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Demand Characteristics for Small-scale Private Irrigation Technologies: Knowledge Gaps in Nigeria

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THE NIGERIA STRATEGY SUPPORT PROGRAM (NSSP)
WORKING PAPERS

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- Enhanced knowledge, information, data, and tools for the analysis, design, and implementation of pro-poor, gender-sensitive, and environmentally sustainable agricultural and rural development polices and strategies in Nigeria;
- Strengthened capacity for government agencies, research institutions, and other stakeholders to carry out and use applied research that directly informs agricultural and rural polices and strategies; and
- Improved communication linkages and consultations between policymakers, policy analysts, and policy beneficiaries on agricultural and rural development policy issues.

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Abstract

Small-scale private irrigation (SPRI) schemes make up most of the irrigated area in Nigeria, although they constitute only about three percent of the cultivated area in the country. Farmers' demand for SPRI is potentially affected by diverse sets of agroecological, socioeconomic and risk factors. While the constraints on SPRI expansion have been well investigated by many studies in Nigeria, key knowledge gaps in at least four areas, still need to be resolved. These gaps are: (1) lack of knowledge of water sources; (2) perceptions of risks associated with rainfall and access to good quality water; (3) transaction costs associated with investments in irrigation; and (4) effectiveness of public institutions activities in SPRI.

Executive summary

It is estimated that only about three percent of the cultivated area (0.9 hectares) in Nigeria use water management techniques, of which approximately 0.2 million hectares are irrigated with equipment such as pumps and tube wells. Of the cultivated area that benefits from water management, more than 95 percent uses farmer-managed small-scale irrigation schemes. The cultivated area in Nigeria that adopts irrigation techniques can therefore expand rapidly, if the constraints to private irrigation are addressed to help meet farmers' demand for small-scale private irrigation (SPRI). This paper reviews the factors that determine the demand for SPRI in Nigeria and identifies the associated knowledge gaps.

The factors that determine the demand for SPRI differ substantially across farmers in Nigeria, and may be categorized as 1) agroecological, 2) socioeconomic, and 3) risk.

Agroecological factors: Various types of water bodies exist in Nigeria (both surface and underground), and are widely used for SPRI. The majority of Nigerian farmers generally lack the capacity to store water in private facilities such as artificial earth ponds, and rely heavily on the body of water available to them naturally. As a result, the ability to privately harvest and store water may affect whether or not a farmer adopts SPRI. The demand for SPRI is also determined by climatic conditions such as the length of the dry season, which can last for up to six months in the North compared to only two months in the South of the country. Vegetation also affects the demand for irrigation. The land clearing needed for irrigation is more easily achieved in the North where the land is grassy and can be easily burned, than in the South where vegetation is thick and land is often marshy.

Socioeconomic factors: SPRI in Nigeria has become popular because of favorable output-market conditions brought about by, for example the growing demand for vegetables in peri-urban areas, and the import ban on wheat in the 1980s. Modern irrigation tools are, however, usually imported and expensive for most farmers. The shortage of maintenance personnel and spare parts raises the costs of the irrigation operation. Irrigation is also still labor-intensive in Nigeria and increasing urbanization may thus be a limiting factor for private irrigation. Adoption of SPRI is further limited by the lack of access to other inputs such as fertilizer, improved seeds, credit, fuel, and electricity, despite activities to resolve these issues by Water User Associations (WUAs). Irrigation is a predominantly male affair, particularly in the North. Female farmers tend to use traditional water lifting devices such as buckets, in contrast to their male counterparts who tend to use motorized pumps. Many Nigerian farmers see their land tenure as insecure, are often unaware of their legal rights for occupancy or are distrustful of law enforcement mechanisms, and thus discouraged from making long-term irrigation investments on their plots, particularly in the South where uncultivated land is relatively scarce. Rights to water are perceived as insecure because farmers share the water from the same sources and practice irrigation at the same time of the day, temporarily exhausting water sources.

Risk factors: Nigerian farmers face various types of risks including the possibility of equipment breakdown or theft, damage of the irrigation pump or other equipments, poor quality and limited accessibility of water shared with other farmers, weak water management skills, and changes in inputs costs and output prices.

This Working Paper identifies four key areas of knowledge gaps in understanding Nigerian farmers' demand for SPRI: (a) lack of knowledge of water sources; (b) perception of risks associated with rainfall and access to good quality water; (c) transaction costs associated with investments in irrigation and (d) effectiveness of activities of public institutions to support SPRI.

The cost of detecting and accessing water, whether from surface or underground sources, may highly affect a farmer's decision to invest in SPRI. The public sector can play an important role in obtaining information on the location of water sources, and share it with farmers. Little empirical information is, however, available in Nigeria regarding the capacity of the government and the public sector to manage the data and information on the type, volume, and location of bodies of water, and to provide easy access to such information to farmers. Also unknown is whether the government has a comparative advantage over private actors (particularly farmer-to-farmer networks,) in disseminating such information.

Empirical information in Nigeria is scarce on how demand for irrigation is affected by the types of risks unique to irrigation technologies, particularly rainfall predictability and access to good quality water. Since rainfall predictability varies significantly within Nigeria, empirical information on how farmers' demand for irrigation technology responds to this unpredictable factor will help the government effectively target regions with greater need for support in adopting irrigation technology. Similarly, empirical information on farmers' perceptions on their rights and access to good quality water will also help the government determine the necessary interventions required to enforce laws and regulations associated with water use.

Due to an unfamiliarity of irrigation technologies, farmer often incur high transaction costs when making irrigation investments. For farmers, the main transaction costs associated with irrigation technologies are the costs of obtaining information on where and when to buy equipment, repairing the equipment in the event of breakdown, operating and maintaining the irrigation facilities, and obtaining information on best production practices using such irrigation technologies. Despite the potential importance of reducing transaction costs, empirical information is scarce regarding the impact of such costs on farmers' adoption of irrigation technologies.

Finally, empirical information is lacking on the impact of the activities of key public institutions in supporting SPRI. For example, it is not clear how many and which types of farmers benefit from the irrigation activities associated with the Agricultural Development Projects (ADPs) and the National Fadama Development Project (NFDP).

Introduction

In Africa, where the majority of farmers are still smallholders with one to three hectares (ha), small-scale private irrigation schemes (SPRI)[1] are likely to bring higher returns per hectare than government-led schemes, as observed in Zimbabwe (Rukuni 1997). SPRI allows irrigation schedules to be adjusted in accord with crop needs, providing the right amount of water at the right time to farmers (Dauda et al. 2009), and compensating for localized problems of erratic rainfall (Phillip et al. 2009). SPRI thus offers flexibility for African farmers, who are, generally, highly constrained in managing their production schedules. Such flexibility is one of the critical factors missing in the large-scale public sector irrigation schemes in Nigeria.[2]

In Nigeria, SPRI benefits farmers in a variety of ways. It usually leads to higher profitability of various crops (Yaro 2004). It also benefits farmers (including female farmers) by producing more food crops in the "slack" period of rain fed agriculture (Ogunjimi and Adekalu 2002). SPRI enables households to irrigate garden vegetables, water livestock, and undertake microenterprises (Westby et al. 2005). And with relatively favorable market conditions, particularly in urban areas, irrigation technologies should be widely adopted as they become available. Overall, SPRI has been the major driving force behind the expansion of irrigated land in Nigeria, as in many other sub-Saharan African (SSA) countries. Because of these factors and because the total irrigated land in Nigeria is still well below its potential, effective public support is needed to promote farmers' investment in SPRI.

Effective public support, however, must be based on a detailed understanding of the nature of farmers' demand for SPRI and the specific constraints they face. Only by understanding the complex and diverse nature of farmers' demand for agricultural technologies in Nigeria can the proper policies and support mechanisms be put in place that provide farmers with the resources to meet their production challenges. However, it is difficult to identify all the knowledge gaps for each of the diverse issues affecting farmers' demand for irrigation technology in SSA countries, as existing studies are limited. In general, irrigation studies on Nigeria only suggest the knowledge gaps relevant to the specific issues studied and/or are limited to specific geographic locations and irrigation technologies. Studies that do identify knowledge gaps have focused on a relatively general set of issues and are not specific to a particular country nor capture enough details.. Similarly, many studies using irrigation-related data only provide national empirical information and do not capture the diversity in irrigation practices nor factors affecting such practices within the country.

This review provides information on the major knowledge gaps related to the demand for irrigation technology in Nigeria and the constraints farmers face. It assesses the nature and breadth of empirical knowledge in Nigeria on factors potentially affecting farmers' demand for irrigation with a specific focus on the general set of factors that are perceived to have an effect on farmers' demand for irrigation in SSA; and two of these factors, which have been studied in

[1] Small-scale private irrigation (SPRI) can be defined as irrigation on small plots under the control of farmers, using technology they can effectively operate and maintain (Purcell 1997).

[2] Most of the irrigation done by RBDA (River Basin Development Authority) involves only basin irrigation, in which water is drawn from the main rivers by means of giant pumping engines (located at the bank of each river), and is pumped into the main canal, where it is distributed by gravity to the cropping zones. The zones are plotted out into units of 10 ha, and further divided into 0.5ha that are then allocated to participant farmers on an annual basis (Urama and Mwendera 2005).The most restricting problem of the large scale irrigation project is that farmers are required to follow the strict rotation of public irrigation schemes.

Nigeria or relatively ignored. The review summarizes the existing information on the SPRI, sector and identifies knowledge gaps that can help assess how the public sector can better serve farmers' specific irrigation needs.

This review is solely based on an assessment of the available literature detailing farmer demand for irrigation in Nigeria. This paper provides a framework that helps to understand the complex nature of Nigerian farmers' demand for irrigation technologies in a systematic way, which has heretofore not been done in previous studies on irrigation in Nigeria. It is likely to contribute to directing future research on SPRI in Nigeria to support government policies.

Characteristics of SPRI

Farmers' demand of SPRI in SSA is limited by some general constraints, including (among others) ineffective subsidy provision; low levels of education; inadequate training of farmers by extension agents; and lack of capital, complementary inputs, profitable markets for irrigated products, and certification systems to guarantee the quality of inputs. SPRI also has unique characteristics compared with other production technologies (such as improved seed) that impose specific constraints (see Table 1). Some of the key characteristics include the following

- Irrigation equipment is not scale-neutral (like seed technologies) so a significant initial investment is required, implying some economies of scale. Small-scale farmers who are resource poor may find it difficult to adopt modern irrigation technologies.
- While seed is reproducible, irrigation equipment is not.
- The benefits depend on the availability of water.

Table 1. Comparison of SPRI and improved seed as production technologies

	Improved seed	*SPRI*	*Issues*
Key characteristics	•Recyclable, reproducible (farmers can reproduce modified varieties by mixing improved varieties and landraces)	•Durable, but cannot reproduce technologies with different functions •Pumps can be resold, but this is less likely for other irrigation equipment like boreholes and tubewells •Damage from storage may be less serious than seeds	•Adoption of irrigation technologies may be more attractive when farmers can expect returns from several production seasons •Timing of purchasing irrigation equipment may be less important than for seeds
Scale	Scale neutral	Economies of scale	•High initial fixed cost for irrigation. •Need for hiring maintenance service for irrigation equipment, which is not needed for seeds
Complementary inputs	•Various complementary inputs such as fertilizer	•Water is the most important complementary input •Water cannot be owned personally except under the effective water rights system	•Information on location of water bodies should be shared
Risks mitigated by technology	•Mitigates risks such as weather, pest, diseases	•Mitigates rainfall-related risk	•Demand for irrigation technology higher in regions with unpredictable rainfall
Risks added		•Breakdown of tools and no access to spare parts	
Farmers' familiarity	•Every farmer uses seed	•Not every farmer uses irrigation technology •Only a fraction use irrigation pumps	•Costs associated with obtaining information on technology may be higher for irrigation

Nigeria's unique characteristics also affect the SPRI sector. Nigeria has seen relatively faster urbanization than the rest of SSA, resulting in an aging farmer population and greater need for labor-saving irrigation devices, as well as more demand for irrigation technology in urban or peri-urban agriculture.

Irrigation systems in Nigeria

The type of irrigation system used in West Africa is determined by 1) the type of water source (i.e. surface water or groundwater); 2) the specific forms of the water bodies; and 3) length and timing of irrigation practices (Table 2). In much of West Africa, the location and form of available water highly constrains the choice of the irrigation system adopted. Moreover, the seasonal use of irrigation may reflect the land use/tenure system in the country. For example, dry season irrigation is often practiced by irrigators renting land.

Most types of SPRI found in other parts of SSA are observed in Nigeria (Table 2). In Nigeria, a typical traditional small-scale irrigation system includes dry season irrigation of river flood basin and pumped irrigation. On large flood plains, surface water storage and shallow ground water is exploited using lifting devices (Kay 2001). The type of irrigation system employed differs across crops/commodities and regions (Table 2). The equipment used for SPRI has been gradually modernized, but Nigerian farmers still widely use such traditional water-lifting devices as *shadouf* (a long slender pole with a container, usually made from animal skin, attached to its end), calabash, and rope and bucket. Nevertheless, the various types of pumps, from pedal/treadle pump to diesel-fueled motorized pump, have been quickly adopted in certain regions. In particular, the use of shadouf on the main riverbank seems to have been gradually overtaken by engine pumps (Pasquini et al. 2004). The motorized pump is appropriate for irrigating more than 1 ha of land (Table 3). Since a typical Nigerian agricultural household has 1 ha or more of farmland; the potential demand for using a motorized pump in Nigeria is high. A detailed understanding of the requirements and benefits of each system is therefore important in shaping effective public sector support for farmers' investment in irrigation.

Table 2. Types of private irrigation systems reported in Nigeria categorized by water source and seasonality

Seasonality	Surface water based	Groundwater based		Other	
	River, pond, canals	Shallow aquifer (Pedal pump, treadle pump)	Deep aquifer	Recession	Runoff water harvesting
Mostly Seasonal	Water is lifted using shadouf/ bucket with small motor pump (Etkin 2002)	Captures water from shallow aquifers using dug wells (Tarhule and Woo 1997). Common for tomatoes and other vegetables in Nigeria (Ramalan and Nwokeocha 2000)		Residual moisture along the river is captured after the rainy season (Goes 1999). Flood recession farming comprises most of the un-equipped irrigation system in Fadama regions (Adeoti 2009).[a]	Captures and stores runoff water using circular or semi-circular bunds (low ridges of earth) (Adekalu et al. 2009)
Mostly Non-seasonal	Basin irrigation Border irrigation Furrow irrigation (Urama and Mwendera 2005)	Captures water from shallow aquifers throughout the year	Bore-hole (wash bore) were reported in various locations in Nigeria, and promoted through Fadama II program[a]	Stored wastewater irrigation in urban/peri urban area is reported in Kano (Mashi and Alhassan 2007), for vegetable production in Sokoto (Yakubu, Garba, and Habibullah 2008); and for spray irrigation of lettuce in Plateau (Damen et al. 2007)	

Source: Adapted from Namara (2009).

Table 3. Average cost of water-lifting devices for small-scale private irrigation in Nigeria[a]

Device	Functions	Price in West Africa (Snell 2004)
Calabash	• Irrigates 0.01-0.05 ha (Adeoti 2009) • Lift water from an open well • Low cost	N/A
Shadouf	•Irrigates up to 0.1 ha per shadouf •Very laborious and time-consuming •Low discharge and flow rates, therefore, inadequate for large areas •Low cost	$5–20 (Adeoti 2009)
Treadle pump	•Irrigates 0.2 to 0.5 ha •Comparable to calabash and shadouf •Increased command area for irrigation •Reduces irrigation frequency to 2-3 times weekly week, thereby reducing labor requirements •Not liked by men or women (Adeoti 2009)	$70 in Kenya
Motorized pump	•Irrigates at least 1 ha of farmland •Considerable water delivery capacity relative to traditional irrigation devices •Extraction from the river is the cheapest, from the tubewell it is the most expensive (Adeoti 2009) •Farmers using the shallow aquifer in downstream areas typically use 2–3 inch pumps that draw water from a maximum depth of 6 m (Goes 1999)	•Japanese brand (1.5-4 kW output): $300-$600 (gasoline), $1000 (diesel) •Indian brand: $180 •Chinese brand: $110 •Tubewell: $100 •Single-cylinder, multi-purpose water-cooled diesel motor (preferred by well-off farmers): motor, pump and tubewell cost $950 (Adeoti 2009)

[a]The Fadama experiment allowed irrigation on 1~2 ha of land at an average cost US $350 to US $700 per hectare with drilled tube wells and water pumps made available to farmers at subsidized cost (Orubu 2006)
Source: Adapted from Omilola 2007.

Determining Factors for Farmers' Demand for Private Irrigation

Current evidence on factors affecting farmers' demand for SPRI in Nigeria

Farmers' demand for irrigation technology is affected by various agroecological, socioeconomic, and risk factors. In order to properly identify the knowledge gaps present in the current literature, this section discusses the specific factors likely to impact farmer demand for irrigation technology and details which of these factors has been reported in the existing literature. Tables 4a, 4b, and 4c provide summaries of the available information.

Agroecological factors

Key agroecological factors determining farmers' demand for irrigation in SSA include water availability, topography and soil type, and climatic conditions. Currently available evidence indicates that these factors are also important to farmers in Nigeria.

Water availability: Natural water bodies come in several forms such as rivers, ponds, runoff water, and underground aquifer. The forms of water bodies are determined by the rainfall, river flow, landscape, soil types, and/or seasons. Water is also available with varying qualities. In SSA countries, farmers' irrigation practices highly depend on the nature of nearby water bodies. The availability of water and the costs of accessing water are key factors in farmers' demand for irrigation technologies.. Yet SSA farmers often lack the capacity to store water in easily accessible forms.

Such diversity is also observed in Nigeria. Aside from river tributaries, shallow depth aquifers that are rechargeable are scattered widely in northern Nigeria (Kay 2001). Similarly, runoff water associated with erratic rainfall can be captured through water harvesting (Adekalu et al. 2009).

While surface water accounts for the majority of water supply in Nigeria[3], groundwater sources provide a potential for further expansion of irrigated areas in Nigeria. Extractable groundwater alone has the potential to irrigate about 0.5 million ha in Northern Nigeria (Adeoti 2009). Fadama areas are rich in underground aquifers that are often replenished during the rainy seasons and can be extracted during the dry seasons after the river water recedes. Such conditions in Fadama areas enabled traditional Fadama irrigation to expand from 120,000 ha in 1958 to 800,000 ha in 1978 (Carter et al. 1983). Similar to surface water, the cost of obtaining groundwater depends on where such water bodies are naturally located. The diversity of water sources used for irrigation indicates that farmers still rely heavily on the naturally available forms. Farmers' ability to detect bodies of water at low cost may strongly affect their demand for irrigation technology.

Topography / soil type: Topography both at the regional level and at the plot level affects the demand for irrigation. Unfavorable topography limits the construction of dams and thus public irrigation facilities, leading to relatively higher demand for private irrigation facilities. Topography at the plot level also affects the costs of distributing water across the plot, and determines the necessity for land clearing. Land clearing for irrigation is easier in northern Nigeria as the land is mostly vegetated with grasses which can be easily burned for clearing, than in southern Nigeria where vegetation is thick and terrain is marshy (Dauda et al. 2009). Irrigation cost is also affected by the soil type, including the extent of water-holding capacity and water infiltration rates.

Table 4a. Agroecological factors affecting farmers' demand for private irrigation system

Sub-categories	General description of factors	Relevant (unique) situations in Nigeria
Water availability	• Water varies in forms and quality • Form of available water determines the types of private irrigation practices	• Abundance of shallow depth aquifers in northern Nigeria (Kay 2001), runoff water (Adekalu et al. 2009) • High groundwater potential (Adeoti 2009, Carter et al1983)
Topography and Soils	• Topography affects the decision to locate a dam, which affects the demand for private irrigation • Type of plot level topography influences the water application method used • Soil type affects the water-holding capacity and infiltration rate	• Relatively easier land clearing for irrigation in northern Nigeria (Dauda et al. 2009)
Climate	• Amount of rainfall, humidity, and wind • Temperature range • Evaporation rate • Length of dry season • Flood potential	• Larger income-increasing effects for Fadama II farmers in drier regions (Nkonya et al. 2008) • Significantly longer dry season in north central Nigeria (6 months) (Pasquini et al. 2004) compared to the southern region (2 months) (Dauda et al. 2009) • Mitigated demand for irrigation because farmers' indigenous knowledge and coping capacity (Hartenbach and Schuol 2005)

[3] For 221 km^3 of annual internally produced resources, 214 km^3 is from surface water and 87 km^3 is from groundwater (surface water and groundwater overwrap for 80km^3) (Aquastat, 2010)

Climatic conditions: Demand for irrigation is also affected by various climatic conditions including rainfall, temperature ranges, humidity, wind, evaporation rates, length of dry season, and potential for flooding. In Nigeria, private investment in irrigation facilities under the Second Fadama Development Program (Fadama II) increased farmers' income, particularly in the dry-Savannah region where the lack of rainfall (Nkonya et al. 2008) and high risks associated with rainfall variation are major constraints to productivity growth. The length of dry season irrigation typically ranges from 2 months (Dauda et al. 2009) in southern Nigeria to 6 months in north central Nigeria (Pasquini et al. 2004), implying significantly higher demand for irrigation in the north during the dry season. Some farmers in northern Nigeria have also managed to develop a production system adapted to drier conditions (Hartenbach and Schuol 2005). The exact demand for irrigation due to climatic conditions, therefore, needs to be assessed in combination with farmers' capacities to cope with such conditions.

Socioeconomic factors

Key socioeconomic factors determining farmers' demand for irrigation include the nature of output markets, input markets other than land, land market, and transaction costs associated with the purchase of irrigation equipment. In SSA, farmers' demand for irrigation facilities is reported to vary significantly across regions, reflecting a range of socioeconomic factors. Profitability of SPRI is affected by whether suitable crops are grown; costs of acquiring and operating irrigation equipment such as pumps (affected partly by domestic manufacturing and by the price and accessibility of diesel, electricity, and so forth); and costs of acquiring complementary inputs (land, seed, fertilizer, labor, and credit), which include not only the price of these materials but also transaction costs. Profitability of SPRI is also affected by institutional factors such as local laws, customs, and traditions which affect individual farmers' rights to water and access to land. Customary division of labor by gender also limits female farmers from obtaining required inputs and knowledge for appropriate irrigation practices.

Output markets*:* The nature of output markets that affect the demand for irrigation depends on which crops are grown (with particular water requirements, effective root depth, compatibility to soil), whether farmers have access to market for cash crops, and whether farmers are less occupied during the dry season. In Nigeria, the spread of private irrigation among farmers was in part driven by the improvement of terms of trade for agricultural commodities, the import ban on wheat (Acharya 2004), and the growing market for vegetables possibly due to rapid urbanization (Ogunjimi and Adekalu 2002).

Input markets (other than land)*:* For irrigation to be effective, various complementary inputs such as irrigation equipment (pump, tubewells), machinery, fertilizer, improved seed, and credit are required. As a result, market dynamics for these inputs will affect the demand for irrigation. In addition, the markets for irrigation equipment and machinery are generally undeveloped in SSA, due in part to insufficient government support for agricultural engineering (Purcell 1997). The markets for inputs used for irrigation equipment (Diesel, gasoline, electricity) are also only emerging. Investment in irrigation particularly requires sufficient capital or credit. The low profitability of agriculture, however, generally decreases farmers' capacity for irrigation investment (Binswanger 2007). Differences in the gender roles in irrigation practices and adoption rates of modern irrigation inputs are also potentially significant.

There is empirical evidence indicating that many of the constraints observed in the rest of SSA regarding machinery also hold for Nigeria. Frequent breakdown of pumps and poor availability of spare parts are common (Ogunwale et al. 1994, cited in Shah et al. (2002)**.** In addition, very

few people are qualified to perform maintenance on irrigation and water supply pumps in Nigeria (Ogunjimi and Adekalu 2002).

Irrigation in Nigeria is also labor intensive (Adeoti 2006) partly due to the lack of affordable modern machinery, implying that rising rural wages and urbanization could generally limit the demand for irrigation. Household labor allocation to irrigation during the day seems relatively less flexible as irrigation tends to be done primarily in the morning (Sabo and Zira 2009). The differing role of gender in irrigation practices noted in other parts of SSA are applicable in Nigeria, but with substantial variation across regions. Hausa culture in the North is sometimes reported to limit female farmers' involvement in farming, and thus irrigation is predominantly a male affair. There is, however, widespread involvement of women in agriculture observed in Yoruba culture in the South (Salisu 2001).

While fertilizer and improved seeds may be relatively accessible for farmers in some Water Users Associations, which provide these inputs in addition to irrigation related services (Shah et al. 2002), it remains to be assessed how many farmers are able to join these associations and how effective are their services. High costs of various complementary inputs in parts of Nigeria often make irrigation less profitable than rain-fed farming (Oramah 1996). Similarly, fuel supply is still irregular in rural Nigeria (Ogunjimi and Adekalu 2002); in particular, availability of diesel and electricity.

With access to credit, many Nigerian farmers may be able to realize higher returns with irrigation. When local NGOs and microfinance institutions provide loans, the recovery rates are relatively high, showing that SPRI farmers can realize high returns even if the interest rate is as high as 25 to32% per year (Adeoti 2009). While SPRI farmers in some regions can also benefit under the smallholder loan scheme provided by certain banks such as the Nigeria Agricultural Cooperative and Rural Development Bank, only a few SPRI farmers have benefited from it (Adeoti 2009). In particular, female farmers face difficulty in accessing credit from banks (Okojie et al 2009) and potential contribution by female farmers to the expansion of irrigation in Nigeria may be significantly untapped.

Land: Farmers' demand for SPRI is also affected by the tenure system as well as land market conditions, particularly during the dry season. Opportunity costs of using land for irrigation are generally low during the dry season, and farmers often have higher incentive to practice irrigation (whether owner-farmed or tenant-farmed). Irrigation systems during the dry season are constructed in ways that will not last beyond the dry season, because the same piece of land is used by the owner for rain-fed crop production.

In Nigeria, many empirical studies mention land related issues and their impacts on demand for irrigation. Tenure insecurity concerns seem widespread in Nigeria, particularly in peri-urban areas. All land is vested in the state government and occupied for use by individuals, with legal rights given to them by a "Certificate of Occupancy." Some farmers are not aware of the need for a certificate or are subject to fraudulent claims invalidating the certificate they hold. In addition, land in some parts is owned by multiple landlords in a fragmented manner and the rotation of water use, water allocation, construction of canals, and enforcement of community level regulation depend on each landlord (Fu et al 2010). As a result, farmers perceive irrigation investment on their plots (construction of canal and so on) as being too risky (ENPLAN Group 2004).

In Nigeria, irrigated land is often leased, while rain-fed land is often inherited (Adeoti 2006). Dry season irrigators therefore often rent the land during the dry season. While there a growing

trend in dry season irrigation in Nigeria (Adeoti 2009) this indicates that the land market system is also developing. The tenure system is still complicated and transaction costs in renting land may still be too high.

Table 4b. Socioeconomic factors affecting farmers' demand for private irrigation system

Sub-categories	General description of factors	Relevant (unique) situations in Nigeria
Output markets	• Profitability of crops • Access to market for cash crops particularly vegetables • Lack of activities in dry season	• Spread of private irrigation among farmers due to market forces such as better terms of trade for agricultural commodities (Acharya 2004), growing market for vegetables, and the slack in dry seasons (Ogunjimi and Adekalu 2002)
Input markets (other than land)	• Access to complementary inputs (irrigation equipments, machinery, fertilizer, seed, labor, credit, etc.) • Underdeveloped agricultural engineering in SSA (Purcell 1997) • Farmers' general lack of capital (Binswanger 2007)	• Irrigation equipment o Breakdown of pumps and lack of spare parts (Ogunwale et al. 1994, cited in Shah et al. (2002)), few people skilled in maintenance (Ogunjimi and Adekalu 2002) • Labor: o Higher labor intensiveness of irrigation (Adeoti 2006) o Labor required in the morning for irrigation (Sabo and Zira 2009) o Gender differences: less female participation in the North and more participation in the South (Salisu 2001) • Complementary inputs in general: o Easier access to non-irrigation services, such as fertilizers and seed in some Water Users Associations (Shah et al. 2002) o Low profitability of irrigation due to high costs of required complementary inputs (Oramah 1996) • Inputs for irrigation equipment: o Irregular and low availability of diesel (Ogunjimi and Adekalu 2002) and electricity in rural area • Credit: o High potential of better access to credit through NGOs and microfinance institutions on SPRI even at relatively high rates (Adeoti 2009) o Low coverage of financial services to SPRI farmers by formal banks
Land	• Tenure system • Land market conditions • Seasonality of irrigation	• Discouraged irrigation investment due to complex tenure systems (Fu et al 2010) and widespread tenure insecurity (ENPLAN Group 2004) particularly in urban and peri-urban areas • Emerging land market for dry season irrigation (Adeoti 2006, 2009), but with potentially high transaction costs and conflicts with pastoralists (Tarhule and Woo 1997;Urama 2005) and higher competition for land in the South (Dauda et al. 2009; Salisu 2001)
Transaction costs	• High transaction costs associated with gathering information on where to find sellers, types of irrigation equipment available in the market, and quality of irrigation equipment	• Little empirical evidence except some indicative results that transaction costs can be significantly high and vary widely across farmers with different characteristics (Takeshima et al. 2010)

Conflict over land is also a serious issue for dry season irrigation. Some farmers in Nigeria used to allow pastoralists to graze on their land in the dry season, as livestock provides manure and nutriments to the land. Starting dry-season crop production with irrigation sometimes causes conflicts with pastoralists who use those lands for grazing (Tarhule and Woo 1997;Urama 2005). Conflict over land may be particularly intense in the South, due to lower availability of irrigable land (Dauda et al. 2009; Salisu 2001).

Transaction costs*:* In SSA, high transaction costs are associated with gathering information on where to find sellers, the types of irrigation equipment available in the market, and the quality of irrigation equipment. Such transaction costs may be higher compared to other inputs like seed because many farmers still rely on traditional irrigation equipment like buckets and are unfamiliar with modern irrigation equipment. In Nigeria, few empirical studies analyze the significance of such transaction costs with the exception of Takeshima et al (2010) that provides empirical evidence that transaction costs can be significantly higher and vary widely across farmers with different characteristics such as gender, land ownership, and distance to the nearest town.

Risk factors

Unknown risks associated with new irrigation technology discourage farmers from adoption (Rosenzweig and Wolpin 1993). Farmers' demand for irrigation can be reduced if these risks are high. Such risks include the uncertainty of the productivity of modern irrigation equipment, the high probability that the equipment will break down, the volatility in the price of fuels used in operating the equipment, the difference in water quality, risks associated with the sharing of water from the same sources (Kay 2001) or sharing irrigation equipment with other farmers (Purcell 1997), and the uncertainty in tenure security. Farmers' general lack of resources to insure themselves against the rainfall risks, however, raises their demand for irrigation technologies.

Risk-averse farmers are generally more willing to invest in irrigation technologies when faced with increasing rainfall risks (total annual rainfall, unknown onset of the rainy season, and so on) or with increasing difficulty accessing natural sources of water (as with depletion of nearby water sources due to frequent drought). Farmers invest more in irrigation technologies if they perceive increasing risks of water shortage (Koundouri et al. 2006).

In Nigeria, many empirical studies point to some of these risks as important determining factors of farmers' demand for irrigation technology. Frequent pump breakdown is a serious limiting factor due to farmers' poor maintenance skills (Ogunjimi and Adekalu 2002). High acidic levels in water have been known to damage irrigation equipment in northern Nigeria (Graham, Pishiria, and Ojo 2006). Water quality also varies and the farmers' skills in managing these variations are often insufficient. In addition, seepage of harvested water often leads to significant losses and farmers' lack of confidence in storing water will discourage them from adopting irrigation (Adekalu et al. 2009). Although there are risks, farmers' demand for education programs to guide them in rehabilitating the environmental damages caused by irrigation schemes (Urama and Hodge 2006) indicates their desire to develop sustainable irrigation strategies.

Protection of farmers' rights to water, land, and irrigation equipment may be incomplete in Nigeria. For example, under the Water Resource Decree (1993) anyone whose land is alongside a river or a stream owns half the riverbed and is entitled to use half of the water on his land — a concept that is seldom implemented by Nigerians (Fu et al. 2010). Similarly, regarding the sharing of water at upstream and downstream locations, intensive application of fertilizer upstream often pollutes the water downstream; particularly the groundwater that will be used for irrigation (Ibe and Agbamu 1999). Some of the risks associated with the sharing of water are, however, mitigated by farmers themselves. For example, farmers use water from shallow wells at specific times of day so that they are replenished for pastoralists to use in the afternoon (Tarhule and Woo 1997), thereby avoiding conflicts.

Table 4c. Risk factors affecting farmers' demand for private irrigation system

General description of factors	Relevant (unique) situations in Nigeria
• Discouraging effect of unknown risks associated with the new irrigation technology (Rosenzweig and Wolpin 1993; Purcell 1997; Kay 2001) • Higher demand for irrigation as a means to mitigate risk of water availability (Koundouri, Nauges, and Tzouvelekas 2006)	• Factors discouraging use ○ risk of frequent pump breakdown (Ogunjimi and Adekalu 2002) ○ uncertainty in water quality (Graham, Pishiria, and Ojo 2006; Ibe and Agbamu 1999) ○ weak water management skills (Urama and Hodge 2006; Adekalu et al. 2009) ○ uncertainty associated with tenure security (Fu et al. 2010) • Existence of farmers' own practices to mitigate uncertainty in sharing water with other users such as clear rules assigning each user a time for using the water (Tarhule and Woo 1997)

Institutional factors

The ideal roles of the public and private sectors for supporting farmers' private irrigation are relatively well understood for SSA countries in general (Purcell 1997; Kay 2001). The SPRI sector in Nigeria is supported by a range of private agents, including irrigation technology service providers, NGOs, Water User Associations (WUAs) as well as public institutions such as the National Fadama Development Project (NFDP), the Agricultural Development Project (ADP), the State Irrigation Department (SID), and state and federal government ministries (Table 5). The involvement of state and federal governments in the SPRI sector (in contrast to public irrigation schemes) has been weak and limited to relatively narrow scopes. The ADPs and NFDP offices are often the major implementation arm of this government support, which includes distributing irrigation equipment as well as other inputs (often at subsidized prices), linking farmers to government and private suppliers of various inputs and trainings, and providing support to private manufacturers or traders. More specifically, the government's involvement under NFDP and National Program of Food Security (NPFS) has mostly been in providing financial assistance to farmers for acquiring irrigation equipment, including pumps, tubewells, and washbores (Okoli 2010). Managing irrigation-related data as well as monitoring and evaluation are also carried out by the ADPs, NFDP, and FMAWR. Through South-South cooperation with China trainings on various water harvesting systems were offered (Okoli 2010).

Table 5. Appropriate support activities for private irrigation sector and the current situations in Nigeria

Activity	Appropriate roles for public sector	Typical roles played by private sector	Reported situation in Nigeria
Acquisition of irrigation equipment ○ pump ○ tubewells ○ washbores	• Direct provision of irrigation equipment to farmers (with subsidies)— provided that: ○ Public sector activities do not crowd out the private sector ○ Targeting certain groups (remote area, female) can be justified for reasons of equity ○ Provision is done in effective and sustainable manner	• Manufacturing irrigation equipment • Marketing irrigation equipment	• Federal Government support irrigation through (Okoli 2010): ○ National Fadama Development Program (NFDP), with World Bank ○ National Program of Food Security, with International Fund for Agricultural Development (IFAD) • Certain ADPs provide equipment to farmers with subsidy • Some NFDPs provide farmers or Fadama Users Association (FUA) a 70% subsidy on mechanized or hand pumps and drilling borehole • Enterprise Works (NGO) supplies treadle pumps to farmers • Private service providers ○ Provide warranty on equipment sold ○ Link repairers to farmers ○ Bring irrigation equipment to farmgate • Water User Associations allow farmers to collectively obtain irrigation equipment through their monthly contribution
Acquisition of complementary inputs ○ Improved seed ○ Fertilizer ○ Agrochemicals ○ Land ○ Credit ○ Other		• Production and marketing of some complementary inputs	• Some ADPs ○ Link farmers to the FMAWR for land acquisition or affordable access to land ○ Link farmers to major seed suppliers (Premier seeds, Alheri seeds) and agrochemicals ○ Provide inputs through farmers association with subsidy ○ Link farmers to other credit institutions (commercial, microfinance) ○ Provide credit in kind (other inputs) • Some NFDPs ○ Provide 70% subsidy on agrochemicals such as fertilizer, herbicides, and pesticides ○ Link farmers with Federal Government for land acquisition ○ Provide grants to Fadama User Group • Private service providers ○ Grant credit to customers with good record
Extension Training of farmers	• Education ○ Support to universities or institutes for training professional engineers and experts in water resource management ○ R&D on locally appropriate irrigation technologies ○ Support to group training of farmers (NGOs, private sector)	• Private companies may train selected farmers to use irrigation equipment to promote sales. ○ Excludes smallholder farmers and those in remote rural areas	• Some ADPs ○ Train SPRI farmers in irrigation technologies, water distribution technologies, and rain water harvesting ○ Hold seminars and workshop for SPRI farmers ○ Assist SPRI farmers in forming user groups for these technologies • Sasakawa SG 2000 (NGO) trains farmers on rainwater harvesting technology • Private service providers offer training to farmers, many of whom are illiterate, to widen their market. • Federal Government supports South-South Corporation tripartite agreements between Nigeria, FAO, and China (Okoli 2010) for research and design of multi-purpose Water Harvesting Structures (micro-earth dams, dikes, and ponds)

Table 5. Appropriate support activities for private irrigation sector and the current situations in Nigeria

Activity	Appropriate roles for public sector	Typical roles played by private sector	Reported situation in Nigeria
Information dissemination	• Workshops • Information on new irrigation facilities and technologies to SPRI farmers • Information on the location of water (groundwater) since it is public good	• Advertisement and promotion of available irrigation equipment • after-purchase care (introduce repairmen to buyers)	• Some ADPs: o Link international organizations supplying treadle pump and SPRI farmers o Disseminate government programs – workshops, seminars by extension officers • Some NFDPs o Inform farmers of improved water lifting / distribution technologies and improved seeds • Private service provider o Link repairers to farmers o Link farmers to manufacturers and inform manufacturers of farmers' needs
Support to private sector	• Provision of credit with flexible repayment terms, or single digit interest rate • Collaboration with private sector through contract (equipment suppliers) • Capacity building for farmers' groups • Gradual transfer of management roles to groups like Water Users Association through training of members		• Some ADPs o Patronize irrigation equipment manufacturers and traders of irrigation equipment o Provide members of the Water Users Association with treadle pumps at subsidized rate o Exhibit equipment by manufacturers and traders' marketing demonstration • Some NFDPs o Assist formation of Fadama group and farmers' collective activities o Assisted farmers' adoption of irrigation pump through community-driven development (CDD) under Fadama II (Nkonya et al. 2008)
M & E	• Data collection • Financial support to the local research institutions		• Some ADPs disseminate information to farmers and farmers groups, and provide training • Some NFDPs provide data collection and management • Federal Government provides environmental assessment for further expansion of irrigated agriculture
Law and regulation	• Legislation of water rights • Certification of irrigation equipment such as pumps • Legislation of irrigation-related farmers group such as WUA • Insurance schemes for natural and man-made risks		• Water laws allow private, group, and collective water rights, which is conferred by the land tenure system (the land tenure dictates the right of access to the resources) (Adeoti 2009) • National Agricultural Insurance Corporation (NAIC) provide insurance on weather-related risks (Okoli 2010) • National Center for Agricultural Mechanization (NCAM) is responsible for certification, although the enforcement level is low and various types of imported equipment are used without certification (Okoli 2010)
Irrigation sector policy	• Implement trade policy		• Federal Government formulates policy and operate through the ADPs

Source: Based on literature review, including Adeoti (2009) and Okoli (2010).

Knowledge gaps on factors affecting farmers' demand for SPRI in Nigeria

The previous section summarized the current level of empirical information on the effect of agro-ecological, socio-economic, and risk factors on farmers' demand for SPRI. This section summarizes key knowledge gap for these three types of factors.

Agroecological factors

One key agroecological knowledge gap is farmers' knowledge of the location of water sources. If known, this information would allow researchers to assess whether the low level of irrigation investment is due to the cost of obtaining water or other reasons, such as cost of irrigation equipment or the lack of a market for irrigated crops. Moreover, empirical evidence on the costs of accessing water sources can assist the public sector in designing initiatives that reduce these costs for farmers. Some studies have examined either the cost of accessing water or the lack of output markets, but these issues are rarely investigated together, as would be necessary in order to identify which is the more binding constraint for farmers in expanding irrigation. Other agroecological factors that need to be better understood include the relationship between topology or soil type and farmers' preferred irrigation systems, and the impact of soil type on the cost of irrigation facilities.

A second gap is the level of farmers' knowledge about irrigation. It is unclear if farmers have good information about where and at what price irrigation equipment can be obtained and relevant production practices. Therefore, an assessment of farmers' knowledge on irrigation is critical. This assessment could also provide insight on how farmer-to-farmer networks function in sharing information. Understanding the level of farmers' knowledge of irrigation activities would indicate whether farmers' investment in irrigation is constrained by the cost of obtaining this information.

Socioeconomic factors

The Nigerian context and several irrigation sector actors help determine the socioeconomic-related knowledge gaps to be explored. Three initial knowledge gaps exist. First, there is a need to understand the constraints on farmers that can be best overcome by irrigation technology. This information can guide the priorities of irrigation development relative to other production technologies, such as seeds, fertilizer, agrochemicals, and mechanization.

Second, more information is needed on which complementary inputs critically affect the farmers' decisions about what irrigation technology to adopt. While there are many studies that mention bottlenecks caused by the lack of complementary inputs and markets, very few analyze which of these bottlenecks impact decisions on irrigation equipment use. Filling this knowledge gap could help prioritize support for reducing specific constraints in other input sub-sectors that impact the irrigation sector in order to let the irrigation sector develop further.

Lastly, there is a need to understand how the environment for developing the irrigation sector and the adoption of irrigation equipment is similar or different in Nigeria from other SSA countries. Understanding these similarities and differences can direct how the experiences of other SSA countries can be applied to assess similar issues in Nigeria and how Nigeria's experience may be applicable to other SSA countries.

Risk factors

In general, SSA farmers are expected to be highly sensitive to risks, but farmers' perceptions of risks are not well understood in Nigeria. Table 4 provides a limited overview of all the potential sources of risks for Nigerian farmers regarding irrigation, but empirical studies are needed to identify which types of risk are more important to Nigerian farmers and their impacts on farmers' adoption of irrigation technologies. This evidence can guide public sector efforts in mitigating these risks.

Institutional factors

The key players supporting the SPRI sector in Nigeria are well known, but more information is needed to understand the effectiveness of current government support to the SPRI sector. To assess this effectiveness, information is needed specifically on the government capacity to provide information on water sources, government constraints, and the effectiveness of the activities of public institutions.

Capacity to provide information on water sources: As mentioned in the section on agroecological factors, the cost to access a body of water (whether surface or ground water) may be a key factor that affects farmers' investment in irrigation technologies. As water in this context is generally a public good, the social benefit of detecting the source of water may be higher than the individual farmer benefit. The public sector can thus play an important role in obtaining information on the location of water sources to be shared with farmers. However, few empirical studies are available regarding government capacity to conduct an accurate assessment of the types, volume, and locations of water bodies; manage the data; and provide farmers easy access to the data. Therefore, it is unclear what comparative advantage the government has relative to private actors—particularly, farmer-to-farmer networks—to perform these activities. The capacity of the government to identify and communicate the location of water sources needs to be analyzed empirically and compared to that of the private sector and farmers.

Government constraints Similar to other agricultural input sectors, both federal and state governments face constraints in implementing their policies in the private irrigation sector. Current policies for supporting the SPRI sector, as stipulated in National Irrigation and Drainage Policy and Strategy in Nigeria (FMAWR 2006) only mention the goals of expanding the SPRI sector through increased participation of private sector firms in equipment manufacturing, supply, management, and operation without offering specific implementation strategies. In addition, due to federal budget limitations most of these programs are carried out with the support of external funding bodies (World Bank for the NFDP, International Fund for Agricultural Development (IFAD) for the NPFS, and the Food and Agricultural Organization of the United Nations (FAO) and China for South-South Cooperation). While such collaborations do help to develop the SPRI sector, sustainability of the system will depend on the commitment of the Nigerian government through two critical roles: 1) enacting laws and regulations regarding farmers' use of water and rights to water, and 2) certifying irrigation equipment.

Water laws already exist in some states (Adeoti 2009), but their effects are unclear in relation to the private irrigation scheme (ENPLAN GROUP 2004) and have not been thoroughly studied in Nigeria. In particular, it is unclear how widely and effectively the water laws and regulations (as well as certifications of irrigation equipment) are enforced or publicized. For example, to what extent are farmers aware of existing regulations on water use, water rights, and the need for certification? More empirical information is needed from all the agents involved in production, marketing, and use of irrigation equipment and water—including farmers, manufacturers, traders, and officials in local law enforcing units—in order to assess the impact and effectiveness of these laws, regulations, and certifications on the development of private sector irrigation.

Effectiveness of activities by public institutions*:* More empirical information is needed on the impacts of the activities of major institutions such as ADPs and NFDPs. Some studies indicate that most farmers obtain pumps through the market than through ADPs (Sabo and Zira 2009); moreover, many of the irrigation pumps supplied by the Kano State Agricultural Supply Company (KASCO) were obtained by middlemen rather than the targeted farmers, to be re-sold to the intended beneficiaries at exorbitant prices (Omilola 2007). Therefore, it is important to assess the percent of farmers that benefit from activities supported by each type of institution and assess the type of farmer that tends to benefit from these activities. In addition, empirical information is needed to understand the comparative advantages of different institutions in providing services to the irrigation sector. For example, the activities of the ADPs and the NFDPs seem to overlap. More detailed empirical information is needed on their activities and the benefits to the farmers to determine how the two institutions may be able to synergize their activities, or alternatively, re-allocate essential tasks.

Conclusion

This sector review attempts to identify the key knowledge gaps regarding farmers' demand for private irrigation technologies in Nigeria. The review indicates that more empirical studies are needed in Nigeria to assess how farmers' demand for irrigation technologies is affected by specific agroecological and socioeconomic characteristics, and how their adoption of such technologies may be hampered by poorly functioning markets. Questions that require more information include: Which agroecological and socioeconomic constraints are most serious for particular farmers? Which problems can best be addressed by irrigation technologies rather than other production technologies? How much do farmers know about accessible sources of water for mechanized irrigation?. Finally, there is a need to know more about how farmers perceive various types of risks associated with investing in irrigation technologies: rainfall variation, quality of water, insecure title to land, quality of irrigation equipment in the market, and reliability of other complementary inputs including fuel or electricity and spare parts. Empirical information on all these issues is essential for designing effective and appropriate public support systems for the private irrigation sector in Nigeria.

The information provided in this review is useful in a variety of ways. First, the review provides descriptions of factors affecting farmers' demand for irrigation in SSA, which has been done by few studies in Nigeria. Second, a diverse set of individual evidence reported in Nigeria is brought together and categorized systematically. Simultaneously, for categories with relatively abundant empirical information in Nigeria, the review validates in the context of Nigeria the effects of some of the key constraints considered important in other SSA countries.

There are certain limitations to this review. The studies reviewed are not exhaustive, and thus there are likely to be other Nigerian studies not covered in this review. It is also difficult to draw many factual conclusions on the situations of farmers' demand for irrigation in Nigeria, as nationally representative data that capture the detailed nature of irrigation practices are unavailable. The systematic information presented in this review is, however, still useful for both the Nigerian research community and policymakers. For the Nigerian research community, this review highlights knowledge gaps that need to be empirically analyzed with greater focus. Sections summarizing the major knowledge gaps can point to important directions for future research efforts in Nigeria. For policymakers, such systematic presentation of factors is informative. With the information from the constraint categories, policymakers can more easily identify and prioritize constraints to help the government efficiently allocate limited public resources in support of the SPRI sector in Nigeria.

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