher income from sugarcane production will encourage more production for better income and livelihood of the farmers in the study area. This finding is in line with the work of Ajayi *et al.* (2016) who posited that the ability of smallholder farmers to increase households' needs only possible from higher income generated from their farm produce.

Table 4.5: Mean respondents' income from sugarcane production in Naira

Output	Minimum (Kg)	Maximum (Kg)	Mean (Kg)
Rain-fed	43,500	2,500,000	777,946
Irrigated	25,000	2,904,000	1,426,906.94
Pooled	25,000	2,904,000	1,081,356.00

Source: Field Survey, 2019

4.3.3 Respondents' Level of Income

Distribution of respondents according to level of income from sugarcane production in the study area is presented in Table 4.6. The pooled result revealed that most (57.1%) of the respondents realized an annual income from sugarcane production between ₦500,001 and ₦2,000,000 with a mean annual income of ₦1,081,356.00. However, majority (73.1%) of the respondents under rain-fed farming system realised an annual income from sugarcane production between ₦500,001 and ₦2,000,000 with a mean annual income of ₦777,946.30, while 38.9% of the respondents under irrigated farming system realized an annual income from sugarcane production between ₦500,001 and ₦2,000,000 with a mean annual income of ₦1,426,906.90. This implies that the respondents under irrigated farming system generate more income as compared to those under rain-fed which could be due to their ability to carry out sugarcane production more than one time in a year. This is in line with the findings of Tashikalma *et al.* (2014) who reported that irrigated farmers earned higher income than rain-fed farmers because they could produce both during dry and wet season of the year.

Table 4.6: Distribution of Respondents according to level of income

	Rain-fed		**Irrigated**		**Pooled**	
Income (₦)	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**
< 500,001	32	26.1	40	37.0	72	31.2
500,001 – 1,000,000	63	51.2	24	22.2	87	37.7
1,000,001 – 1,500,000	26	21.1	12	11.1	38	16.4
1,500,001 – 2,000,000	1	0.8	6	5.6	7	3.0
> 2,000,000	1	0.8	26	24.1	27	11.7
Total	**123**	**100.0**	**108**	**100.0**	**231**	**100.0**
Mean	**₦777,946.30**		**₦1,426,906.90**		**₦1,081,356.00**	

Source: Field Survey, 2019

4.3.4 Costs and Returns of Sugarcane production under rain-fed and irrigated farming

The result of costs and returns analysis on sugarcane production under rain-fed and irrigated farming system in the study area is presented in Tables 4.7. The pooled result of the respondents showed that the total variable cost for sugarcane production was ₦361,301.76 constituting about 95.24 per cent of the total costs of sugarcane production per hectare, while the total fixed cost of sugarcane production was ₦18,051.62representing 4.76 percent of the total cost for sugarcane production per hectare in the study area. This implies that variable costs incurred during sugarcane production are usually higher than the fixed cost of production. More so, the total revenue generated from sugarcane production in the last farming season under pooled result was found to be ₦1,081,356.00; with gross margin of ₦720,054.24; net farm income of ₦702,002.62. The profitability ratio recorded was ₦1.85 kobo, this implies that for every ₦1.00 invested in sugarcane production, ₦1.85 kobo was realized. Thus, sugarcane production in the study area is a profitable enterprise.

However, from the result, the total variable cost under rain-fed and irrigated farming system were ₦347,907.48 and ₦479,209.67 respectively. This constituted about 95.68 and 95.79 percent of total costs of sugarcane production per hectare respectively in the study area. While the total fixed cost of sugarcane production under rain-fed and irrigated farming system were ₦15,696.57 and ₦21,058.84, respectively representing 4.32 and 4.21 percent of the total cost for sugarcane production per hectare respectively in the study area. This implies that variable and fixed costs incurred under irrigated farming system is higher compared to rain-fed farming system which could be due to irrigation facility materials utilized under irrigated farming system and its two cycle production in a year. In most agricultural production, the variable cost is the cost incurred in production items such as cost of planting material, fertilizer/manure, agrochemicals and other management expenses like labour, storage and transportation costs as well as commission fees or levies.

Meanwhile, from table 4.7, the highest variable cost incurred by the respondents during last sugarcane production season under rain-fed was cost of transportation (₦97,791.17; 26.89%) and it is followed by cost of labour (₦95,234.47; 26.19%) and fertilizer/manure (₦78,480.84; 21.58%) and under irrigated farming system labour topped by cost (₦187,073.38; 37.39%), this is followed by cost of transportation (₦94,986.74; 18.99%) and fertilizer/manure (₦82,662.00; 16.22%). The pooled revealed that transportation had the highest cost (₦96,923.61; 25.55%), followed by labour (₦90,250.06; 23.79%) and fertilizer/manure (₦80,287.35; 21.16%). This implies that labour and transportation costs were the highest expenses incurred on sugarcane production under rain-fed and irrigated farming system as over half of the expenses incurred from sugarcane production in the study area were from labour usage and transportation. Labour is one of essential factor of crop production, while transportation services are vital factor in moving farm produce from the farms or the mills places to consumers. This in line with Tashikalma (2014), whose study on farm budgeting analysis, found labour among other factors to be very significant at 1% level and inversely related to farm profit in irrigation farming system. Also Yadav *et al*. (2018) based their studies on cost of labour and the machinery used in sugarcane production, which revealed that cultural practices are very tedious most especially planting, intercultural, plant protection and harvesting processes; hence modern technologies (machines) and labour saving devices reduced cost of sugarcane cultivation. In the same vein, Nagendran (2014) in his study indicated that sugarcane production being a labour intensive crop in its cultivation, almost 60-70% of cost labour, therefore, utilization of machine such as automatic caneplanter, cultivator, harrow rotavator, hoeing machine, power sprayer and ratoon management devices (RMD) to mention a few, could save almost 40-50% of total cost of sugarcane production. In addition, according to Singh *et al*. (2018), production cost could be significantly reduced by introduction of mechanical-based sugarcane farming, particular harvesting processes or other operations which required high number of intensive labour and its cost, but with the introduction of De-thrasher-cum-harvester which resulted to well-timed operations, better quality work, cutting off of drudgery and also capable of cleared the field for next cropping to mention a few among its advantages; thus this ensured higher the output of sugarcane farming in general. Therefore, the use of mechanical-based in sugarcane production by farmers definitely resulted to reduce total production costs and this ensured increasing in farmers' net income.

Other expenses incurred under rain-fed, cost of planting materials (₦33,328.50, 9.17%), commission fees or levies (₦21,574.47, 5.93%), cost of storage (₦14,625.00, 4.02%) and cost of agro-chemicals (₦6,873.03, 1.89%), while on the other hand, the cost of fertilizer/manure (₦82,662.00, 16.52%), cost of planting materials (₦53,806.90, 10.76%), commission levies (₦22,727.65, 4.54%), cost of storage (₦20,000.00, 4.00%) and cost of agro-chemicals (₦17,953.00, 3.59%) were the expenses incurred on irrigated farming system. This result implies that cost of fertilizer/manure, planting materials, commission levies, storage and agro-chemicals usage under irrigated farming system were highest as compared to the costs incurred under rain-fed farming system, this could be as a result of high cost and unavailability of fertilizer, planting material, agro-chemicals and commission fees in the study area. This result is in line with the findings of Akanbi *et al.* (2011) who reported that fertilizer, labour and agro-chemicals were parts of the most important inputs in crop production in Nigeria. The total revenue generated from sugarcane production in the last farming season under rain-fed and irrigated farming system was found to be ₦777,946.30 and ₦1,426,906.90, respectively. The gross margin realized from sugarcane production under rain-fed and irrigated farming system was ₦430,038.82 and ₦947,697.23, respectively, while the net farm income for sugarcane production was ₦414,342.25 and ₦926,638.339, respectively. This implies that sugarcane production under irrigated farming system recorded the highest revenue, gross margin and net farm income as compared to those generated under rain-fed farming system in the study area. However, the profitability ratio recorded under irrigated farming system was ₦1.85 kobo, while the profitability ratio recorded under rain-fed farming system was ₦1.14 kobo this implies that for every ₦1.00 invested in sugarcane production under irrigated and rain-fed farming system, ₦1.85 kobo and ₦1.14 kobo was realized, respectively, implying that sugarcane production is a profitable enterprise in the study area. Although, irrigated farming system has the highest return in naira invested as compared to rain-fed farming system in the study area. This finding agreed with Kundell (2008) that irrigation farming system give more farm output than rain-fed farming system and this view is supported by Masuku (2011) finding result says profitability of cane is determined by yield per hectare, sucrose content in the sugarcanes and with other factors such as farmers experience, and distance between the farm and mill. However, land, fertilizer, and agro-chemical were significant at varying level and positively related to profit (Tashikalma, 2014).

Table 4.7: Costs and Returns Analysis of Sugarcane Production under Rain-fed and Irrigated Farming System

	Rain-fed (n = 123)		Irrigated (n = 108)		Pooled (n = 231)	
Items	**(₦)/hectare**	**% Cost**	**(₦)/hectare**	**% Cost**	**(₦)/hectare**	**% Cost**
Variable costs						
Cost of planting material	33,328.50	9.17	53,806.90	10.76	42,902.81	11.37
Cost of labour	95,234.47	26.19	187,073.38	37.39	90,250.06	23.79
Cost of fertilizer/manure	78,480.84	21.58	82,662.00	16.52	80,287.35	21.16
Cost of agro-chemical	6,873.03	1.89	17,953.00	3.59	12,640.48	3.33
Cost of transportation	97,791.17	26.89	94,986.74	18.99	96,923.61	25.55
Cost of storage	14,625.00	4.02	20,000.00	4.00	16,416.67	4.33
Commission fees/levies	21,574.47	5.93	22,727.65	4.54	21,880.78	5.77
Total Variable Cost (TVC)	**347,907.48**	**95.68**	**479,209.67**	**95.79**	**361,301.76**	**95.24**
Fixed cost						
Depreciation of fixed assets (Cutlass, hoe, sickle, sprayer, water pump, etc)	15,696.57	4.32	21,058.84	4.21	18,051.62	4.76
Total Fixed Cost (TFC)	**15,696.57**	**4.32**	**21,058.84**	**4.21**	**18,051.62**	**4.76**
Total cost	**363,604.05**	**100.00**	**500,268.51**	**100.00**	**379,353.38**	**100.00**
Returns						
Revenue	777,946.30		1,426,906.90		1,081,356.00	
Gross Margin (GM) =TR – TVC	430,038.82		947,697.23		720,054.24	
Net Farm Income (NFI) = GM – TFC	414,342.25		926,638.39		702,002.62	
Profitability Ratio (PR) = NFI/TC	1.14		1.85		1.85	

Source: Field Survey, 2019

4.4 Utilization of Recommended Technologies under Rain-fed and Irrigated

Table 4.8show the results of recommended technologies utilized by the respondents under rain-fed farming system. In terms of soil requirement for sugarcane production, more than half (56.1%) of the respondents utilized light texture soil with good drainage, while 54.5% utilized heavy soil with good drainage and 44.7% utilized optimal soil pH level (6.0 to 6.5). This implies that good soil is a requirement for sugarcane production. Sugarcane grows best on medium heavy soils but can also be raised on lighter soils with good drainage. Also, most (69.9%) of the respondents utilized raising sugarcane nursery site during land preparation before sugarcane planting, while 63.4% of the respondents utilized ploughing depth of 30cm and 42.3% of the respondents utilized pre-manuring of farmland before planting as a means of land preparation. This implies that to prepare the field for sugarcane production, ploughing are carried out to break soil clods and stubbles. In some cases, deep-ploughing with tractors using mould-board plough are carried out to prepare the sugarcane field, this facilitate good growth and sugarcane development that eventually result to good productivity in the study area. This corroborate Maraddi *et al.* (2017) that more than half, 53% of their respondents practice or have knowledge of Sustainable Cultivation Practice (SCP) in sugarcane production in Belgium and Bagalkot District of Karnataka.

With regards to planting, majority (71.5%) of the respondents utilized Autum planting (September to October), and 48.8% of the respondents utilized Spring planting (February to March), while 56.1% of the respondents planted sett horizontally in the furrow, 53.7% utilized long and thick stem of about 40cm. Sugarcane is mostly planted by either stem planting or setting with the roots and shoots into a furrow. Availability of good quality cane materials are essential for better germination, good growth and development. More so, majority (76.4%) of the respondents' utilized hand weeding by hoe, while 68.3% utilized de-trashing as weed control measure and while 39.8% utilized weed free environment and 28.5% of the respondents utilized mulching as a means of weeding prevention during sugarcane production. Weeding of sugarcane field is required during the first three months of planting for better yield. Hand weeding by hoe is usually done two to three times during production season to help suppress weed germination for good or healthy growth and development that will result to high yield of the sugarcane and consequently give high productivity. This agreed with Masuku (2012) finding in sugarcane production that revealed that profitability was realized through good and proper crop husbandry practices such as timely weeding and application of fertilizer as well as appropriate irrigation practice.

Furthermore, with respect to application of agro-chemical in sugarcane production, some of the respondents under rain-fed farming system applies NPK (31.7%)NPK at 112kg, 25kg and 48kg rate/ha in 30th and 60th after planting, agro-chemical-atrazine (26.0%) and soil fallow (24.4%). Essentially, adequate fertilizer and herbicides application are essential for sustained high yield. Fertilizer application in sugarcane production is recommended to be two-third of nitrogen with other one-third being phosphorus and potash. In addition, most (64.2%) of the respondents utilized manual harvesting, followed row thinning (55.3%), ratooning (43.1%), earthing-up (30.1%), stumble shaving (27.6%), propping (26.8%) and mechanical harvesting (7.3%) among other recommended type of technologies utilized in the study area. With result from finding by Singh *et al.* (2018) that fertilizer recommendation is based on targeted yield which need to be developed for sugarcane production in different climatic zones. This also support Takeshima and Adesugba (2015) that revealed productivity of available land can be enhanced through irrigation farming system and other agricultural inputs, which including, fertilizer, herbicide, insecticide and other agro-chemical material. So also as was revealed by Dayo *et al.* (2009) that low yield could result from low or inadequate use of agricultural inputs and this eventually translate to low or small earning and poverty of our farmers.

Table 4.8: Respondents' Utilization of Recommended Technologies under Rain-fed (n=123)

Variables	Utilized		Not Utilized	
	Frequency	**Percent (%)**	**Frequency**	**Percent (%)**
Soil requirement				
Heavy soil with good drainage	67	54.5	56	45.5
Light texture soil with assured irrigation	69	56.1	54	43.9
Soil with good Ph	55	44.7	68	55.3
Land preparation				
Ploughing depth of 30 cm	78	63.4	45	36.6
Pre-manuring of farmland before planting	52	42.3	71	57.7
Raising nursery	86	69.9	37	30.1
Planting				
Long and thick stem of about 40 cm	66	53.7	57	46.3
Sett planted horizontally in the furrow	69	56.1	54	43.9
Autum planting (September to October)	88	71.5	35	28.5
Spring planting (February to March)	60	48.8	63	51.2
Weeding				
A weed free environment	49	39.8	74	60.2
Hand weeding by hoe	94	76.4	29	23.6
De-trashing	84	68.3	39	31.7
Mulching	35	28.5	88	71.5
Application of atrazine	32	26.0	91	74.0
Fertilizer application				
Soil fallow	30	24.4	93	75.6
Application of NPK	39	31.7	84	68.3
Types of Harvesting				
Row thining	68	55.3	55	44.7
Earthing up	37	30.1	86	69.9
Propping	33	26.8	90	73.2
Manual	79	64.2	44	35.8
Mechanical (Harvester)	9	7.3	114	92.7
Ratooning	53	43.1	70	56.9
Stumble shaving	34	27.6	89	72.4

Source: Field Survey, 2019

Similarly, results of recommended technologies utilized by the respondents under irrigated farming system is presented in Table 4.9. The results showed that most (62.0%) of the respondents utilized ploughing depth of 30cm during land preparation, while 57.4% of the respondents utilized spacing of more than 45cm in land preparation and 55.6% of the respondents utilized pre-germinated nursery setts as a means of land preparation. This impliesthat ploughing is the most improved technology utilized by the respondents in land preparation for sugarcane production. With regards to planting, most (65.7%) of the respondents utilized sowing depth of 30cm, followed by 59.3% of the respondents who utilized modified planting method, 47.2% utilized pit diameters of 75cm and 42.5% inter-row spacing. Other improved technologies utilized by the respondents during planting of sugarcane under irrigated farming system includes inter-cropping with tomatoes (39.2%), centre to centre by 105cm (38.0%), space transplanting (38.0%), ring pit (35.2%), intra-row spacing (32.4%) and seed rate technology (25.0%). Sugarcane is mostly planted by either stem planting or sett with the roots and shoots into a furrow. Availability of good quality cane planting materials are essential for better germination and good growth.

More so, more than half (59.3%) of the respondents utilized combination of cultural and chemical methods for weeds prevention and control in sugarcane plantation under irrigated farming, while 39.8% of the respondents utilized weed sensor technology and 28.7% utilized weed seeker technology for managing weed infestation in sugarcane plantation. Weeding of sugarcane field is required during the first three months of planting for better yield. Hand weeding using hoe is usually done two to three times in sugarcane production to assist suppress weed germination. In terms of water application (irrigation) in sugarcane cultivation, majority (74.8%) of the respondents utilized application of water once in every 7 days during growing phase of sugarcane, followed by 56.9% of the respondents who utilized application of water once in every 10 days during tillering phase and application of water once in every 15 days during maturity phase of sugarcane, respectively. Other improved recommended technologies utilized by the respondents in irrigated sugarcane cultivation includes variable rate technology (44.4%), skip furrow technology (42.6%) and application of water in furrow (40.7%). Furthermore, with respect to application of fertilizer in sugarcane production, some of the respondents under irrigated farming system applies inorganic fertilizer (31.7%) and suitable organic fertilizer (24.4%) during production. Thus, fertilizer application in sugarcane production is recommended at two-third of nitrogen, while the remaining one-third being phosphorus and potash. More than half (54.6%) of respondents utilized early harvesting (10 – 11 months) and 50.9% mid-season harvesting (11 – 12 months) This corroborate finding of Singh *et al.* (2017) who posit the use of early and mid-late maturing varieties as planting materials in sugarcane production to have bomber harvest or good harvest and this eventually prevent loss from harvest processes.

Table 4.9: Respondents' Utilization of Improved Technologies under Irrigated (n = 108)

Variables	Utilized		Not Utilized	
	Frequency	**Percent (%)**	**Frequency**	**Percent (%)**
Land preparation				
Ploughing depth of 30 cm	67	62.0	41	38.0
Use of pre-germinated nursery setts	60	55.6	48	44.4
Spacing of > 45 cm apart	62	57.4	46	42.6
Planting				
Modified planting method	64	59.3	44	40.7
Sowing depth of 30 cm	71	65.7	37	34.3
Pit diameters of 75 cm	51	47.2	57	52.8
Center to center by 105 cm	41	38.0	67	62.0
Space transplanting	41	38.0	67	62.0
Seed rate technology	27	25.0	81	75.0
Inter-row spacing	46	42.6	62	57.4
Intra-row spacing	35	32.4	73	67.6
Ring pit	38	35.2	70	64.8
Inter-cropping with tomatoes	43	39.2	65	60.2
Weeding				
Combination of cultural and chemical	64	59.3	44	40.7
Weed sensor technology	43	39.8	65	60.2
Weed seeker technology	31	28.7	77	71.3
Water application				
Water application once 10 days at tillering	70	56.9	53	43.1
Water application once 7 days at growing	92	74.8	31	25.2
Water application once 15 days at maturity	70	56.9	53	43.1
Water application at the furrow	50	40.7	73	59.3
Variable-rate technology(VRT)	48	44.4	60	55.6
Skip furrow technology	46	42.6	62	57.4
Fertilizer application				
Suitable organic manure	50	46.3	58	53.7
Inorganic fertilizer	59	54.6	49	45.4
Harvesting				
Early harvesting (10 – 11 months)	59	54.6	49	45.4
Mid-season harvesting (11 – 12 months)	55	50.9	53	49.1

Source: Field Survey, 2019

4.5 Constraints associated with Sugarcane Production under Rain-fed and Irrigated

As presented in Table 4.10, the pooled result of perceived constraints associated with sugarcane production in the study area, revealed inadequate capital and access to credit facilities ($\bar{X}$= 2.58), inadequate extension services ($\bar{X}$= 2.45), high cost of farm inputs ($\bar{X}$= 2.32) and poor access to training on sugarcane production ($\bar{X}$= 2.32) ranked 1st, 2nd and 3rd, 4threspectively, among the severe constraints perceived by the respondents in the study area. Table 4.10also revealed, the major perceived constraints associated with sugarcane production that are severe under rain-fed farming system in the study area to includes inadequate capital and access to credit facilities ($\bar{X}$= 2.74), inadequate extension services ($\bar{X}$= 2.63) and high cost of farm inputs ($\bar{X}$= 2.44) ranked 1st, 2nd and 3rd, respectively. Similarly, the major constraints associated with sugarcane production perceived to be severe by the respondent under irrigated farming system includes inadequate capital and access to credit facilities ($\bar{X}$= 2.41), poor access to training on sugarcane production ($\bar{X}$= 2.31) and inadequate extension services ($\bar{X}$= 2.24) ranked 1st, 2nd and 3rd, respectively. This implies that inadequate capital and access to credit facilities, inadequate extension services, high cost of farm inputs and poor access to training on sugarcane production are the major constraints associated with sugarcane production under both rain-fed and irrigated farming system in the study area. This agreed with Sulaiman *et al.* (2015) that identified inadequate funding or credit facilities in sugarcane farmers' perception, the challenges and response to climate change in Kaduna State, Nigeria. In the same vein, Oravee (2015) sees lack of funding in the river basin and rural development lead to ineffectiveness of the scheme. In extension services, Mgbenka *et al.* (2015) identified access to credit and extension contact to be paramount among other factors in maximizing productivity. So also, Giroh (2012) in his study on efficiency of latex production and labour productivity in rubber plantation in Edo and Delta States, Nigeria; revealed that extension services among other factors enhances the allocation efficiency of rubber production in the study area. This is also in line with Martina and Dilipsinh (2012) that examined and posited the constraints to sugar production and found that the main factors that hinder good and expected output and productivity are; inadequate farm size and late allocation of farmland to farmers, poor credit facility, unavailable or shortage of fertilizer and cane setts, labour prices paid by millers to sugarcane growers, returns on sugarcane, high returns from other alternative crops than sugarcane, shortage of rainfall and poor irrigation facility, unfavourable government policies; others are high cost of sugarcane production which reduces the profit margin of the sugarcane farmers; soil type, planting time, varieties, inputs use and unavailability of irrigation water.

Other constraints perceived by the respondents under rain-fed farming system to be severe in the study area, were unavailability of improved sugarcane seedlings ($\bar{X}$= 2.41), poor market policies and linkages ($\bar{X}$= 2.36), inadequate and high prizes of labour ($\bar{X}$= 2.35), poor access to training on sugarcane production ($\bar{X}$= 2.33), poor rural road networks from farm to market ($\bar{X}$= 2.30), inadequate storage facilities for sugarcane ($\bar{X}$= 2.28), poor access to farm inputs ($\bar{X}$= 2.28), lack of standardized means of measurement ($\bar{X}$= 2.17), poor value addition for sugarcane production ($\bar{X}$= 2.08) and problem of pests and diseases infestation ($\bar{X}$= 2.01) ranked 4^{th}, 5^{th}, 6^{th}, 7^{th}, 8^{th}, 9^{th}, 11^{th}, 12^{th} and 13^{th}, respectively. Meanwhile, constraints such as shortage of land for sugarcane farming ($\bar{X}$= 1.67), low demand for sugarcane by consumers ($\bar{X}$= 1.67), problem of drought ($\bar{X}$=

1.63) and insufficiency of irrigation water ($\bar{X}$= 1.72) ranked 14th, 16th and 17th, respectively, were perceived not to be severe by the respondents under rain-fed farming system.

Meanwhile, other constraints perceived by the respondents under irrigated farming system to be severe were inadequate or access to farm inputs ($\bar{X}$= 2.19), high cost of farm inputs ($\bar{X}$= 2.18), this is identified by Dayo *et al.,* (2009) who found that low yield or output can be as a result inadequate use of farming inputs such as fertilizer, herbicide and other agro-chemical in any farming system and this translate to small earning to the farmers and hence, high poverty level. Problem of pests and diseases infestation ($\bar{X}$= 2.11), In case of problem of pests and diseases was reported by Ikeme (2009) that Nigeria is currently experiencing increasing incidence of diseases and witness declining in agricultural production. This is in line with finding of Viswanathan and Rao (2011) who found 30-40% yield loss were due to severe disease associated with sugarcane crop in sub-tropic zone. However, early detection of incipient pathogen through serological and molecular techniques could help to check the spread of the disease at early stage of infection, also selection of healthy improved planting seed material or varieties and seed treatment using fungicide before planting could also be helpful in the control of fungal diseases. Moreover, use of disease resistant varieties along with good seed nursery management can form a basis to prevent/control diseases in sugarcane production and this eventually help to check the yield loss caused by disease infestation; unavailability of improved sugarcane seedlings ($\bar{X}$= 2.03), low demand for sugarcane by consumers ($\bar{X}$= 2.00) and poor market policies and linkages ($\bar{X}$= 2.00) ranked 4th, 5th, 6th, 7th and 8th, respectively. Moreso, poor rural road networks from farm to market ($\bar{X}$= 1.95),inadequate and high prizes of labour ($\bar{X}$= 1.91), poor value addition along sugarcane value chain($\bar{X}$= 1.81).The problem of drought ($\bar{X}$= 1.80), insufficiency of irrigation water ($\bar{X}$= 1.71).this is in line with finding posited by Cosmas *et al*. (2010) and Olayide *et al*. (2016) that insufficiency of supply water for sugarcane production during rainfall or and for irrigation cannot sustain the production of growing food demand, therefore, water resources for irrigation should be developed, because it plays a key role in agricultural and economic growth in the country (Mugagga and Nabaasa, 2016). This is also in collaboration with Akande *et al.* (2017) that posited agriculture and irrigation are intertwined especially in Nigeria where there is spatial-temporal variation of rain fall across the country, therefore every plans toward agricultural development must also extend to irrigation development system in Nigeria. Inadequate storage facilities for sugarcane ($\bar{X}$= 1.72), lack of standardized means of measurement ($\bar{X}$= 1.65) and shortage of land for sugarcane farming ($\bar{X}$= 1.67) ranked 10th, 11th, 12th, 13th, 14th, 15th, 16th and 17th, respectively, were the constraints perceived not to be severe by the respondents under irrigated farming system in the study area.

Table 4.10: Respondents' Constraints to Sugarcane Production under different Production Systems

	Rain-fed System (n = 123)				Irrigated System (n = 108)				Pooled (n = 231)			
Constraints	**WS**	**WM**	**Rank**	**Remark**	**WS**	**WM**	**Rank**	**Remark**	**WS**	**WM**	**Rank**	**Remark**
Inadequate capital and access to credit facilities	337	2.74	1st	Severe	260	2.41	1st	Severe	597	2.58	1st	Severe
Inadequate extension services	324	2.63	2nd	Severe	242	2.24	3rd	Severe	566	2.45	2nd	Severe
High cost of farm inputs	300	2.44	3rd	Severe	235	2.18	5th	Severe	535	2.32	3rd	Severe
Unavailability of improved sugarcane seedlings	296	2.41	4th	Severe	219	2.03	7th	Severe	515	2.23	6th	Severe
Poor market policies and linkages	290	2.36	5th	Severe	216	2.00	8th	Severe	505	2.19	7th	Severe
Inadequate and high prizes of labour	289	2.35	6th	Severe	206	1.91	11th	Not Severe	495	2.14	8th	Severe
Poor access to training on sugarcane production	287	2.33	7th	Severe	250	2.31	2nd	Severe	537	2.32	3rd	Severe
Poor road networks from farms to market	283	2.30	8th	Severe	211	1.95	10th	Not Severe	494	2.14	8th	Severe
Inadequate storage facilities for sugarcane	281	2.28	9th	Severe	186	1.72	14th	Not Severe	467	2.02	11th	Severe
Inadequate or poor access to farm inputs	280	2.28	9th	Severe	237	2.19	4th	Severe	517	2.24	5th	Severe
Lack of standardized means of measurement	267	2.17	11th	Severe	178	1.65	16th	Not Severe	445	1.93	13th	Not Severe
Poor value addition for sugarcane production	256	2.08	12th	Severe	196	1.81	12th	Not Severe	452	1.96	12th	Not Severe
Problems of pests and diseases infestation	247	2.01	13th	Severe	228	2.11	6th	Severe	475	2.06	10th	Not Severe
Shortage of land for sugarcane farming	206	1.67	14th	Not Severe	170	1.57	17th	Not Severe	376	1.63	16th	Not Severe
Low demand for sugarcane by consumers	206	1.67	14th	Not Severe	216	2.00	8th	Severe	422	1.83	14th	Not Severe
Problem of drought	200	1.63	16th	Not Severe	194	1.80	13th	Not Severe	394	1.71	15th	Not Severe
Insufficiency of irrigation water	186	1.51	17th	Not Severe	185	1.71	15th	Not Severe	371	1.61	17th	Not Severe

Source:Field Survey, 2019

Note: VS= VerySevere (3), S= Severe (2), NS = Not Severe (1), WM = Weighted Mean and WS = Weighted Sum. The bench means score Value is 2.0.

The result of the Kendall coefficient of concordance as presented in Table 4.11. It revealed that the sum of mean rank of the constraints under rain-fed was 153.00 which is lower than chi-square value of 395.67 at 1% level of probability with Kendall *W* value of 0.201. More so, sum of mean rank of the constraints under irrigated was 150.01 which is lower that the chi-square value of 286.52 at 1% level of probability with Kendall *W* value of 0.166. The result on constraint pooled revealed sum of mean rank of 143.32 which is lower than the chi-square value of 574.08 at 1% level of probability with Kendall *W* value of 0.155. This implies that there was a general agreement among the respondents with respect to constraints associated with sugarcane production in the study area.

Table 4.11: Kendal Coefficient estimates of the constraints to Sugarcane Production

Constraints	**Rain-fed Mean Rank (n=123)**	**Irrigation Mean Rank (n=108)**	**Pooled Mean Rank (n=231)**
Inadequate capital and access to credit facilities	12.33	11.70	12.04
Inadequate extension services	11.55	10.65	11.13
High cost of farm inputs	10.53	10.32	10.44
Unavailability of improved sugarcane seedlings	10.43	9.43	9.96
Poor market policies and linkages	10.20	9.11	9.69
Inadequate and high prizes of labour	9.95	8.57	9.31
Poor access to training on sugarcane production	9.84	11.09	10.42
Poor road networks from farms to market	9.72	8.88	9.33
Inadequate storage facilities for sugarcane	9.65	7.52	8.66
Inadequate or poor access to farm inputs	9.61	10.42	9.99
Lack of standardized means of measurement	9.00	6.92	8.02
Poor value addition for sugarcane production	8.32	8.13	8.23
Problems of pests and diseases infestation	8.08	9.86	8.91
Low demand for sugarcane by consumers	6.37	9.15	7.67
Shortage of land for sugarcane farming	6.17	5.89	6.04
Problem of drought	5.92	7.99	6.89
Insufficiency of irrigation water	5.33	7.38	6.28
Sum of mean rank	153.00	150.01	143.32
Kendall *W*	0.201	0.166	0.155
Chi-square	395.67***	286.52***	574.08***

Source: Field Survey, 2019

4.6 Test of hypotheses

4.6.1 Hypothesis I

The null hypothesis I which stated that there is no significant difference between the productivity of sugarcane farmers under irrigated and rain-fed farming system in the study area was tested using t – test statistics. The result of the pair-wise t – test as presented in Table 4.11revealed t – statistic value of 9.579 at 1% level of probability. This implies that there was a significant difference in the mean output level of the sugarcane farmers under irrigated and rain-fed farming system in the study area. The null hypothesis was, therefore, rejected, while the alternative hypothesis which stated that there was a significant difference between the productivity of sugarcane farmers under irrigated and rain-fed farming system was accepted. This implies that the sugarcane farmers under irrigated farming produce more output efficiently due to available resources and inputs with best farm management practices utilized by sugarcane farmers in the study area.

Table 4.12: T-test estimate for null hypothesis I

	Mean (kg)	**Standard dev.**	**t – value**	**Decision**
Irrigated sugarcane productivity index	1824	147.39	9.579***	Reject
Rain-fed sugarcane productivity index	382	21.74		
Mean difference	1442			

Source: Field survey, 2019 * = significant at 1% probability level**

4.6.2 Hypothesis II

The null hypothesis II which stated that there is no significant difference between the income of sugarcane farmers under irrigated and rain-fed farming system in the study area was also tested using t – test statistics. The result of the pair-wise t – test as presented in Table 4.12revealed t – statistic value of 4.009 at 1% level of probability.

This implies that there was a significant difference in the mean income of the sugarcane farmers under irrigated and rain-fed farming system in the study area. The null hypothesis was, therefore, rejected, while the alternative hypothesis which stated that there was a significant difference between the income of sugarcane farmers under irrigated and rain-fed farming system was accepted. This implies that the sugarcane farmers under irrigated farming system generate more income as compared to those under rain-fed farming system and higher income from sugarcane production tends to enhance adoption of improved agricultural technologies in the study area.

Table 4.13: T-test estimate for null hypothesis II

	Mean (₦)	**Standard dev.**	**t – value**	**Decision**
Irrigated sugarcane income	1,426,904	157,328	4.009**	Reject
Rain-fed sugarcane income	792,127	37,395		
Mean difference	634,780			

Source: Field survey, 2019   * = significant at 1% probability level**

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Based on the findings emanating from this study, it can be concluded that the respondents under irrigated and rain-fed sugarcane farming systems were in their mid-age and most productive stage of life with capacity to produce sugarcane. Males were the dominant sex in sugarcane production, while most of the respondents were married and able to cater for their family needs. There was relatively low literacy level among the respondents, while, most of the respondents had attained one form of formal education or the other with at least primary education. The respondents had been into sugarcane farming over a relatively long period of time and also had large household size which is a good source of family labour, they are small-medium scale farmers while the farmers under rain-fed farming system have more farmland as compare to those under irrigated farming system. However, both the respondents under rain-fed and irrigated farming system had limited access to credit facilities and some of them have no contact with extension services and were members of cooperative societies in the study area.

The sugarcane farmers under rain-fed and irrigated farming systems produced below the optimum level as indicated by the mean productivity. Although, sugarcane farmers under irrigated farming system had high sugarcane output as compared to those under rain-fed farming system.

With respect to costs and returns of sugarcane production under rain-fed and irrigated farming systems, labour and transportation costs were the highest expenses incurred during sugarcane production representing over fifty percent of the total costs incurred. However, the total revenue generated from sugarcane production by the respondents under irrigated farming system was higher than the rain-fed farming system. Thus, sugarcane production is a profitable enterprise with irrigated farming system having the highest return in naira invested as compared to rain-fed farming system in the study area.

Improved technologies utilized by the respondents under rain-fed farming system were on soil requirement, land preparation, planting, weeding, fertilizer application and harvesting, while those utilized under irrigated farming system were land preparation, planting, weeding, water application (irrigation), fertilizer application and harvesting. However, sugarcane farmers under irrigated farming system tends to utilize more improved technologies especially in planting, weeding and water application (irrigation) as compared to those under rain-fed farming system.

The major constraints associated with sugarcane production under rain-fed farming system were inadequate capital and access to credit facilities, inadequate extension services and high cost of farm inputs, while constraints perceived by the respondent under irrigated farming system includes inadequate capital and access to credit facilities, poor access to training on sugarcane production and inadequate extension services. Based on the hypotheses tested, there was a significant difference in the mean productivity level of the sugarcane farmers under irrigated and rain-fed farming system, while there was also a significant difference in the mean income of the sugarcane farmers under irrigated and rain-fed farming system.

5.2 Recommendations

From the findings of this study, the following recommendations among others are put forward:

i. The study revealed that the respondents were young and active in their most productive stage of life but educational level was low which could impede adoption of new innovation or improved technologies for high productivity of sugarcane production. It was therefore recommended that skill acquisition training centres should be provided by NGOs and relevant stakeholders to educate and develop the skills of the farmers through capacity building; workshop and field trial.

ii. Both sugarcane farmers under rain-fed and irrigated farming systems were found to have limited access to credit. It was therefore recommended that, formal financial institutions especially Bank of Agriculture (BOA) and Microfinance Banks should provide flexible policy on credit with single digit interest rate that will enhance access to credit by resource poor farmers for increase sugarcane production. Also farmers' cooperative societies should be encouraged to secure loans, providing farm inputs and organizing agro-business shows with awards to motivate sugarcane farmers in the study area.

iii. It is also recommended that the sugarcane farmers should come together and adequately participate in cooperative societies in order to collectively establish cottage industry (i.e. sugarcane processing centres) that will add value to sugarcane value along the value chain. Membership of cooperative societies will also encourage utilization of improved sugarcane technologies and through this avenue the farmers able to get access to adequate agricultural incentives (inputs).

iv. Productivity of sugarcane was found to be below the optimum level in the study area. It is, therefore, recommended that agricultural extension agencies should intensify their efforts in educating and sensitizing sugarcane farmers on how to appropriately and practically combine available resources to realise optimum output in the study area.

v. Government both at federal and state level should formulate a favourable policies that will give and encourage positive enabling environment for sugarcane farmers and attract foreign investments and industrialization in the study area.

vi. Inadequate or poor access to farm inputs was one of the constraint by the respondents under rain-fed and irrigated farming system. It is therefore recommended that aappropriate measures by the Government agencies and NGOs should be put in place for proper planning and execution of input supply as well as provide logistics that will ensure efficiency in the inputs supply chain by bringing farm inputs closer to the farmers at affordable or subsidized prices, and also this should be available in right quantity, quality and at right time in the study area; and finally, if the government at all levels can provide irrigation infrastructures to these small-scale and medium scale sugarcane farmers it will go long way in improving yield.

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APPENDIX I

DEPARTMENT OF AGRICULTURAL EXTENSION AND RURAL DEVELOPMENT,

SCHOOL OF AGRICULTURE AND AGRICULTURAL TECHNOLOGY,
FEDERAL UNIVERSITY OF TECHNOLOGY,
MINNA NIGER STATE, NIGERIA

RESEARCH QUESTIONNAIRE

Dear Respondents,

I am a Master student in the Department of Agricultural Extension and Rural Development, Federal University of Technology, Minna Niger State. I am currently conducting an academic research on the topic ***"Assessment of irrigated and rain-fed farming system on sugarcane production in Bauchi State, Nigeria".*** Please, you are expected to answer the following questions based on facts and personal experience. Kindly tick (√) or fill in the blank spaces appropriately. All information provided will be kept confidential.

Thanks for your anticipated co-operation.

ADEMOLA, Thompson Oluwole
MTECH/SAAT/2017/6821

Preliminary Information

Name of respondent…………………………………………………………………………

Phone number (GSM No) ……………………………………...……………………...

Date of Interview…….……………………………………….…………….…………….

Name of Local Government Area (LGA)…………………….………………………….

Name of the Community……….……………………………..………………………….

Questionnaire Number…………………………………….………………………….

Category of Respondents

a. Rain-fed sugarcane farming system [ ]
b. Irrigated sugarcane farming system [ ]
c. Both rain-fed and irrigated system[ ]

SECTION A: SOCIO-ECONOMIC CHARACTERISTICS OF THE RESPONDENTS

1. What is your Age? ………………………………………years
2. Sex: (a) Male [ ](b) Female [ ]
3. Marital status:
   (a) Single [ ] (b) Married [ ] (c) Divorced [ ] (d) Widowed [ ]
4. What is your highest educational attainment ?
   (a) Primary [ ] (b) Secondary [ ] (c) Tertiary [ ] (d) Adult [ ] (e) Quranic [ ]
5. How many years did you spend in formal school? …………....................................
6. What is your household size in numbers? ....
7. How long have you been into sugarcane farming? ……………………………years
8. What is your secondary occupation?
   (a) Crop farming [](b) Livestock farming [ ](c) Fish farming [ ](d) Trading [ ]
   (e) Civil service [ ] (f) Artisan work [ ] (g)Agro-processing [ ] (viii) Others (specify)………….
9. What is your total farm size?.....................................hectares

10. How did you acquire your farmland?
    (a) Inheritance [ ] (b) Purchased [ ] (c) Borrowed [ ] (d) Rented [ ] (e) Others (specify)…
11. If rented, how much did you pay as rent last cropping season?₦..
12. If purchased, how much did you pay for the land? ₦..
13. Do you have contact with extension agent? (a) Yes [ ] (b) No [ ]
14. If yes, kindly indicate the frequency of visit by the extension agent(s) in the last season.
    (a) Weekly [ ] (b) Bi-weekly [ ] (c) Monthly [ ] (d) Quarterly [ ] (e) Annually [ ]

15. If yes, how many times did extension staff visit you last season?....................time(s).
16. If no, indicate why?...
17. Do you have access to credit? (a) Yes [ ] (b) No [ ]
18. If yes, how much? ₦……………………………………………………………………..….
19. If yes, what is the source of your credit?
    (a) BOA [ ] (b) Commercial banks [ ] (c) Family & Friends [ ] (d) Cooperatives [ ] (e) Micro-finance bank [ ] (f) Others (specify)…………………………………...……
20. Do you belong to cooperative society? (a) Yes [ ] (b) No [ ]
21. If yes, how many years have you been in the cooperative? ....……………..…...……
22. If yes, how many cooperative societies do you belong to? ………………………………

SECTION B: PRODUCTIVITY OF SUGARCANE PRODUCTION

23. What is your total farm size for sugarcane production?................................hectares
24. What types of labour do you employ?
    (a) Family [ ] (b) Hired [ ] (c) Communal [ ] (d) Hired and Family [ ]
    (e) Other (specify)………

25. Please, kindly indicate your labour usage in mandays for sugarcane production.

	Family labour						**Hired labour**					
	Adult male		**Adult female**		**Children**		**Adult male**		**Adult female**		**Children**	
Operations	No	Days	No	Days	No	Days	No	Days	No	Days	No	Days
Land clearing												
Planting												
Fertilizer app.												
Agro-chemicals												
Weeding												
Water management												
Harvesting												
Transportation												
Others specify.......												

26. Please, kindly indicate wages paid for labour usage in your sugarcane production

S/No	Operations	AMWage (₦)	AFWage (₦)	CHWage (₦)	Total
1	Land clearing				
2	Planting				
3	Fertilizer application				
4	Agro-chemical				
5	Weeding				
6	Water management				
7	Harvesting				
8	Transportation				
9	Others specify……………..				

Note: AM = Adult Male, AF = Adult Female and CH = Children

27. Kindly fill in the table provided on your produce

Produce	Quantity harvested (kg)	Quantity consumed (kg)	Quantity sold (kg)	Price/kg (₦)	Total value sold (₦)
Sugarcane					
Others…………					

SECTION C: COST AND RETURNS OF SUGARCANE PRODUCTION

28. Kindly fill in table on the variable inputs used in sugarcane production.

Variable inputs	Quantity	Price/Unit	Amount (₦)
Sugarcane seedlings			
Fertilizer in kg			
Agro-chemicals (litres)			
Manures			

29. Kindly fill in the table on the fixed inputs used in sugarcane production.

Fixed Inputs	Quantity	Price/Unit	Amount (₦)
Cutlass			
Hoe			
Sickle			
Wheel barrow			

Boots			
Sprayer			
Water pump			
Others (Specify) …………………			

30. What is the cost of storage? ₦……………………………………,,……….…………
31. What is the cost of transportation?
    i. From farm to house? ₦……………………………………….……….…………..
    ii. From farm to market? ₦……………………………………….…………………
    iii. From house to market? ₦…………………………………………………………..
32. How much do you pay as a commission, fees or levies? ₦……………………………….

SECTION D: IMPROVED TECHNOLOGIES UTILIZATION UNDER IRRIGATED SUGARCANE PRODUCTION

33. Kindly indicate the improved technologies utilized under irrigated sugarcane production

Technologies	**Utilized**	**Not Utilized**
(a) Land preparation:		
*Ploughing depth of 30cm		
(b) Nursery management:		
*Use of pre-germinated setts		
*keeping of > 45cm gap apart between seedlings		
(c) Planting:		
*modified planting methods (mother shoot technology)		
*Sowing depth of 30cm		
*Pit diameter of 75cm		
*Center to Center of 105cm that gives 9000pits per hectare		
*Space Trans-Planting (STP) from 1:10cm to1:40cm for 25-30 days		
*Seed Rate Technology of 4000 to 6000 seedlings/ha		
*Inter-row spacing between 60 to 100cm		
*Intra-row between 45 to 120		
*Ring pit, deep trench and paired rows		
*Inter cropping of sugarcane with tomatoes, onions or potatoes		
(d) Weeding management:		
*Combination of cultural (hoeing) and chemical (Atrazine 2.0kgai/ha) weed control methods at first and second irrigation.		
*Weed sensors technology which regulate the amount of herbicides to be spray in sugarcane plantation		
*Weedseeker technology which identify and sprays only where the herbicides is needed in sugarcane plantation		

(e) Irrigation:		
*Irrigation water application once in 10 days during tillering stage (36 – 100 days)		
*Application once in 7 days during at growing period (101 – 270 days)		
*Application once in 15 days during maturity stage (from 271 days till harvesting period)		
*Variable-Rate Technology (VRT) for regulating irrigation water at different rate across the sugarcane plantation		
*Skip Furrow Technology		
(f) Fertilizer application:		
*Suitable organic manure (farmyard manure) is 200kg/acre		
*Inorganic fertilizer (chemical fertilizer) especially NPK at 112kg, 25kg and 48kg rate/hain 30th and 60th after planting		
(g) Harvesting:		
*10 – 11 months age (for early varieties)		
*11 – 12 months age (for mid-season varieties)		

34. Do you use other technologies not mention above? (a) Yes [ ] (b) No [ ]

35. If yes, others (specify)

……………………………………………………………………….

SECTION E: IMPROVED TECHNOLOGY UTILIZATION UNDER RAIN-FED SUGARCANE PRODUCTION

36. Kindly indicate the improved technologies utilized under rain-fed sugarcane production

Technologies	Utilized	Not Utilized
(a) Soil requirement:		
*Heavy soil with good drainage,		
*Light texture soil with assured irrigation		
*Soil with good pHof 6.5 – 7.5 (i.e. loamy or clay loam soil)		
(b) Land preparation:		
*Ploughing with 30cm depth		
*Pre-manuring of farmland before planting seedlings		
*Raising nursery (2 – 3 budded sugarcane setts for planting)		
(c) Planting:		
*Long and thick stems of about 40cm long (setts)		
*The setts planted horizontally in the furrows		
*September to October (autumn planting)		
*February to March (spring planting)		
(d) Weeding:		

*A weed-free environment essential for efficient intake of nutrients mechanically by deep ploughing		
*Hand weeding by hoeing 30, 60 and 90 days after planting		
*De-trashing (removal of excess and unproductive leaves)		
*Mulching (covering of soil with leaves or grasses around the sugarcane to check weeds and erosion.		
(e) Agro-chemical application:		
*Application of Altrazine chemical to control pests and diseases		
(f) Fertilizer application:		
*Soil testing to get required type and quantity of fertilizer		
*Application of NPK at 112kg, 25kg and 48kg rate/acre		
(g) Harvesting:		
*Row thinning (removal of cane rows for easy lifting during harvesting)		
*Earthing up (putting of soil at the root zone of the sugarcane)		
*Propping (to give support to the cane to avoid lodging)		
*Manual harvesting (by setting the field on fire chase or kill snakes hiding in the plantation)		
*Mechanical harvesting using machines		
*Ratooning (leaving the lower part of the plant along with the roots uncut at the time of harvesting)		
*Stumble shaving (cut with sharp knife or blade above ground level to helps buds sprout and establish very deep root system)		

SECTION E: CONSTRAINTS ASSOCIATED WITH SUGARCANE PRODUCTION

37. Kindly indicate the level of severity of constraints/challenges encounter in your production

Constraints	Very Severe	Severe	Not Sever
Poor access to training on sugarcane production			
Inadequate capital and access to credits facility			
Inadequate extension services			
Inadequate storage facilities for harvested sugarcane			
Shortage of land for sugarcane farming			
Inadequate access to farm inputs (such as fertilizer, pesticides, herbicides, etc.) at affordable prizes			
High cost of farm inputs			
Low demand for sugarcane by consumers			
Poor road networks from farms to market			
Unavailability of improved seedlings for sugarcane			
Problem of infestation of sugarcane by pests and diseases			
Lack of standardized means of measurement (scale and weigh)			
Inadequate and high prizes of labour			

Poor market policies and linkages			
Insufficiency of irrigation water			
Problem of drought			
Poor value added products for sugarcane			

38. Others

(specify)……………………………………………………………………………….……

39. How do you think the problems or constraints of sugarcane production can be solved?..
....
....