FEDERAL UNIVERSITY OF TECHNOLOGY MINNA

IRRIGATION DEVELOPMENT AND FOOD SECURITY IN NIGERIA

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INAUGURAL LECTURE SERIES 15

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1. Introduction

It is a well-known fact that Nigeria is largely a food-insecure nation. Overwhelmingly large proportions of both the rural and urban populations have no access to adequate food of the right quantity and quality. Domestic food demand has continued to outstrip supply, resulting in high food prices which are further driven through the roof by the high agricultural production costs. Even the resort to massive food importation witnessed over the years has not succeeded in reducing prices to levels that would permit access to adequate food by a major proportion of the poverty-stricken population. The food security situation in the country has been further exacerbated by the soaring world food prices. The effect of the global food crisis and the high prices of food, particularly grains, which it engendered, has been felt most severely in sub-Saharan African countries most of which rely heavily on imported food and food aid. Nigeria was not insulated from this shock which began about 2008. The salutary lesson of the global food crisis should be that as much as possible, any serious country has to look inwards by producing most of the food she consumes. Reliance on food imports is usually costly (and a heavy drain on scarce foreign exchange), unreliable and impinges on the dignity and self-respect of a nation.

It is paradoxical that Nigeria should be grappling with the problem of food security. The country has an estimated land area of 94 million hectares, most of which is suitable for agricultural production. In fact, the country still has abundant land which has not been cultivated. Land is perhaps, the most critical input in agricultural production and the country has this in abundance. Furthermore, not less than 60% of Nigeria's labour force is engaged in agricultural production. Why then, should the country be unable to feed herself even when so much resources are committed to the agricultural sector?

The woes of Nigeria's food security situation could also not be attributed to a lack of well-intentioned policies and programmes aimed at transforming the agricultural sector. In fact, successive governments in Nigeria have over the years, rolled out a plethora of programmes which were intended to raise agricultural production in order to ensure food security, reduce poverty and supply raw materials to the agro-allied industry. Some of these are the National Accelerated Food Production Programme (introduced in 1972), Operation Feed the Nation (1976), River Basin Development Authorities (1976), Agricultural Credit Guarantee Scheme (1977), Green Revolution Programme (1979), World Bank-assisted Agricultural Development Projects (1986), the Directorate of Foods, Roads and Rural Infrastructure (1986), Better Life Programme (1989), National Agricultural Land Development Authority (1991), National Fadma Development Programme (1993), Family Support Programme (1995), Family Economic Advancement Programme (1997), and National Poverty Eradication Programme (2001).

In spite of these efforts, the agricultural sector has not adequately responded to the food and raw materials requirements of the country. The problem is that the sector is dominated by smallholders, most of whom still use traditional inputs and tools and are characterised by low productivity.

2. Nigeria's Agricultural Sector

Nigeria's agriculture is largely rainfed. 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 rainfed and irrigated agriculture are dominated by small-scale farmers most of whom cultivate less than five hectares. These farmers use traditional tools and inputs in the production process. The production is characterised by low productivity. The low productivity on individual farms has resulted in low aggregate food production for the country as a whole. The causes of low agricultural productivity are numerous but have been too adequately documented elsewhere (see for instance Baba, 2009) to warrant a full listing here. Suffice it to highlight some of the more important ones as follows:

One of the major causes of low productivity is inappropriate agricultural technologies. In spite of several decades of agricultural research and extension, agricultural scientists have not been able to substantially change the production systems of many Nigerian farmers. There appears to be a wide gap between research and the farmers. Majority of the farmers continue to use traditional, but time-tested technologies in spite of far "superior" modern ones developed by research. This has resulted in wide disparities between potential and actual crop and livestock yields. It will be difficult to achieve food security in Nigeria without modernisation of the production systems.

Another important cause of low productivity is inadequate supply and high cost of production inputs. Two of the modern inputs that triggered the Green Revolution in Asia are high-yield seeds and fertilizer. But the level of use of these inputs in Nigeria in particular, and Africa generally, is still very low because they are out of the reach of the resource poor farmers. It is reported for instance, that fertilizer use in sub-Saharan Africa is at an average of 8kg/ha, representing only 9% of world average. This is in spite of the promising resolutions reached by African leaders at the "All African Fertilizer Summit" held at Abuja in 2006 (Iwunna, 2009).

Low agricultural productivity is also caused by the small, uneconomic production units of the farmers. Most Nigerian farmers operate on very small and often fragmented land holdings. Some rigidities, including unsuitable land tenure arrangements, low levels of capital, and high costs of labour and material inputs, seem to have limited the sizes of farms farmers could effectively maintain, thereby denying them the benefits of scale economies.

Poor development of vital infrastructural facilities is yet another factor limiting agricultural productivity. For instance, rural roads and other avenue for transportation (which could ease market access for both input purchase and output disposal) are not adequately developed. This, in addition to poor storage facilities, poor market information, long marketing channels and high number of middlemen, has resulted in inefficient marketing system which, in turn, does not give farmers the needed incentive (in terms of remunerative prices) to increase production. For instance, prices of agricultural products which are sometimes so high at the retail level as to prohibit consumption do not adequately reflect at the farmers' level to stimulate production.

There is also the problem of low investment in agriculture. Investment in agriculture at the level of government and individual farmers is very low. Investment at the individual farmer level is also low mainly because most of the farmers are poor, but also because they have limited access to credit. The resulting under-capitalisation has negative implications, not just for farm sizes, but also for the purchase and use of improved inputs and, *ipso facto*, agricultural yields.

Finally, there is the problem of an almost complete reliance on rainfall by the farmers because of limited development of irrigation facilities. It is a fact that a great proportion of Nigeria's land mass falls within the semi-arid zone receiving limited rainfall spread over a period of five months or less. This implies that without irrigation, farm resources are idle or remain underutilised for at least seven months in a year and no agricultural output could be obtained. Reliance on rainfall alone is becoming even more precarious in view of climate change. As pointed out by Janneh (2008), climate change is resulting in falling precipitation and increased climate variability resulting in low yields. Irrigation is becoming increasingly imperative for efforts aimed at attaining food security. The purpose of this Lecture therefore, is to demonstrate the potential role that effective irrigation development could play in the attainment of food security in Nigeria.

3. Human and Food Security

3.1 Human Security

The common notion of human security is freedom from violence that may hurt, injure or harm human beings as individuals. But it has been argued that the concept must be viewed in a broader sense to include not only freedom from physical violence or its threat, but also from hunger, disease, poverty, illiteracy, environmental pollution or degradation, powerlessness and oppressive structures. For example, the draft African Non-Aggression and Common Defence Pact states: "human security means the security of the individual with respect to the satisfaction of the basic needs of life; it also encompasses the creation of the social, political, economic, military, environmental and cultural conditions necessary for the survival, livelihood, and dignity of the individual, including the protection of fundamental freedoms, the respect for human rights, good governance, access to education, healthcare, and ensuring that each individual has opportunities and choices to fulfill his/her own potential" (Cilliers, 2004). According to Poku *et al.* (2007), the new notion of human security has to do with the challenge of meeting the basic needs and aspirations of millions of people in Africa, Asia and beyond. In other words, contemporary view of security is tied to the complex and multiple challenges of development.

3.2 The Concept of Food Security

Food security is said to exist when "all people at all times have access to safe nutritious food to maintain a healthy and active life" (FAO, 1996). Food security is not just a production matter. The World Bank (2001) as cited in Obamiro *et al.* (2003) identified three pillars underpinning food security; these are food availability, food accessibility, and food utilization. Food availability for the farm household means ensuring sufficient food is available for them, through own production, throughout the year. Food accessibility means that it should be affordable. Food utilization means ensuring a good nutritional outcome (Obamiro *et al.*, 2003). For there to be food security therefore, food must be available, affordable and of the right nutritional quality (Baba, 2009). And to achieve this, you either produce what you need or you have adequate income to purchase food of the right quantity and quality. Unfortunately, Nigeria and most other countries in Africa are not food secure. The United Nations has designated 82 countries as low-income food deficit countries; 42 of those are in Africa ((Fleshman, 2008). Further, of the 36 countries identified by the United Nations Food and Agriculture Organization (FAO) to be in the grip of a food security crisis, 21 are in Africa. It is worrisome that even the food producers suffer from food insecurity because of low yields and incomes.

3.3 Agriculture and Food Security

Given the broad view of human security, it is not difficult to establish that there can be no human security without food security. Food security has direct bearing on many other dimensions of human security. For instance, people who are food insecure are not likely to be healthy and are unlikely to be in a position to seriously think about conquering other necessities of life that would have given them a comprehensive human security. In fact, where the population of hungry people is large, there is potential for instability and conflict, implying that food insecurity is a precursor to other forms of human insecurity. Furthermore, hungry or undernourished people cannot contribute meaningfully to the development process because of their reduced capacity for productive work. In fact, it is estimated that malnutrition could cause a 6% reduction in GDP of developing countries (Sheeran, 2009).

The development of the country's agriculture is perhaps the most feasible way of ensuring food and human security. A developed agricultural sector would raise productivity and increase aggregate food production which would be expected to increase food availability and accessibility. In addition, given that a large proportion (60-70%) of Nigeria's labour force is employed in the agricultural sector, increased agricultural production is likely to raise the income of the populace, thereby reducing poverty. Poverty is a well-known threat to food security. When people have money in their pockets and food is available, the problem of food insecurity is attenuated. Furthermore, health is related to nutrition. A developed agricultural sector that provides adequate nutrition for the people is also improving their health. Poor health is a human security threat which could to some extent, be avoided by adequate and appropriate food intake. In fact, in the Nigerian and African context where agriculture still depends largely on manual labour, health and agriculture are mutually reinforcing (Baba, 2009). A healthy person is able to produce more food which also enhances his/her health by making available more food.

4. Irrigation

4.1 Definition and Types of Irrigation

Irrigation refers to the artificial application of water to the soil for the purpose of supplying moisture essential for plant growth. It is also undertaken to provide an insurance against droughts, for cooling the soil and atmosphere thereby providing a more favourable environment for plant growth; to wash out or dilute salts in the soil, to reduce the hazard of soil piping, and to soften pillage pams (Israelsen and Hansen, 1962; Baba, 1993). It is therefore, used to assist in the growing of agricultural crops, maintenance of landscapes, and revegetation of disturbed soils in dry areas and during periods of inadequate rainfall. Additionally, irrigation also has a few other uses in crop production, which include protecting plants against frost, suppressing weed growing in grain fields and helping in preventing soil consolidation.

Irrigation methods are of various types. Some of the more common types include surface (gravity) irrigation, sprinkler irrigation, drip irrigation, sub-irrigation, manual irrigation and pump irrigation. In **surface** irrigation systems, water moves over and across the land by simple gravity flow in order to wet it and to infiltrate into the soil. Surface irrigation can be subdivided into furrow, borderstrip or basin irrigation (Wikipedia, 2010). It is often called **flood irrigation** when the irrigation results in flooding or near flooding of the cultivated land. Historically, this has been the most common method of irrigating agricultural land. **Drip** irrigation, also known as trickle irrigation, functions as its name suggests. Water is delivered at or near the root zone of plants, drop by drop. This method can be the most water-efficient method of irrigation, if managed properly, since evaporation and runoff are minimised. In **sprinkler** or **overhead** irrigation, water is piped to one or more central locations within the field and distributed by overhead high-pressure sprinklers or guns. A system utilizing sprinklers, sprays, or guns mounted overhead on permanently installed risers is often referred to as a *solid-set* irrigation system. Higher pressure sprinklers that rotate are called *rotors* and are driven by a ball drive, gear drive, or impact mechanism. Rotors can be designed to rotate in a full or partial circle. Guns are similar to rotors, except that they generally operate at very high pressures (Wikipedia, 2010).

Sub-irrigation, also called ***seepage** irrigation,* has been used for many years in field crops in areas with high water tables. It is a method of artificially raising the water table to allow the soil to be moistened from below the plants' root zone. Often those systems are located on permanent grasslands in lowlands or river valleys and combined with drainage infrastructure. A system of pumping stations, canals, weirs and gates allows it to increase or decrease the water level in a network of ditches and thereby control the water table (Wikipedia, 2010). **Manual** irrigation as the name suggests is accomplished manually using buckets, calabashes, or shadouf to lift water. In some places, manual irrigation is assisted with animal power. In the case of **pump** irrigation, water is lifted from the source with the aid of a motorised pump which may be powered by fuel or electric power.

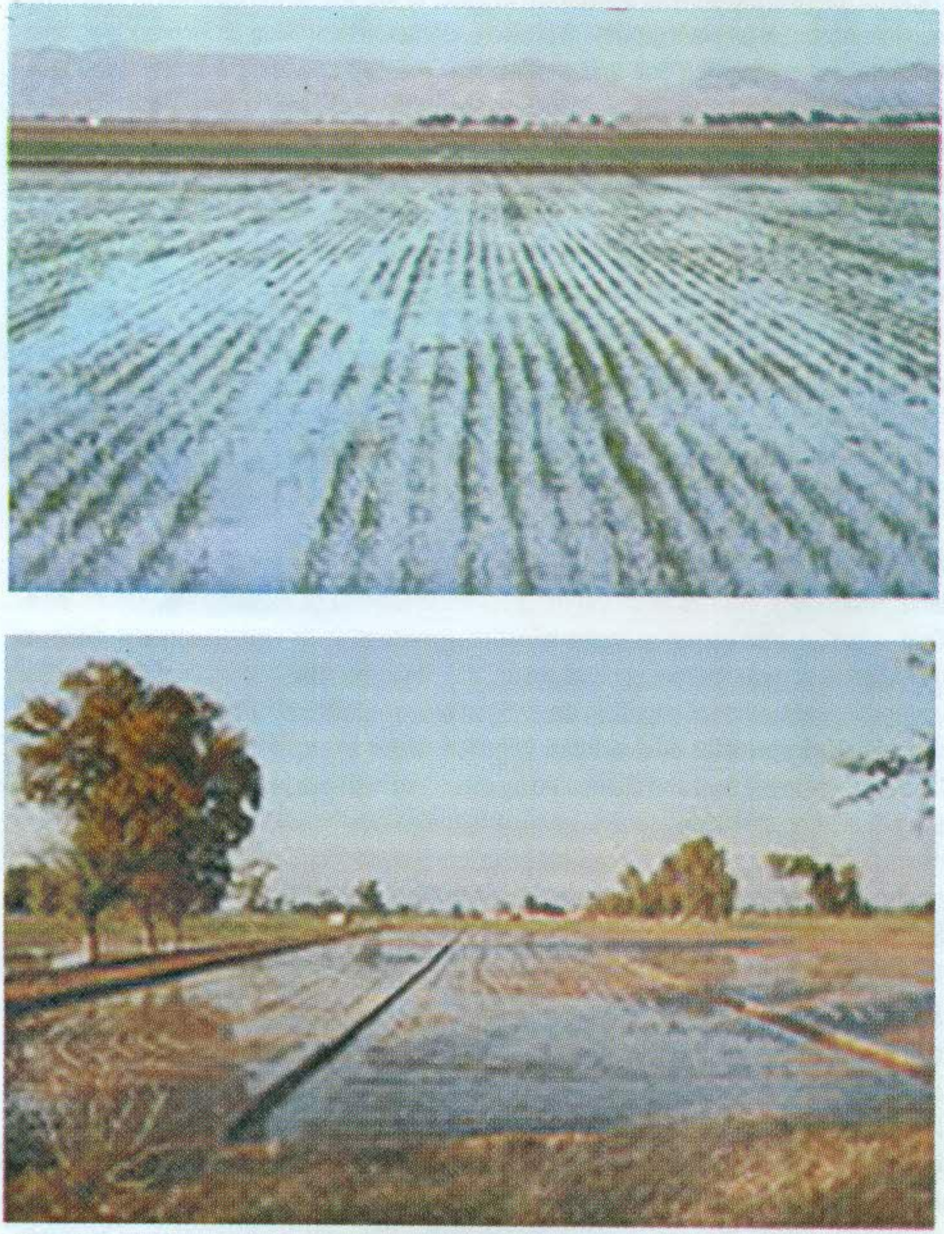

Figure 1: Basin flood irrigation. Source: Wikipedia (2010)

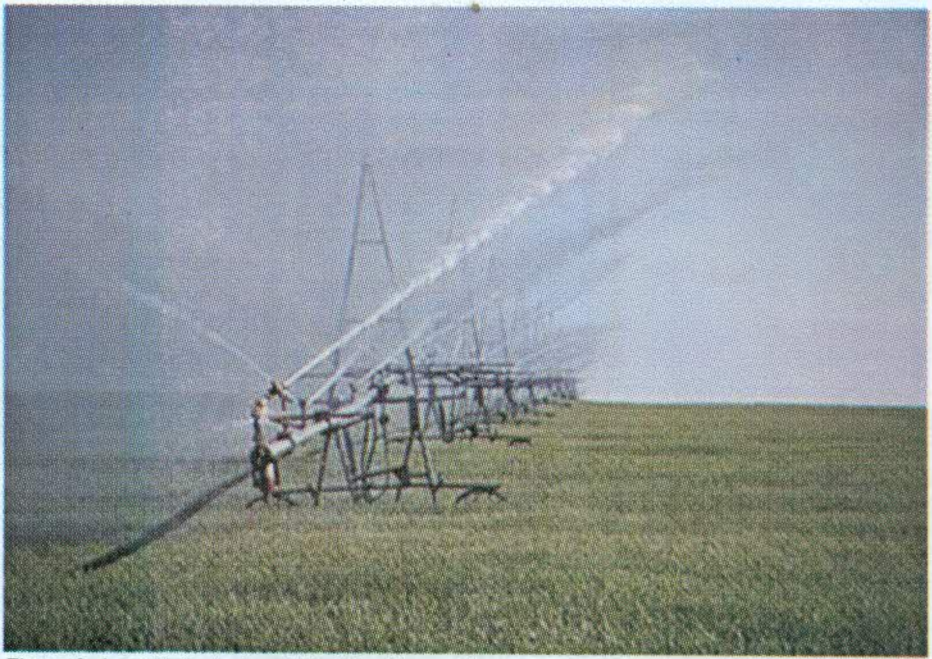

Figure 2: A sophisticated sprinkler irrigation system. Source: Wikipedia (2010)

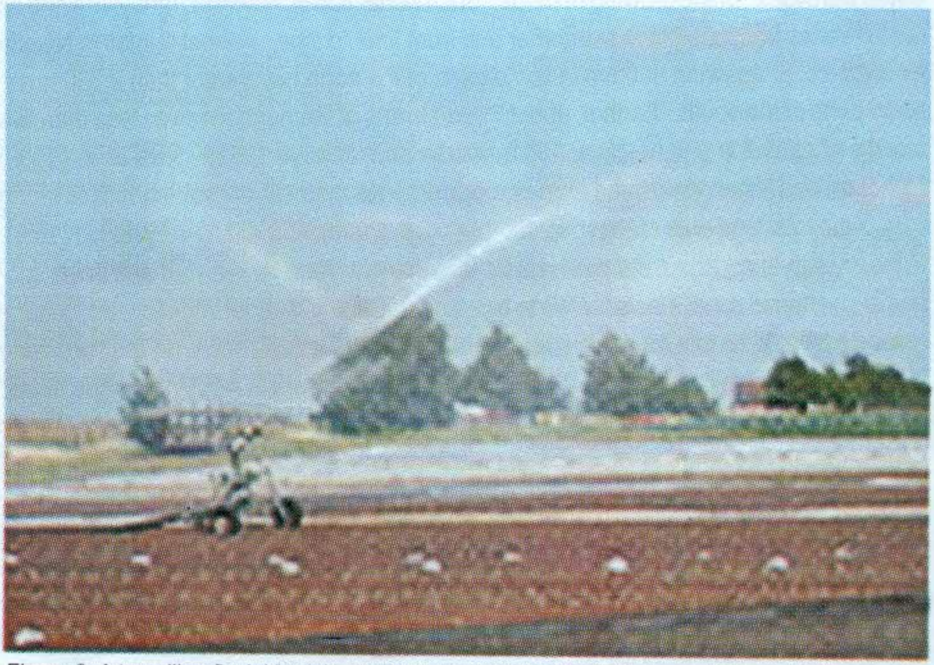

Figure 3: A travelling Sprinkler-it is easily moved around the field. Source: Wikipedia (2010)

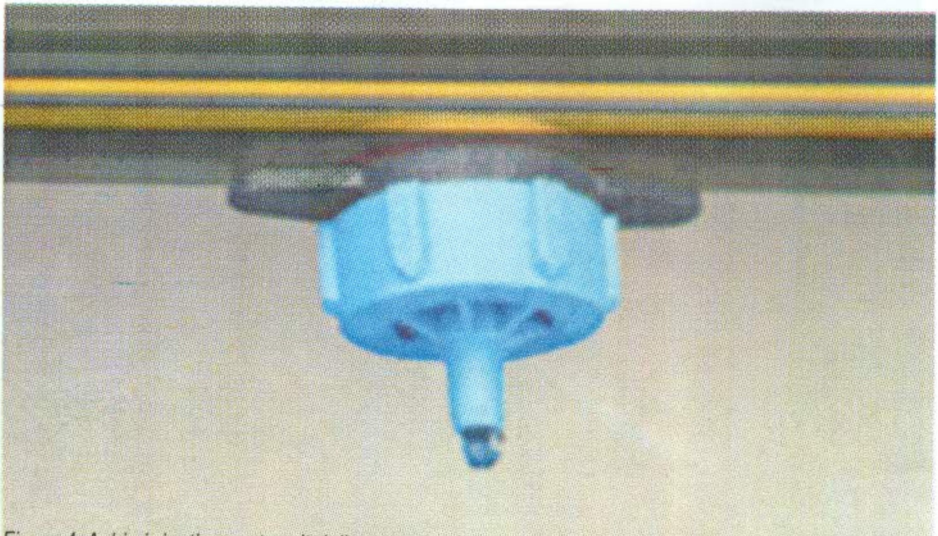

Figure 4: A drip irrigation system-it delivers water directly to the base of the plant. Source: Wikipedia (2010)

4.2 Why Irrigate in Nigeria?

Irrigation would not be necessary, if rainfall, the most important source of agricultural water, were ideal for the growing of crops. Such perfection is, however, rarely attained as rainfall varies from one place to another and from time to time. Annual rainfall in Nigeria for instance, is less than 500mm in some parts of the north but greater than 2,300mm in some parts of the south. Further, about three-fourths of the north receives less than five months of rainfall in a year (Nwa, 1981, Nwuba and Onwuyi, 1982). Nwa *et al*. (1999) further divided Nigeria into three agro-ecological zones, namely, dry sub-humid (covering 31% of the total land area of Nigeria), sub-humid and humid (53%) and very humid (16%). In the dry sub-humid zone, rainfall lasts for less than five months in a year and in the sub-humid and humid zone, it lasts for five to six months. Clearly, without irrigation, agricultural resources would be idle for more than half of the year in these zones. In the third zone (very humid), rainfall varies from 1,300mm in the north to about 4,000mm in the south. Even here, Nwa *et al*. (1999) observed that potential evapotranspiration is greater than rainfall during five months of the year, which is one of the reasons irrigation is still necessary in the zone. This suggests that irrigation even if it is supplementary, is necessary in almost all parts of Nigeria, if agricultural resources are to be fully exploited as a means of achieving self-sufficiency in food and fibre production.

Furthermore, due to the climate change phenomenon, there is evidence of declining rainfall which has also become more erratic and unreliable. Droughts are also becoming more frequent while desertification and desert encroachment are advancing. These coupled with the increasing population pressure on cultivable land, makes effective irrigation development in Nigeria very mandatory. With regard to population pressure, it has to be understood that meeting the rising food demand implies that cultivation will ultimately be extended to areas hitherto considered unsuitable due to soil moisture deficit. And the only feasible way of doing this is through effective irrigation development.

4.3 Irrigation and Agricultural Development

Irrigation development contributes to agricultural development and food security in many ways. First, irrigation permits multiple cropping within the year. This implies that the land could be cultivated all year round, resulting in higher agricultural output. Second, irrigation permits the introduction of new and high-value crops. This, in addition to increasing the income of farmers, also increases the variety of products that are available, thereby increasing food security.

Third, irrigation permits fuller employment of resources. In other words, such resources as land, labour and material inputs which would have remained unemployed or underemployed are put to use and they generate output and income for the farmers. In fact, the development of irrigation usually creates a multiplier effect by impacting positively on the economic activities of others, such as agricultural processors, marketers, improved inputs manufacturers and suppliers, and the agro-allied industries which depend directly or indirectly on agriculture.

Fourth, irrigation has been known to substantially increase crop yields over rainfed production. For instance, it is on record that crop yields in irrigated agriculture in Africa are 2.2 times higher than under rainfed production (Sonou, 1999). Average rice yield under irrigation in Nigeria has been estimated at 3t/ha, compared to just 1.8t/ha under rainfed conditions. Similarly, average irrigated rice yield of 7t/ha has been reported as against 3t/ha for rainfed production in Sengal and Cote d'Ivoire (WARDA and NISER, 2001). This implies that resources tend to be more productive in irrigated farming than rainfed agriculture. This is attributable to two main factors. Irrigation allows the crops to receive reliable moisture as against dependence on uncertain natural precipitation in rainfed agriculture. The second reason is that irrigation makes it feasible to use yield increasing inputs. Arising from the possibility of higher yields is the fact that areas under irrigation compared to rainfed are usually small, but contribute significantly to overall output. For instance, in 43 African countries, it is reported that only about 6.5% of the 124 million hectares under cultivation is irrigated but that this accounts for up to 20% of the total agricultural production (Sonou, 1999).

Fifth, irrigation lessens the danger of crop failure and the range of yield fluctuations, thereby reducing uncertainty that generally characterises agricultural production. Sixth, it increases the size of the total farm business. That is, when the farmers add the rainfed production to the irrigated production, the total area as well as gross returns, are higher than under rainfed farming alone.

Seventh, irrigation permits stability in the supply of farm products. Without irrigation, availability of some farm products tend to be seasonal. With irrigation, the consumer benefits from availability of the products all the year round and the producer enjoys stability in income. The consumer also benefits from the availability of a wide variety of products, the production of which is made possible only by irrigation.

To further underscore the indispensability of irrigation to agricultural development, FAO (Paper 42, 1987) and Kortenhorst *et al.* (1989) concluded that Nigeria is among the nations where irrigation is the only way left to grow enough food for the population, the size of which is believed to have surpassed (or will surpass) the limit of the carrying capacity of traditional rainfed agriculture.

5. Irrigation Development in Nigeria

5.1 Historical Perspective of Irrigation Development in Nigeria

Farmers in Northern Nigeria have perhaps irrigated their crops using simple devices such as the shadouf, calabashes and buckets for centuries. It is widely believed that irrigated agriculture involving the use of shadouf was brought into Nigeria by the Arabs along the trade routes at about 9th Century A.D. However, the first recorded government attempt at irrigation development dates back to 1918 when flood waters were impounded from Sokoto and Rima Rivers, following a study conducted by a military engineer (Erhabor, 1982; Nwa and Martins, 1982). The colonial government thereafter constructed some small dams and diversions in parts of the north in the 1920s. Some of these include the Daya, Abadan, Gamboru, Kano, Wurno and Edozhigi projects. These projects, according to Enwerem (1999), were poorly planned and failed within a relatively short period of time. A new start was made in 1949 when an irrigation division was created in the then Northern Province's Agricultural Department and an irrigation training school established in Sokoto. The division initiated a village irrigation scheme and by 1960, a total of about 3,400ha was under formal irrigation in Northern Nigeria, increasing to about 9,000 ha by the end of the 1960s. Irrigation development took off much later in the South; the first irrigation engineer was appointed in the Southeast in 1960.

However, as pointed out by Baba (1989), the year 1973 marked the beginning of organised federal government involvement in irrigation development. This was when the

Chad-Basin and the Sokoto-Rima Basin Development Authorities were established. The year 1975 witnessed the establishment of the Ministry of Water Resources at the federal level. And in 1976, nine additional River Basin Development Authorities (RBDAs) were created and the existing two reconstituted. The idea of establishing RBDAs was motivated by the 1972-74 droughts which ravaged the northern parts of the country, but also by the available abundant river systems which give the country an estimated annual surface water of $193 \times 10^9 m^3$. The RBDAs increased to 18 in 1984 before they were again reduced to 11 in 1986. Today, there are 12 RBDAs in existence and they include, the Chad, Hadejia-Jama'are, Sokoto-Rima, Upper Niger, Lower Niger, Upper Benue, Lower Benue, Ogun-Oshun, Anambra-Imo, Benin-Owena, Cross River, and Niger Delta Basin Development Authorities.

The RBDAs are charged with a range of responsibilities including the harnessing, management, and exploitation of the country's water resources for agricultural production and other purposes. They are at the center of the federal government strategy towards irrigation development. The RBDAs have established various (mostly) large-scale irrigation projects within their respective areas of jurisdiction.

In addition to the federal government efforts some state governments have also attempted to establish some irrigation schemes, but these are not very significant compared to the schemes established by the Federal Government. Beginning mainly in the early 1990s, efforts have been made by both federal and some state governments to support small-scale fadama irrigation under the World Bank-assisted National Fadama Development Programme.

5.2 Irrigation Policy in Nigeria

Irrigation Policy in Nigeria has been driven mainly by two factors. The first of these is the Sahelian drought of the early seventies (1972-1974) which ravaged the country particularly the semi-arid northern areas and precipitated food shortages in the country. Following this drought, it seems to have dawned on the government that sustainable agricultural development and the attainment of food security could not be achieved by sole reliance on rainfall, which as the droughts showed had become the unreliable. Consequently, it was declared in the Third National Development Plan that the agricultural potentials of Nigeria could not be attained without the development of her water resources for irrigation and other purposes. To back this up with action, huge financial allocations were made in the Plan for water resources development. These led to the establishment of the River Basin Development Authorities (RBDAs) in the country between 1973 and 1976.

The second factor is the oil boom and the huge revenue it generated for the government.

Encouraged by the availability of funds, the country opted for a policy of large-scale irrigation which is necessarily capital intensive. Therefore, most of the irrigation projects established by the RBDAs were large-scale schemes requiring the construction of dams and impounding of large volumes of water in reservoirs. In such circumstances, it also seemed alright for the government to do most of the things required for a successful irrigation for the farmers at little or no cost to them. Therefore, as pointed out by Enwerem (1999), the government built the schemes, funded their operation and maintenance and, in some cases, virtually did most of the farming operations for the farmers. In some cases, farmers were expected to pay minimal charges for such services as mechanised land preparation and harvesting. Eventually, water charges were introduced but were fixed at levels which could not support adequate scheme operation and maintenance. In fixing the water charges, there was no consideration for the actual cost of delivering water to the farmers' fields (Enwerem, 1999). In fact, the RBDAs were conceived as both water resources and rural development agencies and some therefore, provided extension services, agro-service and produce marketing centres, potable water, telephone lines, road network, rural health centres and connection to electricity all at subsidised cost to users.

But then came the oil glut of the eighties when oil revenue all but evaporated. The schemes started to deteriorate due to poor funding which resulted in poor operation and maintenance. The coffin on the large-scale irrigation schemes and the RBDAs which established them was finally nailed when in the wake of the economic crisis and the Structural Adjustment Programme, the schemes were partially commercialised in 1988. The policy of commercialisation was accompanied by a directive for all the RBDAs to dispose of their "non-water" and "non-land" assets, which they did. This implied that all the other services provided which were not directly related to water delivery were discontinued. Even with the commercialisation and disposal of the assets, however, the schemes have continued to deteriorate.

Apparently disappointed with the performance of large-scale schemes, policy interest shifted in the 1990s, towards the development of small-scale irrigation based on ground water using shallow tubewells and motorized petrol pumps. The small-scale irrigation development has been spear-headed by the World Bank-assisted National Fadama Development Programme (NFDP) which commenced in 1993. In supporting private irrigation development, the NFDP at the beginning pursued the objectives of constructing 50,000 shallow tubewells in fadama lands, simplifying drilling technology for shallow tubewells, constructing fadama infrastructure, organising fadama farmers for irrigation management, cost recovery and easy access to credit, marketing and other services, carrying out of aquifer studies, monitoring and grading irrigation technologies and completion of full environmental assessment of future fadama development (Ingawa, 1998). The NFDP was to be implemented in phases and is presently in its third phase. During the second phase (Fadama II), a bottom-up approach based on the concept of community driven development (CDD) was adopted. The activities of the Project during this phase included rural infrastructure development, acquisition of productive assets and provision of demand-driven advisory services. In all of these, the beneficiaries were required to make certain financial contributions to the projects to be executed. Reports on the Project suggest that it has been quite successful in promoting small-scale irrigation (Ingawa, 1998) and rural development. It has therefore, been scaled up in the current third phase to cover all the 36 States and the Federal Capital Territory, Abuja compared to just five states in the first phase.

Figure 5: Culvert under construction as part of rural infrastructure development support by Fadama II Project in Lavun Local Government Area of Niger State. (Courtesy of NSFCO, Minna)

5.3 Small versus Large-Scale Irrigation in Nigeria

Large-scale irrigation in Nigeria focuses on the establishment of dams across major rivers. The water impounded is then used to irrigate large expanses of land which are cleared, leveled, cultivated and then rented out to farmers (Baba, 1993). The schemes are characteristically capital-intensive and require the importation of complex foreign technologies. They have been associated with other short-comings. For instance, high level of non-participation by local farmers has been reported (Etuk and Abalu, 1982,; Kolawole, 1982). Wallace (1979) also noted that establishment of such schemes has forced developing countries to be dependent on advanced countries which have the technology and expertise to design, construct and manage them. Similarly, it has been observed that large-scale irrigation schemes typically involve the use of heavy equipment for leveling, which seriously disturbs the soil. Further, the establishment of such schemes has adverse effects on farming and fishing downstream of the dams and often involves displacement of human settlements with potential for social upheaval. Similarly, it has been observed that the change in the microclimate usually occasioned by the damming of rivers for irrigation results in the appearance of new diseases (affecting both man and animals) and weeds.

Figure 6: Grinding mill belonging to a fadama user group in Lavun Local Government Area of Niger State – its acquisition was supported by the Fadama II Project (Courtesy of NSFCO, Minna)

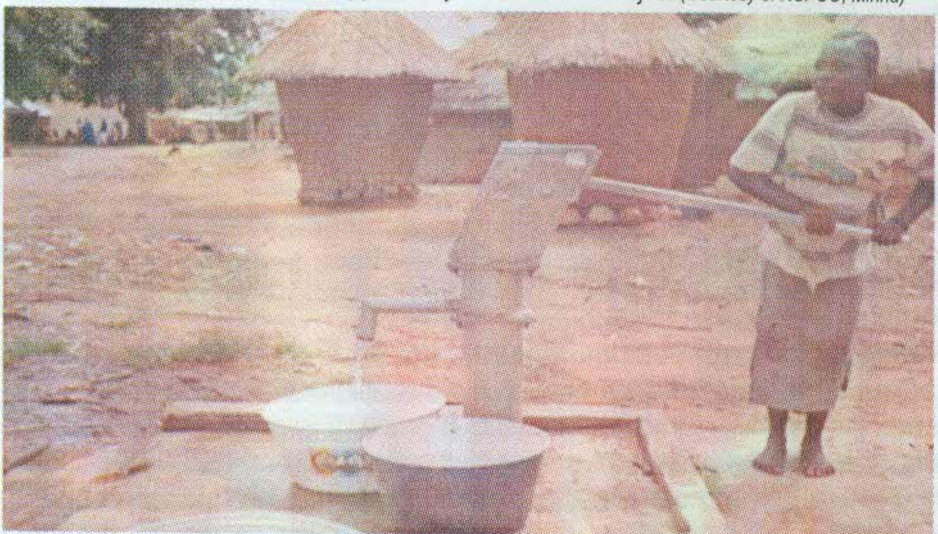

Figure 7: Borehole project supported by Fadama II in Lapai Local Government Area of Niger State (Courtesy of NSFCO, Minna).

It is then argued that a switch in emphasis to small-scale irrigation would avoid these pitfalls. Perhaps, it is felt that small-scale irrigation systems which are usually owned and managed by the farmer would require less spending by government and would be more sustainable. Furthermore, it has been argued that small-scale irrigation technologies are simple and easily operated by the farmers as against complex technologies required for large-scale irrigation. The small-scale technologies, it is further maintained, offer the farmer the better control over the time and rate of water application.

In fact, it is generally believed that small-scale private irrigation schemes have so far performed better than the large-scale schemes. Fadama (small-Scale) farmers are reported to be self-sustaining, cost-effective, and require little assistance from government or aid agencies (World Bank, 1998; Musa, 1999). Nevertheless, Musa (1999) has concluded that their success may be short-lived as a result of growing signs of over exploitation of the shallow aquifers and their attendant grievous environmental consequences. Baba and Singh (1998) as well as Baba and Alassane (1997) have drawn attention to sustainability challenges posed by continuous fadama land irrigation with ground water. These challenges have to do, *inter alia*, with sustainability of soil fertility, environmental degradation, sustainability of the ground water itself and sustainability of the technologies used in small-scale fadama irrigation (see section 6.9 for more details on this).

It is evident from the above review therefore, that there are serious challenges, with both small and large-scale irrigation. But given the advantages associated with irrigated agriculture, efforts have to be made to overcome them. Irrigation has successfully worked in many countries even in Africa (for example in Egypt, Sudan and Madagscar). Similarly, the green revolution in Asia was achieved with the combination of three inputs: high-yield seeds, fertilizers and irrigation water. If irrigation schemes, whether private or public are properly managed in Nigeria, they could well be the solution to our quest for food security and self-sufficiency.

5.4 Extent of Irrigation Development in Nigeria

It is generally believed that given her land mass and population, the area under irrigation in Nigeria is low. When compared with Asian countries and even some countries in Africa, Nigeria lags far behind in terms of irrigation development. Table 1 shows a list of some countries and the land areas under irrigation. It can be seen that Nigeria, with an irrigated area of 2,820 km^2 (282,000 ha), ranks 62nd in the world, behind African countries such as Egypt, Sudan, South Africa, Morocco, Madagascar, Libya and Ethiopia. And she rank's far behind Asian countries such as India (ranked 1st in the world), China, Pakistan, Bangladesh, Thailand, Indonesia and Nepal. No wonder most of these Asian countries are not just food secure, but they are net exporters of food some of them to Nigeria.

Table 1: List of some Asian and African countries by irrigated area

Country	Irrigated land (km^2)	World ranking
India	558,080	
China	545,960	2
Pakistan	182,300	4
Thailand	49,860	8
Bangladesh	47,250	9
Indonesia	45,000	11
Egypt	34,220	16
Sudan	18,630	27
South Africa	14,980	31
Morocco	14,450	35
Nepal	11,700	38
Madagascar	10,860	39
Libya	4,700	54
Ethiopia	2,900	60
Nigeria	2,820	62
Mali	2,360	65

Source: Wikipedia (2010)

Nigeria is said to have the physical potential for irrigation of about 3.14 million hectares. But this is about 10 times more than land now under irrigation (Hundertmark and Abdourahmane, 1999). The areas under irrigation in Nigeria could be divided into two; the area under formal and informal irrigation. The former consists of areas under public irrigation schemes established by either the federal government through the RBDAs or the State governments through their respective State Irrigation Departments (SIDs). The informal irrigation consists of irrigated land developed and managed by the farmers with or without support from government. This normally consists of fadama lands which are irrigated by the farmers with the aid of buckets, calabashes, shadouf, or small motorised pumps. They are farmer-owned and farmer-operated. These, are one or two hectare plots irrigated by farmers who locate, deliver and apply their own water (Nwa *et al.*, 1999). The area of land under this type of irrigation system in Nigeria is not reliably known. One estimate suggests that there are 100,000ha equipped with 40,000 wells and gasoline pumps which are used by smallholders (Hundertmark and Abdourahmane, 1999). In contrast, in spite of all the financial commitments, only a combined area of about 50,000ha is actually irrigated by all the schemes under the RBDAs (Musa, 1999). This is a far cry from the planned (commandable) area of 320,000ha. The irrigated area is even smaller than the area (70,000ha) which has been developed and equipped for irrigation by the RBDAs. Musa's estimate of area irrigated is however, smaller than the data provided by Nwa *et al.* (1999) as shown below.

In the Dry Sub-humid Zone where Hadejia-Jama'are, Sokoto-Rima and Chad RBDAs are located, only about 43,550 ha are irrigated under the RBDAs. In this zone also, about 4,660 ha are irrigated under the state government irrigation schemes while the area irrigated under the small-scale farmer owned irrigation schemes is about 126,350 ha (Nwa *et al.*, 1999). In the Sub-humid and Humid zone covering Upper Niger, Lower Niger, Upper Benue and Lower Benue RBDAs, only about 24,000 ha are irrigated. The area irrigated in the last zone (Very Humid zone) where Anambra-Imo, Benin-Owena, Cross River, Niger Delta, and Ogun-Oshun RBDAs are located is not reliably documented. However, it appears that less than 2,000 ha were irrigated as at 1999 by the RBDAs.

5.5 Performance of Formal (Government) Irrigation Schemes in Nigeria

As noted earlier, most of the public irrigation schemes in Nigeria are large-scale and were expected to transform agricultural production towards the achievement of food self-sufficiency for the country and higher standard of living for those involved. But the performance of the schemes has been disappointing. The most discouraging outcome of large-scale irrigation strategy which has been adopted in the past four decades is low capacity utilisation at the schemes. Not only are there wide discrepancies between irrigable areas (planned areas) and irrigated areas, there are equally large differences between areas developed for irrigation and areas actually irrigated. These differences cut across virtually all the schemes.

For example, the projects under the Chad Basin Development Authority were jointly expected to irrigate an area of 112, 500 ha out of which 49,500 ha were developed, but only about 15,500 ha are irrigated (Nwa *et al.*, 1999). Similarly, of the planned area of 80,500 ha at the Hadejia-Jama'are RBDA, only 16,000 ha are irrigated. Projects under the Sokoto-Rima RBDA had a total planned area of 52,500 ha, out of which 25,000 ha were equipped, but only about 12,050 ha are irrigated (Nwa *et al.*, 1999).

Coming to specific projects, the Kano River Irrigation Project (under the Hadejia-Jama'are River Basin Development Authority) is described as the most successful large-scale irrigation scheme in Nigeria. Nevertheless, there is still a wide gap between the planned area of 62,000 ha (for the two phases of the Project) and the less than 15,000 ha that is actually irrigated (Kazaure and Yusuf, 1999). This is just about 24% capacity utilization. When the Project started, things appeared to have gone on satisfactorily. For instance, Okoh (1999), in a review of the performance of the project, reported that through its extension services, the Project had modernised agricultural production by promoting the introduction of new crops and the use of improved inputs. She also noted that the

Project had increased food production by 60,252.38 metric tons yielding a total revenue of ^27,159,949.5 to the farmers in 1985. Furthermore, the Project improved transportation in the area by constructing a network of rural roads and also established agro-service centres which also provided inputs and credit facilities to farmers. Most of these gains, it must be pointed out, have been reversed since 1988 when the Project was partially commercialised and the non-water and land related functions withdrawn.

The Tungan Kawo Irrigation Scheme in Niger State is under the Upper Niger River Basin Development Authority and has a commandable (planned) irrigation area of 800 ha. However, the area currently irrigated is less than 400 ha, which indicates less than 50% capacity utilisation. This area is likely to decrease in the near future because the irrigation infrastructure (canals, drop structures etc) are deteriorating, while the dam reservoir is getting silted up. The situation is even less attractive in the case of the Swashi Dam and Irrigation Project also in Niger State. Of the planned area of 2,900 ha, less than 200 ha (representing less than 7% utilization) is actually irrigated even though most of the required irrigation infrastructure are in place. In fact, here, local farmers have not shown much interest in participating in the scheme. Therefore, the infrastructures which have been put in place at considerable cost lie in waste. Here too, due to poor maintenance, the irrigation facilities are in deplorable state.

The Bakolori Irrigation Project (under the Sokoto-Rima River Basin Development Authority) is one of the best known public irrigation schemes in Nigeria. Its reputation in part derives from the fact that its establishment triggered an uprising from the local communities resulting in riots that caused the death of many people and destruction of properties. The project had a planned net irrigable area of 23,000 ha which was fully equipped for irrigation. Of this, 8,000 ha was developed for gravity irrigation, while the remaining 15,000 ha was equipped for sprinkler irrigation. According to Enwerem (1999), only the gravity section was able to irrigate the full 8,000 ha even at the beginning. But due to poor maintenance, coupled with damage to canals by floods, only about 3,900 ha was irrigated by gravity as at 1998. The performance of the sprinkler section was worse. Due to irregular power supply and theft of irrigation pipes, less than 400 ha was under sprinkler irrigation in 1998. Jointly, these figures represent about 19% capacity utilization at the Bakolori Irrigation Project. It may be noted that like many other large-scale irrigation projects in Nigeria, the dam at Bakolori Project was supposed to be multipurpose. In addition to irrigation, fisheries and livestock development, it was to be a source of domestic water supply and electric power generation. The pursuit of the latter two purposes, from all indications, ended on paper.

At inception, it was anticipated that the irrigating of 23,000 ha would produce 30,000 tons of wheat, 20,000 tons of paddy rice, 60,000 tons of tomatoes, 40,000 tons of sugar cane, and 30,000 tons of onions during one dry season. During the rainy season it was expected that the cropping of the 23,000 ha would yield 50,000 tons of traditional crops such as millet, sorghum, maize, groundnut and cowpea. With the dismal capacity utilisation at the Project, these targets have remained a mirage. But they show the huge potentials of irrigated agriculture in solving the problem of food insecurity, provided the right measures are taken.

At the Lower Anambra Irrigation Project (under the Anambra-Imo River Basin Development Project), a net area of 3,850 ha was developed and equipped for irrigation. At a point in time, 3,000ha were actually irrigated. But due to deteriorated infrastructure, only 1,000 ha were irrigated in the 1998/99 irrigation season (Nwa *et al.*, 1999). At Optimal production level, the Project has the potential to produce an average of 30,800 tons of paddy rice annually which was valued in 1999 to be worth one billion naira (Anambra-Imo River Basin Development Authority Management, 1999). But the achievement of even one-half of this target has been elusive.

The story of under-performance applies to state owned irrigation schemes as well. For example, Uzo-Uwani and Adani irrigation schemes in Anambra State with a total planned area of about 3,000 ha, only equipped and irrigate approximately 600 ha.

The low capacity utilisation of formal irrigation schemes is therefore, a national problem. What is even more worrisome is that the capacity utilisation seems to be decreasing over time. For instance, Table 2 shows the area developed, area irrigated and capacity utilisation at the Bakolori Irrigation Project between 1978 and 1998. For the surface irrigation section, the capacity utilisation which rose from 36% in 1978 to a peak of 89% in 1986, declined continuously to 54% in 1998. In the case of sprinkler irrigation, the capacity utilisation increased from 47% in 1979 to a peak of 65% in 1985, and then declined drastically to slightly above 3% in 1998. The trend is quite similar for the Jibiya Irrigation Project established under the Sokoto-Rima River Basin Development Authority in Katsina State. The Project has a developed area of about 3,450 ha. The capacity utilisation rose to about 87% in 1992/93 and 1993/94 and declined to about 25% in 2004/2005 irrigation season.

Table 2: Developed area, irrigated area and capacity utilisation under surface and sprinkler irrigation at Bakolori Irrigation Project

	Surface irrigation			Sprinkler irrigation		
Year	Area Developed(ha)	Area cultivated(ha)	% utilisation	Area Developed(ha)	Area cultivated(ha)	% utilisation
1978	630	227	36.0	1,400	-	-
1979	1,800	657	36.5	1,800	847	47.0
1980	2,650	1,190	44.9	3,150	957	26.2
1981	4,200	2,115	50.4	8,500	4,174	49.1
1982	5,500	3,669	56.4	11,000	4,863	44.2
1983	7,250	5,783	79.8	12,800	7,418	57.9
1984	8,000	6,264	78.3	15,000	7,765	51.8
1985	8,000	6,912	86.4	15,000	10,410	65.4
1986	8,000	7,126	89.0	15,000	7,302	48.0
1987	8,000	7,105	88.8	15,000	4,377	29.2
1988	8,000	6,090	76.1	15,000	2,597	17.3
1989	8,000	5,576	73.4	15,000	4,196	28.0
1990	8,000	5,940	74.3	15,000	2,820	18.8
1991	8,000	5,205	65.0	15,000	2,672	17.8
1992	8,000	5,474	68.4	15,000	1,423	9.5
1993	8,000	5,259	65.7	15,000	1,866	12.4
1994	8,000	5,082	63.5	15,000	2,078	13.8
1995	8,000	4,926	61.5	15,000	1,398	9.3
1996	8,000	7,754	59.4	15,000	1,149	7.0
1997	8,000	4,396	54.9	15,000	581	3.9
1998	8,000	4,339	54.2	15,000	517	3.4

Source: Adamu (1999)

Table 3: Trend in area cultivated and capacity utilisation at the Jibiya Irrigation Project

Irrigation season	Area cultivated	% utilization
1991/92	2,500	72.46
1992/93	3,000	86.96
1993/94	3,000	86.96
1994/95	2,000	57.97
1995/96	1,700	49.28
1996/97	206	5.97
1997/98	206	5.97
1998/99	206	5.97
1999/00	930	26.96
2000/01	890	25.80
2001/02	430	12.46
2002/03	206	5.97
2003/04	206	5.97
2004/05	868	25.16

Source: Musa (2008)

5.6 Problems of Large-Scale Irrigation Schemes in Nigeria

After investing huge sums of money in establishing them, the large-scale irrigation schemes were expected to be the vehicle through which the country's desire for achieving food self-sufficiency would be achieved. This hope has however been dashed, as not long after establishing them, many unanticipated problems began to emerge. These problems accounted for the rather dismal performance of the schemes. Some of these problems are highlighted as follows:

(1) Poor operation and maintenance of facilities: This is perhaps, the most critical problem bedeviling the schemes. Irrigation infrastructure including the dams, canals, water channels, pipes and even pumps were not regularly maintained resulting in problems such as siltation of the canals and reservoirs, weed infestation of these infrastructures, as well as their destruction by floods due to blockage. Siltation and weed infestation have reduced water flow in the canals of most schemes by up to 30% of design capacity (Ogunwale and Maurya, 1991). Poor maintenance appears to be a universal problem of virtually all the schemes. The problem has resulted in major deterioration of water conveyance and control structures, and to frequent break-down of pumps and sprinkler lines. Due to these problems, most of the schemes are unable to command even the relatively small areas already developed for irrigation.

(2) Inappropriate design: Some of the schemes have performed poorly because the original design was faulty. According to Ayodeji (1999), a system designed to lift water by diesel or electric power in a place notorious for frequent shortage of diesel or power failure is doomed to perform poorly from the start. This is precisely the case of many schemes in Nigeria. At the Bakolori Irrigation Project, a major proportion of the developed land was designed for sprinkler irrigation. Twenty-six pumping stations were installed to serve the 15,000 ha earmarked for irrigation using sprinklers. However, rising electricity and fuel cost, and their unreliable availability, coupled with high cost and non-availability of spare parts as well as theft of pipes, resulted into almost total failure of this irrigation system at the Project. It is on record that out of the 15,000 ha, only 517 ha were irrigated in 1998 (Adamu, 1999).

(3) Non-involvement of beneficiaries: Most of the schemes were established in the oil boom era when there were adequate funds. It was thought that government alone would shoulder the responsibility of establishing, managing and maintaining the schemes without recourse to the beneficiaries (farmers) who were expected to be passive receivers of government's benevolent gesture. According to Ogunwale and Maurya (1991), government did not only operate and maintain the schemes, but provided agro-support services such as land preparation, seeds, fertilizers and chemicals to farmers.

Farmers virtually had no roles to play except to divert water from the channels and operate their respective farm plots. In other words, the approach was "top-down" all through the planning, establishment, operation and management of the schemes. It was thought unnecessary to involve the beneficiaries even in operation and maintenance of the projects. When the oil revenue later dwindled, government was unable to pay for operation and maintenance or even to maintain qualified staff to run the projects.

(4) Withdrawal of complementary services: Despite its potentials, irrigation will make little contribution to agricultural production in the absence of other inputs and services. Paramount among these are improved inputs such as high-yield seeds, fertilizers and other agro-chemicals. To ensure that farmers use these inputs and other improved technologies correctly, strong extension services are required. Most of the farmers also require financial assistance in the form of credit to purchase the technologies and at the end, they need an efficient marketing system to ensure that they obtain remunerative prices for their products. These services were all in place at most of the schemes at the beginning but were withdrawn in 1988 following the partial commercialisation of the schemes. This has resulted in poor yields and sometimes glut during the harvest season.

(5) Low-pricing of irrigation services: When the schemes began, virtually all services were provided to the farmers either free of charge or at extremely low prices. For instance, farmers were not charged for water while costs of inputs and land preparation as well as rent on land did not reflect the existing market conditions. Eventually, water rates were introduced in some of the schemes, but these were set without regard to the actual cost of delivering water to farmers' field. This was part of the benevolent posture of government. But with declining budgets, this contributed to the inability of the projects to raise funds to maintain their facilities.

(6) Under-funding: The schemes have and still rely mainly on budgetary allocation from government. Since the advent of the oil glut and the economic policies of adjustment later adopted, there has been fiscal pressure in the Nigerian economy resulting in reduced budgetary allocation to virtually all sectors. The irrigation projects were hard-hit in this era of cut-back spending. The schemes are yet to devise means of generating adequate internal revenue to supplement the subvention from government for effective management. The low revenue generation is in part, attributable to the low pricing of their services. But more importantly, it is a result of the highly reduced scope of services they could now render after disposing of their 'non-water, non-land' assets in the wake of their commercialisation.

(7) Apathy of local farmers toward participating in the schemes: For various

reasons, local farmers' participation in many irrigation schemes is low. For instance, most of the farmers farming at the Swashi Irrigation scheme in Niger State are from outside the State. At many other schemes, elite farmers dominate. Some of the reasons for the lukewarm participation of the local farmers are the high cost of irrigation farming in Nigeria, uncertainty (especially) with regard to water availability, low yields and returns resulting from limited use of complementary inputs, lack of irrigation culture (i.e irrigation is alien to some communities), non-involvement of farmers from the beginning to identify and prioritise their needs and to benefit from their indigenous knowledge, lack of appropriate institutional framework for local farmers' participation, as well as the advanced and unfamiliar nature of technologies involved in large-scale irrigation. It is reported that large-scale irrigation actually resulted in forced migration of local farmers away from their communities and change of occupation (Omokore, 1998).

(8) Poor water allocation efficiency: Ideally, only the water required for optimum performance of the crop should be released to the field or applied by the farmer. But because of the nature of the design of most of the schemes, water is usually released without making a distinction as to the water requirements of the various crops. Furthermore, either because water has been grossly under-priced or the fact that most farmers have little or no knowledge of the exact water requirements of individual crops, there tends to be the problem of over-application of water. This, coupled with poor drainage at most of the schemes, negatively affects the performance of crops, raises the water table and precipitates environmental degradation problems.

(9) Environmental degradation: Environmental degradation in an irrigation scheme could arise from the impounding and distribution of the water and/or from the management (or mismanagement) of the irrigation water (Muazu and Abdulmumin, 1991). From the view point of the former, the impounding of water as a result of dam construction changes the environment from one that is terrestrial and riverine to a locustrine one. This, as has been the case in many schemes, resulted in health hazards to man and domestic animals, changes of fish and wild life resources and emergence of plants (mainly aquatic weeds) that are harmful to the environment (Muazu and Abdulmumin, 1991). The environmental effects of irrigation water management arise from rising water table, water-logging and soil salinisation (or alkalisation). At the Kano River Irrigation Project, for example, water table became a problem within seven years of commencement of irrigation during the irrigation season (Abdulmumin and Muazu, 1982; Nwa, 1982; Muazu and Abdulmumin, 1991).

(10) Shortage of relevant manpower: Following the rationalisation and partial commercialization of the RBDAs, many of their staff were retrenched leaving the irrigation schemes with only few personnel, most of whom are not of the right caliber. At the Bakolori

Irrigation Project, the number of staff decreased from 1,300 in 1987 to just 216 as at 1999, and many of the staff remaining were security guards. Engineering and technical staff required to operate and monitor the system were lacking. In fact, it was reported that there was no single engineer left at the Project (Adamu, 1999). The dearth of qualified staff contributed to the deteriorating performance of the schemes.

6. Economics of Irrigated Agriculture

Although both food and cash crops are produced under irrigation in the country, the bulk of the crops produced, whether they belong to what are conventionally known in Nigeria as food crops, are marketed. In view of this, financial viability will determine to a great extent, the decision of a farmer to continue to participate in irrigation farming. This underscores the significance of evaluating the economics of crop production in irrigated agriculture. Consequently, this topic has attracted some research attention of the author with a bias toward small-scale irrigation. The aspects of the economics of irrigated agriculture that have captured the research interest of the author include level of resource-use, nature of enterprises produced, profitability, investment analysis, resource-use efficiency, optimum farm plans, income distribution, and sustainability challenges in crop production mainly under small-scale, farmer-owned and operated, irrigation systems. It is the conviction of the author that research focus on these issues would highlight and draw attention to the potentials and constraints associated with small-scale irrigation in the country. Most of the reminder of this Lecture will therefore focus on these topics.

6.1 Level of Resource Use in Small-scale Irrigation

The term "resources" in agriculture, refers to the means, factors or inputs that go into agricultural production and are generally assumed to be scarce and have to be optimally allocated to satisfy the many competing ends. Agricultural production itself, is the process by which the resources are converted to goods and services called output through the farm unit. The more the resources available to a country or any other political entity, the more the potential the country has to generate output, provided the resources are wisely allocated. Agricultural resources are conventionally classified into four: land, labour, capital and management. While land is a natural resource, consisting of the solid part of the earth on which plants grow and the associated water, minerals, vegetation and sometimes even air, labour refers to the work done by human beings. Capital on the other hand, refers to the produced means of production. In other words, it consists of items or materials which have been produced by human efforts but instead of being consumed are rather used in the production of other materials or services which are useful to man. Management is an entrepreneurial input, which is used to organise and coordinate the other physical inputs in a manner that contributes towards attaining the goals of the farm business which may be profit maximisation, cost minimisation, revenue (or sales) maximisation, output maximisation, cost minimisation, food security or some other outcome or motive preferred by the farm business owner or operator. This resource is not easily quantifiable but this does not deduct from its significance as an important agricultural production factor. Nevertheless, because of the difficulty involved, most economists avoid quantifying it. Others use the level of education or training of the manager or operator as proxy. The levels of resource use in irrigated crop production, as obtained through the author's empirical investigations, are highlighted as follows.

6.1.1 Land

One of the resources whose fuller employment is promoted by irrigation is land, the primary input in farming. Land, as used in this Lecture, refers mainly to fadama which is a Hausa word applied to low-lying relatively flat areas either in streamless depressions or adjacent to the seasonally or perennially- flowing streams and rivers (Nwa, 1976; Kolawole and Scoones, 1994; Baba and Singh, 1998). The term fadama in northern Nigeria is synonymous with bas fond in the Sahel, wadi or khor in Sudan and dambo in southern Africa (Scoones, 1992). They characteristically have high water table and are usually more fertile and nutritionally richer than the tudu (meaning upland in Hausa). The fadama lands available are usually small relative to the upland. This usually makes them a precious resource where they are found.

Since the fadama lands are usually small, it is also expected that the area available to a particular farmer would be small. In a study by Baba and Etuk (1990) among 45 motorised pump users in Bauchi State, it was found that the farmers cultivated an average farm size of 0.67 ha with a range of 0.07 to 2.97 ha. The entire 45 farmers cultivated 30.03 ha. Baba (1993) also found in Bauchi State, that shadouf users cultivated an average fadama farm size of 0.11 ha compared to 0.67 ha cultivated by motorised pump users. Variously known as shaduf, shadoof, counterpoise, dhenkali, kheteraz, and guenina, the shadouf is a simple device for water lifting using the principle of the lever. A container is suspended from one end of a long pole. With the aid of a counterweight at the opposite end of the pole and a fulcrum, water is lifted from a source such as stream, pond or shallow well. However, small-scale fadama irrigators cultivated larger plots in the Wurno area of Sokoto State with pump (and tubewell) users cultivating an average of 1.88ha and shadouf users cultivating 0.51ha (Baba and Adedibu, 1998). In another area in Sokoto State, Baba et al. (1998) reported an average farm size of 0.58 ha (see Table 4 for the distribution of the farmers according to farm size). A study by Baba and Wando (1998) in Magama and Kontagora Local Government Areas of Niger State also found average fadama farm sizes of 1.92ha and 1.55ha cultivated by members of water users' association and non-members, respectively (Table 5).

The areas cultivated by fadama farmers tend to be smaller than upland areas cultivated by small-scale farmers in northern Nigeria. For instance, they are far below the 4.92 and

2.34 ha reported for upland farmers using and not using animal traction in Sokoto State (Baba and Alhassan, 2000) or 2.83 and 1.83ha for similar category of farmers found by Baba and Mabai (2001) in Katsina State.

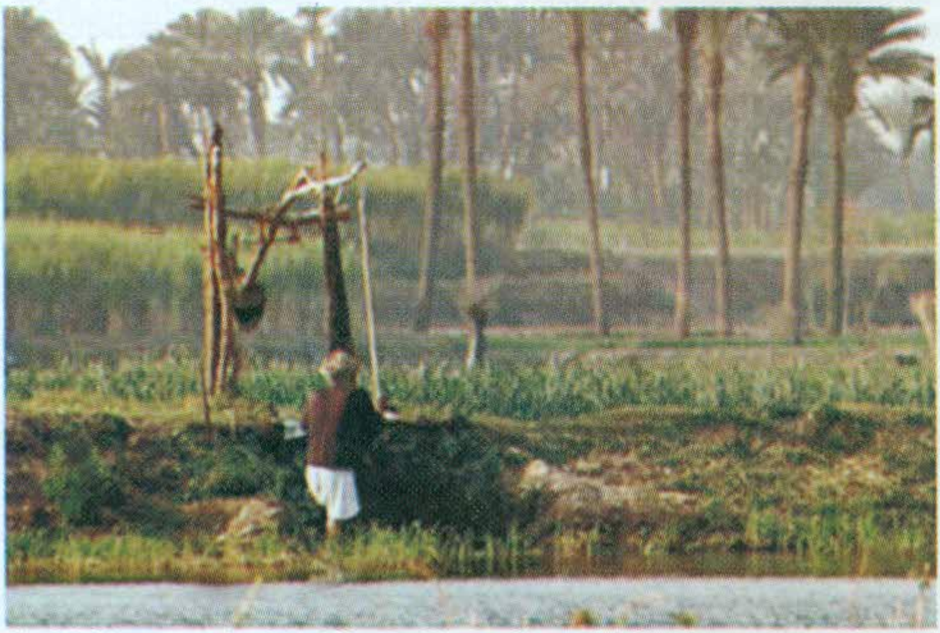

Figure 8: A farmer operating a shadouf system-it is manually operated

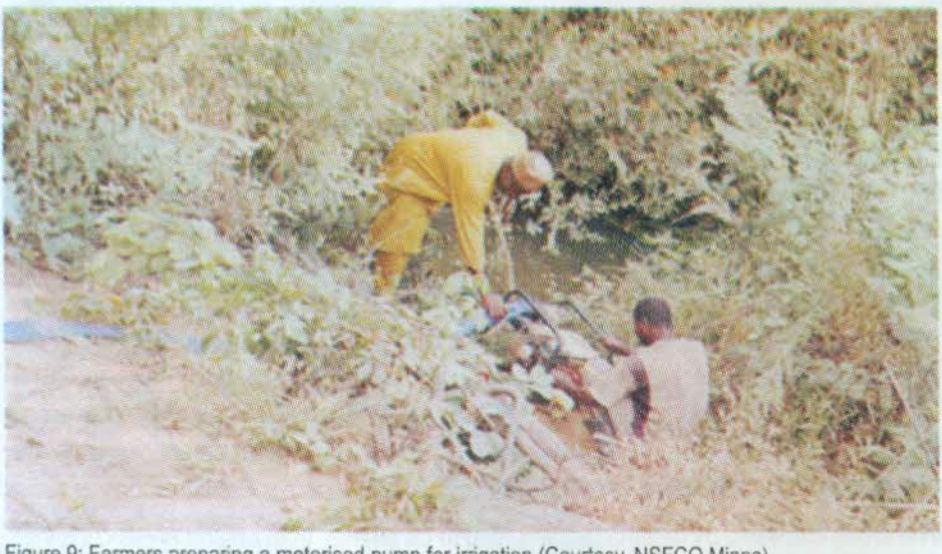

Figure 9: Farmers preparing a motorised pump for irrigation (Courtesy, NSFCO Minna)

Table 4: Distribution of fadama farmers in Sokoto State according to farm size

Farm size (ha)	No. of farmers	%
0.11 -0.25	11	22
0.26 -0.40	6	12
0.41 -0.55	11	22
0.56 -0.70	4	8
0.71 -0.85	8	16
0.86 - 1.00	8	16
>1.00	2	4
Total	50	100

Source: Baba et al (1998)

Table 5: Average levels of resource use and crop yield of fadama farmers in Niger State

Variable	Members	Non - members	t-value
Farm size (ha)	1.92	1.55	0.93^{ns}
Labour (man - hours/ha)	297	298	0.43^{ns}
Fertilizer (kg/ha)	160	126.67	1.88^{*}
Rice yield (kg/ha)	1,850	1,400	2.43^{**}
Tomato yield (kg/ha)	9,360	7,553.3	1.75^{*}

Source: Baba and Wando (1998)

6.1.2 Labour

Labour is a critical production factor and it is more so in Africa where most farm operations are still accomplished manually. Labour may be skilled (if trained) or unskilled (if untrained). Most of the labour input in African agriculture is untrained labour. Labour demand also tends to be seasonal. However, availability of irrigation reduces fluctuations in demand by making agricultural production possible all the year round, thus keeping labour fully employed. There are several sources of labour in African agriculture. Thus we have family labour which is provided by the farmer and members of his family, temporary hired labour, regular or permanent hired labour and communal labour. Usually, family and communal labour are not directly paid for in monetary terms. In the case of communal labour, however, the receiver normally has the obligation to reciprocate by making himself or herself available to work on other people's farm when it is their turn. The family still constitutes the most important source of labour in Nigeria and most other parts of Africa.

Available evidence suggests that labour input may be higher in irrigated than rainfed agriculture. This is so because in addition to other farm operations, irrigation farmers have to water their plots and this usually consumes a lot labour. Data in Table 6 for instance, show that irrigation water application used the highest proportion (23.73%) of total labour input. This was followed by harvesting, weeding and land preparation. Other operations, such as planting and nursery, consumed relatively less labour. More family labour was used than hired labour. Nevertheless, hired labour was used for all operations with the exception of nursery.

In another study in Bauchi State, which compared labour use between pump and shadouf users, it was discovered that the latter used much more labour than the former (Baba, 1993). It was discovered that up to 80% of shadouf users employed more than 2,000 man-hours of labour per hectare compared to just 57% of pump users who fall into this category of labour use (Table 7). Further analysis of the data revealed that up to 38% of total labour input of shadouf users was consumed by water application. This result is explained by the fact that the shadouf is manually operated and Nwa (1982) has estimated that not less than 150 man-hours are required to irrigate just one hectare at a time using the shadouf. It is expected therefore, that shadouf users will use more labour. This result is further corroborated by that of another study conducted by Baba and Adedibu (1998) in Sokoto State where pump users employed an average of 1,949 man-hours of labour per hectare, compared to 2,079 man-hours for shadouf farmers.

In yet another study in Sokoto State, Baba *et al.* (1997) reported that considerable amount of labour was used by small-scale irrigators. The level of hired labour input (33 man-hours out of a total labour input of 2,693) was neglible. Watering which in the area of this study was accomplished using mainly calabashes and buckets, alone consumed more than 77% of the total labour input (Table 8).

As the results of these investigations show, small-scale irrigation has promoted more employment of not just family, but also hired labour which would have remained idle in the dry season. This is a source of income for the farmers who cultivated farms and others who hired out their labour.

Table 6 : Per hectare family and hired labour input by fadama farmers in Bauchi State

	Man-hours of:		Man-hours of:	
Fadama operation	**Family**	**Hired**	**Total labour**	**% of total**
Nursery	12.44	0	12.44	0.47
Land preparation	354.49	101.35	455.84	17.25
Planting	136.82	1.03	137.85	5.22
Water application	620.67	6.76	627.03	23.73
Weeding	502.03	48.77	550.80	20.84
Harvesting	534.42	94.43	628.85	23.80
Others				
Total	2,389.07	253.71	2,642.78	
% of total	90.40	9.60	229.97	100

Source: Baba and Etuk (1990)

Table 7: Per hectare labour use by shadouf and pump irrigation farmers in Bauchi State.

Labour use	Man- Shadouf users		Pump users	
hours per hectare)	Freq. count	%	Freq. count	%
<1,000	0	0.0	6	13.3
1,000 – 2,000	9	20.0	13	28.9
2,000 – 3,000	21	46.7	9	20.0
>3,000	15	33.3	17	37.8
Total	45	100	45	100

Source: Baba (1993)

Table 8: Labour input (man-hours/ha) by small-scale fadama farmers in Sokoto State

	Man-hours of:		Man-hours of:	
Fadama operation	**Family**	**Hired**	**Total labour**	**% of total**
Land preparation	70	-	70	2.6
Watering	2,113	-	2,113	77.5
Weeding	122	-	122	4.5
Manure application	46	-	46	1.7
Fertilizer application	49	-	49	1.8
Harvesting	294	33	327	12.0
Total	2,693	33	2,726	100

Source: Baba et al. (1997)

3.1.3 Capital

It is erroneous to think of capital only in terms of money. In agriculture, capital includes machinery, farm buildings and livestock pens, planted trees, farm tools and implements, irrigation and drainage infrastructure, seeds, feeds, fertilizers, agro-chemicals, terraces, farm access roads, money and other assets that are man-made and are used in further production. Money is of course the most liquid form of capital and can be easily converted into other forms of capital. From this list, it is evident that capital could be durable, if it is not used up in just one production cycle and non-durable if it is. In small-scale fadama irrigation, durable capital items include hoes, cutlasses, irrigation pumps, shadouf structure, water hoses, calabashes, buckets, baskets, footpaths and so on. The non-durable items include seeds and seedlings, fertilizers, pesticides and herbicides. Capital is often said to be the most limiting constraint in traditional agriculture. This is because most of the farmers are poor and operate in the so-called vicious cycle of poverty. Because they earn low income, their savings are low, resulting in low investment which results in low output and, in turn, low income. In essence, it would be correct to state that the farmers are *poor because they are poor*. The sources of capital to many African smallholders, including irrigation farmers, include inheritance, gifts, savings, credit, and creation of capital. Gifts and inheritances make capital available more or less free of charge. However, they are unreliable because they may not be available when needed. Personal savings are low because of low income. And because of low level of technology, creation of capital is limited. Many have therefore, argued that for the farmers to escape from the vicious cycle of poverty, they need external assistance in the form of credit. Credit could come from formal or informal sources. But in spite of all efforts to reach Nigerian smallholders with formal credit, it seems that such credit continues to elude them. The informal sources which are relatively more accessible are either too exploitative, or have inadequate loan portfolio. Thus, inadequate capital has remained the bane of agricultural expansion among smallholders, including small-scale fadama farmers. For instance, when small-scale farmers in Bauchi State were asked to indicate constraints they faced in irrigated crop production, all of them identified among others, lack of credit as a major constraint (Table 9).

Table 9: Constraints to increased crop production under pump irrigation in Bauchi State

Constraints	No. of farmers	Percentage
Non-availability of land	-	-
Non-availability of labour	2	4.4
Non-availability of credit	45	100
Lack of tractor for land preparation	45	100
Low produce prices	45	100
Inadequate supply of fertilizer	34	75.6
Non-availability of improved seeds	34	75.6
Lack of extension advice	30	66.7
Shortage of irrigation water	34	75.6
Non-availability of pump	12	28.7
Pest and disease attack	10	22.2

Source: Baba and Etuk (1991)

Notwithstanding the limited access to credit, small-scale fadama farmers still use some durable and non-durable capital items. The durable items typically include hoes, cutlasses, irrigation canals, pumps and accessories, tubewells, washbores, baskets, and calabashes in some cases. The non-durable items include fertilizer, seeds and agro-chemicals. The fertilizer rates applied by the farmers are often inadequate. For example, in a study in Sokoto State, Baba and Adedibu (1998) reported average fertilizer use of about 333 kg/ha which, as they pointed out, was below the recommended rate of 500 kg/ha for fadama. A lower rate of 243kg/ha was even reported in another study (Baba *et al.*, 1997). The farmers attributed this to the difficulty and high cost of obtaining the input. Table 10 gives further insight into rates of fertilizer use by fadama farmers.

In a number of studies, such as Baba and Etuk (1990) in Bauchi State, and Baba *et al.* (1997) in Sokoto State, farmers did not apply any form of agro-chemical apart from fertilizer. However, in another study, in a different part of Sokoto State, some use of pesticides was reported (Baba and Adedibu, 1998). In all the studies, only few farmers used improved seeds of the various crops they cultivated. It should be pointed out that the full potentials of irrigation cannot be attained unless farmers adopt the improved complementary inputs of fertilizer, high-yield varieties of crops cultivated and crop protection chemicals, which must be applied at the recommended rates.

Table 10: Distribution of small-scale fadama farmers in Sokoto State according to rates of fertilizer used (kg/ha)

Fertilizer rate	No. of farmers	%
1-200	15	37.5
201-400	13	32.5
401-600	8	20.0
>600	4	10.0
Total	40	100

Source: Baba et al. (1997)

6.2 Crop Enterprises in Irrigated Fadama Farms

One of the advantages of irrigation is that it allows the production of crops which would either not have been possible at all, or would have performed poorly if grown in the rainy season. For instance, certain crops such as wheat and cabbage which thrive under cold weather conditions could only be profitably produced during the hamarttan season in northern Nigeria. Others, such as vegetable fruits could be grown in the rainy season but perform better in the dry season when the weather is less conducive for their diseases and pests. Therefore, a wide range of crop enterprises are produced under irrigation in northern Nigeria. They consist mainly of cereals and vegetables. The prominent cereals include maize, rice, sugarcane and wheat, while the vegetables include tomato, pepper, onion, garlic, garden egg, carrot and leafy vegetables. In addition, tuber crops such as irish and sweet potato are produced in some places.

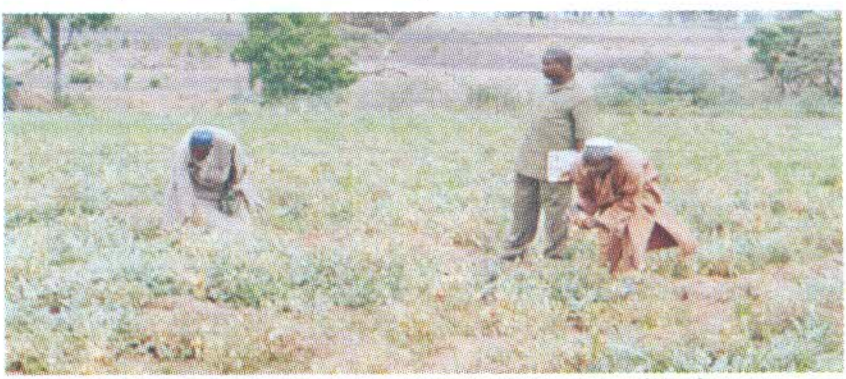

Figure 10: Tomato crop under small-scale fadama irrigation in Mariga Local Government Area of Niger State (Courtesy, NSFCO Minna)

Figure 11: Maize crop under small-scale fadama irrigation in Mariga Local Government Area of Niger State (courtesy, NSFCO Minna)

The enterprises may be grown sole or in mixture. For instance, in one of the Bauchi studies, it was found that 67% of the farmers, who produced mainly tomato, pepper, onion and garden egg, grew the crops sole, and the others, in mixtures (Baba and Etuk, 1990). In one of the Sokoto studies, the enterprises produced are as shown in Table 11. It is evident that more of the farmers produced their crops sole. In another study in Sokoto State, however, those who produced in mixture were more than those who produced sole (Table 12). The crop enterprises and the mixtures were much more diversified in Zamfara State, as reported by Baba and Ribe (2005) (see Tables 13)

Table 11: Distribution of fadama farmers according to crops grown

Type of crop	No. of farmers	%
Tomato/hot pepper	4	10.0
Tomato/onion	3	7.5
Sole onion	15	37.5
Sole tomato	16	40.0
Sole egg plant	2	5.0
Total	40	100

Source: Baba et al. (1997)

6.3 Crop Yield

Crop yields are generally supposed to be high under irrigated conditions. This is because the farmer is able to control the water application to his crops instead of relying on rainfall over which he has no control. Where irrigation is carried out strictly as recommended, the farmer is able to deliver water optimally to meet the exact water requirements of the crops. This way, the crops are free of water stress or excessive moisture and they perform well.

Another reason for higher yields under irrigation is that it is mainly undertaken in the dry season when the growth conditions for some crops are suitable and when problem of pests and diseases is reduced. Nevertheless, yields could still be much lower than their potentials if complementary yield-improving inputs are not used. For example, in one of the studies conducted in Sokoto State, mean yields of 7,939kg/ha, 7,844kg/ha, 4,500kg/ha and 5,8522kg/ha were recorded for tomato, onion, garden egg and hot pepper, respectively (Baba *et al.*, 1997). These yields are quite low. If we take tomato, for instance, the yield falls far short of the 13,924kg/ha reported by Baba (1993) in Bauchi State (Table 14) or even the 12,345kg/ha reported by FAO (1990) as national average. The low yield was attributed to limited use of improved inputs by the farmers.

Table 12: Distribution of fadama farmers in Sokoto State according to crops grown

Crop	No. of respondents	%
Onion/pepper/tomato	26	52
Pepper/cassava/tomato	1	2
Onion/okra/potato	10	20
Rice	12	24
Wheat	1	2
Total	50	100

Baba et al. (1998)

6.4 Farm Incomes in Small-scale Irrigation

As with any other business, the decision of a farmer to sustain irrigated crop production would be influenced greatly by the profitability of the venture. It is therefore, necessary to examine costs and returns in small-scale irrigation. If the gross returns exceed the total costs, then irrigation could be said to have contributed not only to employment creation, but also to have raised the income of farmers, which, *ceteris paribus*, would increase their standard of living, which is one of the major objectives of irrigation development. The author therefore, investigated the profitability of irrigation in a number of studies.

Enterprise	Participants		Non participants		Total	
	Freq.	%	Freq.	%	Freq.	%
Rice	2	13.33	-	-	2	6.67
Sweet potato	1	6.67	-	-	1	3.33
Onion	6	40	1	6.67	7	23.33
Sugarcane	3	20	1	6.67	4	13.33
Tomato	7	46.67	-	-	7	23.33
Amaranths	1	6.67	-	-	1	3.33
Hot pepper	4	26.67	-	-	4	13.33
Garden egg	-	-	1	6.67	1	3.33
Maize	1	6.67	-	-	1	3.33
Lettuce	1	6.67	2	13.33	3	10
Wheat	3	20	-	-	3	10
Sugarcane/tomato	1	6.67	2	13.33	3	10
Lettuce/amaranths	2	13.33	1	6.67	3	10
Lettuce/cabbage	1	6.67	-	-	1	3.33
Hot pepper/sweet pepper	1	6.67	-	-	1	3.33
Tomato/onion	1	6.67	2	13.33	3	10
Cassava/okra	1	6.67	-	-	1	3.33
Cassava/maize	2	13.33	-	-	2	6.67
Tomato/lettuce	1	6.67	-	-	1	3.33
Tomato/hot pepper	1	6.67	4	26.67	5	16.67
Tomato/okra	-	-	2	13.33	2	6.67
Sugarcane/okra	-	-	1	6.67	1	3.33
Sugarcane/garden egg	-	-	1	6.67	1	3.33
Sugarcane/tomato/okra	-	-	1	6.67	1	3.33
Hot pepper/lettuce/ amaranths	1	6.67	-	-	1	3.33
Hot/pepper/onion/tomato/amaranths	-	-	1	6.67	1	3.33

Source: Baba and Ribe (2005)

Table 14: Crop yield under shadouf and pump irrigation systems in Bauchi State

Crop	Irrigation system [1]	Mean yield (kg/ha)	t-value
Tomato (*Lycopersicon lycopersicum*)	1	11,189.59	2.08**
	2	13,924.98	
Pepper (*Capsicum annum*)	1	8,510.85	1.56^{ns}
	2	9,887.41	
Onion (*Allium cepa*)	1	7,692.54	2.15**
	2	10,575.54	
Eggplant (*Solanum melongena*)	1	12,809.87	1.34^{ns}
	2	14,821.72	

[1] 1, shadouf; 2, pump

**, t-value significant at 5 % level; ^{ns}, t-value not significant

Source: Baba (1993)

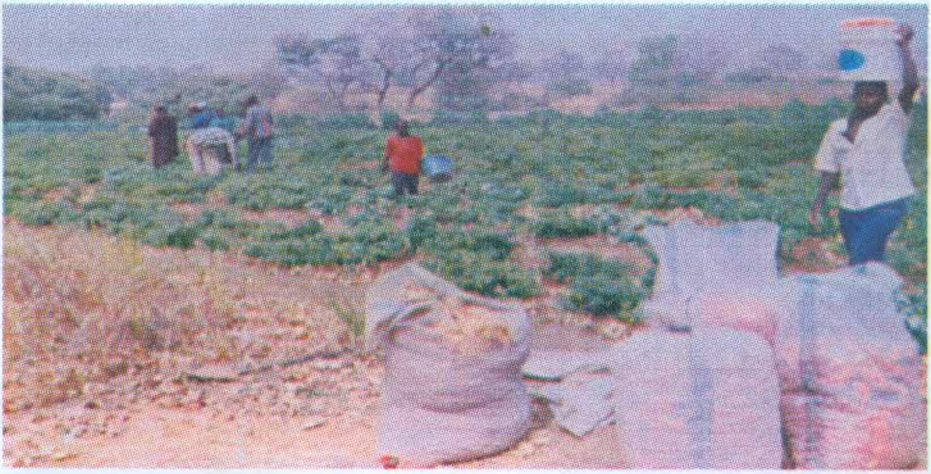

Figure 12: Harvesting of pepper produced under small-scale fadama irrigation in Mariga Local Government Area of Niger State (Courtesy, NSFCO Minna)

Figure 13: A small irrigated farm land in Mariga Local Government Area of Niger State (Courtesy, NSFCO Minna)

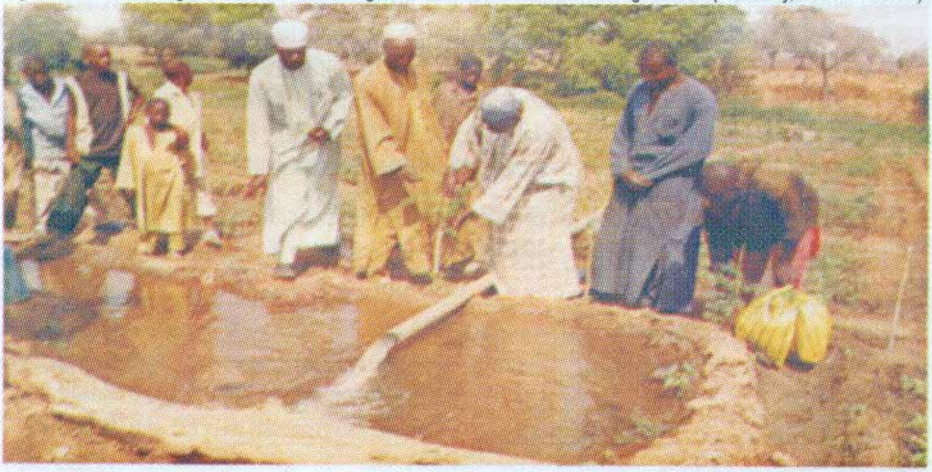

Figure 14: Farmers pumping water into an irrigation channel (Courtesy, NSFCO Minna)

Table 15 shows the costs and returns structure in small-scale irrigation as reported by Baba and Etuk (1990) in their study in Bauchi State. It is evident from the Table that the imputed cost of unpaid family labour (62%) dominated the production costs. Further, fixed costs representing depreciation on farm fixed assets was low probably because of low fixed capital investment by the farmers.

Table 1 5: Cost return structure in crop production under irrigated farming in Sokoto State

Cost/return item	Cost (naira per hectare)	%
Variable costs		
Seed/seedling	182.78	4.79
Fertilizer	207.33	5.44
Pump repair	122.70	3.22
Fuel	245.65	6.44
Hired labour	225.45	5.92
Family labour	2,358.85	61.85
Marketing and others	258.70	6.70
Total variable cost	3,601.76	94.44
Fixed cost		
Depreciation on tools and equipment	212.16	5.56
Total cost	3,813.92	100
Gross returns	6,372.38	
Net farm income costing family labour	2,558.46	
Net farm income not costing family labour	4,917.31	
Rate of return on investment when family labour is costed	67%	

Source: Baba and Etuk (1990)

Table 15 shows that farmers earned a positive net income both when family labour was costed and when it was not, indicating that the small-scale fadama irrigation ventures were profitable, on the average. In fact, the farmers earned a return on investment of 67% even when family labour was costed. Similar positive returns were obtained in another study in Bauchi State (Table 16). In the latter study comparing shadouf and pump, it was discovered that pump users earned more profit in all crops except onion. For both categories of farmers, tomato was the most profitable and onion the least.

Table 15: Average gross margins for crop enterprises under shadouf and pump irrigation systems in Bauchi State (naira per hectare)

Enterprise	Shadouf	Pump
Tomato	4,833.70	6,934.84
Pepper	3,099.36	4,128.70
Onion	2,317.40	2,030.44
Eggplant	3,904.00	6,333.21
Total	14,154.70	19,427.19

Source: Baba (1993)

The results of one of the studies in Sokoto State (Baba *et al.* 1997) also show a general profitability of small-scale irrigation. However, a few (7.5%) of the farmers incurred losses. The distribution of the farmers according to net income earned shows that majority of the farmers earned between zero and ten thousand naira per hectare (Table 16).

Our study in Niger State also revealed that fadama farmers who were members of water users' association earned a net income of N15,845/ha compared with N13,695 for non-members. All the results presented above attest to the profitability of small-scale irrigation in various parts of northern Nigeria.

Table 16: Distribution of small scale fadama farmers in Sokoto State according to Net farm income

Net farm income (N/ha)	**No. of respondents**	**%**
<0	3	7.50
0 - 10,000	30	75.00
10,000 – 20,000	5	12.50
>20,000	2	5.00
Total	40	100

Source: Baba et al. (1997)

6.5 Investment Analysis of Small-scale Irrigation

Recognising the fact that investment in small-scale irrigation is a strategic one with costs and returns spread over many years, a study was conducted in Bauchi State to ascertain the viability of the investment over the assumed life span of the major fixed assets required for irrigation (Baba *et al.*, 1999). The following assumptions were made to facilitate the analysis:

1. The cost of pumps, washbores, water hoses, cutlasses and hoes, together, constituted the initial investment requirements for dry season irrigation farming using motorised pumps.

2. While pumps and washbores have a lifespan of five years, water hoses, hoes and cutlasses were assumed to last three years.

3. The cost of production increased at an annual rate of 49.27%, while returns increased at an annual rate of 25.74% (Baba *et al.*, 1990).

4. The discount factor was 19.5% which was the ceiling lending rate in 1988.

5. The first year of investment was 1988 which was when the field survey was conducted.

The net present value (NPV) and the internal rate of return (IRR) were used as the discounted measures of investment worth. Two scenarios were considered. In the first instance, the two measures were computed costing family labour and in the second, not costing family labour. The results are as presented in Tables 17 and 18. In Table 17, it can be seen that up to 53% of the farmers obtained negative NPV. The average NPV was just N502.44/ha. Similarly, the internal rate of return on investment was 24% which did not exceed the cost of capital (19.5%) by far. These will appear to cast doubt on the economic viability of small-scale irrigation when treated as a strategic investment. But there was a peculiar problem in the year of survey from which projections were made. Farmers had no reliable sources of water as the ponds as well as the washbores from which they obtained water dried up mid-way into the season and some of the crops failed. This underscores the need for reliable sources of water to ensure the success of irrigation farming. Perhaps, instead of wasbores, tubewells or boreholes would have done better.

When family labour was not costed, on the other hand, the situation was remarkably different. In this case, only 11% of the farmers earned negative NPV and the mean NPV was N15,582.64 (Table 18). The IRR of 159% was also very high.

Table 17: Distribution of small-scale fadama farmers in Bauchi State according to their net present value (NPV) when family labour was costed.

NPV (^/ha)	Frequency	%
<0	24	53.33
1 – 5,000	2	4.44
5,001 – 10,000	5	1.11
10,001 – 15,000	6	13.33
15,001 – 20,000	2	4.44
20,001 – 25,000	1	2.22
25,001 – 30,000	2	4.44
>30,000	3	6.67
Total	45	100

Source: Baba et al. (1999)

Table 18: Distribution of small-scale fadama farmers in Bauchi State according to their net present value (NPV) when family labour was not costed

NPV (N/ha)	Frequency	%
<0	5	11.11
1 – 5,000	4	8.89
5,001 – 10,000	9	20.00
10,001 – 15,000	7	15.56
15,001 – 20,000	5	11.11
20,001 – 25,000	2	4.44
25,001 – 30,000	2	4.44
>30,000	11	24.44
Total	45	100

Source: Baba *et al*. (1999)

6.6 Resource Use Efficiency in Small-Scale Irrigation

The full potentials of irrigated agriculture cannot be attained unless the resources used in crop production are allocated efficiently. Farmers who produce at a loss may be doing so because resources are not being efficiently utilised. Those who are making profit may still have room for increasing the profit through resource adjustment. It is therefore, important to examine the efficiency with which resources are being allocated in a production system. Such an examination will not only provide information about the efficiency status of the farmers, but it will also reveal information about the direction and magnitude of resource adjustment required to bring about efficiency. Three types of production efficiency can be distinguished. These are technical, allocative and economic efficiency. Technical efficiency is measured by relating the level of output achieved to the level of inputs used to produce that output. A firm is said to be technically efficient if it yields the maximum possible output per unit of the variable resource. In such a firm, resources are combined in such a way that they cannot be rearranged to give a greater output with the same collection of resources, or the same physical output with less of one or more of the resources.

Although technical efficiency is a necessary condition for the overall efficiency of a firm, it is not a sufficient condition. To ascertain whether a firm is really efficient, price relationships have to be employed to denote maximum profit (Heady, 1952). This brings us to the concept of allocative efficiency. Allocative efficiency is defined only if resources and enterprises are chosen and combined in such a way that they attain or are near economic optimum. If we assume a single-variable response function, economic optimum is attained where the marginal physical product equals the resource: product price ratio. Put in another way, economic optimum is attained where the value of the product of an extra unit of input (marginal value product) equals the cost of that unit (marginal factor cost). If it is a two-variable response function, economic efficiency is attained where the marginal value products of the two inputs are simultaneously equated with their respective marginal factor costs. This condition can be generalised to a response function with more than two factors.

The author has attempted to measure allocative efficiency in small-scale fadama irrigation in a number of studies. In the process, several functional forms of production function (typically linear, quadratic, double-log, semi-log and exponential) were specified and estimated through multiple regression to obtain the regression coefficients which were then used to compute the marginal products of the respective factors included in the production functions. Input and output price information were then used to obtain the marginal value products and the marginal factor costs of the inputs. Efficiency index for each input was then obtained by dividing its marginal value product by the marginal factor cost. An index of one signals efficient utilisation of the input while an index greater than one shows that the input is underutilised. The input is considered overutilised if the efficiency index is less than one.

The results obtained from one of the studies in Bauchi State are as presented in Table 19 which shows that four factors, namely seedlings (plant population), labour, fertilizer and irrigation water were considered. Only information about the marginal value products and marginal factor (or acquisition) costs are presented. The marginal value products were, of course, obtained from regression coefficients derived from estimated production function for each crop.

Table 19: Marginal value products and marginal factor costs of inputs used in crop production by fadama farmers in Bauchi State (naira per unit)

Input (factor)	Marginal factor cost	Marginal value product by crop			
		Tomato	Pepper	Onion	Garden egg
Labour (man -hour)	0.99	-0.74 (-0.74)*	-0.40 (-0.40)	-0.37 (-0.37)	1.34 (1.35)
Plant population (number)	0.003	0.11 (36.67)	0.10 (33.33)	0.01 (3.33)	0.18 (60.00)
Fertilizer (kg)	0.29	1.07 (3.69)	6.02 (20.76)	5.53 (19.07)	18.45 (63.62)
Irrigation water (ha -cm)	8.00	148.25 (18.53)	200.77 (25.10)	109.10 (13.64)	353.99 (44.25)

*, Values in parentheses are efficiency indexes

Source: Baba and Etuk (1991)

Results in Table 19 show that all the resources were inefficiently allocated. Specifically, labour was overutilised in all the enterprises except garden egg. In contrast, plant population (i.e seedlings), fertilizer and irrigation water were underutilised in all the crop enterprises. The overutilisation of labour was attributed to the low opportunity cost of the input during the dry season in the study area. The underutilisation of seedlings was blamed on the possibility that the farmers were not aware of the correct specification of plant density, throwing up a challenge to extension agencies. The sub-optimal use of fertilizer was attributed to scarcity and high cost of the input. The underutilisation of irrigation water was expected, given the shortage of irrigation water in the area.

These results show that although farmers may be making profit in small-scale irrigation, they are not maximising profit. There is opportunity for increasing profits by adjusting the levels of inputs used. Farmers would make more profit by using less labour and more of seedlings, fertilizer and irrigation water.

Fairly different results were obtained in a similar study in Sokoto State where it was found that only fertilizer was underutilised among fadama farmers. The other inputs, including labour, seed and irrigation labour were overused (Table 20). But the results still confirm that resources were not efficiently allocated. While fertilizer use needed to be increased, the use of other inputs was to be reduced in order to attain economic efficiency.

Table 20: Marginal value products and marginal factor costs of resources used in small-scale irrigation in Sokoto State (naira per unit)

Input	Marginal value product	Marginal factor cost	Efficiency index
Fertilizer (kg)	7.37	5.45	1.35
Labour for all operations except irrigation (man-hour)	0.90	13.33	0.07
Seed (kg)	0.30	11.42	0.03
Irrigation labour (man-hour)	0.11	13.33	0.008

Source: Baba et al. (1997)

6.7 Optimum Farm Plans in Small-Scale Irrigation

Apart from the production function approach discussed above, another technique for ensuring that farmers use their resources optimally, is by examining the organisation of the resources and enterprises of the farms and comparing this with the optimum organisation or plan to see if there is room for re-organising the enterprises in order to achieve maximum possible profit within the limits of the resource endowments of the farms. One of the most commonly used techniques for obtaining the optimum farm plan is linear programming. If the range of enterprises (activities) that are produced (or that could be produced) is known, along with the constraints (upper limits of available resources), and the per unit resource requirement of each of the enterprises, linear programming could be used to determine the optimum farm plan for a farmer or a group of farmers. The final solution of the linear programming procedure will normally contain information, amongst others, about the right enterprises to be produced, the levels of the resources to be committed to each enterprise, the maximum net returns obtainable as well as the shadow prices of the resources. This information constitutes the optimum farm plan for the farmer(s). The optimum plan could then be compared with the existing plan to see if the adoption of the optimum plan would increase the net returns from the farm(s).

In our study in Zamfara State, linear programming was used to compute optimum plans for the average fadama farmer in Gummi and Kaura Namoda agricultural zones. In each zone, separate computation of the optimum plan was made for farmers who participated in the National Fadama Development Project (NFPD) and those who did not. The results in Table 21 show that, out of the various crops produced in the area, only few entered the optimum plans. In the Gummi zone, for example, only hot pepper and sweet pepper/hot pepper/tomato mixture were competitive enough to make the optimum plan for participants. Similarly, only onion and sweet pepper entered the optimum plan of non-participants. In the Kaura Namoda zone, tomato and maize/cassava mixture entered the plan, of the participants compared with onion and sugarcane/okra mixture for non-participants. If the production goal of the farmers was profit maximisation, these are the enterprises they should be producing.

The results further show that land was exhausted in all the optimum plans and labour was equally exhausted in all but one plan, suggesting that these resources could be constraints to further expansion of irrigated crop production in the area. The Table also reveals that there were wide disparities between the net revenues of the optimum plans and the existing plan. When the returns are expressed on per hectare basis, differences of between 71 and 133% were obtained. There were also major differences between the total net revenues of the optimum plans of farmers participating in the NFDP and non-participants, with the net revenue per hectare of participants in some cases exceeding that of the non-participants by up to 131%.

In general, the study shows that there were opportunities for the fadama farmers to increase their income through reorganisation of their resources and enterprises. This contrasts with the notion that allocative efficiency is high in traditional African agriculture

(Shapiro, 1973; Cisse, 1987). The argument has been that since allocative efficiency was already high, it is not possible to increase productivity and profit through reorganisation of existing resources and enterprises. Therefore, the argument continues, productivity increase could only be attained through the introduction of new technology. While the introduction of improved technology is a necessity for accelerated agricultural development and must be pursued, farm incomes could also be increased through re-organisation of resources and enterprises in crop production.

Table 21: Optimum farm plans for fadama farmers in Zamfara State

Item		Gummi zone		Kaura Namoda zone	
	Unit	Participants	Non-participants	Participants	Non-participants
Onion	Ha	0	0.31	0	0.13
Tomato	Ha	0	0	1.03	0
Hot pepper	Ha	0.52	0	0	0
Sweet pepper	Ha	0	0.66	0	0
Maize/cassava	Ha	0	0	1.13	0
Sugarcane/okra	Ha	0	0	0	0.318
Sweet pepper/hot pepper/tomato	Ha	1.25	0	0	0
Total land used in optimum plan	Ha	1.77	0.97	2.16	0.45
Total land used in existing plan	Ha	1.77	0.97	2.16	0.45
Total labour used in optimum plan	Man-day	83	58.20	115	37
Total labour used in existing plan	Man-day	83	64	115	37
Total capital used in optimum plan	^	21,941.55	13,453	29,237.14	1,441.21
Total capital used in existing plan	^	24,831.00	13,453	29,428	8,710
Shadow price of land	^	138,920.00	58,461.37	28,734	43,070.55
Shadow price of labour	^	20	0	629.17	68.31
Shadow price of capital	^	0	0.14	0	0
Total net returns from optimum plan	^	247,539.40	58,625.60	134,420.15	21,909.18
Total net returns from existing plan	^	137,481.10	25,179.65	78,509.40	9,393.27
Net returns per ha from optimum price	^	139,852.77	60,438.76	62,231.55	48,687.07
Net returns per hectare from existing plan	^	77,672.94	25,958.40	36,346.94	20,873.93
Increase in net returns per hectare of optimum price over existing pan	%	80.05	132.83	71.22	133.24

Source: Baba and Ribe (2005)

6.8 Income Distribution in Small-Scale Irrigation

One of the goals of irrigation development is to increase the production of food and fibre. Another crucial objective is to increase the incomes of farmers and others who are involved in processing and marketing of the products of irrigated agriculture, with the ultimate aim of improving their living standards. This objective would not be achieved if the benefits of irrigation accrue to only few people. It is therefore, important to examine income distribution to see how evenly it is spread among participants in irrigated agriculture.

The author in conjunction with some others conducted a study to evaluate income distribution in an irrigation scheme in Sokoto State using the Gini coefficient and the Lorenz curve. This technique is used to determine concentration of income among a group of people. In the study conducted at Wurno Irrigation Scheme, the distribution of incomes from crops grown under irrigation and those grown rainfed were compared (Dogondaji and Baba, 2009). Using the decile ratio test, it was found that the 10th decile received the highest share of income from both rainfed (20.56%) and irrigated (22.74%) crops, while the first decile received just 1.23% and 2.57%, respectively. Furthermore, the Gini coefficient was 0.60 and 0.62 for incomes from irrigated crops and rainfed crops, respectively. This shows that income inequality was less for irrigated, than rainfed crops. This is further confirmed by Figure 15, which shows that the Lorenz curve for income from irrigated crops lies slightly closer to the line of equality than that for rainfed income.

According to Todaro (1981), Gini coefficients of some economic variables with high unequal distribution of subjects or items involved, typically lie between 0.5 and 0.7, while those for relatively equitable distribution normally lie between 0.2 and 0.35. It could be inferred therefore, that incomes from both irrigated and rainfed crops in the Wurno irrigation scheme were concentrated among few farmers.

Table 21: Distribution of incomes of farmers from rainfed and irrigated production

				Irrigated crops				Rainfed crops			
Decile Group	% of farmers	x	Cum. % of farmers	% of aggregate income	Cum. % of aggregate income	y	xy	% of aggregate income	Cum. % of aggregate income	Y	xy
1st 10%	10	0.1	10	2.57	2.57	0.0257	0.0026	1.23	1.23	0.0123	0.0012
2nd 10%	10	0.1	20	4.54	7.11	0.0711	0.0071	3.15	4.38	0.0438	0.0044
3rd 10%	10	0.1	30	6.31	13.42	0.1342	0.0134	4.59	8.97	0.0897	0.0090
4th 10%	10	0.1	40	7.75	21.17	0.2117	0.0212	6.46	15.43	0.1543	0.0154
5th 10%	10	0.1	50	8.85	30.02	0.3002	0.0300	8.66	24.09	0.2409	0.0241
6th 10%	10	0.1	60	8.96	38.98	0.3898	0.0381	10.88	34.97	0.3497	0.0350
7th 10%	10	0.1	70	9.96	48.94	0.4894	0.0489	12.94	47.91	0.4791	0.0479
8th 10%	10	0.1	80	12.86	61.80	0.6180	0.0618	14.46	62.37	0.6237	0.0624
9th 10%	10	0.1	90	15.36	77.16	0.7716	0.0772	17.06	79.43	0.7943	0.0794
10th 10%	10	0.1	100	22.74	100	1	0.1	20.56	100	1	0.1
Total	100	1		100			0.4003	100			0.3788
G							0.60				0.62

Source: Dogondaji and Baba (2009)

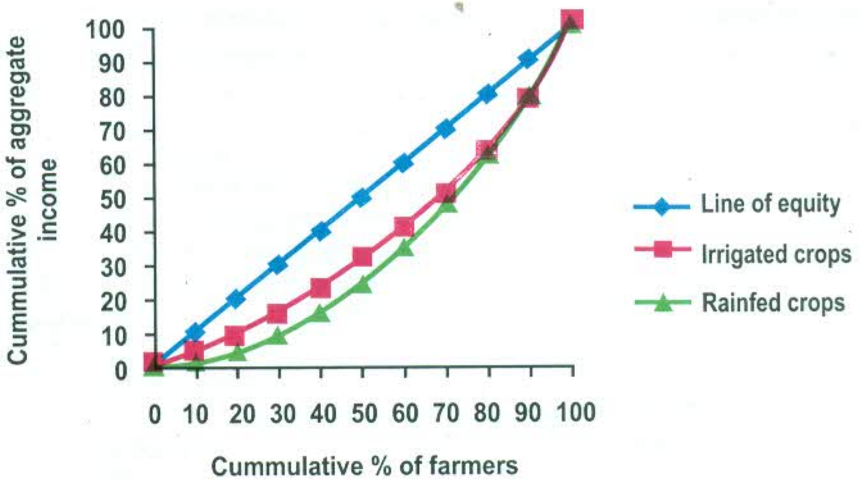

Figure 15: Lorenz curve for irrigated and rainfed income distribution among farmers

6.9 Sustainability Implications of Small-scale Fadama Irrigation

In three of our studies, sustainability of fadama irrigation were examined (Baba and Alassane, 1997; Baba and Adedibu, 1998; Baba and Singh, 1998). The motivation for this is the fact that irrigation, whether large or small-scale, usually engender some modification in the environment and it is important to ask whether such modification could, in the short or long-term, be deleterious. There are other concerns as well beside the environment. Following is a summary of some of the sustainability concerns regarding small-scale irrigation discussed in the studies cited above.

(i) Sustainability of water source

Small scale irrigation in many fadama areas in northern Nigeria, is made possible by virtue of ground water development through drilling of tubewells and washbores, and pumping using small motorised petrol pumps. It is argued that continuous extraction of ground water could lead to depletion (lowering) of the ground water table. The lowering of ground water table could result if the rate of evapotranspiration (ET) exceeds the annual ground water recharge by rainfall and/or ground water movement. As a result of the high temperatures and dry winds in northern Nigeria, ET on irrigated fields tend to be very high. In an analysis of rainfall and ET patterns in various savanna ecological zones in Nigeria, Owonubi *et al.* (1991) noted that potential ET exceeds the annual rainfall by more than 1,600mm in some zones. While site-specific measurement of actual ET is required to make definite conclusions, the magnitude of this difference emphasises the need to continuously monitor the ground water in fadama irrigation sites and nearby areas. It is quite possible that in the semi-arid northern Nigeria, ground water may eventually not be available to continuously support fadama irrigation, unless ameliorative steps (such as water conservation measures) are taken.

(ii) Environmental degradation

The possibility of ground water depletion described above is itself an environmental degradation problem because it could result in the drying up of the top soil which could promote erosion. Furthermore, ground water used for irrigation normally contains high concentration of salts. The salts are usually left on the soil surface or within the rhizosphere (root zone) after the water has evaporated. The continuous accumulation of salts results in soil salinisation and could render the soil unsuitable for crop growth. Yields and incomes would then rapidly decline, thereby endangering the sustainability of irrigation. To avoid this problem, continuous soil testing is required at the various irrigation sites so that ameliorative measures (such as soil treatment) could be adopted when evidence of salinisation appears.

(iii) Sustainability of fadama development technologies

While the technologies involved in small-scale fadama irrigation are much simpler than those required for large-scale irrigation, a number of them such as the motorised pumps and even tubewells have foreign components. The maintenance and dependency problems associated with foreign technologies are well-known. Furthermore, pumps rely on petroleum products and the prices of such products are constantly rising. Whether such products will continue to support profitable fadama irrigation long into the future is the question. A challenge to irrigation researchers is to develop reliable renewable energy sources that could ultimately replace fossil fuel powered irrigation technologies.

(iv) Sustainability of suitable land

We have earlier indicated the problem of soil salinisation which could render fadama soils unsuitable for profitable production. But even if the soils do not develop such a problem, they could lose fertility as a result of continuous use. Although the fadama soils are inherently more fertile than the surrounding upland soils, they are also used more intensively. Most of them are under cropping in both the rainy and dry seasons and are used year after year, with little or no room for fallow. Managing soil fertility under such a situation is therefore a challenge which must be treated as an integral part of the fadama development strategy. Continuous soil testing is required to monitor soil fertility changes and to make appropriate fertilizer recommendations when necessary. In addition, planting legumes either in rotation or in mixture with other crops should be given concerted attention in fertility management of fadama soils. The possibility of inoculating the leguminous seeds with appropriate strains of rhizobia in order to increase symbiotic nitrogen fixation should be considered; so also the use of organic fertilizer.

(v) Conflicts among fadama users

It has been pointed out that conflicts over land use are likely to focus on areas of high productivity especially if these areas provide seasonally critical resources (Scoones, 1991). The fadama lands because of their high levels of fertility and water retention compared to the upland, are highly productive, and because their sizes are usually very limited, are critical resources. These make the fadama lands an area of conflict par excellence. The conflicts could and do arise between the various users of fadama resources including arable crop farmers, pastoralists and fishermen. The conflict could arise even among members of a particular group of users, if there is perceived injustice. Protecting the interests of the various users and establishing suitable conflict resolution institutions could help avoid or mitigate the effects of conflicts which are known for wasting resources and in some cases causing human deaths.

The foregoing discussion shows that there are serious challenges in small-scale fadama irrigation. But the discussion has also shown that the challenges are surmountable if appropriate steps are taken to overcome them. In particular, monitoring the fadama soils and water tables and protecting the interests of all users is crucial.

7. The Way Forward for Irrigation Development in Nigeria

Irrigation, whether small or large-scale, offers some benefits, but also pose challenges. However, the question now is not whether or not Nigeria should invest in irrigation development. Already, considerable amounts of private and public funds have been invested in both large and small-scale irrigation development. What should be of concern is how to improve the performance of the schemes by addressing the challenges posed. Some suggestions on how to improve the performance of irrigation in Nigeria are outlined as follows.

(1) Re-introduction of agro-service centres: Irrigation cannot be successful unless productivities are sustained at high levels. One major advantage of irrigated, over rainfed agriculture is the prospect of substantially increasing crop yields. This requires that farmers have easy access to improved inputs such as high-yield varieties, fertilizers and crop protection chemicals, which agro-service centres should provide. Such centres should be integrated in nature, providing not only inputs but also credit, warehousing (storage) and marketing services. The latter two would ensure that farmers obtain remunerative prices while credit is to relieve the capital constraint usually experienced by resource-poor farmers. These centres should service farmers participating in large and small-scale schemes.

(2) Re-introduction of extension services: The extension services role transferred to the World Bank-assisted Agricultural Development Projects (ADPs) should be returned to the irrigation schemes. The premise for this is that irrigation is a specialised type of farming and requires extension personnel specifically trained for it. Using all-purpose extension personnel of the type provided by the ADPs will not do. Such specialized extension personnel could serve both private irrigation famers and those at public irrigation schemes in the respective areas of jurisdiction of the RBDAs.

(3) Appropriate pricing of services: It has been proven that government is either unwilling or unable to fund irrigation schemes as attested to by dwindling budgetary allocation to irrigation schemes even in the face of rising costs. It will therefore be a tall order to expect government to provide the services suggested in paragraphs "(2)" and "(3)" above either free of charge or at heavily subsidised rates as was the practice in the past. Government could aim at full cost recovery for the services including irrigation water provision, the charges for which should reflect the actual cost of delivering water to the farmers' field. Experience elsewhere has shown that if farmers receive good prices for their products, they are usually not averse to paying for services they consider to be effective. Some cost could be recovered even for the specialised extension services if appropriate arrangements are put in place to overcome the public good characteristics and externalities that are usually associated with their provision (Baba, 1997, 2004). The argument is that most farmers undertake irrigation to earn profit. Thus, if they obtain good yields and reasonable returns, they are likely to accept the idea of paying for services. But since this may be a radical departure from past practice, such extension services have to be perceived to be effective and should be demand-driven. Introduction of payment must start on a pilot scale and should be preceded with adequate sensitisation and mobilisation of the farmers.

(4) Mobilisation of farmers to participate in operation and maintenance: Starting in the 1990s, many large-scale irrigation schemes in Nigeria have been making efforts to organise farmers into water users' associations to, among other things, mobilise them for participating in maintenance work at the schemes and to also facilitate the collection of land and water fees. Similarly, agencies promoting private small-scale fadama irrigation have also mobilised farmers into fadama users' associations to facilitate acquisition of inputs and services and for marketing of produce. These steps are in the right direction and should be scaled up. These groups should form the basis for the provision of all services, including extension, mentioned earlier.

(5) Rehabilitation of infrastructure and other irrigation facilities at the large-scale schemes is of paramount importance: Most schemes cannot command even the developed areas because of the deplorable state of the infrastructure. This is largely responsible for the rather low capacity utilisation at the schemes. Without the rehabilitation of the infrastructure, it would imply that the huge sums already sunk will have been wasted. On the other hand, if the schemes are made to cover the developed areas and all necessary support services are put in place, the schemes are bound to make the desired impact on food security and the nation's economic development.

(6) Development of the planned areas: The suggestion in "(5)" is a short-term measure. In the long-run, the schemes should aim at developing and equipping the remaining planned areas. It is a fact that, not only are the sizes of developed areas a far cry from the planned areas, but at some schemes, no irrigation areas were developed at all. In such cases, the dams were completed and water impounded and then literally

abandoned. The reservoir capacities of such schemes have been described as dormant (Musa, 1999) since they serve little purpose. There is the need therefore, to develop all the planned areas. Presently, there is little private sector input in large-scale irrigation development. Government should explore ways of attracting private funds into irrigation development through public private partnership. Private interest may be attracted to irrigation development if farmers are expected to pay for services as earlier suggested.

(7) Effective demand-driven research: The current situation is that yields of irrigated crops both under small and large-scale schemes are low. Research is needed to continuously generate new technologies and practices that would enhance crop yields at minimum costs. This is necessary to sustain the interest of farmers in irrigation.

(8) Monitoring the environment: Both small and large-scale irrigation have negative effect on the environment. Therefore, it is essential that soil and water quality in irrigated areas be closely monitored to ensure that ameliorative measures are adopted when signs of deterioration are noticed. It is also important to ensure that adequate drainage is maintained at irrigated fields and that loss of water in the conveyance and distribution channels are minimised. Furthermore, health status of community members in irrigation areas should be continuously monitored so that problems are detected early.

(9) Recruitment of relevant personnel: As earlier mentioned, most of the irrigation schemes are short of qualified staff. There is need to reverse this for proper operation and maintenance of the schemes.

(10) Continued emphasis on small-scale irrigation: The present emphasis on small-scale schemes, given their advantages, seems to be correct. Government should consider stopping the establishment of new large-scale schemes and instead concentrate on making the existing ones effective and efficient, while supporting the development of private small-scale irrigation which appears to be less problematic.

(11) Cropping patterns: Presently, cropping is haphazard at some of the large-scale schemes. For efficient management of irrigation water and to satisfy the needs of the country in certain priority crops, it may be better if specific crops are prescribed for the different sectors of an irrigation scheme. This will in addition, make planning of services provision relatively easy.

Conclusion

Nigeria is a largely food insecure nation as many of her citizens have no access to adequate food of the right quality. Prices of most food products that would provide a balanced diet are out of the reach of a large segment of the population. To reverse this trend, successive governments have adopted policies and programmes aimed at promoting agricultural development. One of these is irrigation development. Attention was focused on the creation of river basin development authorities under which many large-scale irrigation schemes were established. But these schemes have performed rather poorly and their capacity utilisation has been dismal despite the colossal sums of money invested in them. But even though their performance has been rather poor, they still remain an asset which is lying untapped. Most of the schemes have irrigable areas which are commandable but undeveloped. In most of the schemes, even parts of the areas already developed and equipped are not being irrigated. It is the argument of this Lecture, that these schemes have very much to contribute to food security of this country, if they are properly developed and managed. Several measures have been suggested in this Lecture on how to resuscitate the schemes. Paramount among these is the need to rehabilitate the irrigation infrastructure and facilities in a public private partnership, and to re-introduce agricultural support services which should be appropriately priced in order to make partnership with the private sector work. Relevant demand-driven research and the need to continuously monitor the schemes to detect impact on the environment, amongst others, are also stressed.

In addition to the public irrigation schemes, private farmer owned and managed small-scale irrigation has been going on in Nigeria for many centuries. This has proceeded without much government support until the early 1990s when support came mainly through the National Fadama Development Programme. This irrigation type is based mainly on ground water development and lifting by motorised pumps. The Lecture has attempted to demonstrate some of the potentials of this type of small-scale irrigation by looking at its effect on resource use, yield, income level, income distribution and resource use efficiency. Results show that small-scale irrigation has great potentials and could contribute significantly toward food security. Nevertheless, certain challenges must be overcome for its contributions to be sustainable. These have to do with how to maintain the quality of irrigation water and land, and how to minimise effect on the environment. Research and continuous monitoring of the water and soil quality is essential. There is the need to research into renewable alternative power sources to reduce the present dependence on fossil fuel. Protecting the interests of all users of irrigation services in both small and large-scale schemes is important. There is also the need to resolve crises that may arise among users through traditional institutions of conflict resolution.

Finally, given its potentials for resolving the problem of food insecurity and alleviating poverty, governments and other agricultural development planners in Nigeria have to take irrigation development more seriously in order to achieve vision 20: 20-20. It is our firm believe that the best form of freedom is freedom from hunger and the most worthy conquer, is conquer of poverty.

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I must pay glowing tribute to my parents not just for their love and care, but also for working tirelessly to see that I get educated to the highest level despite their modest means. In fact, sending a child to school at a time when the concern of many was with how many hands they could get on the farm was a major sacrifice. To have sent two children to fees-paying schools at that time really required foresight and determination. Today, I am happy to state that their sacrifices and foresight were not misplaced as both children are now professors, coming from a remote village with a population of less than one thousand persons. Nevertheless, I pray that Allah rewards them with Al-Jannah Firdaus.

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