THE NIGERIAN RICE ECONOMY IN A COMPETITIVE WORLD:
CONSTRAINTS, OPPORTUNITIES AND STRATEGIC CHOICES

Challenges and Opportunities for Improving Irrigated Rice Productivity in Nigeria

By

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1 Introduction

With more than 124 million inhabitants in 1999, Nigeria is by far the most populous country in Africa. The farm sector has been the backbone of the economy since independence, employing more than 70 percent of the country's population. Small farmers dominate the sector and provide the bulk of the nation's domestic food supply. The Nigerian farm sector is characterized by low productivity that has persisted since the early sixties. World Bank reports put the growth rate in total food production at less that 1.5% in the 1990s, compared to an average annual population growth rate of about 3% during the same period. This has placed tremendous pressure on the farm sector and the economy at large, as limited foreign reserves have to be allocated to food importation in order to meet consumption requirements.

Rice is an important cereal in Nigeria, with the share of rice in cereals consumed increasing from 15% in the 1970s to 26% in the early 1990s (Akpokodje, Lancon and Erenstein, 2001). Projections from the FAO indicate rice consumption growth rates of 4.5 percent per annum through the 2000s, which will represent a 70% increase in total rice consumption by the end of the decade. Although total rice production has increased over the last two decades, the increases have not been sufficient to meet the increasing demand from the rapidly growing population. Mean annual paddy production increased from 332,800 metric tons during the period 1961-1975 to 3,189,833 metric tons during 1995-1999. However, most of this increase has been attributed to an expansion in the area under cultivation. During the same period, rice imports increased from 2036 to about 687,925 metric tons (Maclean et al., 2002). The inability to meet rice consumption needs through local production has resulted in high cash outlays for importation. In 1998 for example, the value of rice imported into Nigeria was estimated at US$ 259 million. Recent policies have placed emphasis on increasing local rice production in order to reverse import trends and free up limited foreign reserves for use in other sectors.

Irrigated rice cultivation in Nigeria has a long history dating back to the colonial era, but it was not until the droughts of the early-to-mid seventies that concerted efforts were paid to irrigation development in the country. A substantial government investment of more than US$ 200 million was put into irrigation development between 1976 and 1990 (Musa, 1997). Irrigation perimeters range from large and medium-scale schemes found in the north where drought effects are more probable, to small-scale schemes developed in inland valley bottoms in the south and other parts of the country. Rice is the main irrigated crop, but other crops such as wheat and vegetables are also important (Shaib et al., 1997). Irrigated rice systems account for 10-16% of the total rice area in the country (Fagade, 1997). In addition to the variability in scheme sizes, these systems encompass varying levels of water control, ranging from partial water control in intensive lowland systems to full water control with possibilities for double cropping.

Average irrigated rice yields of 3.5 tons/ha are generally higher than yields obtained in other rice production systems, but much lower than the potential yield of more than 6 tons/ha for irrigated rice. The relatively poor performance of irrigated rice schemes in the country can be attributed to a number of biophysical, socioeconomic and institutional constraints (Fagade and Nguyen, 2001). These factors have together contributed to low irrigated rice productivity, and the performance of irrigated rice schemes in northern Nigeria continues to be below those of similar schemes in the Sahel region of West Africa. Also, an important issue revolves around the viability of large and medium-scale irrigation schemes in terms of investment, maintenance and operational costs. Current low productivity will continue to undermine the competitiveness of irrigation agriculture vis-à-vis other production systems that have relatively low operating and maintenance costs. Identifying and addressing constraints and opportunities for improving the performance of these schemes will result in significant increases in productivity and farm incomes, improve the competitiveness of the domestic rice sector and reduce rice importation needs.

1.1 Goal and Objectives

In collaboration with Nigerian partners, WARDA is implementing a two-year rice sector project funded by the United States Agency for International Development (USAID). The project aims at formulating a feasible strategy to enhance the competitiveness of Nigerian rice producers through research and a policy dialogue with major stakeholders in the sector. Project implementation began in 2001 with emphasis on stocktaking, institutional and policy reviews, and the identification and consultation of partners and stakeholders. In the second year of project implementation, a producer survey was designed and executed to up-date current knowledge on the rice economy of the country. A separate study was initiated to assess the performance, potentials and constraints of the irrigated rice sector. This study complements the producer survey by providing an in-depth analysis of the irrigated rice sector. The overall goal of the irrigated rice sector study is to assess the potentials for improving irrigated rice productivity in the country. Specific objectives are to: assess the performance of selected irrigated rice schemes, identify and prioritize constraints and opportunities for improving productivity, determine the potential for replicating and transferring technological and methodological advances from other Sahel countries, identify key partners/stakeholders and assess their roles and contributions to the development of the irrigated rice sector.

2 Study Methodology

2.1 Sample Selection

The study sample was selected using a two-stage stratified sampling process. During the first phase, study sites were purposely selected to represent the major irrigated rice production systems in the country. The sites were chosen along a north-south and east-west gradient in order to account for the different agro-ecologies. Because of the wide variability in scheme sizes, a range of small, medium and large schemes were considered in the sample selection. Secondary data were used to categorize schemes by level of performance, and the sample was selected to include a performance gradient. In each of the selected sites, groups representing the different stakeholders in the irrigated rice sector were randomly selected for field discussions and informal interviews.

The following sites were selected based on the criteria discussed above:

1. The South Chad Irrigation Project, representative of a large, poor performing scheme located in the Sahel Savanna zone in Borno State in the North-east region;
2. The Kano River Irrigation Project at Kadawa is representative of a large, well performing scheme in the Sudan Savanna zone in Kano state in the North Central region of the country.
3. The Watari Irrigation scheme built and managed by the Kano state is smaller than the Kadawa scheme. It was selected because of its proximity to Kadawa and opportunities for comparative assessment;
4. The Bakolori Dam Irrigation Project represents a medium sized, intermediate performing scheme in the northern Sudan Savanna zone in Sokoto State, Northwestern Nigeria.
5. The Badeggi irrigation scheme was chosen to represent a medium sized scheme. The scheme is located in the northern Guinea Savanna zone in Nigeria’s middle belt, Niger State;
6. The Bende irrigation scheme represents a small scheme with partial water control located in the forest zone in southeastern Nigeria, Abia State.

Stakeholder groups selected for individual, field level and group discussions included policy makers, scheme level management personnel, extension and research officers, and farmers of different resource categories. Discussions were also held with state and federal government officials involved in the management of the different schemes.

2.2 Data collection

In addition to secondary data reviews, informal and semi-structured interviews were used for the generation and analysis of field data. Themes were selected to represent a broad range of issues relevant to the understanding of the structure, performance, constraints and opportunities for improving productivity of irrigated rice systems in the country. Background information on the different schemes was obtained from baseline data. Information generated from the baseline reviews included basic environmental data, historical profiles, scheme management and production goals. Field discussions with farmers' groups focused on developing a more detailed analysis of each scheme. The key themes for the field discussions were: general information on the history of irrigated rice production in the site, land tenure, cropping patterns, gender roles, and cooperative organization; the evolution of performance at the scheme and plot levels; land preparation/related activities and costs; sowing/related activities and costs; fertilizer, weed and water management; analyses of opportunities and constraints; and general issues.

During discussions with research personnel, information was generated on the focus and expertise of different institutions; analyses of crop performance, available technologies and important constraints; and the availability of crop management technologies for irrigated rice cultivation. Discussions with policy makers generated information on long-term views for irrigation agriculture, future focus of research and development efforts, and technical options for improving the productivity of irrigation schemes. Extension personnel provided information on the adequacy of extension coverage, availability of crop management recommendations, training of extension staff and farmers, availability of training materials, important constraints, etc. Information sought from enterprises engaged in post harvest processing (milling) included kinds of mills, opportunities and constraints in the industry, clientele groups, grain quality issues, etc. Input retailers provided information on the structure of input markets, sources and availability of key inputs, and the major constraints in input marketing.

3 Overview of Study Sample

3.1 South Chad Irrigation Project (SCIP)

Environment

The South Chad irrigation scheme is located at the southwestern shore of Lake Chad. The scheme is situated in the southern Sahel zone, often referred to as wet Sahel. The region has an annual precipitation of about 550 mm. Rainfall distribution is mono-modal and most rains fall from July to September. The length of the growing period is less than 90 days (for rainfed crops). Air humidity is high during the wet season and very low during the dry season. Minimum temperatures occur from November to February, and highest temperatures occur in March and April. Daily temperature variation is high during the dry season and low in the wet season.

Lake Chad and the South Chad irrigation scheme are situated in the Chad basin, a huge depression filled with quaternary deposits. Fine lacustrial deposits overlay sandy sediments in a large region around the lake, indicating the geologically recent retreat of the lake. The fine deposits are the parent material for the dominating vertisols in the scheme, which are very fertile but make heavy machinery necessary for soil preparation. Soil reaction is neutral, and soil organic matter content and cation exchange capacity are high (pH: 7.2; SOM: 3.4%; CEC: 41.3 me per 100 g soil; see more details in table 1).

Profile of the scheme

The South Chad irrigation scheme was commissioned in 1979 with construction planned in three stages. Stage 1 with an area of 18000 ha became operational in 1984. Only 4000 ha were developed out of the 27000 initially planned for stage 2. Construction of stage 3 (22000 ha planned) was not started. Total area cultivated at New Marte (stage 1) and Ngala (stage 2) are 800 and 1000 hectares respectively. Irrigation water from Lake Chad is led to the main pumping station via a 39 km long intake channel. The station lifts water ten meters into a combined main canal, from where it is distributed to the different perimeters that comprise the two operational stages. A 30 MW power station provides power for the pumping stations and other uses.

The project is managed and coordinated by the Chad Basin Development Authority (CBDA), with its headquarter in Maiduguri (about 80 km southwest of the scheme). Resident offices and personnel are located at New Marte and Ngala respectively. In addition to managing the infrastructure, the CBDA has responsibility for allocating land to farmers. However, local communities in the area legally own the land. Land is distributed each season to local farmers and other non-registered farmers from outside the communities. Also, the irrigation authority provides land preparation, irrigation and harvesting services. Farmers pay for these services in kind. Farmers at New Marte and Ngala respectively allocate 40% and 30% of their production to cover charges for these services. When wheat is cultivated during the dry season, service charges increase to 50% of total output due mainly to higher water pumping costs. Farmers purchase inputs from either the irrigation authority or local markets in the area.

Rehabilitation of the schemes was identified as a major concern. The canals are heavily silted and are reported to have not been rehabilitated since establishment. The pumping stations and powerhouse are functional but highly under-utilized. Non-operational agricultural machinery and unavailability of fuel are other major constraints for the functioning of the scheme.

Research and extension institutions

The Lake Chad Research Institute, located in Maiduguri, initially had the mandate for agricultural research for the North East of Nigeria until 1975. The crop mandate of the institute is now limited millet, barley and wheat (crops considered specific to the agro-ecological zone in this region). Although the research institute does not undertake rice research, it participates in discussions related to the crop during monthly technology review meetings of the six Agricultural Development Projects in the zone. Also, the institute is a coordinating center and focal point for research and training activities of some institutions operating in the region (e.g. ICRISAT).

Nine and six extension officers are employed at New Marte and Ngala respectively. Extension workers are required to have detailed agricultural knowledge, and do not receive any formal training after employment. Some training is provided through informal discussions between colleagues and the head of extension at New Marte gives a monthly briefing/training on his initiative. Official meetings with farmers are organized three times a season (early, mid and towards the end of the season), mainly to organize activities the rice season. Extension staff is more involved in scheme management than providing needed services to producers. Major constraints identified by extension officers were; inadequate transportation facilities for field/farmer visits, severe bird pressure, lack of regular training for extension workers, and unreliable water supply. Crop management, diseases or soil degradation were not seen as major problems.

3.2 Kano River Irrigation Project, Kadawa

Environment

The Kano River Irrigation Project is located at Kadawa, about thirty-five kilometers south of Kano city. The Kadawa scheme is situated in the Sudan Savanna agro-ecological zone, which is characterized by a mono-modal rainfall distribution averaging 550 to 1000 mm per annum. The length of the growing period is 90 to 165 days (for rainfed crops), with most rains occurring between May and September. Air humidity is high during the wet season and very low during the dry season. Minimum temperatures occur from November to February, and highest temperatures occur in March and April. Daily temperature variation is high during the dry season and low in the wet season.

Geo-morphologically, the Kano region is situated in the Western African plains, with a flat to slightly undulating surface, bordering the Jos plateau in the northeast. The strongly weathered Western African basement complex and respective sediments in the lower landscape positions dominate the geology. The main soil type of the Kadawa scheme is the reddish-brown to brown regosols, with mainly sandy to clay loam texture. The soils tend to be slightly alkaline, and soil organic matter content and cation exchange capacity are low (pH: 8.0; soil organic matter content: 0.26%; CEC: 1.34 me per 100 g soil; see more details in table 1), The latter indicates a dominance of kaolinitic clay minerals.

Profile of the scheme

The Kano River Project was initiated with the construction of the Tiga dam between 1970 and 1974 to irrigate a total area of about 62000 ha in two phases. The first phase with a potential of 22,000 ha irrigated area was completed in 1974 (Kadawa scheme) and continues to be largely operational. The irrigation system is by gravity from the Tiga dam through an 18 km long concrete lined, main irrigation canal and a 320 km long main drain (HJRBDA, 1989). Other (smaller) schemes in the region are Watari, Thomas, Jehavade and Jigawa.

Although the scheme was initiated by the Kano state government, the management of the water resources in the scheme was taken over by the Hadejia Jamaree River Basin Development Authority (HJRBDA) following the creation of several states within the former Kano state. The Authority has a total of 45000 km^2 arable land in its area of jurisdiction in Kano and Jigawa states. The area has irrigation potential of 87000 and 125000 ha in the Hadejia and Jamaree valleys respectively. The HJRBDA is also responsible for maintaining the irrigation infrastructure, and currently large-scale rehabilitation of irrigation canals is ongoing in the Kadawa scheme. Two categories of land ownership exist at the scheme. At the onset of the scheme, farmers were allocated one-acre plots each, with a considerable portion of the land remaining state owned. There have been significant changes in land ownership over the years, and large numbers of farmers who were initially landowners now have to rent land from others. The Kano State Agricultural and Rural Development Authority (KNARDA, located at Kano) is responsible for providing extension services to farmers in the scheme. Farmers access inputs from the Kano State Input Supply Company (KNISC) or private dealers in the area.

Research and extension institutions

The International Institute of Tropical Agriculture (IITA) and The International Crops Research Institute for the Semi Arid Tropics (ICRISAT) have regional research stations located in Kano. The station has greenhouse facilities and a research farm in the Kadawa scheme (rainfed and irrigated conditions). IITA has a team of scientists and postgraduate students working at the station on various projects. Although the team focuses on millet and cowpea cropping systems and soil fertility management in rainfed uplands, researchers at the site have also been evaluating a triple crop system of rice - wheat – cowpeas in irrigated perimeters in the area. Initial results after 4 years indicate an average paddy yield of 4.2 t ha^{-1}, with a total crop yield of about ten tons per hectare per annum. Under this system, there is a need for short duration rice varieties to reduce pressure in the cropping calendar.

The Institute of Agricultural Research (IAR) has a substation located at the Kadawa scheme. Although rice is not its mandate crop, the institute conducts farming systems research and provides support to extension activities of the Agricultural Development Projects (ADPs) in the northwest. Extension services at the Kadawa scheme are provided by KNARDA. At the onset of the scheme, an extension worker was responsible for 350 farmers. With current staffing constraints however, one extension officer is allocated to a cell that comprises 8 sub cells with a maximum of 500 farming families per sub-cell. Under the unified extension service system, extension officers cover all crops in their domain. Extension officers receive training in Quarterly Technical Review Meetings (QTRM) lasting 2 days. Training is provided by subject matter specialists (SMS) from research institutions, with topics adapted to season, crop and management practices.

Extension officers identified the high cost of inputs as a primary constraint. Other important areas for improvement were identified as: (i) the need for short duration varieties with high yield potential and disease resistance; (ii) better orientation and training of extension staff.

3.3 Watari Irrigation Scheme, Kano

Environment

The Watari scheme is located about 100 kilometers north east of Kano city. Like the Kadawa scheme, it is situated in the Sudan Savanna agro-ecological zone. The geology and climate are very similar to the environment at the Kadawa scheme, with slightly lower average precipitation.

The scheme is situated in an inland river valley, and covers the valley bottom and parts of slopes on both sides. Heavy clay soils with high organic matter content dominate the valley bottom (natural swamps, which are flooded during the wet season), but lighter textured soils (sandy loam) are found in the higher positions.

Profile of the scheme

Water is supplied by gravity from the Watari Dam, constructed by the state in 1990. The scheme was commissioned for cultivation in 1991 as a pilot phase, with initial plans to develop 8 blocks with a total area of 1354 hectare. However, only five blocks were developed between 1991 and 1999, with a total operational area of 689 ha. In addition to this, farmers also use water from the scheme to crop about 300 ha in the surrounding areas of the scheme. Land in the scheme belongs to the farmers who are organized in water user associations (up to 30 associations per block). The total number of farming families in the scheme is about 3000.

Research and extension institutions

No research station is present or in close vicinity of the Watari scheme. KNARDA is responsible for providing extension services to farmers in the Watari scheme. A total of 15 extension officers work in the scheme, with coverage of about 200 farming families per extension officer. Tasks and training of extension officers are similar to the descriptions given for the Kadawa scheme. The main constraints mentioned by the extension officers in Watari were high prices of inputs (fertilizer and agro-chemicals) and soil degradation along the riverbanks. Farmers and extension personnel identified the latter as «soil salinity», but from the characteristics described and based on the environmental conditions, zinc and/or phosphorus deficiency seems more probable. Important issues for improving productivity of the scheme were identified as (i) new varieties with a higher yield potential, (ii) better orientation and training of extension staff, and (iii) cheaper inputs.

3.4 Bakolori Dam Irrigation scheme

Environment

The Bakolori irrigation scheme is located about 70 km south east of Sokoto in the Sokoto River Valley. The scheme is situated in the northern Sudan Savannah zone, with an annual precipitation of about 650 mm. Rainfall distribution is monomodal and most rains fall from June to September. The length of the growing period is slightly above 90 days for rainfed crops. Air humidity is high during the wet season and very low during the dry season. Minimum temperatures occur from November to February, and highest temperatures occur in March and April. Daily temperature variation is high during the dry season and low in the wet season.

The scheme is situated in the Western African plains, on the northwestern fringes of the Jos plateau. A flat to slightly undulating surface characterizes the geomorphology. The strongly weathered Western African basement complex and respective sediments in the lower landscape positions dominate the geology. Sandy loam soils are dominant on the slopes, whereas the valley bottoms are dominated by black soils with clayey texture developed in river sediments.

Profile of the scheme

The Bakolori irrigation scheme was commissioned in 1979, and construction of a major portion of the scheme was completed by 1983. In total, 23,000 hectares were developed, of which 15,000 ha were planned for pump irrigation and 8000 ha for irrigation by gravity. Sprinkler systems installed in the area developed for pump irrigation (15,000 ha) are no longer operational. The area with functioning irrigation is therefore limited to 7,500 ha, irrigated by gravity. Irrigation water is supplied from the Bakolori dam across the Sokoto River and water supply is sufficient for the area currently cultivated. More than 80% of the total cultivated irrigated area is used for irrigated rice production.

Farmers own ninety percent of the land, with the Government owning the rest. Farm sizes are variable but small-scale farmers dominate. The main actors in the scheme apart from the farmers are the

Agricultural Development Project (ADP) and the Sokoto Rima River Basin and Rural Development Authority (SRRBRDA). The ADP provides fertilizer to farmers, and the SRRBRDA is responsible for irrigation management and extension services.

Research and extension institutions

The Institute for Agricultural Research has a station located at Talata Mafara, but active research had stopped at the station six years ago. During the years 2001 and 2002 however, 28 varieties were examined in preliminary yield trials (PYT) conducted in collaboration with WARDA.

The extension service at the scheme currently employs 23 officers. Initially, formal training for extension staff was provided at an extension training school in Bakura. Currently however, most extension officers do not get any formal training after employment. Extension staff at the scheme is more involved in irrigation management at scheme level than in providing extension services to farmers. Periodic training of farmers is undertaken only when new products (seed, chemicals etc.) are introduced. Important constraints identified were; few and expensive tractors, increasing bird pressure (quailer birds). Other constraints identified by a researcher at the agricultural research institute were; the need for earlier maturing, high yielding varieties, and problems of low soil fertility.

3.5 Badeggi Irrigation scheme

Environment

The Badeggi irrigation scheme is located about 20 km east of Bida in the Musa River Valley, a tributary of the Niger River. The scheme is situated in the Guinea Savannah agro-ecological zone, and the region has an annual precipitation of about 1250 mm. Rainfall distribution is mono-modal, and most rains fall from April to October. The length of the growing period in the zone is between 165 and 270 days for rainfed crops. Air humidity is very high during the wet season and remains high almost throughout the dry season. Monthly average temperatures range between 24 and 28 °C, and daily temperature variations are small. Rice is rarely affected by temperature stress in this agro-ecological zone.

The scheme is situated on the outer fringes of the Lower Niger valley. Geomorphology, the scheme site (in the Musa River Valley) is typical of West African inland valleys. The strongly weathered Western African basement complex and respective sediments in the lower landscape positions dominate the geology. Sandy clay soils and clay loam soils developed from recent river sediments dominate in the area. Soil reaction is acidic, and soil organic matter content and cation exchange capacity are medium (pH: 4.9; SOM: 1.0%; CEC: 12.0 me per 100 g soil; see more details in table 1).

Profile of the scheme

Construction of the Badeggi scheme started in 1950, and it represents one of the oldest irrigation schemes in Nigeria. Total irrigated rice area has increased from 200 ha at the inception to a current level of almost 900 hectares. Irrigation water is diverted from the Musa River, and is driven by gravity. The Niger Agricultural Development Project based at Bida is the responsible authority managing the scheme. In the past, the Niger ADP maintained irrigation canals, but farmers now maintain canals through a farmers union (Water Users Association). Currently, small dams and tube wells are constructed within several scheme blocks to supplement the seasonal variable river water resources. Farmers are the landowners, but they are assisted by the ADP.

Research and extension institutions

The National Cereals Research Institute (NCRI) located at Bida is under the aegis of the Federal Ministry of Agriculture and Natural Resources. The institute undertakes research into the production, processing and industrial capacity utilization of rice, acha (hungry rice-Digitaria), oilseeds (soybean and beniseed) and sugarcane. It also fabricates simple agricultural tools like planters, shellers, threshers, fertilizer spreaders, rice processing machines, rice mills, processing plants for brown sugar production, etc. Twenty-two of the 50 scientists working at the institute undertake rice research.

Current rice research activities are (i) variety development (selection, hybridization), (ii) development of integrated crop management practices for the various rice ecosystems, and (iii) dissemination of improved crop production practices. Important biotic and abiotic constraints mentioned were blast, African rice gall midge, rice yellow mottle virus, birds, weeds and iron toxicity.

Extension services are available in the scheme, but only one extension officer is permanently attached to the Badeggi Irrigation Scheme. In the past, extension officers were trained monthly but now the zonal head extension officer meets extension officers intermittently for consultation and to address specific problems. The extension officer at the Badeggi scheme is in direct contact with only few farmers and addresses larger groups during "field days" where selected farmers present their good practices to other producers.

Constraints of rice production mentioned by the extension officer included: (i) the need for improved seed quality, (ii) the high cost of inputs (e.g. fertilizer, herbicides, agro-chemicals), and (iii) iron toxicity in some parts of the scheme.

3.6 Bende Irrigation Scheme

Environment

The Bende Irrigation Scheme is located about 100 km north east of Port Harcourt. It is situated in the equatorial forest zone, with an annual precipitation of more than 1500 mm in the region. Rainfall distribution is bimodal, with most rains falling between June and October. The length of the growing period is more than 270 days for rainfed crops. Air humidity is high year round and the dry season is very short. Monthly average temperatures range between 25 and 27 °C, daily temperature fluctuations are very small, and rice is never affected by temperature stresses. The almost constant cloud cover reduces incoming radiation, lowering the yield potential.

The scheme is situated at the outer fringes of the Niger delta, at the foothills of the Western African plateaus and plains. Geomorphology at the scheme site is typical for West African inland valleys. The strongly weathered Western African basement complex and respective sediments in the lower landscape positions dominate the geology. Dominating soils have a sandy loam texture, are acidic, and have a high soil organic matter content and cation exchange capacity (pH: 5.0; SOM: 4.4%, CEC: 39.6 me per 100 g soil; see more details in table 1).

Profile of the scheme

Construction of the Bende irrigation scheme was a World Bank project and started in 1970. The irrigated area in the Bende scheme increased from 200 ha at inception (1972) to about 500 ha during the late 1980s and the cultivated area remained at that level. The State Government owns most of the land, and only the farmers' cooperatives can get access to the land.

The surface irrigation infrastructure (e.g. the dam and irrigation channels) is only partly functional and at least half of the formerly irrigated area has no access to irrigation water. Farmers in these areas undertake rainfed lowland rice production. This is also the reason why only one crop per year is grown on most of the surface of the scheme.

Research and extension institutions

The National Cereals Research Institute (NCRI), located at Amakama-Olokoro, has a research farm in the Bende irrigation scheme where trials in lowland and irrigated systems are conducted. Variety multi-location trials with screenings for African rice gall midge and iron toxicity tolerance or resistance are some of the current activities at the site. Research is conducted in close collaboration with the NCRI institute at Bida. Apart from these research activities NCRI employees also serve as advisers to the local farmers e.g. in the case of disease or insect infestations or to assist the extension service. Researchers identified the main constraints for rice cultivation in the region as: the African rice gall midge, unavailability or high cost of labor, high input costs, poor state of the irrigation infrastructure and soil acidity.

Eight extension officers under the supervision of an extension agent supervisor work in the Bende scheme, and all of them are fully employed by the state. The scheme represents one extension block and is divided into 8 sub-blocks. One agent is responsible for one sub-block. Every two weeks, extension agents have block review meetings and training at the Ohajia Zone office (F.N.I.) together with agents from other extension blocks. Extension agents regularly meet farmers in the fields. Selected farmers of each sub-block are gathered annually and trained at the zonal headquarter. Major constraints mentioned by the extension agents were: high input costs, poor state of the irrigation infrastructure and the high cost and shortage of labor.

Table 1: Characteristics of selected paddy soils

	Badeggi	**Bende**	**Kadawa**	**Ngala**
Texture	Clay loam	Clay	Clay loam	Clay
pH $_{H20}$	4.9	5.0	8.0	7.2
pH $_{CaCl2}$	4.4	4.8	7.0	6.7
Soil Organic Matter (%)	0.9	4.4	0.26	3.4
Total Nitrogen (%)	0.05	0.34	0.01	0.09
Bray1 Phosphorus (ppm)	12.0	28.0	7.5	-
CEC (me per 100g soil)	12.0	39.6	1.34	41.3
Active Fe (ppm)	0.35	0.80	-	0.13
Amorph. Mn (ppm)	8.0	108.8	-	14.5
Available Si (mg per 100g soil)	9.0	16.0	-	9.8

Source: Adapted from Fagade and Ayotade (1978)

4 Cropping Systems and Production Practices

4.1 South Chad Irrigation Project

The cropping system consists of rice in the wet season and wheat in the dry season. Greater emphasis was placed on wheat production at the onset of the scheme. The focus has however shifted to rice production, which is considered cheaper and more viable (lower water needs for rice cropping in the wet season when wheat cannot be grown). This change took place in New Marte about five years ago and in Ngala only about two years ago. Due to the low water level in Lake Chad, there were no cropping activities in the years 1984 and 1985. Because of to low rainfall in this region, supplementary irrigation requirement in the wet season is more than 50% of total water needs. Farmers in New Marte produce for home consumption and cash, whereas farmers in Ngala produce rice mainly for cash. Women participate in rice production, and their activities include manual weeding, manual harvest and winnowing. Farmers are not organized in unions.

Soil preparation is done with machines by the irrigation authority. Most producers plant by direct seeding. Farmers procure inputs (seed, fertilizer and herbicides) partly through the irrigation authority and partly on the local markets. In New Marte, paddy is harvested with combine harvesters while manual harvest is common in Ngala. Maximum yields are about 7.5 t per hectare, and the average yields reported by farmers are about 4.7 and 5 tons ha^{-1} in New Marte and Ngala respectively.

Existing cropping recommendations are as follows:

- After land preparation with basal application of 247 kg NPK (15/15/15) per hectare, dry seed is broadcasted. Sowing should be finalized by the end of June. Then fields are irrigated, supplemented by rains. The field is continuously flooded throughout the season (about 20 cm deep) after germination.
- The first weeding by herbicide application or manual weeding is recommended two weeks after germination. The second (manual) weeding is recommended 35 days after germination.
- Urea (46/0/0) at the dose of 125 kg per hectare should be applied immediately after the second weeding. Irrigation is stopped ten days before the harvest (determined by yellowing rice plants), to allow access for combine harvesters. Manual harvest is necessary in low-lying areas (wet areas).

4.2 Kano River Irrigation Project, Kadawa

In general two crops per year are grown at the Kadawa scheme. The main wet season crop is rice, but maize is grown in areas with inadequate irrigation (higher landscape positions, outside the perimeter). Dry season crops are maize, cowpea, wheat, pepper, tomato, onions and vegetables. Most farmers interviewed have a long history of rice cropping and irrigated agriculture. Rice is produced mainly for cash, and production is sold individually to traders. Women are active in rice cultivation among small-scale farmers, taking part in activities such as uprooting of seedlings, transplanting, weeding, harvest and winnowing. There are no organized farmers' groups at the Kadawa scheme.

Irrigation is obligatory in the dry season. In the wet season however, irrigation is undertaken only to complement water from rainfall. Small-scale farmers use small bunded plots (about 5 x 5 m) to retain rainwater and minimize surface runoff. The same technique is used outside the perimeter for rainfed cropping. Lower lying areas of the scheme are completely flooded during the wet season, and rice cropping is the only option in these areas. In general however, irrigated rice fields are not permanently flooded. Rice fields with only saturated soils were observed regularly during field visits.

Optimal rice planting date is May to June. With late planting, low temperatures in November result in elongation of the crop cycle and can cause spikelet sterility. Farmers mostly use medium duration varieties. Crop establishment techniques include broadcasting (of dry seed), drilling (seed placement with a stick, often practiced in a row) and transplanting. Harvesting occurs from October to December. Straw remaining in the field after harvest is either burnt or consumed by cattle entering the scheme between cropping seasons. Agricultural machines are scarce and most small-scale farmers conduct most fieldwork by hand. A researcher of the national Institute of Agricultural Research for irrigated schemes estimated average farmers' yields today at 4.6 to 5.6 t ha^{-1}. The IITA institute measured an average rice yield of 4.2 t ha^{-1} in three consecutive seasons in a cropping system with three crops a year (rice-wheat-cowpea). Rice yields were relatively high for a considerable period after establishment of the perimeter, reaching averages of 5 t ha^{-1} in farmers' fields and up to 10 t ha^{-1} on research plots (Fagade 2001). Significant yield declines were recorded towards the end of the 1980s, down to about 3 t ha^{-1} in farmers' fields and about 3.5 t ha-1 on research plots by the mid 1990s. The main reasons given for this development were the low dose of applied chemical fertilizers (associated with the period of structural adjustment) and overall soil nutrient depletion.

Recommended crop management practices for rice in the scheme are as follows:

- Land preparation by ploughing and harrowing, followed by direct seeding (broadcast or drilling) or transplanting (spacing 0.1 x 0.1 m with one plant per hill).
- Initial weed control in broadcast seeded rice using pre-emergence herbicides or manual weeding, best in May or June (after the first rains). Post emergence herbicides are recommended alone or in combination with manual weeding 21 days after seeding (14 days after transplanting). Second weeding (herbicides/manual weeding) is recommended 3 to 5 weeks after seeding or transplanting respectively. Manual weeding should be done after irrigation, because moist soil eases manual weeding and renders it more effective.
- Transplanting of seedlings is recommended between July and August.
- Fertilizer should be broadcasted two days after the first post emergence weeding (250 kg NPK composite fertilizer per hectare). The second fertilizer dose should be applied 6 to 8 weeks after seeding or transplanting (125 kg urea per hectare).

4.3 Watari Irrigation Scheme, Kano

The Watari scheme is relatively new, with most farmers owning their land. Small-scale farmers dominate the scheme. Rice is mainly produced for cash, and production is sold individually to traders or on the market. Women are mainly involved in seedling uprooting, transplanting, weeding and winnowing. Unlike Kadawa where there are no organized unions, Watari farmers are organized in water user associations. In general, transplanting is the preferred establishment technique for rice. Some farmers in the Watari scheme produce three crops per year (rice-wheat-vegetables). Farmers at the site have a shorter history of irrigated rice cultivation (maximum of 10 years of experience), but were engaged in rainfed lowland cultivation prior to the establishment of the irrigated scheme.

The cropping system in the Watari scheme is similar to that of the Kadawa scheme. Average paddy yields mentioned by the extension officers were about 6.2 t ha^{-1}, with the best farmers obtaining upto 7.4 t ha^{-1}. Extremely high land rental fees (24700 Naira ha^{-1} and per season) paid by some farmers may be indicative of highly productive land in the area. No yield declines were observed by either farmers or extension officers.

4.4 Bakalori Dam Irrigation Scheme

Like their counterparts in Kadawa and south Chad, farmers at the Bakalori scheme in the Sokoto Rima RBDA have 2 cropping seasons per year. The main wet season crops are millet, guinea corn, cowpea, groundnut and cotton. During the dry season, rice, maize, wheat, sweet potatoes, cowpea, groundnut and vegetables are the major crops. Some confusion remained with respect to rice in the wet season. None of the farmers interviewed mentioned rice as a wet season crop, but the official report on production area and produced crops reported 6500 ha of rice lands cropped and 9750 metric tons rice produced for the 2002 wet season. In the valley bottoms usually only one crop is grown, whereas two crops are grown on the slopes, depending on water supply. Most producers are small to medium scale farmers, and the small-scale farmers often rent land for cultivation. Small farmers produce mainly for home consumption whereas medium to large farmers produce rice for cash. The role of women in rice production is mainly restricted to winnowing. Farmers are not organized in unions.

The experience of farmers in rice cropping ranged between 7 to 25 years for the groups of farmers interviewed. The dry season for rice starts normally in February to March. Soil preparation is mainly conducted with hired tractors. The main crop establishing technique is direct seeding (dry seed) in a row with a stick (drilling). Farmers use a part of their own production as seed for the following season. The crop is harvested in most cases manually. Most farmers indicated high yields (up to 6.8 t ha^{-1}) after establishment of the scheme and a decline thereafter. Average paddy yield reported by the irrigation authority for the dry season 2001 (3981 ha irrigated rice) was 4.9 t ha^{-1}. Average value-cost ratio mentioned in the same report was 1.8.

4.5 Badeggi Irrigation Scheme

The dominant wet season crop is rice, whereas farmers grow potato, cowpea and vegetables in the dry season. Farmers at the site undertook rainfed rice cultivation prior to the establishment of the scheme. They produce rice mainly for home consumption, but sell part of their harvest on the local markets or to middlemen coming to the village. Women participate only little in rice production and their activity is mainly restricted to winnowing. Farmers are organized in an "Association of Irrigated Rice Growers" to facilitate access to inputs. In addition they founded a "Water Users Association" for the management and maintenance of irrigation infrastructure.

Rice fields are prepared manually. Sowing is conducted towards end of June until early July. Transplanting in a row is the main establishment technique and is done in early August. Urea is top dressed after transplanting (120 kg ha^{-1}) and NPK compound fertilizer is top dressed just before flowering (185 kg ha^{-1}). Most farmers apply fertilizers every season. Herbicides are rarely used and fields are weeded one to two times. Irrigation is managed by farmers themselves and occasionally there are shortages of water. Harvest is conducted manually. Average yield of the farmers interviewed was 2.8 t ha^{-1}. Fagade (2001) conducted a yield trend analysis for a selection of farmers in the Badeggi scheme and for researcher managed trials, and found a hyperbolic yield trend for both between 1954 and 1996. Farmer's initial yields were about 1.5 t ha^{-1}, reached a peak of 4.0 t ha^{-1} around 1985 and decreased to 1.5 t ha^{-1} in 1996. Researchers yield followed the same trend, although at a higher level (3.5 t ha^{-1} in 1954, 6.5 t ha^{-1} in 1986 and 3.1 t ha^{-1} in 1995/96). Apart from management and technical factors, the main reasons for this development were the dose of applied chemical fertilizers (increasing initially and decreasing since introduction of structural adjustment policies) and soil nutrient depletion. Research shows average farmers yields in the region are about 2.5 t ha^{-1}, compared to potential yields of up to 7 t ha^{-1}.

4.6 Bende Irrigation scheme

Only one crop per year is grown, and the main crop is rice. Other crops are vegetables, cassava, yam, maize, sweet potato, cocoa and palm trees. Farmers are organized in a union that is largely non-functional. Most farmers have considerable experience in rice growing and produce rice since more than 25 years. They produce rice mainly to earn cash and sell their production individually on the village market. Women are active in irrigated rice cultivation, participating in activities like for uprooting of seedlings, transplanting, weeding, bird scaring, harvest, threshing and winnowing.

Most farmers undertake rainfed lowland rice cropping due to the poor state of the irrigation infrastructure. Soil preparation is undertaken manually as most tractors in the area are non-functional. All farmers use transplanting for crop establishment and they transplant in May/June or July/August. Most farmers apply NPK fertilizer top-dressed two weeks after transplanting and urea about eight weeks after transplanting. Two manual weedings are mostly practiced. Harvesting is done manually in October, November and December.

The average paddy yield in the scheme reported by NCRI for the years 2000 and 2001 was 1.8 t ha^{-1}. The yield trend analysis for a selection of farmers in the Bende scheme and for researcher managed trials (Fagade, 2001) showed initial yields of 5.5 (farmers) to 8.0 t ha^{-1} (research) which subsequently declined continuously to current yields of about 3.0 t ha^{-1}. Farmer's yields were only initially lower than researchers yields and even outperformed researchers yields in the last 15 years. The limited use and decreasing dose of chemical fertilizers as well as soil nutrient depletion were given as reasons for the observed yield decline.

Table 2: Rates of selected inputs used by sample farmers

	Quantity									
Input Type	**Kadawa** *Small*	**Kadawa** *Medium*	**Kadawa** *Large*	**Watari** *Small*	**N. Marte** *Small*	**Ngala** *Small*	**Bakolori** *Intake E* (Small)	**Bakolori** *Intake F* (Small)	**Badeggi** *Small*	**Bende** *Small*
Seed (kg/ha)	20	20	138	20	138	120	94	90	40	40
Urea (kg/ha)	124	124	247	124	124	124	56	150	124	100
NPK (kg/ha)	124	247	247	247	247	247	131	225	185	100
Herbicide (l/ha)	2.47	7.41	4.94	2.47	2.47	1.24	2.47	2.47	0	0

5 Performance of Selected Schemes

5.1 *Yield performance across farm categories, schemes and agro-ecological zones*

Farmers in each of the study sites were engaged in informal discussions aimed at assessing the evolution of the performance of selected irrigated rice schemes in key agro-ecological zones. In the much drier Sudan Savannah and Sahel zones at the Kano, Sokoto and Chad Basin schemes, there was a consensus on declining yields over the years. Farmers' reported yield declines range from moderate levels among small farmers at the Watari scheme at Kano, to drastic levels among medium and large-scale farmers at the same site. Yield declines range from 10 to 50 percent across agro-ecological zones and farmer groups. Similar results were found at the Bende and Badeggi schemes. The decline in yields was attributed to the different constraints presented in this study and the 'general neglect' of irrigation agriculture as perceived by farmers. Respondents strongly linked the general decline in irrigated rice yields to the dismantling of state support for irrigation that accompanied structural adjustment policies. Most producers indicated significant decreases in input levels following the removal of subsidies for fertilizer and herbicides. One conclusion from the discussions is that inconsistent policies and inadequate support has resulted in significant yield declines on farmers' fields.

A second discussion focused on analyzing current yields for different farm size categories. In general, average yields were higher for schemes in the drier Sudan Savannah and Sahel zones. There were however performance differences between farmer categories within each of the schemes. Extremely high yield variability was also reported within farm categories. Among small-scale farmers at Kano, average yields of 4.6 and 8 tons per hectare were reported by farmers at Kadawa and Watari respectively, with individual plot yields ranging from 3.7 – 6.5 and 6.2 – 9.9 at the two sites. It must be noted that Watari is a recently developed small scheme, and the currently high yield levels may be indicative of crop response to inherent soil fertility at this site. Medium-scale farmers at Kadawa reported an average yield of 3.8 tons per hectare (with individual plot yields in the range of 1.9 to 6.1 tons per hectare) while large farmers at the same site reported average yields of only 2 tons per hectare (with plot yields varying from 0.5 to 3.0 tons per hectare). Observed yields are therefore much higher for smaller farmers at the Kano schemes (south Sudan Savannah zone). At the New Marte site of the South Chad project (Sahel Zone), small-scale farmers reported an average yield of 4.68 tons per hectare, varying from 1.9 to 7.5 tons among different farmers. Ngala farmers at the same scheme reported a mean yield of 5 tons per hectare, ranging from 4.8 to 5.2 tons. Small and medium scale farmers at the Bakalori sites of the Sokoto Rima scheme reported mean yields of 5.25 and 4.73 tons per hectare respectively, with individual plot yields ranging from 3.8 – 6.8 and 4.5 to 5.0 tons per hectare respectively. Reported average yields are much lower in the wetter Guinea Savannah and Equatorial zones. Average yields of small farmers at Badeggi (Guinea Savannah) and Bende (Equatorial Forest) were 2.78 and 1.75 tons per hectare respectively. Individual plot yields at the two sites ranged from 2.8 to 5.6 tons per hectare at Badeggi and 1.6 to 6.3 tons at Bende.

Analysis of discussions on observed farm yields demonstrate that: irrigated rice yields in the drier Sudan Savannah and Sahel zones are much higher than yields obtained in the wetter Guinea Savannah and Equatorial Forest zones. Yields of small-scale farmers in the Sudan savannah and Sahel zones are much higher than those obtained by medium and large scale farmers. The results also show extremely high yield gaps between farmers in all categories, suggesting high yield variability among producers. Although farmers in the Sudan savannah and Sahel zones in Nigeria generally outperform their counterparts in other zones, they continue to lag behind irrigated farmers in similar regions in other west African countries such as Senegal and Mali.

Table 3: Yields of Sample farmers in the different schemes

	Crop yield (tons per hectare)									
	Kadawa *Small*	**Kadawa** *Medium*	**Kadawa** *Large*	**Watari** *Small*	**N. Marte** *Small*	**Ngala** *Small*	**Bakolori** *Intake E* (Small)	**Bakolori** *Intake F* (Small)	**Badeggi** *Small*	**Bende** *Small*
Highest	6.48	6.11	3.00	9.88	7.50	5.19	6.75	4.95	5.56	6.25
Lowest	3.71	1.85	0.50	6.18	1.85	4.82	3.00	4.50	2.78	1.25
Average	4.63	3.98	2.00	8.03	4.68	5.00	4.25	4.73	2.78	1.75

5.2 Production Costs

Input use, cost, yield and output price data generated from the field discussions were used to undertake benefit cost analyses aimed at assessing the profitability of the different schemes and farm groups. Analyses were undertaken for small, medium and large-scale farmers to determine performance of different irrigated rice typologies in the study sites. In deriving production costs (table 4), we assume that small-scale farmers rely primarily on family labor for most field activities, using hired labor to meet shortfalls in the availability of family labor. We allocate seventy percent of the total labor supply of small farms to unpaid family sources, and 30 percent to hired sources. We also assume that hired labor is the major source of labor supply for large and medium scale farmers. Where family labor is used, opportunity costs for labor are derived based on field discussions with farmers. We caution that the analysis in this section is based on qualitative discussions, and the results reflect indicative values from relatively small numbers of respondents in each site.

Analyses of production costs showed important differences between farmers of different farm size categories in the southern Sudan Savannah zone in Kano. Production costs incurred by small farmers at the Kadawa and Watari schemes were significantly lower than those of medium and large farmers. The highest production costs were recorded for medium and large-scale farmers respectively. In addition to the use of herbicides, medium scale farmers at the Kadawa scheme reported high expenditures on hired labor for manual weeding, significantly driving up the cost of weed control. There are also differences in fertilizer expenditures, with large and medium scale farmers spending more than their counterparts in the small-scale category. The higher expenditures on these inputs translate into relatively high production costs for these producers. Small-scale producers at the Kadawa scheme rent land from larger farmers at extremely high rates. The willingness of these farmers to pay more than five times the official rate for land may be indicative of their perceptions of high productivity of irrigated rice-land in the area. Although most small farmers at the Watari scheme own irrigated rice-land, they indicated a high opportunity cost of land that they cultivate. The major expenditure items for small farmers at the Kadawa scheme are: land, fertilizer, harvesting and weeding costs. Medium and large-scale farmers identified weeding, fertilizers and harvesting as their major expenditure items. Among the predominantly small scale farmers at the Watari scheme, weeding, fertilizer, harvesting costs were the most important expenditure items for irrigated rice cultivation.

At the south Chad project in the Sahel agro-ecological zone, irrigation costs are extremely high at both New Marte and Ngala. The scheme relies on pump irrigation for water supply, and the high operation and maintenance costs associated with this system has significant implications for production costs. Harvesting charges are also high, and this is mainly attributed to the use of combine harvesters by the irrigation authority. Other important expenditure items at the south Chad scheme are fertilizer and land preparation.

At the Bakalori scheme of the Sokoto Rima project in the northern Sudan Savannah, production costs incurred by small-scale farmers are higher than those of medium scale farmers. The cost difference here is attributed mainly to high land rental fees incurred by small-scale farmers. The important budget items for small farmers at this site are land, harvesting, weeding and fertilizer costs. For medium scale farmers at this scheme, weeding, fertilizer and harvesting costs are the most important.

Fertilizer, harvesting, crop establishment and weeding costs were identified as major budget items at the Badeggi scheme in the Guinea Savannah zone. Land preparation, fertilizer, weeding and crop establishment were identified as major cost items at the Bende Scheme in the equatorial forest agro-ecological zone. These schemes represent intensive inland cultivation systems with no direct irrigation costs.

Analysis of production costs by agro-ecological zone shows much higher values for schemes in the Sudan savannah and Sahel zones than those in the equatorial forest and Guinea Savannah zones. These differences can be partly attributed to higher expenditures on external inputs like fertilizers and herbicides in the drier northern zones, and the high cost of irrigation in the Sahel zone. Greater levels of water control characterize schemes in the north, and this may partly explain the willingness to invest more in external inputs. The general argument is that with less control over irrigation water as is evident in the intensive lowland systems in the equatorial forest zones, producers will reduce investments in external inputs. Also, the lower yield potential in the forest zones (generally associated with lower solar radiation) may explain the lower levels of input use in these areas. An interesting observation here is that farmers do invest in external inputs in systems of partial water control, and could benefit from technologies that emphasize intermediate input levels with good crop management practices.

Fertilizers, weed control and harvesting operations account for the bulk of the factor cost shares for most irrigated rice farmers in the sample. Improving the efficiency and cost effectiveness of these factors will have important implications for increasing productivity and profitability.

Table 4: Production costs and cost shares of key production factors

	Production costs (Naira/ha) and share of total production cost (%)									
	Kadawa *Small*	**Kadawa** *Medium*	**Kadawa** *Large*	**Watari** *Small*	**N. Marte** *Small*	**Ngala** *Small*	**Bakolori** *Intake E* (Small)	**Bakolori** *Intake F* (Small)	**Badeggi** *Small*	**Bende** *Small*
Land Preparation	6000 (10)	8892 (10)	8892 (16)	6000 (10)	8892 (11)	8892 (11)	4400 (6)	6500 (12)	7000 (12)	7163 (20)
Crop Establishment	6100 (10)	6100 (7)	4895 (9)	6100 (11)	4343 (5)	3974 (5)	6000 (8)	5929 (11)	7700 (14)	7475 (21)
Fertilizers	8504 (14)	12827 (15)	14432 (25)	12580 (22)	12256 (15)	12750 (15)	7206 (10)	12400 (22)	11862 (21)	6950 (20)
Weeding	13638 (22)	41973 (50)	12950 (23)	16746 (29)	9586 (12)	4949 (6)	10128 (14)	13014 (23)	13875 (25)	5928 (17)
Water Charges	1482 (2)	1482 (2)	1482 (3)	494 (1)	32500 (40)	34109 (40)	2000 (3)	2006 (4)	62 (0)	0 (0)
Harvesting	12969 (21)	12537 (15)	11214 (20)	15234 (26)	12999 (16)	18041 (22)	16104 (22)	12303 (22)	14204 (25)	7342 (21)
Land rental fees	12350 (20)	1976 (2)	1729 (3)	0 (0)	0 (0)	0 (0)	23000 (32)	0 (0)	0 (0)	2400 (7)
Transportation	625 (1)	921 (1)	1406 (2)	921 (2)	463 (1)	360 (0)	3000 (4)	3585 (6)	1313 (2)	181 (2)
Total cost	**61668**	**84731**	**56858**	**58075**	**81039**	**83066**	**71838**	**55732**	**56085**	**35040**

5.3 *Assessment of Benefits*

Calculated net benefits for the different schemes and farm categories are presented in table 5. It must be noted here that the values for the calculations were derived from discussions with farmers and extension staff. Calculated net profits per hectare are positive for all farm categories in sample. However, the net benefits obtained by small-scale farmers are much higher than those of medium and large-scale producers. The higher profitability of small farms is partly explained by lower production costs and higher yields. Value-cost ratios are generally higher for producers in the small farm category. Lowest net benefits are recorded for the Badeggi and Bende schemes respectively. Value-cost ratios for the two schemes are lower than those of small farms at the other sites.

The results show positive net benefits for farmers in all schemes covered in the study. In general however, net benefits and associated value-cost ratios are higher for small-scale farmers than medium and large-scale producers. This suggests that smaller farmers are more cost effective and efficient. Net benefits are also higher in the Sudan savannah and Sahel zones than in the wetter guinea savannah and forest zones, suggesting higher returns to irrigation agriculture in drier areas.

Table 5: Benefit-cost analyses based on data from field discussions

	Revenue and cost (Naira per hectare)									
	Kadawa *Small*	**Kadawa** *Medium*	**Kadawa** *Large*	**Watari** *Small*	**N. Marte** *Small*	**Ngala** *Small*	**Bakolori** *Intake E* (Small)	**Bakolori** *Intake F* (Small)	**Badeggi** *Small*	**Bende** *Small*
Total Revenue	154365	132765	66666	180619	137178	143375	153998	138598	75958	49000
Total costs	61668	84731	56828	58075	81039	83066	71838	55732	56085	35040
Net Revenue	92697	48034	9838	122544	56139	60309	82160	82867	19873	13960
Value-cost ratio	2.5	1.6	1.2	3.1	1.7	1.7	2.1	2.5	1.4	1.4

6 Assessment of Constraints and Opportunities for Improving Productivity

Perceptions of important opportunities and constraints of actors in the irrigated rice production sector were evaluated through informal field discussions, semi structured interviews and secondary reviews. The discussions highlight the important constraints that must be addressed in order to improve the productivity of irrigated rice systems in the different agro-ecological zones of the country. The constraints, covering a wide array of issues, include agro-economic, biophysical and agro-ecological factors.

6.1 Input Costs and Access to Farm Credit

High cost of inputs and lack of credit were identified as primary constraints across all farm categories and agro-ecological zones. Large, medium and small farmers in all sites indicated that fertilizers and herbicides were too expensive, and that formal credit for the purchase of inputs was largely unavailable. Most farmers have responded to this situation by using less than what they consider optimal input application rates, or obtaining credit at high interest rates in the informal credit market. Irrigated rice production is associated with investments in external inputs like fertilizers and herbicides. However, it must be noted that a significant proportion of farmers engaged in irrigated rice production are considered resource poor and have limited access to credit for input purchases. Prior to the introduction of structural adjustments in several countries in sub-Saharan Africa, credit and input subsidies were major components of farm support programs for these farmers. These programs enabled farmers to obtain fertilizers and other external inputs at relatively low costs. The phasing out of farm subsidies and limited access to credit that accompanied structural adjustments resulted in sharp increases in input prices, making it difficult for small-scale farmers to continue maintaining investments in fertilizers and other external inputs. This problem was compounded by the fact that output price increases from adjustment policies were generally lower than expected. Farmers reacted to this situation by reducing external input use and shifting to production practices and systems that depend less on expensive external input use levels.

It is important to reiterate that irrigated rice production is relatively input intensive and requires initial cash outlays for the purchase of inputs. Because a large proportion of the actors in the production sector are resource poor and often cannot afford to make required investments for optimal yields, the issue of access to credit is extremely relevant to the debate on the primary constraints to irrigated rice production in the country. A functional and decentralized credit mechanism would enable producers to make the required investments to improve productivity at the plot and scheme levels.

6.2 Farmer's management practices

Addressing the problem of high input costs can be viewed from two perspectives. One option is for the reinstatement of input subsidies as a way of reducing costs incurred by producers. This is however highly unlikely given the costs involved and trends in international trade policies. A second, and perhaps more realistic option, is to focus efforts on improving productivity as a means of decreasing the per unit cost of inputs. The experience of WARDA in the Sahel shows a significant scope for improving input use efficiency in order to increase the productivity of irrigated rice systems in West Africa. Gaps between potential yield and average yields achieved by farmers are partly due to the limited use of inputs (e.g. fertilizers, agro-chemicals), but a considerable part of the gap is caused by sub-optimal management practices. General examples are (i) the use of old seedlings for transplanting regularly observed in the schemes (Kadawa, Badeggi, Bende), (ii) the use of NPK compound fertilizers at all survey sites although K is rarely a limiting element for irrigated rice at the yield ranges observed, and (iii) application of NPK fertilizers at booting (Badeggi) although P is generally needed during early plant development. Such sub-optimal crop management practices exist at both the scheme and individual field plot levels, resulting in the considerable yield variability reported at all sites. In order to improve (and homogenize) farmers management skills, WARDA developed "Integrated Crop Management (ICM) options" which address the whole rice production process from soil preparation to post-harvest issues. Results obtained from countries such as Senegal and Mauritania (Haefele et al., 2000; Kebbeh et al., 2001) show that the use of improved input management strategies could significantly increase irrigated rice yields and revenues. This is more appealing because the focus is on better management of resources, requiring little or no investments in additional inputs. It may be useful to determine the extent to which irrigated rice farmers in Nigeria can increase productivity from improved management. Given the high variability in yields between farmers and scheme types, it would be realistic to assume that irrigated rice producers in Nigeria would benefit significantly from improved crop and resource management strategies.

6.3 Access to Improved Varieties and Good Planting Material

Access to improved varieties and good quality seed was cited as a principal constraint during the surveys. In the drier Northern Sudan Savannah, Sahel and Southern Sudan Savannah zones in the North (Sokoto, Chad Basin and Kano irrigation schemes respectively), the emphasis was on short duration and high yielding varieties. Farmers and extension personnel in these zones indicated a preference for varieties that perform well in these agro-ecologies. Moving to the wetter Guinea Savannah and Equatorial Forest zones (Badeggi and Bende irrigation schemes), the need for high yielding varieties that are tolerant to pests and diseases that are prevalent under these conditions becomes important.

Availability of good quality seed was also identified as an important constraint. All farmers in the study indicated using seed from their previous harvests or purchasing seed from local markets. This is consistent with report by Fagade (2001) showing the rate of utilization of certified to be 5-15%, 10-20%, and 30% among producers at Badeggi, Bende and Kano respectively. Results obtained by WARDA scientists in the Sahel suggest that use of poor quality seed contributes to low yields in irrigated rice production.

Opportunities exist for addressing these problems using the experience of WARDA in the Sahel. High yielding short duration varieties adapted to Sahelian conditions are already extensively used in Senegal, Mauritania, and to a lesser extent in Mali and Burkina Faso. Efforts to adapt these varieties to similar conditions in Northern Nigeria would go a long was in addressing the problems of access to improved varieties. Also, inter-specific varieties developed for irrigated rice systems of West Africa could be evaluated for adaptation to varying levels of water control in intensive lowland and irrigated rice systems in the different agro-ecological zones.

6.4 Small Machinery for Harvest and Post-Harvest Operations

The unavailability of appropriate harvest and post harvest equipment is a major constraint across agro-ecological zones in the study areas. In the drier regions of the North, farmers either harvest manually or use combine harvesters that are generally unreliable and unavailable when needed. Manual harvesting is labor intensive, expensive and associated with crop losses due to late harvesting that result from chronic labor shortages. Where there is access to combine harvesters, as is the case in the South Chad Irrigation Project, the machines are generally insufficient, not available on time and unsuitable for use in heavy soils that may be wet during harvest period. There is also the added problem of frequent breakdowns and the unavailability of spare parts for the maintenance of machines. In the wetter Guinea Savannah and equatorial forest zones, producers overwhelmingly rely on manual labor for crop harvest, and labor shortages and extensive crop losses are common.

Cost-effective and efficient small machinery for harvest and post harvest operations could have significant impact on irrigated rice production in the country. In addition to mitigating labor shortage, minimizing crop loss and improving grain quality, efforts in this area would significant reduce expenditure on imported spare parts for repairs. Small threshing equipment developed by WARDA and Senegalese partners have been successfully adapted to local conditions in Mali, Burkina Faso, and Mauritania. Similar work has been completed in Ghana and Ivory Coast. The establishment of partnership between WARDA and Nigerian partners could build on the experiences from the other countries.

6.5 Pests and Diseases

Insect and bird damage were identified as the pest problems in the Kano, South Chad and Sokoto regions. Stem borers, locust/grasshoppers and birds were specifically mentioned in different sites in the Southern Sudan Savannah, Sahel and Northern Sudan Savannah zones. In the Guinea Savannah and Equatorial forest regions of Badeggi and Bende however, diseases and insects were identified as the key problems. The important diseases in these areas are the African rice gall midge and the rice yellow mottle virus. Stem borers were identified as the primary insect problem in Bende. With the exception of extensive bird scaring efforts in the northern regions, no clear control measures were suggested or observed for the problems in the different sites. Fagade (2001) attribute potential crop losses of 10 to 100 % to pest and disease problems.

6.6 Soil Degradation

Iron toxicity was the major soil related problem reported in the Guinea Savannah and Equatorial forest zones of Badeggi and Bende. The production systems in these zones can be categorized as intensive lowlands or partially irrigated systems. In the much drier zones of the north, farmers did not directly identify specific soil degradation problems. There was however mention of stunted crop growth associated with phosphorus and zinc deficiency in some areas. Localized zinc deficiency was observed in schemes in Kano and South Chad.

6.7 Marketing

Access to markets did not emerge as a major constraint in any of the study sites. In all areas, farmers indicated they could readily sell paddy or milled rice after harvest. Discussions with other stakeholders in the sector supported the responses of farmers on this issue. The readily available market for locally produced rice offers significant opportunities for the rice production sector in the country. There are indeed opportunities for rice to become a major cash crop in the country, and this possibility gives additional incentives for investment in the sector. However, most farmers reported receiving relatively low prices resulting from excess supply immediately after harvest.

6.8 Research and Extension Support

Producers in all study sites rely heavily on basin development authorities and state or federal officers for research and extension support. Access to information on improved technologies and crop management strategies is critical to improving productivity in the irrigated rice sector. These services are woefully inadequate in almost all sites visited. There is no effective research support in the Sudan Savannah and Sahel zones, which are the major irrigated rice producing regions in the country. Research-extension-farmer linkages are extremely weak in all sites covered in this study. In the much larger schemes at Kano and South Chad for example, extension staff are more involved in scheme management than providing needed services to producers. Also, most extension personnel are poorly trained and lack necessary training materials.

7 Summary, conclusion and recommendations

7.1 Summary and conclusion

The sector is characterized by a wide array of irrigated rice-based production systems in different parts of the country, from systems with complete water control found in the Sahel and Sudan Savannah zones in Northern Nigeria to systems with partial water control found in some parts of the savannah and equatorial zones in the Middle Belt and Southeastern parts of the country. Irrigation schemes in the north of the country are generally much larger than those in other regions. In addition to problems with maintenance and operation of schemes, there is widespread underutilization of irrigation infrastructure at all schemes visited in the north. This observation has important implications for increasing irrigated rice productivity and production in the country. Significant production gains can be achieved by better utilization of existing infrastructure. Irrigation development policy should focus on improving the performance and efficiency of existing irrigation infrastructure, rather than investment in new schemes.

There is wide diversity of land and resource endowment, ranging from small farmers with access to less than one hectare of irrigated rice land to large-scale producers cultivating more than one hundred hectares. There is a strong relationship between extent of water control and levels of investment in external inputs like fertilizers and herbicides. In general, the input rates or dosages are much higher in systems with greater water control. Although farm level decision-making continues to be dominated by men, female farmers continue to play important roles in the irrigated rice sector. Women are actively involved in various production and post harvest operations.

In general, yields are much higher in the Sahel and Sudan savanna zones than in irrigated rice systems in the other agro-ecological zones in the country. In most sites however, there have been significant declines in irrigated rice yields over the last decade. Actual yields are also much lower than potential yields. Yields obtained by farmers in Northern Nigeria are much lower than those obtained by farmers in similar environments in the Sahel. Yields and profits obtained by small-scale farmers in the study sample are generally higher than those obtained by medium scale and large scale farmers. Similarly, benefit:cost ratios are higher among small-scale producers.

Research and extension support for irrigated rice-based systems in the Sahel and Sudan savannah zones are highly inadequate. The scope of adaptive on-farm research and development is very limited. Farmers make little, if any, contribution to the debate on the major constraints and priority research and extension themes. Current mechanisms of extension support for irrigated rice production are rigid and emphasize a top-to-bottom extension process. In general, extension staff is not adequately trained and lack access to relevant training materials and other resources
Major constraints identified in the study sites are:

- High input costs and limited access to farm credit.
- Use of inappropriate crop and resource management practices, due to general lack of knowledge of improved technologies.
- Limited access to improved varieties (duration and yield), and persistent use of poor quality seed.
- Lack of appropriate small farm machinery for harvest and post-harvest operations.
- Inadequate Research and Extension Support, especially in the Sahel and Sudan Savannah zones.
- Localized problems of soil degradation.

7.2 Recommendations for research and development interventions

- Development and adaptation of small farm machinery for harvest and post harvest operations (Thresher-cleaner, reaper-harvester).
- On-farm evaluation and adaptation of improved irrigated rice varieties.
- Site specific adaptation of improved integrated crop management technologies.
- Limited number of key sites (one or two) for participatory on-farm research and development (R&D) activities.

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