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Constraints and Knowledge Gaps for Different Irrigation Systems in Nigeria

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THE NIGERIA STRATEGY SUPPORT PROGRAM (NSSP) REPORTS

ABOUT NSSP

The Nigeria Strategy Support Program (NSSP) of the International Food Policy Research Institute (IFPRI) aims to strengthen evidence-based policymaking in Nigeria in the areas of rural and agricultural development. In collaboration with the Federal Ministry of Agriculture and Water Resources, NSSP supports the implementation of Nigeria's national development plans by strengthening agricultural sector policies and strategies through

- 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.

ABOUT THESE REPORTS

The Nigeria Strategy Support Program (NSSP) reports either contain preliminary results or support ongoing research. They are circulated in order to stimulate discussion and critical comment.

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Abstract

Irrigation systems in Nigeria take various forms and most are privately managed by individual farmers. This diversity reflects the farmers' needs to minimize setup costs and maximize the returns from these systems. Thus, in order to design appropriate policies to support irrigation expansion in Nigeria, it is critical to understand how choices are made in the installation of different irrigation systems and the constraints faced in the process. This working paper provides a framework for comparing constraints of different irrigation systems and the associated knowledge gaps. Available empirical data indicates differences in constraints between types of irrigation systems, but a review of the literature highlights the need for empirical studies on the specifics of these differences.

Executive Summary

Nigeria's irrigated acreage is made up mainly of small-scale private irrigation operations. The type of irrigation system installed is based on the diversity of agroecological and socioeconomic conditions, the type and quantity of inputs required to operate the system, the crops to be grown, and market conditions. In order to design appropriate policies to support expansion of the sector, it is necessary to understand how choices are made under different irrigation systems and the constraints faced by smallholder farmers in the installation of these systems..This working paper provides a framework for making such an assessment.

This report categorizes the various irrigation systems in Nigeria based on the following three parameters: 1) water source (whether water is obtained from surface sources or underground sources), 2) water application methods (furrow, basin or hand watering method), and 3) seasonality (seasonal or non-seasonal). A farmer chooses an irrigation system based on the type, amount and costs of inputs needed to build and operate the system. The farmer also considers the expected return from the system, which is influenced by agroclimatic and socioeconomic conditions, and existing government policies.

Irrigation systems that rely on surface water sources require limited labor to detect and construct the required facilities. Land irrigated by surface water is often concentrated near the water, typically beside rivers and natural ponds, leading to intense competition for acquisition, thereby resulting in high cost. Water from surface sources is generally stable in its quality in terms of purity and chemical content so there is minimal cost for cleaning. With this relatively stable water quality, the expected return from surface water irrigation is high.

Irrigation drawn from underground water sources requires labor, experience, and technical know-how to find and gain access to water, as well as equipment to construct tube wells and boreholes. Underground water is usually associated with uncertain water quantity and quality, which makes the supply unreliable, and possibly more expensive. Irrigation pumps or tube wells are expensive and may be unaffordable without financial support for the majority of Nigeria's farmers.

The furrow method of irrigation often requires high-capacity water pumping machines to distribute water over relatively large plots. It may also require land-clearing machinery or draft animals (or both) for grading and leveling plots. Land used for furrow irrigation should have soil with high infiltration rates, a fairly smooth surface, and relatively large, rectangular-shaped, and unfragmented plots. Soil erosion is common for furrow irrigation systems, with negative impacts on long-term productivity. Favorable market conditions for irrigated outputs may be needed to achieve adequate returns and encourage farmers to adopt furrow irrigation.

Basin irrigation requires a large amount of labor at the beginning of the production season. Land used for basin irrigation requires fertile soil with low infiltration rates, which is widely available in northeastern Nigeria. Basin irrigation is commonly used for rice and vegetables in Nigeria. Urbanization raises the expected return of this type of irrigation, particularly in peri-urban areas. However, it tends to cause waterlogging of the plots, which could be detrimental to crops.

Hand watering may require more labor than furrow or basin irrigation, particularly during the plant growth process. Hand watering is used for small plots and is likely to be applied to farms very close to water bodies. Hand watering may be adopted when a farmer grows multiple crops on the same plot, to hedge production and market risks.

Dry-season irrigation is often practiced by farmers who are not originally from the locality and have no permanent access to land because of land tenure constraints. Rental cost could thus be high as a result of competition by other users such as pastoralists. The cost of water can also be high because of supply constraints such as water pollution, particularly in peri-urban areas, due to lack of the rain to flush some of the polluted water. Vegetables are commonly grown in Nigeria under dry-season irrigation, and the system has a potentially high return.

Farmers practicing nonseasonal irrigation may be more likely to use their own land in both the dry and rainy season without migrating to other regions. Potentially high labor costs in the rainy season may limit irrigation to peri-urban areas with higher profitability and relatively abundant labor. Nonseasonal irrigation may need to deal with possible negative factors for land productivity, including waterlogging, salinization of soils, and soil erosion.

In view of the above, smallholder farmers in Nigeria are likely to adopt irrigation systems which use surface water sources, hand watering, and are operated only during the dry season. Smallholder farmers are less likely to use underground water sources because of limited access to affordable equipment and they are less likely to use furrow and basin irrigation because of high labor and capital costs required for land preparation at the beginning of production season. Nonseasonal irrigation also requires access to profitable markets as well as cheap labor during the rainy season, thus making it less likely to be adopted by smallholder farmers.

In conclusion, more research is needed on where each irrigation system is practiced in Nigeria, the number of farmers involved, and the constraints faced by these farmers in making choices among alternative systems. In addition, a better understanding is needed of the profitability structure and impact of irrigation systems on agricultural productivity, to identify how government support can promote smallholder farmer adoption of irrigation systems.

Introduction

Increasing adoption of irrigation technology is an important requirement for increasing Nigeria's agricultural productivity. Despite the government's effort to expand irrigated areas through large-scale public irrigation schemes, a significant majority of Nigeria's irrigated acreage is the result of small-scale private irrigation operations: "small plots under the control of farmers using technology they can effectively operate and maintain" (Purcell 1997). Private irrigation systems across Nigeria are more diverse than public irrigation systems, as farmers design systems that meet their diverse needs within their agroecological and socioeconomic environments. Such diversities include their capacity to access water and distribute it to their plots. Therefore, the type of irrigation system installed is based on the agroecological and socioeconomic conditions in which it is installed, the type and quantity of inputs required to operate the system, the crops to be grown, and market conditions.

Understanding the diversity in irrigation systems and their relevant constraints can shed light on the type of assistance farmers might need over time. Although information is rich on the general constraints commonly applicable to many irrigation systems, relatively few studies clearly describe the types of constraints that particular kinds of irrigation systems face. More specifically, there is a need to identify the constraints smallholder farmers face in the installation of these systems, as these farmers account for the majority of Nigeria's food production and their constraints differ from those of commercial large-scale farmers. This knowledge could assist in determining the viability of certain irrigation systems for smallholder farmers.

This report provides a simple typology of irrigation systems used in Nigeria and discusses how the constraints associated with them may differ based on simple economic principles and available empirical evidence. The report then assesses why the irrigation systems viable for smallholder farmers may be limited and provides information on the public support to smallholder farmers needed for adoption of more advanced irrigation systems. The review focuses on identifying the constraints specific to irrigation systems rather than a detailed categorization of all irrigation systems in Nigeria. The typology of irrigation systems presented in this report may therefore not completely follow the standard typology in other studies.

The review contributes to policymaking by summarizing empirical evidence, which improves our understanding of farmers' needs in operating particular irrigation systems or planning future adoption of a particular system. It also identifies knowledge gaps that may be useful for government in determining areas for future research.

Nigeria's irrigated areas

The amount of land irrigated under private schemes (183,000 ha) is estimated to be much greater than that under public schemes (35,840 ha) (Table 1). Given that there is no specific data on the amount of irrigation land in Nigeria, the estimate is inferred from the number of units of irrigation equipment purchased (Table 1). For example, the Federal Ministry of Water Resources based its estimate of the area under private small-scale schemes (128,000 ha) on the 80,000 pumps distributed by the Agricultural Development Project (ADP)/Fadama project (AQUASTAT 2010). Similarly, the World Bank based its estimate of the irrigated areas under the improved Fadama (55,000 ha) on the number of pumps distributed (Enplan Group 2004). It is, however, not clear how the area for the unequipped Fadama (681,914 ha) has been estimated and how much of it is actually irrigated.

Table 1. Estimated area under water management in Nigeria

Scheme type	Equipped area (ha)	Actually irrigated area (ha)
Public irrigation scheme	**104,517**	**35,840**
River Basin Development Authority	92,317	29,140
State schemes	12,200	6,700
Private irrigation scheme	**188,600**	**183,000**
Sugar schemes	5,600	0
Private small-scale schemes	128,000	128,000
Improved Fadama (equipped lowland)	55,000	55,000
Unequipped Fadama	**681,914**	**681,914**
Total	975,031	900,754

Source: AQUASTAT (2010).

Irrigation systems typology

Irrigation may be defined as "the process by which water is diverted from a river or pumped from a well and used for the purpose of agricultural production" (FAO 1997). Areas under irrigation would thus refer to areas equipped for lifting and conveying water. Other production methods that use water management technology but do not divert or use irrigation equipment – such as flood recession cropping, which relies on residual moisture and wetland cropping – are not considered irrigation in this report. Studies have categorized irrigation systems in different ways (Kay 2001, Namara 2009, Walker 1989), but they all characterized them by a set of common key parameters, which reflect farmers' agroecological and socioeconomic conditions. This section describes the key parameters for irrigation systems in Nigeria.

This report categorizes the systems based on the following three parameters: 1) water source, 2) water application methods, and 3) seasonality (Table 2).

Table 2. Key parameters defining irrigation systems

Water Sources	Water Application Methods	Seasonality
• Surface • Underground	• Gravity-flow • Furrow irrigation • Basin irrigation • Hand watering • Pressurized • Drip • Sprinkler	• Seasonal • Nonseasonal

Source: Authors' modifications based partly on Namara (2009).

Water sources

Water source refers to the location of water. Is it on the surface or underground? Surface water sources include rivers and their tributaries, canals, natural ponds, and runoff water, while underground water sources include aquifers of varying depth: 2 - 3 m below the surface during rainy season; 6 m during dry season in lowlands, and more than 10 m below in uplands (Goes 1999). Surface water accounts for the majority of renewable[1] water resources in Nigeria. Of the estimated 286.2 km^3 available in Nigeria, almost 280 km^3 are surface water, while only about 7 km^3 is solely groundwater (AQUASTAT 2010). Surface water is therefore the dominant source for private irrigation systems, although there are no exact figures. Although it is often difficult to distinguish between irrigation based on groundwater from that based on surface water, groundwater is often used for the livestock sector and domestic household use rather than for crop production (Giordano 2006).

[1]Renewable water resources include average annual flow of rivers and recharge of aquifers generated by precipitation within the country, as well as inflows from upstream countries and part of the water of border lakes or rivers (Frenken 2005).

Water application methods[2]

In irrigation, water is applied either through gravity flow distribution, pressurized distribution (Walker 1989), or hand watering. Most private irrigation systems in Nigeria are hand watering or gravity flow distribution. Hand watering occurs when the farmers cast water from buckets to the soil and plants with their hands. Among gravity flow distribution systems, furrow irrigation and basin irrigation are common. In furrow irrigation, the farmer digs rows of ditches that are typically 120 - 150 cm wide (Mkpado 2008). The water is supplied at the top end of the plots and flows down to the bottom. In basin irrigation, water is stored in small compartments encircled by earth banks built on the plots. Pressurized irrigation (i.e., drip and spray irrigation) is still rare in Nigeria, possibly because of the high initial outlay required for installation.

Seasonality

Seasonal irrigation systems are often observed during the dry season, while nonseasonal irrigation systems operate in both the dry and wet seasons. Dry season irrigation is typically used for growing vegetables or other food crops, and often involves rental of unused land (Kay 2001, Ogunjimi and Adekalu 2002). Nonseasonal irrigation may be practiced even during the rainy seasons, if farmers perceive irregularity in the rainfall pattern. The practice of nonseasonal irrigation is relatively rare in Nigeria. The popularity of wet season irrigation in more arid countries like Mali (Underhill 1984), however, indicates that it could also be practiced by farmers in extremely arid regions in Northern Nigeria.

Constraints under different irrigation systems

This section reviews the key inputs in irrigation systems in Nigeria, establishes the potential constraints associated with these inputs, and assesses how they might differ across alternative irrigation systems. The analysis is conducted largely on the basis of a review of existing literature with the objective of identifying knowledge gaps that will require further in-depth research.

Conceptual framework

The decision to invest in a certain irrigation system is a function of several key factors:

> Irrigation system = *F*(Type and amount of inputs needed, Cost of inputs, Return | Agroclimatic condition, Socioeconomic condition, Existing policy framework of the government).

Figure 1 illustrates that the type of irrigation system selected depends on the inputs required to build and operate it. The key inputs associated with irrigation include water, labor, land, and other complementary inputs. The type and amount of each input are further influenced by its cost and the expected returns of using irrigation. All this is further subject to prevailing agroecological, socioeconomic, and policy conditions. The constraints faced by farmers in adopting a particular irrigation system are therefore better understood by identifying the type and amount of inputs involved, the costs associated with the inputs, and the returns expected. Appropriate policies can then be designed for different irrigation systems, which would help lower the costs of relevant inputs and thereby improve the returns on irrigation.

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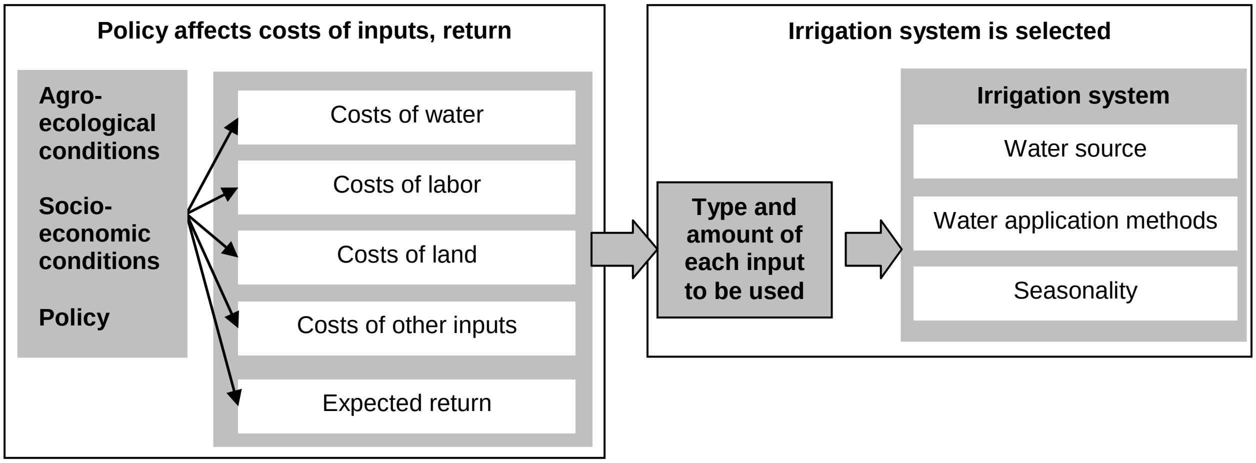
[2] Along with irrigation, drainage of water is also often categorized as surface drainage or subsurface drainage. This report, however, will not touch on the drainage methods. It also has been suggested that drainage is not always practiced by the majority of farmers, and if it is, only surface drainage is employed (Lawal et al. 2007).

Figure 1. Determinants of irrigation systems and relevant constraints



The cost of water will vary depending on its source, quality, and the tools required to extract it. Although manual and skilled labor is used for building and operating irrigation systems, their intensities, and the associated labor cost, differ depending on the system employed. Cost associated with land varies according to its location (distance to the body of water, whether it is located upstream or downstream), the ownership agreement, sizes and shape of plots, topography, and soil qualities. Other complementary inputs, including modern irrigation equipment, fuel and electricity, farm equipment, fertilizer, seed, and agrochemicals, are used at different intensities with different systems, and therefore their availability affects the cost and return of different irrigation systems.

Similarly, the derivation of economic return from irrigation is complex. One component is the value of crops produced with irrigation, measured by the market price, or the farmer's own assessment if consumed at home. A second component surrounds the opportunity cost of collecting and storing water for use in irrigation, which also may be used for other household purposes. A third component is irrigation technologies as a form of insurance for farmers against the risks associated with rainfall uncertainty. The return in such cases is similar to the risk premium farmers must otherwise pay. Lastly, over the long term, return is measured by the effects of irrigation on soil quality, such as soil erosion or changes in soil salinity levels.

Effect of constraints on different irrigation systems

Based on the conceptual framework in the previous section, this section describes the type and amount of inputs needed, cost of inputs, and expected return for each irrigation system defined in Table 2. While much of the discussion is conceptual, relevant empirical studies are cited wherever available.

Water source

Surface water

Input types and quantity: Irrigation relying on surface water sources requires less labor in detecting them and constructing facilities to obtain the water than is required for obtaining water from underground sources. Typically the land in the proximity of natural bodies of water (for example, along a river) is irrigated, as relatively less labor is required to transport water to the plots. The location of irrigation is confined to the reach of the body of water, unless farmers have facilities to convey the water beyond the reach of the source.

Cost of inputs: The cost of detecting water and transporting it to the plots depends on the location of the bodies of water. The cost of accessing water depends on its availability, which is determined by rainfall levels, evaporation rates, water consumption by other users at the regional level (i.e., by users upstream), and water rights policies. Water from surface sources is generally stable in its quality in terms of purity and chemical content so that the cost for cleaning the water is minimal, although there is some evidence of higher levels of pollution with human and animal feces in mining ponds (Damen et al. 2007).

Land used for irrigation from a surface body of water is often concentrated near the water, typically beside rivers and natural ponds, leading to intense competition and higher cost of land. Also, competition among farmers or a complicated land tenure system around the natural body of water may increase the cost of land.

Return on investment*:* Although empirical information is scarce in Nigeria, water from surface sources is more often used for crop production than other agricultural-related production. Therefore, the return may be derived mostly from the crop production. In such cases, the return may be more uncertain, as it depends on the production and market uncertainty of these crops. The relatively stable quality of water described above, however, may reduce some of the uncertainty in quantity and quality of production and therefore mitigate the uncertainty in return.

Underground water

Input types and quantity: Irrigation drawn from underground water sources often requires labor with more experience and technical know-how both in finding the water and gaining access to it (i.e., digging wells). Additional inputs are also required in the form of irrigation equipment like tube wells, boreholes, and digging tools. Although irrigable land from underground systems tends to be limited by proximity to the water – as is the case for surface bodies of water – groundwater is often detected a good distance from surface water. Furthermore, the ability to lift water from such sources allows farmers more options in selecting the location of irrigable lands.

Cost of inputs: Given that more technical know-how and experience are required to detect and access underground water, the cost of accessing such water is higher (Sabo and Zira 2009). With Nigeria's aging farming community, this cost could be lower if this community has learned from experience.

Underground water is associated with uncertain water quantity and quality, which makes the water supply less stable, and therefore possibly more expensive. The quantity of available water from relatively small underground aquifers is determined by the location and by the level of use by others. Aquifers take a relatively long time to replenish, more so in upland aquifers than in floodplains (Goes 1999). Floodplain as a source of shallow aquifer and residual moisture may become less available due to increasing water consumption at upstream urban centers (Acharya 2004), or it may be destroyed unexpectedly by unscheduled releases of water from upstream dams (allafrica.com 2010). Such factors, however, may not significantly raise the costs of obtaining underground water if farmers have sufficient indigenous knowledge of the production environment in nearby regions and knowledge of alternative floodplains (Thomas and Adams 1999).

The quality of underground water (i.e., the degree of freedom from pollution by chemicals such as ammonia and nitrate) tends to be more variable than surface water (Ibe and Agbamu 1999). It is inferred that underground water generally seems to have better quality than surface water in Northern Nigeria (Acharya 2004), while the opposite is true in the Southern Nigeria. Acidity and low chemical fertility are reported in southwest floodplains (Effiong and Ibia 2009) where irrigation relies on groundwater. Floodplains near urban areas may be polluted with heavy metals (Mashi and Alhassan 2007). Farmers with more education or contact with extension agents may have better information about the quality of water and its impact on productivity, and therefore avoid using water from underground sources. They may also have better access to modern irrigation inputs. Farmers without much formal education may have sufficient indigenous knowledge on such issues. However, it is unclear how such quality issues would affect farmers' decisions to invest in underground water sources.

Although irrigation pumps can be used for extracting water from surface sources, availability of pumps may have greater impact in reducing the cost of extracting water from underground sources. Irrigation pumps or tube wells may still be expensive and unaffordable without financial support for the majority of Nigeria's farmers, and they have only been widely adopted as a result of public programs supported by the World Bank and the United Nations Food and Agricultural Organization (FAO) and implemented by the Agricultural Development Projects (ADPs). The cost of irrigation pumps or tube wells to individual farmers can be lowered through community-level development programs like the Second Fadama Development Program (Fadama II). The Fadama II project helped increase farmers' adoption of irrigation pumps, particularly in the more arid areas, by subsidizing them (Nkonya et al. 2008), and by assisting in lowering transaction costs associated with the purchase of pumps, such as the costs of finding pump sellers or assessing the quality of pumps (Takeshima, Adeoti, and Salau 2010). However, the majority of farmers are still without access to such programs even under the third Fadama Development Project (Fadama III) and many continue to face high prices. Cheap fuel in Nigeria has helped facilitate the use of pumps (Kay 2001), but the supply remains volatile, which could limit further adoption (Ogunjimi and Adekalu 2002).

Although access to land remains important in this system, it may be less of a constraint than with surface water systems, particularly if farmers have sufficient equipment for lifting water from the underground sources.

Return on investment: Water from underground sources may be used for purposes other than crop production, such as for livestock or domestic household use. Given that underground water quality is more uncertain, it could possibly negatively affect crop productivity and animal and human health if consumed.

Low salinity and sodicity (amount of sodium in water) of groundwater in certain regions can create a nutrient imbalance in the soil (Graham, Pishiria, and Ojo 2006). Using groundwater for irrigation may therefore have uncertain effects on long-term land productivity.

Water application methods

Furrow irrigation

Input types and quantity: In addition to water, land, and labor, furrow irrigation may require other inputs such as higher-capacity water pumping machines to distribute water over relatively large plots (Mkpado 2008), or land-clearing machinery or draft animals or both for grading and leveling plots. In the absence of machinery, manual labor could be used to grade plots before building furrows so that water would flow smoothly. When farmers lack access to modern machinery for grading and leveling, the land should have a fairly smooth surface as water is distributed across the plot by gravity. Furrow irrigation generally requires a lot of labor (Ogunjimi and Adekalu 2002), particularly at the beginning of the production season. Using fewer furrows by digging a furrow every other row instead of every row may provide reasonable yield (Ramalan and Nwokeocha 2000). A study in South Africa indicates that 54 hours of labor is required per hectare for furrow irrigation (Branscheid 1997), including field preparation and water application. Without agricultural machinery more manual labor may be needed for harvesting and marketing as the furrow methods have shown higher production levels than hand watering.

The type of land used for furrow irrigation may have soil with higher infiltration rates (Mkpado 2008). While basin irrigation and hand watering can be used for plots of varying size and shape, furrow irrigation may require plots that are relatively large, rectangular-shaped, and unfragmented, which lowers the number of water discharges needed per hectare and thus makes production more profitable.

Cost of inputs: The cost for this type of irrigation is high. The cost of equipment and machinery, the cost of labor (particularly at the beginning of production season), and lack of access to plots suitable for such irrigation may serve as significant constraints to furrow irrigation.

Return on investment: Water distribution efficiency and yields under different cropping patterns may differ significantly from basin irrigation or hand watering. However, there are few empirical studies in Nigeria that can shed light on this issue. Soil erosion is common among furrow irrigation systems and can have negative impacts on long-term productivity. Favorable market conditions for the crop (for example, higher profitability and lower price risks) may also be needed for farmers to adopt furrow irrigation. Furrow irrigation tends to be used for crops like maize or cotton, which are grown on broader plots, and less for crops like rice and vegetables. However, applications of furrow irrigation for maize seem to be uncommon in Nigeria because profitable maize production requires more fertilizer and attracts lower prices than vegetables.

Basin irrigation

Input types and quantities: As in furrow irrigation systems, basin irrigation may require significant labor at the beginning of the production season – to build the new basin or repair a basin built in the previous season – albeit with variation. A study by Branscheid (1997) indicates that 68 hours of labor is required per hectare for basin irrigation, including field preparation and water application. Without sufficient agricultural machinery, more manual labor may be needed for harvesting and marketing as this method is likely to lead to more production than hand watering. With high fertility, the type of land used for basin irrigation may require soil with lower infiltration rates (Mkpado 2008).

Cost of inputs: Cost of obtaining land with the low infiltration rates and high fertility suitable for basin irrigation varies across regions. Some parts of Northern Nigeria are covered with vertisols[3] with low water infiltration rates and high fertility appropriate for basin irrigation (Ahmad 1996, Troll 1965), although another study categorizes some of this region under luvisols[4] (FAO 1986), whose suitability for basin irrigation is less clear.

As in furrow irrigation systems, cost of labor can be high in basin irrigation, particularly at the beginning of the production season. In Nigeria, however, the labor cost for basin irrigation may be slightly lower than furrow irrigation as farmers using basin irrigation in Southwest Nigeria complain less about higher labor costs than those using furrow irrigation (Ogunjimi and Adekalu 2002). Similarly, the high cost of land-clearing machines can be a significant constraint.

[3]One of the soil types defined under the FAO soil taxonomy (FAO 1998). Vertisol is dark clay soil found mainly in tropical Africa.
[4]One of the soil types defined under the FAO soil taxonomy (FAO 1998). Luvisol develops under forested conditions.

Return on investment: In Nigeria, the use of basin irrigation is particularly common for rice (Ngatcha 2009) and vegetables (tomatoes and okra); the output markets for these crops significantly affect the return. Increasing urbanization in Nigeria seems to create profitable markets for vegetables grown in the dry season, particularly in peri-urban areas, raising the return of basin irrigation in these areas. Basin irrigation, however, tends to cause waterlogging of the plots, which can damage the crop and lower the long-term soil productivity.

Hand watering

Input types and quantities: Although less labor may be required at the beginning of the production season for land preparation, hand watering may use more labor than furrow or basin irrigation, particularly during the plant growth process. Hand watering generally uses only simple tools like a bucket. Unless labor is plentiful, hand watering is used for small plots and is likely to occur very close to the body of water.

Cost of inputs: Costs of land under hand watering may be lower, given that there are fewer requirements on topography or plot sizes as opposed to the constraints described under furrow or basin irrigation. More manual labor may be needed for watering of plants during the plant growth stage; the costs of labor may be lower for land preparation but higher during the plant growth stage than for furrow or basin irrigation. Costs of water, in terms of applying water appropriately, can be higher than furrow or basin irrigation because broadcasting of water can lead to too much irregularity in water received by the plants. Costs of water, however, may be lower in some cases. While water on the plots under furrow or basin irrigation often covers significant areas of plot surface (including between plants), hand watering can save water by direct application to the plants.

Return on investment: Hand watering is commonly used for vegetable production in peri-urban market gardens, and the return may be subject to the uncertainty in vegetable markets. Hand watering, however, tends to operate on a smaller scale than furrow or basin irrigation. In addition, hand watering may be adopted when expected yield or market conditions are highly uncertain, and there is a need to hedge such risks by growing multiple crops. When farmers prefer mixed farming in order to avoid risk from crop failure or their particular market environment, they may prefer hand watering of targeted crops, instead of irrigating the entire plot with furrow irrigation or basin irrigation, which are more suitable for mono-cropping. The return on hand watering is therefore relatively stable.

Seasonality

Seasonal

Input types and quantities: Dry-season irrigation is often practiced by irrigators migrating from other regions. Water and land used for dry-season irrigation are therefore obtained significantly far from farmers' home base. Labor too may be obtained from outside the home region unless enough workers migrate with the irrigators. Irrigators using the pump or tube wells may either bring their own or rent them at their destinations. Empirical information on how many irrigators obtain required inputs at different locations for seasonal irrigation in Nigeria is scarce.

Cost of inputs: Cost of water can be high as water pollution, particularly in peri-urban areas, may be more serious during the dry season due to lack of the rain that flushes some of the polluted water (Lynch, Binns, and Olofin 2001). When farmers migrate from other regions to practice dry-season irrigation, they rent the plots at their destinations. As observed in certain regions of Nigeria such as Kwara State (Adeoti 2006), these irrigators may have less information on local conditions (such as accessibility of water near the land, soil conditions of the plots, and output market conditions). The cost of water may thus be higher under these schemes and profitability more uncertain.

The cost of obtaining land for dry-season irrigation in Nigeria can be more affected than nonseasonal irrigation systems by the availability of land in the floodplain. Dry-season irrigation in Nigeria is popular on the floodplain using the residual moisture after the flooding during the rainy season. There are uncertainties in the availability of such floodplain land, as the availability is determined by the amount of precipitation during the rainy season, as well as when the flooding recedes (Hartenbach and Schuol 2005). The cost of land is also affected by land tenure systems and land market conditions, as land is often rented for dry-season irrigation. Land suitable for dry-season irrigation also is often used by pastoralists for grazing. Pastoralists regard the land as theirs, which can lead to friction between the two groups (Kimmage 1991, Tarhule and Woo 1997). The land tenure system in most places in Nigeria is still complicated, as many plots have multiple owners (Fu et al. 2010) and for many farmers the transaction costs of renting the land is high. Such complexity, uncertainty, and potential friction raise the cost of land used in dry-season irrigation.

The cost of land can also rise if the owners renting the land to farmers are concerned about long-term impacts on land productivity, and the rent they charge may reflect these concerns. This is because farmers renting the plot try to maximize the return from the current production season only, and practice irrigation without consideration for potentially harmful long-term effects such as soil erosion, waterlogging, or salinization. Trends in land rental in parts of Nigeria (for example, on the Jos Plateau (Pasquini et al. 2004)) may indicate that the acquisition of land for dry-season irrigation has become easier. Acquiring irrigation equipment can also be costly in dry-season irrigation, particularly if farmers do not have official permits for using the land. A high risk of expulsions from the land may discourage farmers from buying equipment, as it is often difficult to dismantle an irrigation system in seconds in the event of such expulsions (Drechsel et al. 2006).

<u>Return on investment</u>: Dry-season irrigation in Nigeria is often used for growing vegetables – possibly because of lower labor wages during the dry season – but this has not been empirically confirmed. While vegetables can attract higher average returns, particularly when grown in peri-urban areas, they are also perishable, and thus price uncertainty in the market greatly affects the return. Return may be uncertain if farmers rent land with poor soil quality and fertility.

Nonseasonal

<u>Input types and quantities</u>: Unlike seasonal irrigation, nonseasonal irrigation inputs may be obtained by farmers in their home environments, because farmers practicing nonseasonal irrigation may be more likely to use their own land in both the dry and rainy season without migrating to other regions.

<u>Cost of inputs</u>: Many of the issues described under dry-season irrigation are less relevant under nonseasonal irrigation. The wage rate in rural areas, however, may be higher during the rainy season as there are more farmers using labor for farming. Irrigation in Nigeria is labor intensive (Adeoti 2009) and supplementary irrigation practiced during rainy season may also be fairly labor intensive, although less water needs to be lifted or applied. Vegetable production, for which irrigation often is used in both the dry and rainy seasons, may be also labor intensive. High labor costs in the rainy season may limit irrigation to peri-urban areas with higher profitability and relatively abundant labor.

Return on investment: In nonseasonal irrigation, farmers may not only consider the return on investment from irrigation for the current production season, but also the return for the season following that, because they tend to keep using the same land over multiple seasons. Farmers may therefore be more anxious about possible negative impacts of irrigation on land productivity, including waterlogging, salinization of soils, and soil erosion. Farmers using nonseasonal irrigation systems may discount returns from irrigation, and they may even be slightly discouraged from adopting nonseasonal irrigation in the first place.

Smallholder farmers' selection of irrigation systems

Smallholder farmers account for the majority of the food production in Nigeria and therefore it is important to assess which types of irrigation systems are viable for these smallholder farmers. From the descriptions of different irrigation systems in the previous sections, we can very roughly assess which irrigation systems smallholder farmers are likely to adopt, based on the level of resource constraints faced under each system and the associated costs of each system.

The popularity of different irrigation systems with smallholders in Nigeria is roughly consistent with descriptions of the systems in some of the Nigerian studies (Table 3). Smallholder farmers in Nigeria are more likely to adopt hand watering irrigation systems; systems based on surface water sources; systems requiring only minimal traditional tools, with no modern equipment; and systems only operating during the dry season. On the other hand, irrigation from groundwater sources, particularly where it requires the use of equipment such as tube wells, may be less likely to be adopted due to general lack of access to affordable equipment. Furrow and basin irrigation may be difficult for smallholder farmers due to high rural labor costs at the beginning of production season, lack of access to machinery or draft animals for land preparation, and the need for plots without fragmentation. Although dry season irrigation may be adopted, constraints on water quality and availability, or the complicated land tenure system, or both may limit adoption of these systems.

Table 3. Likelihood of adoption by smallholder farmers, by irrigation system

Parameter of irrigation system		Cost	Return	Likelihood of adoption by smallholder farmers
Water sources	Surface	**Low**	**Safe**	**High**
	Underground	**High** (High cost for skilled labor, equipment)	**Risky**	**Medium**
Water application method	Furrow	**High** (High labor costs at the beginning of production season)	**Risky**	**Low**
	Basin	**High** (High labor costs at the beginning of production season)	**High, risky**	**Medium**
	Hand watering	**Low**	**Low, safe**	**High**
Seasonality	Seasonal	**Medium**	**High, risky**	**Medium**
	Nonseasonal	**High** (High cost of labor during rainy season)	**Risky**	**Low**

Source: Authors.

Due to the lack of information, it is very difficult to assess the likelihood for adoption of nonseasonal irrigation among smallholders. The likelihood may, however, be low for the adoption of nonseasonal irrigation, not just because there is large variation in rainfall during the rainy season (though the rainfall is sufficient), but also because labor tends to be more expensive during rainy season as more farmers are engaged in their own farming. Consequently, farmers grow crops such as cereals that are less labor-intensive and require little irrigation, rather than vegetables.

Conclusions

Increasing farmers' adoption of irrigation in Nigeria requires a good understanding of the constraints faced by farmers in using private irrigation systems. While most irrigation systems in Nigeria are gravity-fed, the diverse agroecological and socioeconomic conditions – and farmers' lack of resources to overcome such conditions – suggest that farmers' demand for irrigation technologies may also have diverse characteristics and lead to various forms of irrigation practices. Such diversity would suggest a need for irrigation policies that can meet varying needs of different farmers.

This report attempts to provide a framework to categorize irrigation systems in Nigeria and describe how the constraints can differ, and how such constraints may limit the options for smallholder farmers in adopting irrigation technologies. Two key implications emerge from the review.

First, knowledge gaps are still large in Nigeria regarding the practice of each irrigation system and constraints for each system. Most importantly, the information is still scarce on exactly where each irrigation system exists, the actual number of farmers and extent of areas involved in each of these irrigation systems in Nigeria, and farmers' actual constraints determining their choice of irrigation systems. While currently available empirical information and simple economic principles partly allow us to project the cost and locations of irrigation systems, more empirical information is needed to verify such projections. Similarly, information is scarce on how each irrigation system has impacted agricultural productivity in Nigeria. While the productivity impact is expected to differ across irrigation systems, there has been little investigation in Nigeria of such differences. More empirical information is needed to assess general productivity impacts of irrigation in Nigeria as well as their variation across systems.

Second, the irrigation systems viable for smallholder farmers in Nigeria may be limited to relatively simple designs, such as systems relying on surface bodies of water and hand watering. While furrow and basin methods and systems using water from underground sources also have potential for cost effectiveness, adoption of these irrigation systems may be difficult for smallholder farmers. The potential for future expansion of irrigation by smallholder farmers may therefore be limited to particular geographic locations adjacent to the surface water bodies and to those farmers who have access to such lands and a sufficient labor force. More empirical information is needed to assess the profitability structure of each irrigation system in order to identify how much government support may be needed to incentivize smallholder farmers to adopt other irrigation systems with potentially higher impact on productivity growth.

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