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Innovation Opportunities in the Rice Value Chain in Nigeria

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Summary

As a cereal grain, Rice is the most widely consumed staple food for a large part of the world's human population. To the average Nigerian, rice needs no introduction because it has become one of the most important foods in the country, consumed by both the wealthy and the poor. Massive importation of the commodity from countries like India, China, and Thailand therefore, occur largely because of the estimated amount of rice milled locally is placed at 1.8 million tons.

Most rice farmers in Nigeria are smallholders (90 percent of total), applying a low-input strategy to agriculture, with minimum input requirements and low output. Nigeria rice productivity is among the lowest within neighbouring countries, with average yields of 1.51 tonne/ha. Nigeria is the largest rice producing country in West Africa but is also the second largest importer of rice in the World. Rice is cultivated on about 3.7 million hectares of land in Nigeria, representing approximately 10.6 percent of the 35 million hectares of land under cultivation, out of a total arable land area of 70 million hectares in Nigeria Out of the 3,7million hectares under rice cultivation, 77 percent of the farmed area is rain-fed rice, of which 47 percent is lowland and 30 percent upland. Rice is the third most important cereal grown and consumed globally after wheat and maize. In Nigeria, rice is cultivated in almost all ecological belts available in the country as they all provide favourable environments to support the crop.

Cultivated rice is generally considered a semiaquatic annual grass, although in the tropics it can survive as perennial, producing new tillers from nodes after harvest (ratooning). At maturity, the rice plant has a main stem and several tillers. Each productive tiller bears a terminal flowering head or panicle. Rice is cultivated in virtually all the agro-ecological zones in Nigeria, therefore successful cultivation of rice starts with choice of right rice variety suitable for the site. Because fields differ in their soil quality, the risk of flooding, or the risk of drought, a suitable variety must be selected for each field. Using suitable varieties minimizes the risk of crop loss or failure and ensures good yields. A suitable variety should give good yields, taste good, have a high market price, and many things more.

Paddy fields can be prepared under either dry or wetland conditions; the choice depends on time of operation, soil properties and implements to be used. In either case, the field should be disc ploughed immediately after harvest in November/December to expose the rhizomes of perennial weeds to scorching action of the sun. For direct seeded rice, the field is harrowed just before the first rain, and the crop is seeded. For wet or transplanted rice, the field is flooded with the first rains. In the absence of ploughs, make heaps at the onset of first rains for weed control. Farmers' yields range between 1,200 and 3,000kg ha^{-1} for swamp rice and 1,000 - 1,500kg ha^{-1} for upland rice. With improved practices yields of up to 5,000 - 6,000kg and 2,500 - 3,000kg ha^{-1} of paddy are possible for swamp and upland rice, respectively. Rice should be stored in cool, dry rodent-proof conditions. Infested paddy should be fumigated with phostoxin in air-tight containers at the rate of one tablet/jute bag (100 kg paddy) or 10–15 tablets/t paddy.

Rice is the primary source of carbohydrates and protein besides, rice also contains small quantities of fat, ash, fibre and moisture. Vitamins and mineral are present largely in bran and germ. Its by-products form important components of poultry and dairy feed. The byproducts which we get from paddy milling are rice bran and husk. Rice plants produce approximately 50% rough rice and another 50% straw on weight basis. The rough rice, on milling, produces brown rice, milled rice, germ, bran, broken and husk. Each of these components has unique properties and can be used in a number of ways. The utilization pattern of these components directly or as derivatives decides the extent of value addition in rice. Potential availability of rice husk in the country as a by-product of milling industry is about 24 million tons annually. As a renewable resource, its proper utilization would add enough value to the rice crop. The two major components like carbon and silica present in the rice husk make it possible to develop several value added products.

Since rice is abundant in carbohydrates, it acts as fuel for the body and aids in the normal functioning of the brain. Carbohydrates are essential to be metabolized by the body and turned into functional, usable energy. The vitamins, minerals, and various organic components increase the functioning and metabolic activity of all your organ systems, which further increases energy levels. Eating rice is extremely beneficial for your health, simply because it does not contain harmful fats, cholesterol or sodium. Rice is low in sodium, so it is considered one of the best foods for those suffering from high blood pressure and hypertension. Whole grain rice like brown rice is rich in insoluble fiber that can protect against many types of cancer. Many scientists and researchers believe that such insoluble fibers are vital for protecting the body against the development and metastasis of cancerous cells. Medical experts say that powdered rice can be applied topically to cure certain skin ailments. On the Indian subcontinent, rice water is readily prescribed by ayurvedic practitioners as an effective ointment to cool off inflamed skin surfaces. The phenolic compounds that are found in it, particularly in brown or wild rice, have anti-inflammatory properties, so they are also good for soothing irritation and redness.

Brown rice is said to contain high levels of nutrients that stimulate the growth and activity of neurotransmitters, subsequently helping to prevent Alzheimer’s disease to a considerable extent. The husk part of rice is considered to be an effective medicine to treat dysentery, and some people say that a three month old rice plant’s husks are said to have diuretic properties. Chinese people believe that rice considerably increases appetite, cures stomach ailments and reduces all digestive problems. Rice bran oil is known to have antioxidant properties that promote cardiovascular strength by reducing cholesterol levels in the body.

In the Nigerian context, some identifiable production constraints include but are not limited to;

- Bottlenecks in the land tenure system and policy which limits accessibility to and availability of land.
- Dearth of viable seed for rice farming.
- Resistance and reluctance to frontier technology and farming system.
- Weak fertilizer distribution system for timely resource availability.

- Lack of financial resources to acquire agro-chemical such as herbicides, pesticides etc by farmers.
- The relatively high and rising agrochemical prices in the economy

Innovation system is a network of organization, enterprise, and individuals focused on bringing new products, new processes and new forms of organizations into social and economic use, together with the institutions and policy that affect their behaviour and performance. Rice innovation system embraces the totality of the component actors, and their interaction and the policy environment. It tends to go beyond the creation of knowledge to encompass the factors affecting demand for and use of knowledge in useful ways. Innovative performance depends not only on how the individual actors perform in isolation, but also on how they interact with each other as element of a collective system of knowledge creation and use.

To reduce the dependence on imported rice as well as develop the local rice industry and enhance the adoption process of high yielding varieties and also increase the production level of rice, Nigeria adopted several development innovations, some of which include the African Rice Initiative (ARI) which was established in 2002 to promote the dissemination of high yielding varieties (NERICA) in SSA. The Federal Government of Nigeria launched the Presidential Initiative on Accelerated Rice Production in 2003. Government also banned milled rice imports and put a 50 percent duty on parboiled rice. In addition, a levy of ten percent was imposed on rice imports to create a dedicated fund for the development of the local rice industry, including processing and marketing. Notwithstanding the various policy measures, domestic rice production has not increased sufficiently to meet the increased demand. The existing rice production potential has not yet been realized, as smallholder (small-scale, subsistence and *Fadama* farmers) output is inadequate and paddy processing is substandard. To meet this shortfall, government recognizes the potential of irrigated agriculture, using improved technologies and wishes to promote further expansion of rice production.

Access to improved varieties, good quality seed and availability of good quality seed have been reported as the principal constraints in rice production. The rate of utilization of certified seed is 5-15 percent, 10-20 percent, and 30 percent among producers at Badeggi, Bende and Kano areas respectively. Use of poor quality seed contributes to low yields in irrigated rice production. In recent years, improved seed is being extended in both rain-fed upland areas (mainly NERICA) and rain-fed lowland areas (FARO varieties). Rice, like most other agricultural commodities, uses such inputs as land, fertilizer, seeds, labour and agro-chemicals. Labour comes from family and hiring. Efforts have been made to get fertilizers, improved seeds (varieties) and agro-chemicals to farmers through diverse sources. Most of the farmers in our study (61.2%) own their rice farmlands.

Improvement of agricultural productivity depends on the adoption of a package of improved technologies. In our study 85.8% of our sample of rice farmers indicates the use of one improved technology or another; nearly 70% of the farmers indicate improved rice varieties as the main technology adopted. The average area under all varieties of rice (traditional and improved) was 2.78 ha (n=202) while the average area under improved varieties was 2.09 ha (n=209), giving an adoption rate of 75.2%. The public sector still dominates the input distribution market, with government extension and research agencies jointly accounting for 77.3% of all input sources. The average utilization of inputs at smallholder level in rice production is 1.53ha for farm size, 40.6 man-days/ha for labour, 345 kg/ha for fertilizer, and 11.85 litres /ha for agro-chemicals.

Only 19.1% of the farmers in our sample indicate processing own rice produce. Thus, rice is largely sold in paddy form among the farmers. Nearly 94% of the farmers still market their rice as individuals rather than through groups. Group marketing is known to benefit smallholders in the form of cost sharing, risk sharing, and better access to credit and inputs. The top four channels of marketing rice among the farmers are on-farm to wholesalers (27.1%), sale at the local/village market (25.9%), sale to agro-processors (16.3%) and sale at urban markets within the state (15.1%). We noted that some farmers (12%) are able to sell directly to consumers, which ultimately should improve their marketing margin and efficiency.

A persistent problem in smallholder agricultural production is the inability of farmers to process own raw outputs. This has always led to sales at poor prices, and leaving most of the gains to those who buy, process and sell to others within the value chain. Farmers gain (loose) an average of N5, 795.96 on every 100 kg of rice grain processed (not processed). This is a significant value when viewed across millions of metric tonnes of harvested rice per season. Indeed, the difference between the farm-gate price of unprocessed rice (N11,091.18/100kg) and retail price of processed price (N22,748.35/100kg) is disturbingly high (N11,657.17/100kg), and underscore the enormity of value losses by farmers for not processing rice before selling. Labour cost accounted for most of the cost of producing rice (49%). Jointly, labour and fertilizer accounted for more than 70% of the total cost of producing rice. On the average, the gross margin per hectare for rice is N 1,054,554.22. The return per Naira spend is 8.56, underscoring great opportunities for a profitable smallholder rice production, even with seemingly inflationary situation with input prices.

Introduction

Rice is the seed of the grass species *Oryza sativa* (Asian rice) or *Oryza glaberrima* (African rice). As a cereal grain, it is the most widely consumed staple food for a large part of the world's human population. It is the agricultural commodity with the third-highest worldwide production (rice, 741.5 million tonnes in 2014), after sugarcane (1.9 billion tonnes) and maize (1.0 billion tonnes) (FAOSTAT, 2014). To the average Nigerian, it needs no introduction because it has become one of the most important foods in the country, consumed by both the wealthy and the poor. This position was attained largely on account of its steady demand by the Nigerian populace for both domestic and commercial consumption. Interestingly, Nigeria, which is the largest producer of rice in West Africa and the third in Africa after Egypt and Madagascar producing about 3 million metric tons on the average annually, falls short of meeting its local demand which is placed at about 5 million tons. This particular statistic makes Nigeria the highest consumer of rice in the West African sub region and the second largest importer in the world, buying at least 2 million tons annually. Massive importation of the commodity from countries like India, China, Thailand etc, therefore, occur largely on account of the fact that the estimated amount of rice milled locally is placed at 1.8 million tons. On the average, Nigeria spends 1 billion Naira on rice importation daily (a gruelling 365 billion Naira annually).

Agronomy of Rice

Cultivated rice is generally considered a semiaquatic annual grass, although in the tropics it can survive as perennial, producing new tillers from nodes after harvest (ratooning). At maturity, the rice plant has a main stem and several tillers. Each productive tiller bears a terminal flowering head or panicle. The small wind-pollinated flowers are produced in a branched arching to pendulous inflorescence 30–50 cm long. Plant height varies by variety and environmental conditions, ranging from approximately 0.4meter (m) to more than 5 m in some floating rice. The edible seed is a grain (caryopsis) 5–12 mm long and 2–3 mm thick. The morphology of rice is divided into the vegetative phase (including germination, seedling, and tillering stages) and the reproductive phase (including panicle initiation and heading stages)

Rice is cultivated in virtually all the agro-ecological zones in Nigeria, therefore successful cultivation of rice starts with choice of right rice variety suitable for the site. Because fields differ in their soil quality, the risk of flooding, or the risk of drought, a suitable variety must be selected for each field. Using suitable varieties minimizes the risk of crop loss or failure and ensures good yields. A suitable variety should give good yields, taste good, have a high market price, and many things more. General important criteria are:

- ✓ Plant height: In most fields, varieties of medium height (1-1.2 meter tall) are preferable. Tall varieties (about 1.4 meter tall) give low yields. Very short varieties (less than 1 meter tall) should only be used on favourable fields with low drought or flooding risk.

- ✓ Duration: Late varieties (more than 150 days) are preferable in lower flood-prone fields, early varieties (less than 120 days) are better suited for upper, drought-prone fields.

- ✓ Traditional varieties: usually tall, have few tillers, bold grains, lodge easily, and are low yielding. But they can be the better choice on very poor soils or in flood-prone fields.

- ✓ Improved varieties: usually of medium height, have many tillers, slender grains, respond to inorganic fertilizer, and can give high yields. They are preferable in most fields.

Improved rice varieties currently recommended for the six major agro-ecological zones are as given in Tables 1 and 2

Table 1: Recommended upland rice varieties for the different agro-ecological zones

Agro-Ecological Zone	**Recommended Upland Rice Variety**
Sahel	FARO 45, FARO 46 EX-China, FARO 55 (NERICA 1)
Sudan	FARO 45, FARO 46, EX-China, FARO 38, FARO 39 FARO 55 (NERICA 1)
Northern Guinea Savanna	FARO 46, FARO 39, FARO 38, FARO 11, FARO 45 FARO 55 (NERICA 1), FARO 56 (NERICA 2) FARO 58 (NERICA 7), FARO 59 (NERICA 8), FARO 62 (OFADA 1), FARO 63 (OFADA 2)
Southern Guinea Savanna	FARO 46, FARO 48, FARO 49, FARO 43, FARO 41 FARO 55 (NERICA 1), FARO 56 (NERICA 2) FARO 58 (NERICA 7), FARO 59 (NERICA 8), FARO 62 (OFADA 1), FARO 63 (OFADA 2)
Forest	FARO 46, FARO 48, FARO 49, FARO 43, FARO 41 FARO 55 (NERICA 1), FARO 56 (NERICA 2) FARO 58 (NERICA 7), FARO 59 (NERICA 8), FARO 62 (OFADA 1), FARO 63 (OFADA 2)

Table 2: Recommended lowland rice varieties for different agro-ecological zones

Agro-Ecological Zone	**Recommended Lowland Rice Variety**
Hydromorphic and inland valley swamp	FARO 44, FARO 52, FARO 31, FARO 15, FARO 28, FARO 51 FARO 62 (OFADA 1), FARO 63 (OFADA 2), FARO 60 (NERICA L19), FARO 61 (NERICA L34)
Shallow swamp and irrigated swamp	FARO 44, FARO 52, FARO 51, FARO 27, FARO 29, FARO 37, FARO 60 (NERICA L19), FARO 61 (NERICA L34)
Deep water and floating	FARO 15, CK 73, DA 29, BKN 6986 – 17, ROK 5, IR 54
Mangrove	FARO 15, ROK 5, WAR 77-3-2-2, FARO 28, IR 54

Choice of land
Choose fertile land with a moderately high-water holding-capacity. Heavy soils characteristic of river valleys and Fadamas are preferred. Lands with clayey soils are considered most desirable.

Land preparation
Paddy fields can be prepared under either dry or wetland conditions; the choice depends on time of operation, soil properties and implements to be used. In either case, the field should be disc ploughed immediately after harvest in November/December to expose the rhizomes of perennial weeds to scorching action of the sun. For direct seeded rice, the field is harrowed just before the first rain, and the crop is seeded. For wet or transplanted rice, the field is flooded with the first rains. In the absence of ploughs, make heaps at the onset of first rains for weed control. Construct bunds and cover the paddy field with water to prevent the loss of nitrogen through denitrification.

Time of planting
Rice is planted in May/June when the rains are firmly established. Planting should be early (by the end of June) in flood-prone, waterlogged, and gall midge-attached areas.

Seed rate
Direct sowing needs 55–65 kg/ha grain; raising seedlings to transplanting needs 45 kg/ha grain.

Planting

Direct seeding
This is possible in hydromorphic areas by broadcasting or dibbling. Divide the field into plots of 50m^2 or 100m^2, and construct small bunds. Weeds are the major problem, it is vital to apply herbicides to control them. For dibbling, the spacing should be 20–25 cm between rows and 15–20 cm between plants. Direct seeding can be done with pregerminated seeds in wet soils.

Nursery raising
Soak the seeds in water for 24 hours. Spread them on the floor and incubate them by covering them with polyethylene bags for 48 hours for the seeds to sprout. To provide seedlings for 1 ha of land, raise the nursery in 500 m2 (1/20 acre). Spread the sprouted seeds uniformly on a puddled nursery field. Drain excess water from the field for a week. Ensure that seed beds are raised in high rainfall areas. Avoid bird damage during germination by scaring birds. In gall midge affected areas, apply FuradanTM (Carbofuran) at 1 kg/ha in nursery beds a week before uprooting.

Transplanting
Transplant seedlings from nursery after 21 days. This is done by uprooting the seedlings. Transplant 2–3 seedlings per hill. Spacing should be 20 cm between rows and 15–20cm between plants. Transplant early maturing varieties 15 cm apart and transplant medium and late maturing varieties 20 cm apart.

Gap filling
Gap fill the areas where seeds have not germinated 7–10 days after transplanting. Use remaining seedlings.

Water management
Maintain the level of water in the field up to 5cm one week after transplanting until grain matures. Drain the water a week before harvesting. Cracks should not be seen in the field.

Nutrient Deficiency/Toxicity Symptoms of rice

(i) *Nitrogen Deficiency:* Characterized by stunting, and poor tillering. Leaves are narrow, short, erect and yellowish-green. Old leaves die when straw is coloured.

(ii) *Phosphorus Deficiency:* Plants are stunted with a limited number of tillers. Leaves are narrow, short, erect and dirty-dark green. Old leaves die when brown coloured. A reddish or purplish colour may develop on leaves if the rice variety has a tendency to produce anthocyanin pigment.

(iii) *Potassium Deficiency:* Stunted and weak plants. Leaves short, droopy and dark green. Sometimes; brown spots may develop on the dark green leaves.

(iv) *Magnesium deficiency:* With mild deficiency, no clear-cut symptoms more severe deficiencies usually cause wavy and droopy leaves. Interveinal chlorosis occurs on lower, leaves, sometimes, characterized by orange yellow colour.

(v) Sulphur Deficiency: Yellowish colouration of young leaves.

(vi) *Zinc Deficiency:* The more common symptoms are the appearance of brown blotches streaks on the lower leaves, followed by stunted growth. In the field, uneven growth and delayed maturity are characteristics of Zn deficiency.

(vii) *Iron Deficiency:* Uppermost leaves of the plant become chlorotic with some green colour retained around the veins. The young leaves take on a bleached appearance. Older leaves retain their green colouration at first, but as the deficiency progresses, they become chlorotic with marked interveinal chlorosis. Iron deficiency in rice occurs in irregular patches in the field; green and chlorotic stands have often been seen to grow side by side. Iron deficiency is often associated with soils high in pH (e.g saline -sodic, sodic soils and vertisols).

(viii) *Iron toxicity:* At first, yellowing and tiny brown spots appear on the lower leaves starting from the tips and spreading towards the base. Subsequently, younger leaves become affected and many older leaves completely die. In susceptible cultivars, the leaf colour may be orange, yellowish - brown, reddish - brown, brown or purplish brown, depending on the variety and severity of iron toxicity. Roots of affected plants are generally coarse, sparse dark brown and damaged. Iron toxicity occurs in strongly acid Ultisols and Oxisols, deltaic and estuarine acid sulphate soils and in histosols, and often associated with other stresses such as salinity, phosphorus and zinc deficiencies and low base status.

Fertilizer Sources and Rates

Fertilizer recommendations and/ or suggestions for rice maybe summarized as in Table 3.

Fertilizer Application -Time and Method:

(i) For lowland rice (shallow swamp, irrigated, hydromophic and inland valley swamp) apply half the N and all P and K at planting/transplanting and the remainder broadcast at 6 - 7 weeks after planting/transplanting or at panicle initiation stage.

(ii) For lowland rice (deep water and floating and mangroove ecologies), apply all N, P and K at planting.

(iii) For upland rice in Sahel, Sudan and Northern Guinea, apply half N and all P and K at 1 - 2 weeks after planting, broadcast the remainder of N at 6 weeks after planting.

(iv) For upland rice in Southern Guinea and Forest zones, apply all N, P and K. 1 - 2 weeks after planting and first weeding.

Table 3: Fertilizer recommendations for upland and lowland rice

Nutrient	Fertility class	Upland rice	Lowland rice
N	Low	80kg N	100kg N
	Medium	60kg N	80kg N
	High	40kg N	40kg N
P	Low	30 - 40kg P_20_5	40 - 50kg P_20_5 “b”
	Medium	30kg P_20_5	40kg P_20_5
	High	NIL	NIL
K	Low	30 - 40kg K_20	30 - 40kg K_20
	Medium	30kg K_20	30kg K_20
	High	NIL	NIL

For both upland and lowland rice, additional application of Boost Xtra at the rate of 1l/ha for 4 times foliar starting from 4 weeks of planting/transplanting using a spray volume of 200l/ha water will enhance rice growth

Weed control

Hand weeding: Hand-weed twice at 21 and 40 days after transplanting. Collect all weeds from bunds, and decompose or bury them in one corner of the field to prevent insect attack.

Chemical control; Any of the under-listed herbicides recommendations will control weed in upland and lowland rice:

(i) Propamil + oxadiazon at 3.0kg a.i. ha^{-1} (5 liters Ronstar 400 EC/ha) or
(ii) Glyphosate e.g Roundup (4 - 6 litres ha), 2 weeks before planting followed by either
(iii) Propamil + bentazon at 3.0kg a.i. ha^{-1} or
(iv) Propamil + Fluorodifen at 3.0kg a.i. ha^{-1}or

(v) Propamil + thiobencarb at 3.0kg a.i. ha^{-1} 2 - 3 weeks after planting
(vi) Butachlor at 4l/ha pre-emergence
(vii) Oxadiazon at 4 – 5l/ha pre-emergence but must be applied at least a week before transplanting of rice
(viii) Propanil at 4l/ha Post-emergencePropanil + Triclopyr at 4l/ha Post-emergence

Bird control

Birds are a problem during grain filling. Control them manually by scaring them.

Harvesting Harvest long straw close to the ground 15–20 cm to permit hand threshing. Other operations are as for Upland rice.

Yield Expectancy

Farmers' yields range between 1,200 and 3,000kg ha^{-1} for swamp rice and 1,000 - 1,500kg ha^{-1} for upland rice. With improved practices yields of up to 5,000 - 6,000kg and 2,500 - 3,000kg ha^{-1} of paddy are possible for swamp and upland rice, respectively.

Drying

Dry paddy properly to a safe moisture content of 13–14%, by spreading it on a clean concrete floor, mat or tarpaulin. Sundry slowly for 2–3 DAYS to reduce breakage during milling. On a clear bright day, sun dry for one day only by spreading paddy thinly on clean concrete floor, mat, or tarpaulin. Use a mechanical drier, if possible.

Storage

Rice should be stored in cool, dry rodent-proof conditions. Infested paddy should be fumigated with phostoxin in air-tight containers at the rate of one tablet/jute bag (100 kg paddy) or 10–15 tablets/t paddy.

Production Trend

Most rice farmers in Nigeria are smallholders (90 percent of total), applying a low-input strategy to agriculture, with minimum input requirements and low output (USAID 2011, IFAD 2009). Nigeria rice productivity is among the lowest within neighbouring countries, with average yields of 1.51 tonne/ha. Nigeria is the largest rice producing country in West Africa, but is also the second largest importer of rice in the World.

Rice is cultivated on about 3.7 million hectares of land in Nigeria, representing approximately 10.6 percent of the 35 million hectares of land under cultivation, out of a total arable land area of 70 million hectares in Nigeria Out of the 3,7million hectares under rice cultivation, 77 percent of the farmed area is rain-fed rice, of which 47 percent is lowland and 30 percent upland (Table 4 and Figure 1).The area under rice cultivation increased from 1.8 million ha in 1995 to about 2.72 million ha in 2006 but dropped back to about 1.8 million ha in 2010. Paddy and milled rice production has been increasing steadily from 1961 although with slight decline in 1990, 1994, 2001 and 2007 and a positive peak in 2013 (Figure 2). Fertilizer usage (NPK) increased steadily over the years from merely less than a million tonne in 1961 to a peak of 14.82 Million tons in 1983, before a steady fall in the country fertilizer usage to 8.43 Million tons in 1987, thereafter there was a gradual increase upto 15.32 million ton in 1993. But

Nigeria witnessed another round of steady fall in fertilizer application to rice farms till 2011 when there seems to be a turning point for improved fertilizer usage. In response to the dwindling fertilizer application rice yields across ecosystems over the last 20 years were between 1.3 t/ha and 1.9 t/ha (Figure 2). Despite the recent relative increase in yields, yielding performance remains below potential. Compared to those of neighbouring countries in the region (Benin, Cameroon, Chad, Ghana and Niger), Nigerian rice yields are among the lowest, superseded by yields in Benin, Ghana and Niger (Figure 3)

As shown in Table 5, rice yields are between 46 percent and 56 percent below their potential for different production systems (Ezedinma 2005). Rain-fed agriculture is the main production systems used, while irrigated rice is the best performing in terms of yields (3.5 t/ha), followed by rain-fed lowland (2.2 t/ha) and mangrove swamp (2.0t/ha) (Table 5). Rice production in low land with wet soil zone is favoured within the country, given its resistance to drought. Figure 4 shows the ever-increasing trend in rice consumption in Nigeria despite the steady increase in production and importation of milled rice. This trend demonstrate A huge potential market for locally produced rice exists in urban centers if quality, standards, and grading are addressed. Increasing local rice production means that scarce foreign exchange used to import rice can be used to develop the local rice sector. Imports of rice in 2006 cost Nigeria $695 million, well above the 2001-05 average of US$113 million (GRiSP,2013)

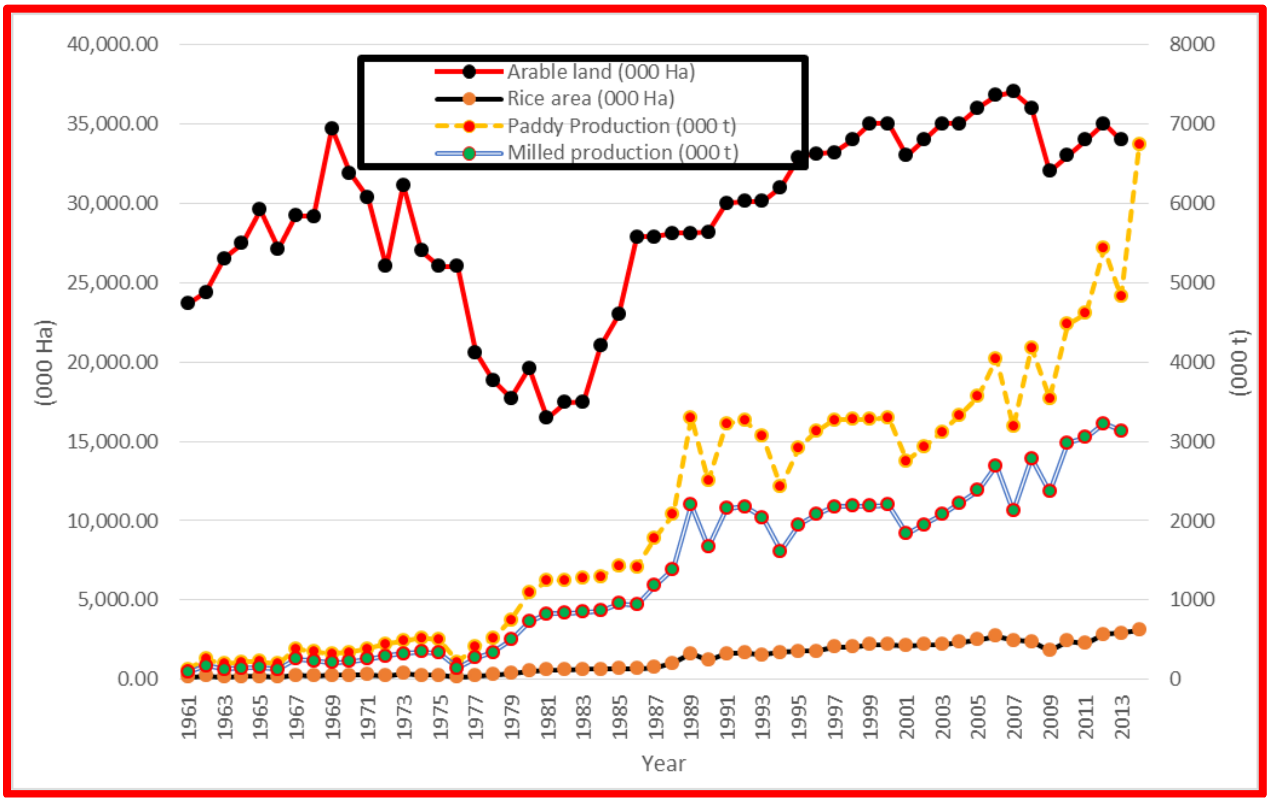


Figure 1: Arable land, rice cultivated area rice paddy and milled production trends in Nigeria

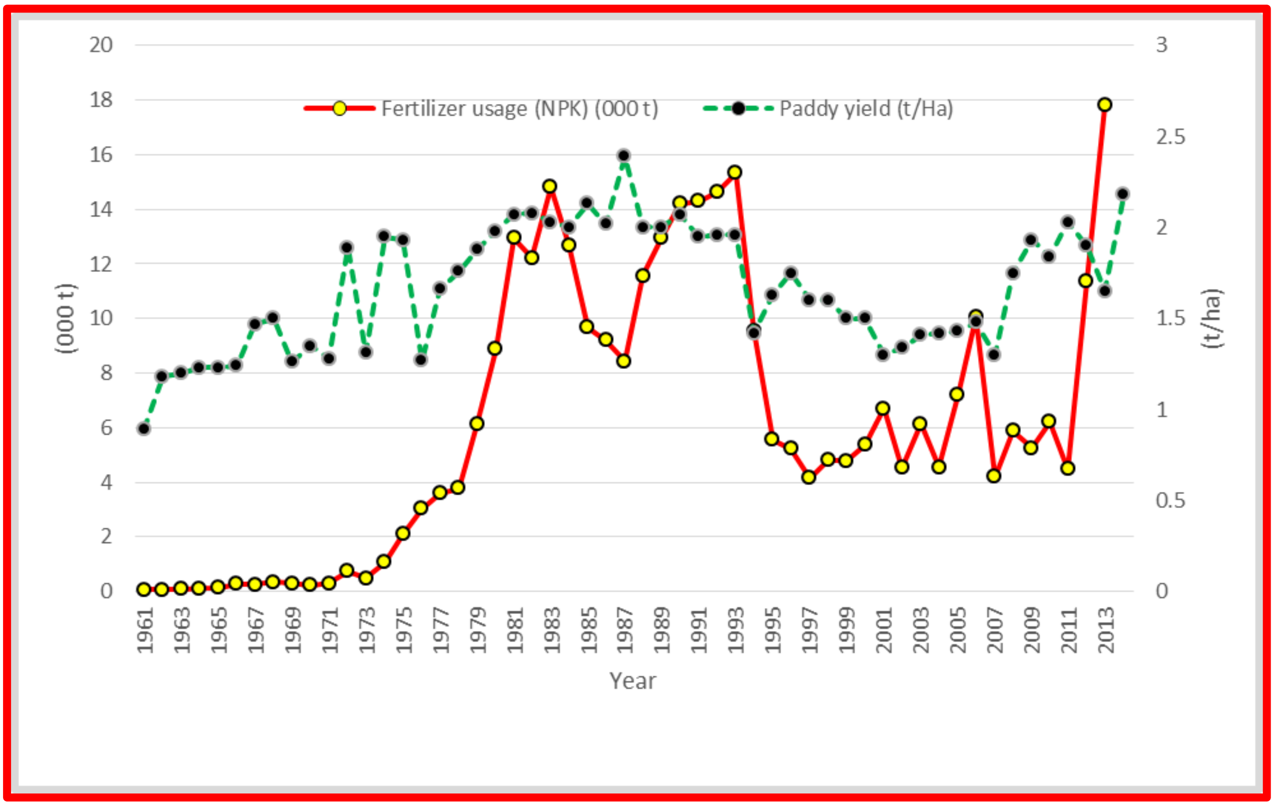


Figure 2: Trends in Fertilizer usage and paddy yields in Nigeria

Table 4: Selected Basic Statistics about Rice, Nigeria

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	30,371	30,000	35,000	37,000	37,500	37,000	3,4000	
Rice area (×10^3 ha)	1,796.0	2,199.0	2,494.0	2,725.0	2,451.0	2,382.0	1,788.2	1,788.2
Share of rice area irrigated (%)	16.00	16.00				2.70	2.70	
Share of rice area under								
Paddy yield (t/ha)	1.63	1.50	1.43	1.48	1.30	1.75	1.90	1.80
Paddy production (×10^3 t)	2,920.0	3,298.0	3,567.0	4,042.0	3,186.0	4,179.0	3,402.6	3,218.8
Milled production (×10^3 t)	1948	2200	2379	2696	2125	2787	2270	2146
Rice imports (×10^3 t)	300.0	785.7	1,187.8	975.9	1,217.0	971.8	1,164.3	1,885.3
Rice exports (×10^3 t)	0.0	0.0	4.4	2.5	0.3	0.0	0.0	0.1
Total rice consumption (×10^3 t)	2,249	2,993	3,182	3,371	3,601	3,323	3,545	
Fertilizer usage in NPK (kg/ha of arable land)	6.03	6.25	7.40	9.98	4.15	7.66	2.12	

Sources: FAO's FAOSTAT database online and AQUASTAT database online, as of September 2012.

Table 5: Rice production systems in Nigeria

Production ecology	Major States Covered	Estimated Share of National Rice-Farmed Area	Share of Total Domestic Production	Average Yield/ha in tonne	Potential Yield/ha in tonne
Rain-fed Upland	Ogun, Ondo, Abua, Osun, Ekiti, Oyo, Edo, Delta, Niger, Kwara, Kogi, Sokoto, Kebbi, Kaduna, FCT, Nasarawa and Benue	30%	17%	**1.7**	**3.5**
Rain-fed Lowland (aka "Fadama")	Adamawa, Ebonyi, Ondo, Ekiti, Edo, Delta, Rivers, Bayelsa, Cross River, Akwa Ibom, Lagos, all major river valleys	47%	53%	2.2	5
Irrigated	Adamawa, Niger, Sokoto, Kebbi, Borno, Benue, Kogi, Anambra, Enugu, Ebonyi, Cross River, Kano, Lagos, Kwara, Akwa, Ibom, Ogun	17%	27%	3.5	6-7
Deep Water Floating	Flooded areas: Rima Valley in Kebbi State and deep flooded areas of Delta State	5%	3%	1.3	2.5
Mangrove Swamp	Ondo, Delta, Edo, Rivers, Bayelsa, Cross River, Akwa Ibom	1%	1%	2	4

Source: Ezedinma 2008

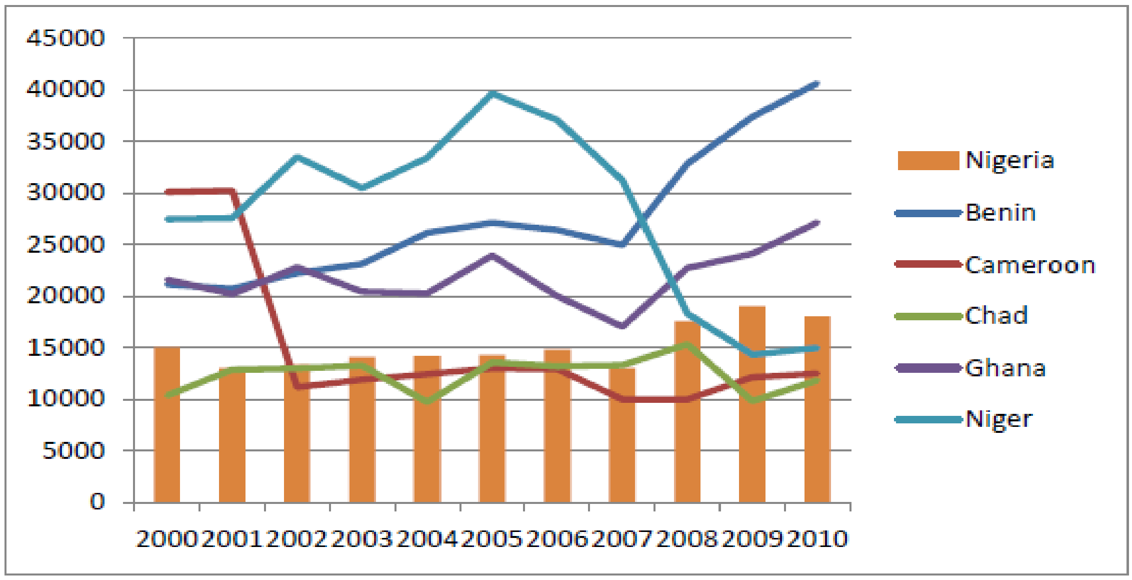


Figure 3: Rice Paddy Yields in selected West African Countries (Hg/Ha)

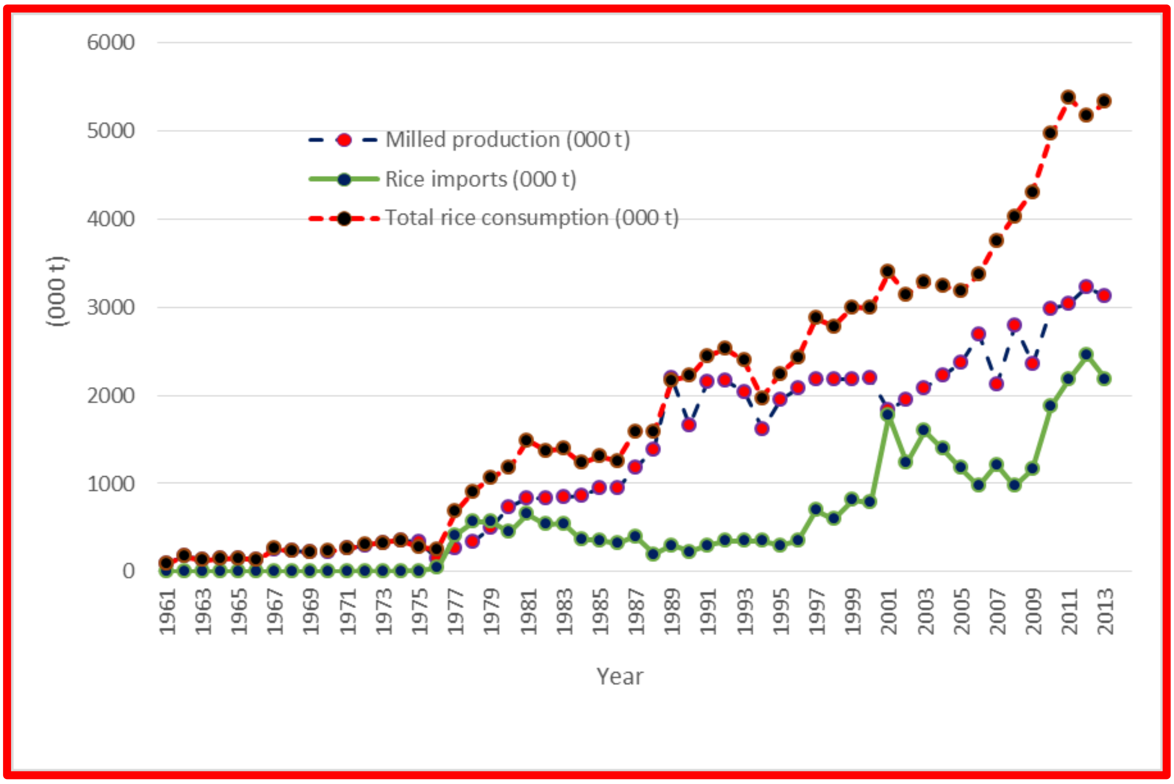


Fig 4: Import, Production and Consumption of milled rice, 1961-2013, Nigeria, '000mt

Rice Consumption/Utilization and Nutrition in Nigeria

Rice is the third most important cereal grown and consumed globally after wheat and maize. In Nigeria, rice is cultivated in almost all ecological belts available in the country as they all provide favourable environments to support the crop. This has made rice a staple crop in the nation as it is consumed by almost every individual in the nation in different forms. On average (2000-2007), rice is the 4th most important crop in terms of calories consumed, following sorghum, millet and cassava. Rice is both a food and a cash crop for farmers, contributing to smallholders revenues in the main producing areas. WARDA estimates that per capita rice consumption in Nigeria has nearly doubled between the 1980s and 2006, growing from 15.4 kg/year to 25.4 kg/year (WARDA 2008). Nutritional Content of rice compared to other staple foods

White, long-grain rice*:* Raw, long-grain white rice is a relatively good source of energy, carbohydrates, calcium, iron, thiamin, pantothenic acid, folate and vitamin E, compared to maize, wheat and potatoes. It contains no vitamin C, vitamin A, beta-carotene, or lutein+zeazanthin, and is notably low in fiber. Nutritional value per 100 g rice is presented in Table 6.

Colored rice: Brown rice retains the bran layer (containing many vitamins and minerals as well as fiber), as this has not been polished off to produce white rice. Red rices are known to be rich in iron and zinc, while black and purple rices are especially high in protein, fat and crude fiber. Red, black and purple rice get their color from anthoncyanin pigments, which are known to have free-radical-scavenging and antioxidant capacities, as well as other health benefits. Calorie Content

The calorie content of 1 cup of cooked rice varies from a high of 241.8 kcals for medium-or short-grain white rice, to 218.4 kcals for medium-grain brown rice, 216.5 kcals for long-grain brown rice, 205.4 kcals for regular long-grain white rice, to a low of 165.6 kcals for 'wild rice'.

Glycemic Index (GI)

Glycemic Index (GI) is a measure of the relative ability of carbohydrates in foods to raise blood sugar levels after eating. High GI food is easily digested and absorbed by the body, which can result in fluctuations in blood sugar levels. Foods with low GI, on the other hand, are those with slow rates of digestion and absorption, causing a gradual and sustained release of sugar into the blood, which is beneficial to health and reduces the chances of developing Type II diabetes. Slow digesting starches lower the body's insulin response, thus helping people with diabetes to normalize their blood sugar. Currently, 285 million people, mostly in developing countries, have Type II diabetes and another 344 million are at risk of developing it due to impaired glucose tolerance. If diabetes is undiagnosed, it leads to chronic conditions and death. Consumption of cereals is not necessarily a cause of Type ll diabetes, but cereals containing particular structures of starch offer a solution for prevention and management of the condition. GIs of 55 or less are considered 'low', those of 56–69 are 'medium' and those of 70 and above are 'high'. A study of 235 types of rice from around the world, by IRRI and CSIRO's Food Futures Flagship, found that the GI varies by type of rice, from a low of 48 to a high of 92 (average 64), with most scoring a low to medium GI. This means that rice and rice products can be part of a healthy diet for the average consumer and part of a low GI diet to help those with Type II diabetes better manage their condition. The research team also identified the key gene that determines the GI of rice. This will enable rice breeders to develop varieties with different GI levels to meet consumer demand for rice and rice-based food products.

Table 6: Nutritional value per 100 g rice

Nutritional value per 100 g	
Energy	130 kcal (540 kJ)
Carbohydrates	28.1 g
Sugars	0.05 g
Dietary fiber	0.4 g
Fat	0.28 g
Protein	2.69 g
Vitamins	
Thiamine (B1)	(2%) 0.02 mg
Riboflavin (B2)	(1%) 0.013 mg
Niacin (B3)	(3%) 0.4 mg
Pantothenic acid (B5)	(0%) 0 mg
Vitamin B6	(7%) 0.093 mg
Minerals	
Calcium	(1%) 10 mg
Iron	(2%) 0.2 mg

Magnesium	(3%) 12 mg
Manganese	(0%) 0 mg
Phosphorus	(6%) 43 mg
Potassium	(1%) 35 mg
Sodium	(0%) 1 mg
Zinc	(1%) 0.049 mg
Other constituents	
Water	68.44 g

Source: USDA Nutrient Database

Rice Products

Rice is the primary source of carbohydrates and protein besides, rice also contains small quantities of fat, ash, fibre and moisture. Vitamins and mineral are present largely in bran and germ. Its by-products form important components of poultry and dairy feed. The by-products which we get from paddy milling are rice bran and husk. The amount of rice bran is approximately five per cent of paddy processed. The rice bran is a pericarp or outer cuticle layer that remains beneath the hull. It gets removed during the milling process. About two decades back, rice bran was considered almost a waste and hence most of it was burnt. It is now viewed to have high nutritive value. Being rich in protein and natural Vitamin, rice bran is used as a cattle feed. The rice bran processing has now gained momentum, with increasing consumer demand for bran oil, extracted from bran.

Use of Rice and it's by products like rice husk, rice bran and paddy straw

Rice plants produces approximately 50% rough rice and another 50% straw on weight basis. The rough rice, on milling, produces brown rice, milled rice, germ, bran, broken and husk. Each of these components has unique properties and can be used in a number of ways. The utilization pattern of these components directly or as derivatives decides the extent of value addition in rice.

Utilization of Rice Straw:

- ✓ At farmers' levels, rice straw is mainly used for thatching, as cattle feed and the woody portion as fuel. Sometimes a portion of the straw is ploughed back in to the soil to be reused as bio-fertilizer.
- ✓ In craft industry, rice straw is used in making certain fancy products like bags, wall hanging etc.
- ✓ Rice straw along with others fibrous materials can be used to prepare pulp for making boards nd papers.
- ✓ Rice straw is cut in to pieces and then used for making beds for growing mushroom.

Utilization of Paddy:

- ✓ Paddy is mainly used for consumption as whole milled rice either in raw or parboiled condition.
- ✓ Beaten rice is a value-added products made from paddy

Utilization of brown rice:
When the outer most layer of paddy (husk) is removed, the resultant product is the brown rice. It is rich in vitamin B1, B2, B3, B6 and Iron as compared to polished white rice. Brown rice can be stored well in hermetic storage or freezing condition.

Utilization of polished white rice:
Polished white rice is mainly consumed as a staple food after cooking. A few value added product like quick cooking rice and rice cake can be produced from this white rice.

Utilization of parboiled rice:
Parboiled rice is also consumed as a staple food in many parts of world and Nigeria in particular .value of this product mainly depends on its quality interms of size (short & long), colour, texture, smell etc. The few value added products that can be made from parboiled rice are: quick cooking parboiled rice and puffed rice.

Utilization of rice broken:

- The broken rice which brings one third the value of whole rice grain in the market for direct consumption or sold as poultry feed. This low value material can be converted into several value added products like rice noodles, rice alcohol, rice flour, and rice ethanol.
- Rice flour is used in many foods including baby foods, chips and crackers. The unique properties of rice flour also make it a prime candidate for producing resistant starch, a food ingredient that acts like a fiber in the human body and thus provides thehealth benefits of fiber.
- Gluten free rice bread is a highly popular value-added product made from rice broken on old rice stocks in Japan.

Utilization of rice husk:
Potential availability of rice husk in the country as a by-product of milling industry is about 24 million tons annually. As a renewable resource, its proper utilization would add enough value to the rice crop. The two major components like carbon & silica present in the rice husk make it possible to develop several value added products.

(a) Direct use of husk:

Use of husk for production of thermal energy using various types of furnaces is quite common these days. Some other uses of husk are soil mulch, poultry litter, making particle board, insulation material, packing material etc.

(b) Products based on carbon compounds:

It is possible to convert the carbon compounds by a process similar to dry distillation of wood such as producer gas, furfural, activated charcoal, lignins, oxalic acid and bear like beverage.

Utilization of rice bran:

- Rice bran is the most valuable by-product of rice milling industry. It contains 18-20% of fat, 14-15 % protein and to some extent of minerals and vitamins. Usually solvent extraction method is employed to extract oil from rice bran. Maximum cash benefit is therefore possible through judicious use of rice bran in a variety of ways.

- The crude rice bran oil can be used for manufacturing of soap, enamel paints, varnishes, detergent, metal soap and squalene (for skin disease) can be extracted from crude bran oil.
- The edible grade rice bran oil can be prepared by refining the crude oil in order to make the refining process economical, the oil may either be extracted or the bran should be stabilized immediately after its removal from brown rice. The free fatty acid of rice bran otherwise increases very rapidly owing to the presence of lipase making the oil uneconomical for refining. Stabilization can be done either by acid treatment or dry/wet heat treatment.
- De-oiled bran is most commonly used as animal feed or as fertilizer.

Health Benefits of Rice

Some of the health benefits of rice are explained below

Great Source of Energy: Since rice is abundant in carbohydrates, it acts as fuel for the body and aids in the normal functioning of the brain. Carbohydrates are essential to be metabolized by the body and turned into functional, usable energy. The vitamins, minerals, and various organic components increase the functioning and metabolic activity of all your organ systems, which further increases energy levels.

Cholesterol Free: Eating rice is extremely beneficial for your health, simply because it does not contain harmful fats, cholesterol or sodium. It forms an integral part of balanced diet. Any food that can provide nutrients without having any negative impacts on health is a bonus! Low levels of fat, cholesterol, and sodium will also help reduce obesity and the health conditions associated with being overweight. It is one of the most widely used and eaten foods in the world because it can keep people healthy and alive, even in very small quantities.

Blood Pressure Management: Rice is low in sodium, so it is considered one of the best foods for those suffering from high blood pressure and hypertension. Sodium can cause veins and arteries to constrict, increasing the stress and strain on the cardiovascular system as the blood pressure increases. This is also associated with heart conditions like atherosclerosis, heart attacks, and strokes, so avoiding excess sodium is always a good idea.

Cancer Prevention: Whole grain rice like brown rice is rich in insoluble fiber that can protect against many types of cancer. Many scientists and researchers believe that such insoluble fibers are vital for protecting the body against the development and metastasis of cancerous cells. Fiber, specifically is beneficial in defending against colorectal and intestinal cancer. However, besides fiber, it also has natural antioxidants like vitamin C, vitamin-A, phenolic and flavonoid compounds, which also act as or stimulate antioxidants to scour the body for free radicals. Free radicals are by-products of cellular metabolism that can do serious damage to your organ systems and cause the mutation of healthy cells into cancerous ones. Boosting your antioxidant levels is a great idea, and eating more rice is a wonderful way to do that.

Skin care: Medical experts say that powdered rice can be applied topically to cure certain skin ailments. On the Indian subcontinent, rice water is readily prescribed by ayurvedic practitioners as an effective ointment to cool off inflamed skin surfaces. The phenolic compounds that are found in it, particularly in brown or wild rice, have anti-inflammatory properties, so they are also good for soothing irritation and redness. Whether consumed or topically applied, substance derived from rice tend to relieve a number of skin conditions. The antioxidant capacity also helps delay the appearance of wrinkles and other premature signs of aging that can affect the skin.

Alzheimer’s disease: Brown rice is said to contain high levels of nutrients that stimulate the growth and activity of neurotransmitters, subsequently helping to prevent Alzheimer’s disease to a considerable extent. Various species of wild rice have been shown to stimulate neuroprotective enzymes in the brain, which inhibit the effects of free radicals and other dangerous toxins that can cause dementia and Alzheimer’s disease.

Diuretic and Digestive Qualities: The husk part of rice is considered to be an effective medicine to treat dysentery, and some people say that a three month old rice plant’s husks are said to have diuretic properties. Chinese people believe that rice considerably increases appetite, cures stomach ailments and reduces all digestive problems. As a diuretic, rice husk can help you lose excess water weight, eliminate toxins from the body like uric acid, and even lose weight, since approximately 4% of urine is actually made up of body fat! The high fiber content also increases bowel movement regularity and protects against various types of cancer, as well as reducing the chances of cardiovascular diseases.

Rich in Vitamins: An excellent source of vitamins and minerals like niacin, vitamin D, calcium, fiber, iron, thiamine and riboflavin. These vitamins provide the foundation for body metabolism, immune system health, and general functioning of the organ systems, since vitamins are commonly consumed in the most essential activities in the body.

Cardiovascular Health: Rice bran oil is known to have antioxidant properties that promote cardiovascular strength by reducing cholesterol levels in the body. We have already spoken about the cardiovascular benefits of fiber, and low levels of fat and sodium. Wild and brown rice varieties are far better than white rice in this category, since the husk of the grain is where much of the nutrients are; the husk is removed in white rice preparation.

Resistant starch: Rice abounds in resistant starch, which reaches the bowels in an undigested form. This type of starch stimulates the growth of useful bacteria that help with normal bowel movements. Also, this insoluble rice is very useful in reducing the effects of conditions like Irritable Bowel Syndrome (IBS), and diarrhoea.

Production constraints and identified hindrances to productivity and profitability

Production constraints to rice farming in Nigeria

Production constraints to rice farming in Nigeria are basically input and process related. However, there are emerging trends that implicate some market and marketing factors as well as historical trends in policy thrust due to strong linkage effects in the economy.
While some of these constraints have immediate short-term impacts, others such as policy impacts are cumulative and appear to impact significantly over a definite and extended period.

In the Nigerian context, some identifiable production constraints include but are not limited to;

- Bottlenecks in the land tenure system and policy which limits accessibility to and availability of land.
- Dearth of viable seed for rice farming.
- Resistance and reluctance to frontier technology and farming system.
- Weak fertilizer distribution system for timely resource availability.
- Lack of financial resources to acquire agro-chemical such as herbicides, pesticides etc by farmers.
- The relatively high and rising agrochemical prices in the economy. For example, the technology driven herbicides common to rice farming in Nigeria are
  - (i) Orozon plus
  - (ii) 2-4-D Select
  - (iii) Nominee Gold

A little just over a year ago, the adequacy threshold for each per hectare was ₦4000, ₦2000, and ₦4000. At current market rates, it is ₦6500, ₦4500 and ₦8000 respectively.

- Increasing incidence of weed resistance to agro-chemical use.
- Agency framer population without replacement.
- Inter sectoral workforce shift from agriculture to other sectors
- Rural-to –Urban workforce shift due to policy neglect of rural and peri-urban but ecologically suitable regions for rice production.
- Low rating for R & D in the quest for self-sufficiency in rice production.

Hindrances to Production and Profitability of Rice in Nigeria

It encompasses the limiting factors across the rice value chain, some of which are production-related act the level of the farmer, policy-induced, service-related between the farm-gate and the consumer table as well as inflation-driven. It is also the case that technology-investment consideration contributes to determining profitability and viability of investment resources in the rice economy.

Significantly, therefore, the following hindrances contribute significantly to the production and profitability of rice in Nigeria.

- The relatively volatile foreign exchange market.
- The restrictive monetary and incomes policy of government.
- The relatively high investment required to add value to rice.
- The invasive tendency of imported brands to crowd the rice market in the economy.
- The consumer taste that has been adopted to regard imported rice brands as fit as superior.
- Application of crude technology among existing rice farmers that still produces rice batches with stones for human consumption.
- Weak extension on framer information infrastructure for dissemination.
- Gaps in packaging that fail to gauge the pulse of consumer for preferred packaging sizes.
- Lack of priority for R & D in Rice value chain.

Other pertinent constraints and identified hindrances to rice productivity and profitability in Nigeria are summarized in Table 7.

Table 7: Constraints and identified hindrances to Rice productivity and profitability in Nigeria

Group	Constraints and identified hindrances to Rice productivity and profitability in Nigeria
Socio economic	Difficult access to sufficient irrigation water
	Unavailability of quality seed
	High cost of irrigation
	Nitrogen fertilizer expensive/in short supply
	Inadequate farmer knowledge/training
	Insufficient access to agricultural information
	High price of inputs other than nitrogen
	Fertilizer access/cost
	Funds/capital/credit access/cost
	Mechanization access/cost
	Herbicides access/cost
	Labor access/cost
	Access/cost of inputs in general
	Produce marketing problems
Abiotic	Drought or intermittent water stress
	Soil fertility depletion
	Nitrogen deficiency

Group	Constraints and identified hindrances to Rice productivity and profitability in Nigeria
	Flooding of low lying fields Flooding problems (incidence; uncertainty; excess)
	Deficiency or toxicity of micronutrients
	Phosphorus unavailability
	Soil physical/structural degradation
	High temperature stress
	Potassium deficiency
	Low temperature (cold) stress
Biotic	Weed competition
	Leaf and stem pests
	Leaf, stem, and panicle diseases
	Birds and Rodent damage
	Storage pests
	Root and soil diseases
	Soil insects
Management-related	Use of low yielding or old variety
	Inappropriate/poor nutrient/fertilizer use
	Late planting of crop
	Inadequate water management
	Poor crop rotations and sequences
	Inappropriate/poor insect/disease management
	Field crop establishment difficulties
	Inappropriate/poor weed management
	Poor seedling nursery management
Environmental challenges	Biodiversity
	Climate change /Weather problems
	Ecosystems
	Natural resource management
	Sustainability
	Crop diversification
	Food security

Rice Innovation Opportunities in Nigeria

Innovation is defined as a co-evolving process of technological (e.g. cultivars, fertilizer, agronomic practices) and socio-organisational (e.g. land tenure arrangements and stakeholder collaboration) changes (Hall and Clark, 2010; Hounkonnou et al.,2012; Leeuwis, 2004). Such changes occur across different levels, and are shaped by interactions between stakeholders and organisations inside and outside the agricultural sector (Kilelu et al., 2013; Klerkx et al., 2010).

Emerging paradigm to sustainable agricultural development and food security, builds on the concept of innovation as a social process which occurs in a social system referred to as innovation system; involving not only scientific research and research organizations, but also other bodies and non-research tasks. By definition it is a system of all major social actors, affecting the revealing, acknowledgement, generation and diffusion of technical and institutional knowledge over time (Clark, et al., 2003; Hall et al., 2001). Walts et al. (2003) further opined that innovation system also include the interactive learning that occurs when organizations engage in generation, diffusion, adaptation and use of new knowledge; and institution (norms, rules) that govern how this interaction and processes occur. Invariably, rice innovation system comprised a network of economic actors- namely research, education, credit, information, government, public extension, private sectors, NGOs, processors, marketers, input providers and transporters that engage in generation, adaptation, diffusion, and use of technical and institutional knowledge over time; the interaction that exist for knowledge generation and use and the policy environment/infrastructure influencing the interaction. In other words, production of rice takes place along the entire commodity chain and according to Erenstein et al. (2003) different actors are involved in each step of production. However, the innovative strength of the whole process is a function of interaction, linkages, alliance and knowledge flow. Janssen and Braunschweig (2003) rightly pointed out that technical change and innovation have become much more interactive processes, which can be led by diverse types of actors.

Innovations are therefore not solely the product of organized research and development activities undertaken within universities, research and development institutes; and it should not be assumed that the results of formal research or increased investments in research and development in science and technology infrastructure will automatically spur innovation or be put into economic use. It is the enabling environment that encourages continuous learning, creativity and knowledge flows which facilitates innovation for socio-economic development (Mytelka, 2000). Innovation system as a network of organization, enterprise, and individuals focused on bringing new products, new processes and new forms of organizations into social and economic use, together with the institutions and policy that affect their behaviour and performance (World Bank, 2006). Therefore, rice innovation system embraces the totality of the component actors, and their interaction and the policy environment. It tends to go beyond the creation of knowledge to encompass the factors affecting demand for and use of knowledge in useful ways. Innovative performance depends not only on how the individual actors perform in isolation, but also on how they interact with each other as element of a collective system of knowledge creation and use.

Use of Improved Rice Varieties in Nigeria

In Nigeria total rice production has increased over the last two decades. Falusi (1997), Fagade (2000), and AfricaRice (WARDA) (2008) noted that rice production has been expanding at the rate of 6% per annum in Nigeria, with 70% of the production increase due mainly to land expansion and only 30% being attributed to an increase in productivity. Due to rice increasing contribution to per capita calorie consumption (Ogundele and Okoruwa, 2006) and growing population in the country, the demand for rice is growing faster than production, thus, making the country depend on imported rice to meet the high demand. The annual demand for rice in the country is estimated at 5 million tonnes, while production is 3 million tonnes, resulting in a deficit of 2 million tonnes (Chinma, 2004). The supply gap is being met through rice imports which represent over 25 percent of all agricultural imports and more than 40 percent of domestic consumption. The inability to meet rice consumption needs through local production has resulted in high cash outlays for importation. In 2010 alone, importation of rice was N356 billion, about N1billion per day (Izeze, 2011).

To reduce the dependence on imported rice as well as develop the local rice industry and enhance the adoption process of high yielding varieties and increase the production level of rice, Nigeria adopted several development innovations, some of which include the African Rice Initiative (ARI) which was established in 2002 to promote the dissemination of high yielding varieties (NERICA) in SSA. The Federal Government of Nigeria launched the Presidential Initiative on Accelerated Rice Production in 2003. Government also banned milled rice imports and put a 50 percent duty on parboiled rice. In addition, a levy of ten percent was imposed on rice imports to create a dedicated fund for the development of the local rice industry, including processing and marketing (Main Report and Working Papers, 2006). Notwithstanding the various policy measures, domestic rice production has not increased sufficiently to meet the increased demand. The existing rice production potential has not yet been realized, as smallholder (small-scale, subsistence and *Fadama* farmers) output is inadequate and paddy processing is substandard. To meet this shortfall, government recognizes the potential of irrigated agriculture, using improved technologies and wishes to promote further expansion of rice production.

Access to improved varieties, good quality seed and availability of good quality seed have been reported as the principal constraints in rice production. A report by Fagade (2000) showed that the rate of utilization of certified seed is 5-15 percent, 10-20 percent, and 30 percent among producers at Badeggi, Bende and Kano areas respectively. Results obtained by WARDA in the Sahel suggest that use of poor quality seed contributes to low yields in irrigated rice production. As a result, agricultural growth will depend more and more on yield-increasing technological change (Ravallion and Datt, 1996). Opportunities exist for addressing these problems. For instance, high yielding short duration varieties adapted to Sahelian conditions are already extensively used in Senegal, Mauritania, Mali and Burkina Faso. In 2006, a conservative estimate of area grown to NERICA varieties in SSA was about 200,000 hectares (WARDA, 2008). Amount of certified seed produced in Nigeria rose to 5,785 tons in 2006. According to NASC, an agency responsible for seed certification, extension rate for NERICA 1 and NERICA 2 in rain-fed upland fields is 32% (2005 - 2006). In recent years, improved seed is being extended in both rain-fed upland areas (mainly NERICA) and rain-fed lowland areas (FARO varieties).

List of rice varieties released in Nigeria in various periods

During the 15-year period 1955-1970, 12 varieties were released (Tables 8 to 11). The greatest number (9) was released for the rainfed lowland ecosystem, followed by two varieties each for upland and deep-water ecosystems. During the 13-year period 1971-1984, 16 varieties were released, of which 12 for rainfed lowland and irrigated, 3 for deep-water and 1 for upland ecosystems. The yield potential of these varieties ranged from 1.5 to 5.0 t/ha.

Table 8: Characteristics of recommended rice varieties in Nigeria, 1955-1970

Cultivar (old name)	Cultivar (new name)	Year of release	Duration (*days*)	Plant height (*cm*)	Grain type	Yield potential (*t/ha*)	Reaction to blast[a]
Upland rice ecosystem							
FARO 3	Agbede	1958	95-120	99-100	B	1.5-2.5	S
FARO 11	OS 6	1966	115-120	103-110	B	1.5-3.5	S
Rainfed lowland rice ecosystem							
FARO 1	BG 79	1955	135-174	100-120	B	2.0-4.0	S
FARO 2	D 114	1958	135-176	110-115	B	2.0-4.0	S
FARO 5 Makalioka	823	1960	135-154	111-115	B	2.0-4.0	S
FARO 6	ICB	1961	176-198	150-160	B	2.0-3.0	MR
FARO 7	Maliong	1962	160-217	150-160	B	2.0-3.5	MR
FARO 8	MAS 2401	1963	155-160	110-115	A	2.5-4.5	S
FARO 13	Sindano	1963	115-162	125-130	A	2.5-4.0	S
FARO 12	SML 140-10	1969	145-160	135-140	A	2.5-4.5	MR
FARO 13	IR 8	1970	35-140	90-100	B	2.5-3.5	S
Deep-water rice ecosystem							
FARO 4	KAV 12	1959	189-220	145-150	B	2.0-3.5	R
FARO 9	SIAM 29	1963	189-220	126-130	A	2.5-3.5	MR

[a] S = susceptible; MR = moderately resistant; R = resistant.

Table 9: Characteristics of recommended rice varieties in Nigeria, 1971-1984

Cultivar (old name)	Cultivar (new name)	Year of release	Duration (*days*)	Plant height (*cm*)	Grain type	Yield potential (*t/ha*)	Reaction to blast[a]
Upland rice ecosystem							
FARO 25	FAROX 56/230	1976	115-120	105-110	B	1.5-3.0	MR
Rainfed lowland and irrigated rice ecosystem							
FARO 15	FRRS - 162-B	1974	145-160	120-130	B	3.0-5.5	MR
FARO 16	FRRS-168-B-111-2	1974	140-160	90-100	B	2.5-5.0	MR

FARO 17	FRRS-148-B-11-3	1974	145-160	100-110	B	2.5-5.0	MR
FARO 19	IR 20	1974	135-140	90-100	B	2.5-5.0	R
FARO 20	BPA 76 (BICOL)	1974	125-130	90-100	B	2.5-5.0	MR
FARO 21	Taichung Native-1	1974	90-110	80-90	C	2.5-4.5	S
FARO 22	IR 627-1-31-3-37	1974	145-150	90-110	B	2.5-5.0	MR
FARO 23	IR 5-47-2	1974	145-150	90-100	B	2.5-5.0	MR
FARO 26	TOS 78	1992	130-135	105-110	B	2.5-5.0	MR
FARO 27	TOS 103	1982	110-115	90-100	B	2.5-3.5	MR
FARO 28	FAROX 188A	1982	135-140	125-130	B	2.5-5.5	MR
FARO 29	BG 90-2	1984	125-135	115-125	B	3.0-5.5	S
Deep-water rice ecosystem							
FARO 14	FRRS-43-111-1	1971	170-198	150-160	B	2.0-3.5	MR
FARO 18	Tjina	1974	165-175	125-135	B	2.5-4.0	R
FARO 24	DeGaulle	1974	135-115	135-145	A	2.5-4.0	S

[a] S = susceptible; MR = moderately resistant; R = resistant.

Table 10: Characteristics of recommended rice varieties in Nigeria, 1985-89

Cultivar (local name	Cultivar (original name)	Year of release	Duration (*days*)	Plant height (*cm*)	Grain type	Yield potential (*t/ha*)	Reaction to blast[a]
Upland rice ecosystem							
FARO 38	IRAT 133	1986	100-105	100-110	C	1.5-3.5	R
FARO 39	IRAT 144	1986	100-105	95-105	C	1.5-3.5	R
FARO 40	FAROX 299	1986	115-120	115-120	B	1.5-3.5	R
FARO 41	IRAT 170	1986	115-120	80-90	B	1.5-3.5	MR
FARO 42	ART 12	1986	115-120	110-115	B	1.5-3.5	MR
FARO 43	ITA 128	1986	115-120	110-115	B	1.5-3.5	MR
Irrigated rice ecosystem							
FARO 30	FAROX 228-2-1-1	1986	110-115	120-125	B	3.0-6.5	MR
FARO 31	FAROX 228-3-1-1	1986	110-115	120-125	B	3.0-6.5	MR
FARO 32	FAROX 228-4-1-1	1986	110-115	110-120	B	3.0-6.5	MR

FARO 33	FAROX 233-1-1-1	1986	110-115	120-115	A	3.0-6.5	MR
FARO 34	FAROX 239-2-1-1	1986	105-115	115-120	A	3.0-6.5	MR
FARO 35	ITA 212	1986	120-135	125-135	B	3.0-6.5	MR
FARO 36	ITA 222	1986	120-135	125-130	B	3.0-6.5	
FARO 37	ITA 306	1986	125-140	127-130	A	3.0-6.0	MR

[a] R = resistant; M = moderately resistant.

Table 11: Rice varieties released in Nigeria, 1990-2000

Cultivar (local name)	Cultivar (original name)	Ecology	Days to maturity	Plant height (*cm*)	Yield range (*t/ha*)	Grain shape	Amylose content	Reaction to blast[a]	Year of release
FARO 44	SIP 1692033	Shallow swamp	115	95	4.0-6.0	Long	26	R	1992
FARO 45	ITA 257	Upland	100	100	2.0-3.0	Medium	17.4	R	1992
FARO 46	ITA 150	Upland	105	110	2.0-3.5	Medium	22.5	R	1992
FARO 47	ITA 117	Upland	115	105	2.0-4.0	Long	10.5	R	1992
FARO 48	ITA 301	Upland	128	100	2.5-4.0	Medium	16.4	R	1992
FARO 49	ITA 315	Upland	120	100	2.0-4.5	Medium	16.2	R	1992
FARO 50	ITA 230	Shallow swamp	125	100	4.0-6.5	Medium	28	R	1992
FARO 51		Shallow swamp	130	100	4.0-6.0	Long	-	R	1997

[a] R = resistant.

Popular improved rice varieties distributed by major seeds company in Nigeria and their characteristics is presented in Tables 12 and 13. Out of many newly improved rice varieties are being developed and used by farmers in Nigeria, Faro 44, is one of the most distributed rice varieties in the Nigerian rice sector. It is an improved local semi-dwarf cultivar of rice grown in Nigeria.

Table 12: Commercialized Upland Rice Varieties and their characteristics

Characteristics	WAB 189 (FARO 54)	NERICA 1 (FAR0 55)
Adaptation	Upland	Upland
Tillering capacity	10 – 12	10 – 15
Plant Height (cm)	110 – 130	110 – 125
Maturity	Early	Early
Days to maturity	100 – 105	100 – 105
Disease reaction	Resistant to Blast	Resistant to Blast
Husk color at maturity	Straw	Golden brown
Yield potential (Ton/Ha)	2.5 – 3.5	3 – 4

Grain Type	Medium B - type	Medium B - type
Outstanding characteristics	Weed competitiveness and drought tolerant	Weed competitiveness, high grain yield, good cooking quality and lodging resistant

Table 13: Commercialized Lowland Rice Varieties and their characteristics

Characteristics	WITA-4 (FARO 52)	SIPPI (FAR0 44)
Adaptation	Lowland / Irrigated swamp	Lowland / Irrigated swamp
Tillering capacity	12 – 18	15 – 20
Plant Height (cm)	95 – 105	110 – 120
Maturity	Late	Early
Days to maturity	125 – 130	110 – 120
Disease reaction	Resistant to Blast	Resistant to Blast
Husk color at maturity	Straw	Straw
Yield potential (Ton/Ha)	5 – 6	5 - 6
Grain Type	A – type	A - type
Outstanding characteristics	High yielding, tolerant to iron toxicity and drought	Long grain and optimum production under low management

Plates 1-3 shows physical features of selected (improved) varieties of rice

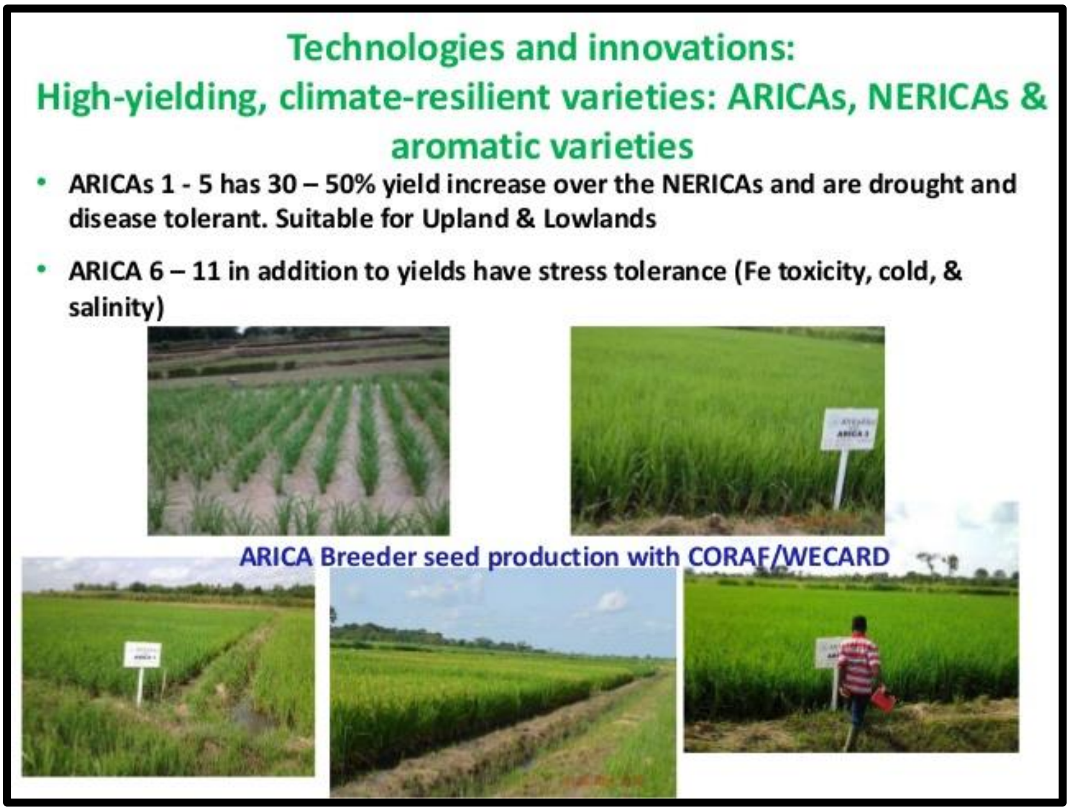


Plate 1

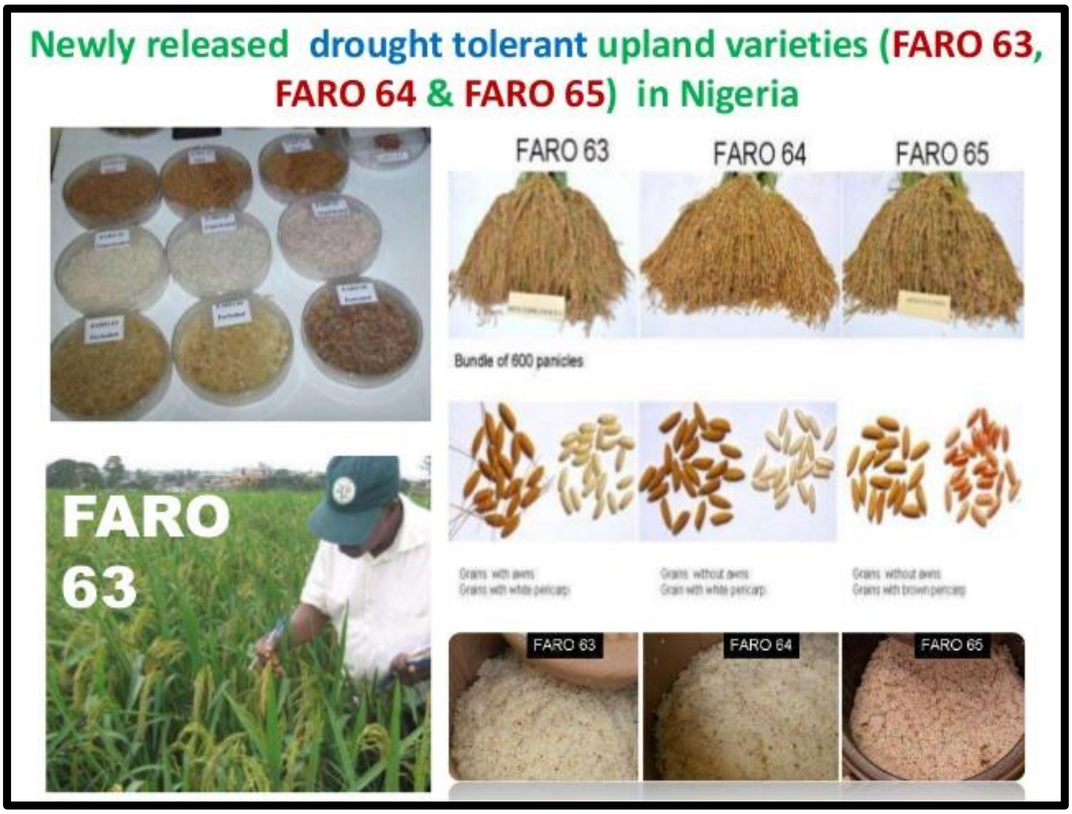


Plate 2

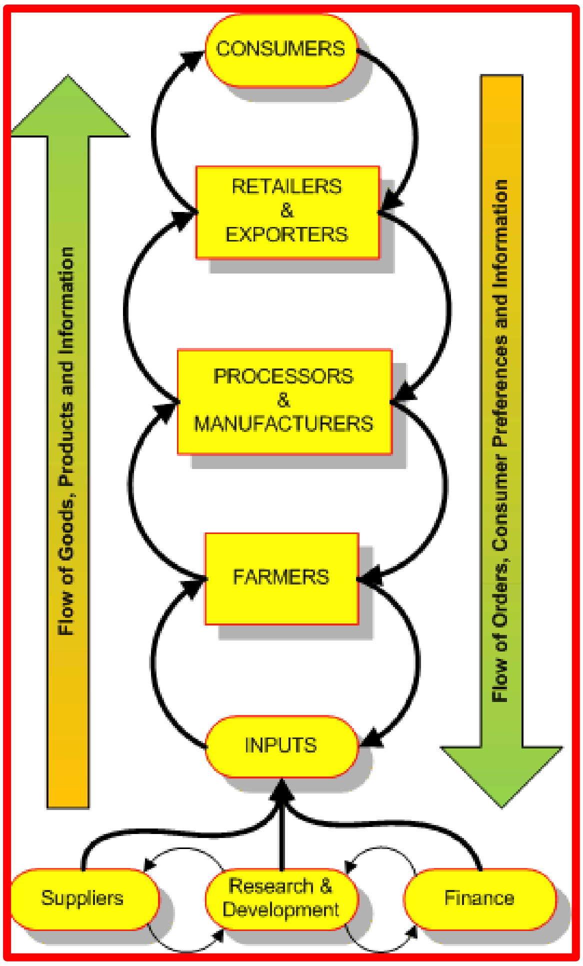
Hybrid rice: 5 best hybrid varieties in Nigeria & Senegal

Variety	Yield(t/ha)	%Yield increase over Faro 44	%Yield increase over Faro 52	%Yield increase over Faro 57
ARS010H	**11.02**	**39.49**	**18.87**	**17.11**
ARS017H	**10.66**	**34.93**	**14.99**	**13.28**
ARS033H	**10.52**	**33.16**	**13.48**	**11.80**
ARS034H	**11.22**	**52.89**	**21.03**	**19.23**
ARS035H	**10.68**	**35.18**	**15.21**	**13.50**
Sahel 108	8.42			
FARO 44	7.90			
FARO 52	9.27			
FARO 57	9.41			
Means	**10.08**			

Plate 3

Rice Value Chain Analysis for Nigeria

In this section we analyse a representative rice value chain in Nigeria. A typical value chain will consist of actors and activities from input procurement and distribution till output utilization. A typical agricultural commodity value chain is presented in Fig 5 (FMARD, 2014).



Source: Federal Ministry of Agriculture and Rural Development. 2014. Agricultural Transformation Agenda (ATA), End of Program Report 2011-2014

Fig 5: A typical crop value chain

In the context of the actors and activities shown in Fig 5, we will now attempt to analyse the rice value chain using available smallholder data.

Farm Input Procurement

Rice, like most other agricultural commodities, uses such inputs as land, fertilizer, seeds, labour and agro-chemicals. Labour comes from family and hiring. Efforts have been made to get fertilizers, improved seeds (varieties) and agro-chemicals to farmers through diverse sources. Table 14 shows alternate means of access to land among a sample of rice farmers. As demonstrated, most of the farmers in the sample (61.2%) own their rice farmlands.

Table 14: Land tenure status among rice farmers

Land tenure	Frequency	Valid Percent
land not owned	112	38.8
land owned	177	61.2
Total	**289**	**100.0**

Source: Phillip (2017)

Improvement of agricultural productivity depends on the adoption of a package of improved technologies. In Table 15, 85.8% of a sample of rice farmers indicate to use one improved technology or another. Table 16 shows a breakdown of the technologies available to the rice farmers, of which nearly 70% of the farmers indicate improved rice varieties as the main technology adopted. The average area under all varieties of rice (traditional and improved) was 2.78 ha (n=202) while the average area under improved varieties was 2.09 ha (n=209), giving an adoption rate of 75.2%.

Table 15: usage of agricultural technology in rice production

Technology usage	Frequency	Valid Percent
No	37	14.2
Yes	224	85.8
Total	261	100.0

Source: Phillip (2017)

Table 16: Main agricultural technology used

Technology	Frequency	Valid Percent
Improved crop variety	151	69.9
Systems rice intervention (SRI)	3	1.4
Threshing machine	41	19.0
Other technologies	21	9.7
Total	216	100

Source: Phillip (2017)

Table 17 shows the actors the main actors in the rice input procurement and distribution. Although the data does not show the specific inputs involved, the picture is that input procurement and distribution involves public and private institutions. The public sector still dominates the input distribution market, with government extension and research agencies jointly accounting for 77.3% of all input sources.

Table 17: Main source of rice technologies used

Source of Technology	Frequency	Valid Percent
Government extension agencies	167	74.2
Private input dealers	19	8.4
NGOs	4	1.8
Farmer groups/Associations	16	7.1
Other farmers	9	4.0
Open market	3	1.3
Agricultural research institutes	7	3.1
Total	225	100.0

Source: Phillip (2017)

Farm Input Utilization

Table 18 shows the average utilization of inputs at smallholder level in rice production, namely 1,53ha for farm size, 40.6 man-days/ha for labour employment, 345 kg/ha for fertilizer, and 11.85 litres /ha for agro-chemicals (Phillip and Jayeoba, 2016). In a related study by Phillip (2017), Table 19 shows the average input usage among another sample of rice farmers, consisting of 2.78ha for farm size, 509.08 kg/ha for fertilizer, and 8.08 litres /ha for agro-chemicals.

Table 18: Average usage levels of inputs for rice

Input	Rice
Farm size (ha)	1.53
Labour used (man-days)/ha	40.6
Fertilizer used (kg/ha)	225.4
Agro-chem used (lit/ha)*	7.7
Seed used (kg/ha)**	83.0

Source: Phillip and Jayeoba (2016)
*Cumulative of herbicides, pesticides, etc., each of which are recommended at about 2-3 litres/ha

Table 19: Estimated average quantities of input use in the rice value chain, 2016

Input	Number of Farmers	Average Quantity
Land (ha)	122	2.78
Labour (m-days)		
Fertilizer (kg)	120	509.08
Agro-chem (litres)	120	8.08
Seeds (kg)	121	85.45

Source: Phillip (2017)

Post-Harvest Activities in the Rice Value Chain

As motivated in Fig 5, post-harvest activities include processing, manufacturing, marketing and exporting. Table 20 shows the distribution of respondents by who process own rice. Only 19.1% of the farmers in our sample indicate processing own rice produce. Thus, rice is largely sold in paddy form among the farmers.

Table 20: Distribution of respondents by who process own product

Product ownership	Frequency	Valid Percent
No	199	80.9
Yes	47	19.1
Total	246	100.0

Table 21 shows the marketing options or methods available to the rice farmers in our sample. Nearly 94% of the farmers still market their rice as individuals rather than through groups. Group marketing is known to benefit smallholders in the form of cost sharing, risk sharing, and better access to credit and inputs.

Table 21: Commodity marketing method 2016

Marketing Method	Frequency	Valid Percent
Individual marketing	168	93.9
Group marketing	11	6.1
Total	179	100.0

Table 22 shows the main marketing channels available to the rice farmers in our sample. A farmer is likely to use more than one marketing channel, but the survey sought to know the most important channel used; this helped to remove incidence of multiple responses. The top four channels of marketing rice among the farmers are On-farm to wholesalers (27.1%), sale at the local/village market (25.9%), sale to agro-processors (16.3%) and sale at urban market within the state (15.1%). It is noteworthy that some farmers (12%) are able to sell directly to consumers, which ultimately should improve their marketing margin and efficiency. Table 23 shows that the use of pickup dominates the mode of transporting rice among the farmers (71.7%) in the survey.

Table 22: Main marketing outlets/ channels 2016

Marketing Outlet	Frequency	Valid Percent
On-farm to consumers	20	12.0
On-farm to wholesalers	45	27.1
By the road side	3	1.8
Local/village market	43	25.9
Urban market within the state	25	15.1
Urban market outside the state	3	1.8
Sale to agro-processors	27	16.3
Total	166	100.0

Table 23: Mode of transporting rice

Mode of transportation	Frequency	Valid Percent
Motorcycle	23	8.0
Saloon cars	57	19.9
Pickup	205	71.7
Trailer	1	.3
Total	286	100.0

Value Addition in Rice Processing

A persistent problem in smallholder agricultural production is the inability of farmers to process own raw outputs. This has always led to sales at poor prices and leaving most of the gains to those who buy, process and sell to others within the value chain. Table 24 shows that farmers gain / loose an average of N5,795.96 on every 100 kg of rice grain processed / not processed. This is a significant value when viewed across millions of metric tonnes of harvested rice per season. Indeed, the difference between the Farmgate price of unprocessed rice (N11,091.18/100kg) and retail price of processed price (N22,748.35/100kg) is disturbingly high (N11,657.17/100kg), and underscore the enormity of value losses by farmers for not processing rice before selling.

Table 24: Estimated changes in value arising from rice processing (Naira/100kg)

Change in value	N	Mean
1.crop price, unprocessed 2016 (per 100kg)	34	11,091.18
2.crop price after processing 2016 (per 100kg)	34	16,877.14
3. value addition through processing (per 100kg)	34	5,795.96
4.commodity village market price 2016 (per 100kg)	91	20,675.82
5.commodity retail market price 2016 (per 100kg)	91	22,748.35

Productivity of Rice among Smallholder Farmers

In the study by Phillip and Jayeoba (2016), the average yield of rice was obtained as 4.53 mt/ha over an average farm size of 1.53 ha. In a related study (Phillip, 2017), rice productivity averaged 3.23 mt/ha over estimated average farm size of 4.55 ha.

Average cost of rice production

Table 25 shows the average unit costs in rice production (Phillip and Jayeoba, 2016), as observed. We have also calculated the percentage contribution of each input to the observed total variable cost for rice. As demonstrated more clearly in Fig 6, labour cost accounted for most of the cost of producing rice (49%). Jointly, labour and fertilizer accounted for more than 70% of the total cost of producing rice.

Table 25: Average cost of production of FIII AF crops

Variable cost (Naira/ha):		Percentage (%)
Labour cost	61441.03	49.85
Fertilizer	31331.36	25.42
Agro-chem cost	12800.79	10.39
Seed cost*	17672.60	14.34
Total variable cost	123245.78	100.00

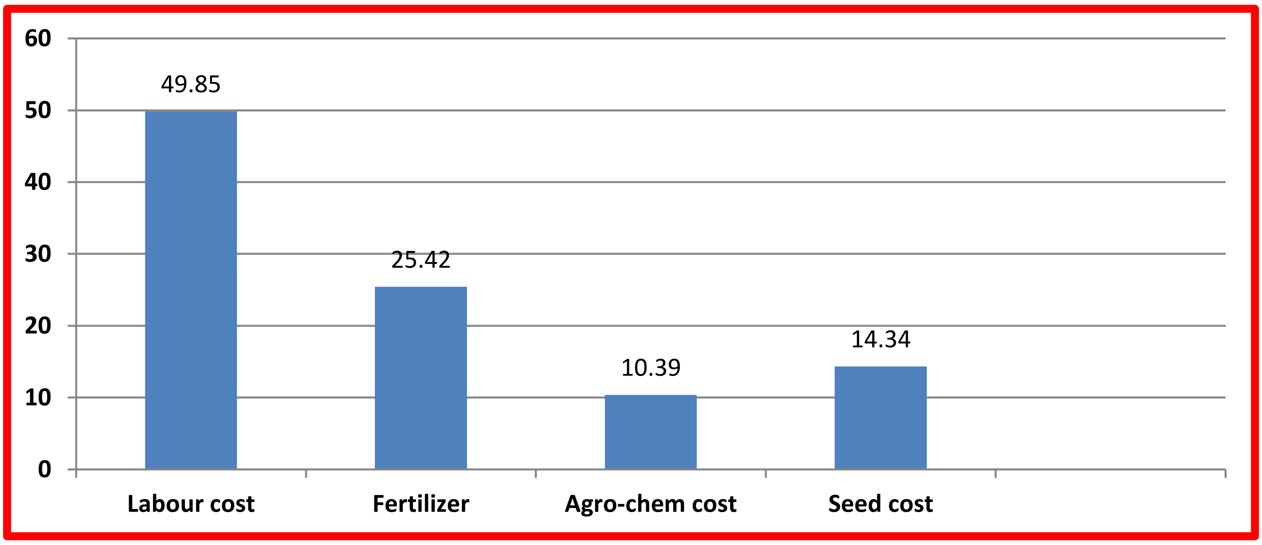


Fig 6: Percentage contribution to total variable cost of rice production /ha

Economic viability of smallholder rice production

Table 26 shows the profitability of rice under a smallholder production system. On the average, the gross margin per hectare for rice is N1,054,554.22 (Phillip and Jayeoba, 2016). The return per Naira spend is 8.56, underscoring great opportunities for a profitable smallholder rice production, even with seemingly inflationary situation with input prices.

Table 26: Estimated economic viability of rice based on Gross margin (Naira/ha)

	Rice
Farm size (ha)	1.53
Labour used (m-d)/ha	40.63
Fertilizer used (kg/ha)	225.44
Agro-chem used (lit/ha)	7.75
Seed used (kg/ha)*	82.97
Wage rate (N/m-d)	1512.06
Fertilizer price (N/kg)	138.98
Agro-chem price (N/lit)	1652.76
Seed price (N/kg)*	212.99
Variable cost/ha:	
Labour cost	61,441.03
Fertilizer	31,331.36
Agro-chem cost	12,800.79
Seed cost*	17,672.60
Total variable cost	123,245.78
Observed yield level (mt/ha)	4.53
Open market price (N/mt)	260,000.00
Total revenue (N/ha)	1,177,800.00
Gross Margin (TR-TVC) /ha	1,054,554.22
Return per Naira invested	8.56

Source: Phillip and Jayeoba (2016)

Conclusion

There is a persistent deficit in domestic production of rice relative to the level of consumption in Nigeria. The consequence had a growing rice import bill, which the country had not reversed successfully to date. To fully eliminate the deficit in rice production, the growing evidence is the need to embrace innovations along stages of the value chain by various actors (producers, marketers, processors and policy makers). These include the adoption of rice varieties that proven to be suited for Nigeria's different ecologies. This will minimize the risk of crop loss or failure.
Use of poor quality seed contributes to low yields in irrigated and upland rice production. In recent years, improved seed has being extended in both rain-fed upland areas (mainly NERICA) and rain-fed lowland areas (FARO varieties). Rice, like most other agricultural commodities, uses such inputs as land, fertilizer, seeds, labour and agro-chemicals. Improvement of agricultural productivity depends on the adoption of a package of improved technologies. Farmers within donor funded projects in Nigeria have indicated substantial familiarity with improved seeds, and needs to be supported to stay on course.

The public sector still dominates the input distribution market, with government extension and research agencies jointly accounting for most of all input sources. From the standpoint of distribution efficiency, more private sector participation will be needed in input marketing in Nigeria. Only few farmers in our study indicate processing own rice produce. Thus, rice is largely sold in paddy form among the farmers. A persistent problem in smallholder agricultural production is the inability of farmers to process own raw outputs. This has always led to sales at poor prices, and leaving most of the gains to those who buy, process and sell to others within the value chain. Thus, innovation must occur across all the stages in Nigeria's rice value chain.

Most of the farmers still market their rice as individuals rather than through groups. Group rice marketing will benefit smallholders in the form of cost sharing, risk sharing, and better access to credit and inputs. Labour and fertilizers account for most of the cost of producing rice among small holders. This underscores great opportunities for a profitable smallholder rice production, if the on-farm and post-harvest constraints can be efficiently managed with the adoption of relevant innovations.

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