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Typology of Farm Households and Irrigation Systems

Some Evidence from Nigeria

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ABSTRACT

Irrigation is considered an important factor for agriculture and food security. Knowledge gaps, however, still exist with regard to how farmers in Africa south of Sahara, including Nigeria, are using irrigation. Given the diverse agroecological and socioeconomic environment in countries like Nigeria, understanding the diverse patterns of irrigation use and their associations with household characteristics is important in designing how irrigation can contribute to the agricultural transformation. This report summarizes the typology of farm households and irrigators in Nigeria. We apply a cluster analysis method to the Living Standard Measurement Survey (LSMS)—Integrated Survey on Agriculture data and various secondary data. We also compare the costs and inputs used across different irrigation crops, as reported in Nigeria. Findings indicate that the three major irrigation systems in Nigeria are (1) labor-intensive diverted stream irrigation of rice, (2) supplementary irrigation of coarse grains and legumes using groundwater, and (3) dry season irrigation of vegetables. Each crop is irrigated during a specific season and using a specific water source and irrigation system. Farmers' choice of irrigation system tends to depend on many factors. For example, in the South, tractorization is often a necessary precondition for rice irrigation. In the North, intensive irrigation of rice and vegetables may make sense only if labor is cheap, whereas irrigation of sorghum and legumes is supplementary and may not affect farm households' behaviors. Although more rigorous studies are needed in the future, observed patterns of irrigation use in Nigeria indicate that the policies aiming to raise agricultural productivity and to develop the value chains of key crops may need to be based on an understanding of why irrigation is used in specific ways in different systems and of what the key constraints in scaling up such systems in other locations are.

Keywords: irrigation, farm household typology, cluster analysis, Nigeria

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1. INTRODUCTION

Irrigation has the potential to play an important role in helping Nigeria achieve its goal of food security through increased food production and poverty reduction. Nigeria has relatively rich water resources, and its irrigation potential can be as high as 3 million hectares (ha) (You et al. 2011), which is 10 percent of the country's cultivated area of 30 million ha. However, it is estimated that only about 0.9 million ha) use water management techniques, of which approximately 0.2 million ha are irrigated with equipment such as pumps and tube wells (Takeshima et al. 2010). Of the cultivated area that benefits from water management, more than 95 percent uses farmer-managed, small-scale irrigation schemes. Because of the dominance of privately managed irrigation schemes, irrigation use in Nigeria may be highly affected by the socioeconomic characteristics of farmers and the agroecological factors of the areas in which those farmers reside. Even among irrigators in Nigeria, characteristics of irrigation systems may vary in terms of crops, water sources, and seasonality (Takeshima et al. 2010; Takeshima, Salau, and Adeoti 2010).

Although there is a broad literature on the profitability of irrigation in Nigeria, relatively few studies provide insights into what types of rural households use irrigation and which resources of those households may be enabling the use of irrigation. Examining such patterns is important for understanding how irrigation contributes to food production in Nigeria, given the characteristics of production technologies, input resource constraints, and profitability of crops grown. Determining what types of rural households are using irrigation also has important implications on the potential of irrigation for enhancing agricultural productivity, as envisaged under Nigeria's Agricultural Transformation Agenda. Are the characteristics of irrigators similar to those of nonirrigators in terms of resource constraints, such as access to market and input costs? If they are similar, then support for the expansion of current irrigation use may make sense. However, if they are different, then the role of irrigation may be limited, at least in the short run, because irrigation can be profitable only under particular environmental conditions. In addition, its profitability may depend a great deal on various dimensions of the resource constraints of households.

In this report, we analyze the typology of rural farm households in Nigeria to understand the types of households that are mainly using irrigation. We then conduct further typology analysis within those irrigators to examine the major types of irrigators based on irrigated crops. From the large typology analysis, we qualitatively examine the hypotheses that (1) the role of irrigation varies widely across farm types; and (2) when irrigation transforms the production characteristics, and when it does not. Furthermore, by constructing a typology of irrigators, we examine the hypothesis that several diverse irrigation systems are defined by crops and seasons, each with distinct characteristics, particularly in terms of input intensity and commercial orientation. We then discuss the interpretation of the observed irrigation typology, key knowledge gaps that need to be addressed in future studies, and potential policy implications of addressing such knowledge gaps.

This report provides descriptive empirical information on the typology of irrigation systems, using a recent national dataset from Nigeria, as well as literature describing the production costs and inputs used under major irrigation systems. Although the discussions in this report are rather descriptive, with more rigorous analyses left for future studies, this report does shed light on important diversity in irrigation practices, irrigation's role in agricultural household economy, and significant constraints to agricultural transformation in Nigeria.

2. IRRIGATION POLICIES IN NIGERIA

Irrigation policies in Nigeria have historically supported both large-scale public irrigation projects and small-scale private irrigation. Throughout the 1960s and 1970s, much focus was placed on developing several large-scale irrigation schemes, particularly in the northern schemes, with the aim of increasing production of certain cereals, such as wheat (Abalu and D'Silva 1980). The Nigerian government also launched large-scale agricultural projects in response to the food shortage following the Nigerian-Biafran War, which lasted from 1967 to 1970, and after the severe drought in 1972–74. These projects included the National Accelerated Food Production Programme, the Agricultural Development Programme, and Operation Feed the Nation (Shimada 1999; Okolie 1995). Many of these initiatives focused on developing large-scale production of staple crops through modern inputs and technologies, including irrigation. River Basin Development Authorities (RBDAs), the public institutions primarily in charge of managing irrigation schemes, began operations in the Sokoto-Rima and Chad basins in 1974 (Akpokodje, Lançon, and Erenstein 2001); by 1976, nine more RBDAs had been launched (Okolie 1995). By the mid-1980s, however, many of these large-scale public irrigation schemes had been found ineffective, mainly due to poor management, difficulty in collecting user fees (Enplan Group 2004), inefficient supply of fertilizer, high labor costs, less-than-expected water supply, low agronomical potential, and low profitability of promoted irrigation crops, such as wheat (Andræ and Beckman 1985). In addition, large irrigation schemes often created negative externalities, such as a change in water flows or displacement of indigenous residents (Okolie 1995; Thomas and Adams 1999; Yahaya 2002). These negative externalities were possibly due to the insufficient ex ante assessment conducted prior to the constructions, though positive effects of dams and large-scale irrigation projects have been found in other countries in Africa South of the Sahara (Strobi and Strobi 2011; Dillon 2011).

A policy shift into small-scale irrigation was observed in the 1980s. Renewed attention was paid to Nigeria's large water resources, including inland valley bottoms (often referred to as *fadama* areas in Nigeria) and indigenous water control, which has long been practiced by farmers using traditional water-lifting devices (Kimmage 1991). More public financial support had been directed toward the construction of boreholes and tube wells, as well as for the distribution of motor pumps (Kimmage 1991). Starting in 1993, three phases of the National Fadama Development Programme were implemented (Fadama I, II, and III), in which financial support was provided to farmers for the acquisition of productive assets, including irrigation pumps, boreholes, and tube wells in *fadama* areas (Nkonya et al. 2012). The focus on small-scale irrigation seems to have had mixed results. When the small-scale irrigation focus was successful, motor pumps seem to have contributed to the agricultural transformation seen in parts of northern Nigeria (Goldman and Smith 1995; Tiffen 2003). However, as is shown later in this report, areas irrigated through small-scale irrigation, such as through the use of pumps and boreholes, remain small. Such low use may be due to the high labor costs needed for other activities than water lifting (Takeshima et al. 2010) and the high maintenance and repair costs of pumps due to insufficient development of a local manufacturing and service industry, which in turn led to high transaction costs and higher costs for using pump based irrigation system (Takeshima, Adeoti, and Salau 2011).

The Agricultural Transformation Agenda (ATA) guides current agricultural policies in Nigeria. It describes Nigeria's key priority goals in the agricultural sectors, including import substitutions of crops, such as rice; development of value chains for key crops, including rice, cassava, sorghum, cocoa, and oil palm; and employment creation through improved finance mechanisms for acquiring a range of inputs, such as seeds, fertilizer, and industrial clusterization (FMARD 2011). Support for irrigation development under ATA is embedded in various aspects of value chain development for relevant commodities—in particular, rice and horticulture. In general, ATA's support focuses on rehabilitating existing irrigation projects where reservoirs already exist and where only the construction of irrigation and drainage canals is required (FMARD 2011). Within the context of rice value chain development, support for small-scale irrigation facilities in *fadama* areas is expected to be provided by the Government (FMARD 2012). At the same time, governments of several states are expected to continue their own support of small-scale irrigation, such as through the distribution of pumps.

ATA's focus on irrigation is mostly on the rehabilitation of existing irrigation facilities. Large-scale irrigation schemes are unlikely to become dominant sources of food production of targeted crops in the short to medium term, because both the areas developed under the large-scale irrigation schemes and the areas currently cultivated within these schemes account for a relatively small share of total irrigated area in Nigeria (Takeshima et al. 2010). In addition, some of these schemes were built in locations that are not necessarily favorable in terms of water availability and soil quality (Andræ and Beckman 1985); thus, potential production growth from rehabilitation is questionable. Substantial growth in agriculture, if achieved under ATA, is expected to come from growth of small-scale private irrigation indirectly induced by other policy measures, such as input subsidies and industrial clusterization, wherever those measures are effective. It is therefore crucial to understand the private small-scale irrigation systems in Nigeria, their linkages with farm household characteristics, and their production intensity.

3. TYPOLOGY OF PRODUCTION SYSTEMS AND CHARACTERISTICS OF IRRIGATORS

Constructing a typology of farm households and irrigators is useful for understanding the key drivers of production system adoptions in which irrigation is used, while also capturing the diversity of agricultural production practices and economic activities, and potentially the role of irrigation in livelihood. Typology analysis has been widely used in the literature. Various typologies of households have been studied using the cluster analysis method in Nigeria and other countries in Africa south of the Sahara (Erenstein et al. 2003; Dorward 2006). The method classifies agents based on the similarity or dissimilarity of their characteristics. Few studies, however, have analyzed the typologies of rural farm households in Nigeria by taking into account multiple crops (as opposed to a single crop) and the households' nonfarm activities or assets, both of which could affect their resource constraints and demand for irrigation.

Cluster Analysis Method

Cluster analysis is often used as a tool for classifying agents into various types (Anderberg 1973). Much literature provides a detailed technical presentation of clusterization methods (Hansen and Jaumard 1997). However, in this report, we provide only the conceptual presentation. Cluster analysis methods typically rely on dissimilarities (such as in numerical values) among the observations. According to the descriptions of cluster analysis by Hansen and Jaumard (1997), our cluster analysis proceeds in the following steps: First, we select a sample $O = \{O_1, O_2, \ldots, O_N\}$ of N observations for analyzing clusters. We then measure p characteristics of the sample, yielding $N \times p$ data matrix X. From matrix X, we compute $N \times N$ matrix $D = d_{k\ell}$ of dissimilarities between samples, where $d_{k\ell}$ usually satisfies

$$d_{k\ell} \geq 0,\ d_{kk} = 0,\ d_{k\ell} = d_{\ell k} \text{ for } k, \ell = 1, 2, \ldots, N.$$

We then apply cluster analysis to dissimilarity matrix D by selecting (1) the types of clustering (partitioning and constructing hierarchy of partitions) and (2) the criteria for expressing homogeneity or separation of clusters and particular algorithms. Hierarchical partitions and K-mean partitions are two commonly used partitioning methods. Agglomerative hierarchical clustering algorithms are one of the most used hierarchical methods. In this algorithm, we start from N clusters consisting of each observation and gradually agglomerate multiple observations that are similar to each other until the number of clusters decreases to the desired level. In K-mean clustering, mean values of each variable are set arbitrarily for each set number of clusters, and observations are assigned into each cluster, depending on their distance to the mean values. For selecting the type of clustering, we combine the hierarchical partitions with K-mean partitions, as proposed by Punj and Stewart (1983) and Siou et al. (2011), because combining two partition methods can significantly improve the accuracy of clustering. Regarding selection of the criteria for expressing homogeneity and separation of clusters, we follow Punj and Stewart (1983) and Siou et al. (2011), in which the standard deviations of variable p are minimized within the cluster, whereas the standard deviations of the cluster mean of p are maximized across clusters. (See Appendix for detailed descriptions of the approach.) Although cluster analysis provides statistical criteria, and although the methodology by Punj and Stewart (1983) and Siou et al. (2011) tends to suggest that the more clusters, the better, we limit the maximum number of clusters to be generated; the interpretation becomes difficult if there are too many types of households. Using hierarchical partitions is useful because the samples tend to be clusterized in hierarchical structure; thus, increasing the number of clusters may not affect most of the other clusters that are already identified.

Variables Used

Tables 3.1 and 3.2 summarize the variables used to create the dissimilarity matrix *D* in the cluster analysis. Variables are selected to capture both the resource constraints (consisting of agroecological and socioeconomic factors) and the production behaviors of the farm households. We use Living Standard Measurement Survey (LSMS)—Integrated Survey on Agriculture 2010 data, supplemented with various secondary data. The LSMS data, which were collected jointly by the National Bureau of Statistics and the World Bank, cover all of Nigeria and represent all types of farm households. Thus, these data are appropriate for analyzing the typology of major farm households in Nigeria. The LSMS data consist of a postplanting (PP) survey, covering the information from January 2010 through August 2010, and a postharvesting (PH) survey, covering the information from September 2010 through March 2011.

Table 3.1—Variables used in cluster analysis

Categories	Variables
Agroecological (Natural resources)	Farming system zones—North and South (LGA level)
	Soil type (majority of types in each LGA)
	Historical rainfall variation (LGA average)
	Distance to major rivers (LGA average)
Market access	Total population density in the region where the household is located
	Distance to towns of 20,000 inhabitants
Resources (Human resources)	Household size
	Level of education and literacy of household head
	Gender of household head
Resources (Assets)	Total value of assets, not including land
	Size of livestock-equivalent stock or value of animal stock owned
Production scale	Total rainfed area
Production scale under irrigation	Whether using irrigation
	Total irrigated area
Production intensity	Overall input intensity, measured as the total value of inputs per farm household
	• Fertilizer
	• Seed (value of purchased seed only)
	• Agrochemicals (pesticide, herbicide)
	Animal traction (number of days per hectare)
	Whether using tractor
	Tractor (number of tractors used per hectare)
	Hired harvesting labor, measured as labor expenditure per hectare of total area
	Whether the household took out any loan or credit (including nonagricultural credit) from either formal or informal sources
Income, nonfarm activities	Total expenditure per person
	Salary/wage income in off-farm activities last month
	Net nonfarm business income last month
	Remittance income last month—other types of income (savings interest, rental of property, and so on)
Labor resource	Real LGA median wage of land clearing or preparation (standardized by maize price)

Source: Authors.

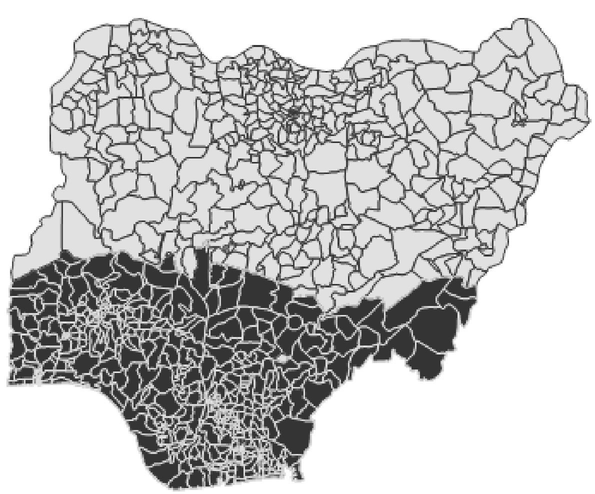
Table 3.2—Crop dummy variables used in cluster analysis

	North	South
Cereals	• Maize • Rice	
Coarse grains	• Millet + Sorghum	
Root crops	• Cassava + Yam + Cocoyam	
Vegetables	• Pepper + Onion + Okra + Tomato	
Legumes	• Ground nuts • Soybean • Cowpea + Sesame	
Tree crops		• Oil palm • Cocoa • Banana + Plantain
Other		• Melon • Pumpkin

Source: Authors.

Agroecological variables are obtained from secondary sources. Farming system zones in Nigeria are roughly distinguished by North and South, as defined in Dixon, Gulliver, and Gibbon (2001)(Figure 3.1). The North system consists of pastoral systems, agropastoral / sorghum and millet systems, irrigated systems, and cereal / root crop mixed systems. The South system consists of root crop systems, tree crop systems, and coastal artisanal systems. Although Dixon, Gulliver, and Gibbon (2001) defined the irrigated system for the North, its definition is unclear, and many irrigators in the North are found outside this system. We therefore included irrigated system as part of the North system. The variable for soil types is a dummy variable, defined at the local government area (LGA) level, indicating whether the soil is alluvial soil and whether it covers the majority of area in each LGA. A soil map was obtained from FAO/IIASA/ISRIC/ISSCAS/JRC (2012). Historical rainfall variation is calculated as an average within each LGA, using data obtained from the University of East Anglia. Distances to the major rivers and dams are Euclidean distances measured in geographical minutes, calculated as the averages for each LGA using the locations of major rivers in Nigeria based on FAO (2000) and locations of dams based on AQUASTAT (2012), respectively. We also use LGA-level population density, and LGA average distance to towns of 20,000 inhabitants, each of which was constructed using data obtained from the Nigeria 2006 Population Census (National Population Commission 2010) and Harvest Choice (2012), respectively.

Figure 3.1—North and South regions defined in this study (unit: local government area)



Source: Authors.

Other variables in Table 3.1 are constructed from the LSMS data to measure human resources, assets, production scale (both rainfed and irrigated), production intensity, income, nonfarm activities, and labor resources. These variables are selected to capture comprehensive types of resource constraints defining agricultural households' economic activities, which play important roles in those households' choices of crop production methods and input use intensity. In addition, we use dummy variables to indicate whether the farmer grows each of the key crops (or a group of crops) in either the North or the South (Table 3.2). The crops listed in Table 3.2 are selected because they represent the different combinations of crops grown in Nigeria, which were assessed based on a separate cluster analysis (results not shown here). Due to scarcity, legumes in the South and tree crops, melon, and pumpkin in the North are excluded from dummy variables.

In the cluster analysis, these variables are standardized for the North and the South systems after dropping outliers, so that their distributions have zero mean and one standard deviation. Out of 5,000 households surveyed in LSMS data, we confine our analysis to farm households that reported the information about at least one crop plot, because our focus is on irrigation; thus, we exclude the 2,018 nonfarm households. Samples for analyses are further reduced due to missing information on key variables, including real farm wages and total farm sizes, as well as other data inconsistencies. Because these data should be more reliable for cultivations of irrigated plots, dropping these samples will not significantly affect our analyses on irrigation typology. After dropping the missing observations and outliers, we have 953 farm households from the South and 1,236 from the North, roughly covering 73 percent of the farm households in the sample. Cluster analysis is conducted independent of sample weights, because the application of sample weights to the aforementioned procedure has not been widely discussed in the literature. Sample weights are used, however, when calculating the proportion of farm households falling into each type.

4. TYPOLOGY OF IRRIGATORS

This section begins with a summary of important irrigation patterns inferred from the descriptive statistics of the Living Standard Measurement Survey (LSMS)—Integrated Survey on Agriculture data regarding crops irrigated, sources of water, equipment used for irrigation, and sales patterns of irrigated crops. We then discuss the results of cluster analysis on the key typology of farm households, including irrigators and nonirrigators and typology among irrigators.

Irrigation Crops, Water Sources, and Water-Extraction Methods

Tables 4.1–4.3 summarize the major crops irrigated, water sources, and water-extraction methods identified in the LSMS data. We assume that all crops (except cassava, yam, or plantain) planted in the dry season are irrigated, even though some data for the dry season (reported in the PH survey and planted between September through December 2010) do not specify the use of irrigation. Tables 4.1–4.3 should not be interpreted as the national figure (although the LSMS data do allow us to calculate the national figure using weights), because some observations were excluded during data cleaning. In addition, water sources and irrigation methods (Tables 4.2 and 4.3, respectively) were available only in the PP survey. Tables 4.1–4.3, however, still provide rough pictures of the diversity of irrigated crops and irrigation systems in Nigeria.

Table 4.1—Major irrigation crops in Nigeria [a]

	Postplanting survey			Postharvesting survey Planted in September–December			Season (R = rainy season)
	Area under irrigation (ha)	Number of farmers using irrigation	Number of obs. using irrigation	Area under irrigation (ha)	Number of farmers using irrigation	Number of obs. using irrigation	
Rice	89,495	184,785	45	22,949	52,136	5	Mostly R
Maize	43,876	131,328	27	1,431	12,819	2	
Sorghum	44,902	130,070	23	384	6,024	1	R
Millet	27,749	145,000	24				R
Cowpea	23,141	104,689	19				R
Ground nut	1,282	8,204	3				R
Soyabeans	1,074	4,777	3				R
Cassava[a]	21,244	58,236	13				
Yam[b]	4,125	33,130	8				
Cocoyam	1,491	29,663	7	3,547	12,602	2	
Sugar cane	6,094	43,548	8	450	2,768	2	
Banana	3,053	19,037	7	64	6,722	1	
Mango	1,109	5,990	4				R
Acha	572	4,166	3				
Oil palm tree	74	4,633	3				R
Cocoa			2	996	7,630	1	
Potato	280	3,884	3	5,787	26,177	5	
Sweet potato	1,991	15,347	5	3,731	12,819	2	
Sesame seed				3,221	4,777	1	
Green vegetables	190	4,112	3	1,696	11,227	2	
Lettuce	193	9,316	4	658	6,787	1	
Cabbage	28	2,529	3				
Carrot	28	2,529	3				
Tomato	2,747	15,843	6	39,177	63,824	17	
Okra	23	7,272	3	11,318	18,178	4	
Onion	191	2,144	3	8,813	23,541	5	
Pepper	9,615	37,712	11	19,726	86,514	17	
Sweet pepper	3,664	14,156	5	7,580	16,102	4	
Ginger	572	4,166	3				

Source: Authors' calculation based on Living Standard Measurement Survey – Integrated Survey on Agriculture (LSMS) 2010 data.

Note: [a] Figures in the table are obtained using sample weights and may be subject to large standard errors. For mixed cropping plots, the area for each crop was divided equally by the number of crops grown. Even if some crops are simply left growing on the same plots where other crops are irrigated, they are nevertheless counted as irrigated.

Table 4.2—Crop and irrigation sources in Nigeria (ha): Postplanting survey[ab]

	1: Well	2: Borehole	3: Lake/pond	4: Created pond	5: River/stream
Rice	785	12,109	3,303	703	43,808
Maize	2,813	1,805	10,806	3,137	18,824
Sorghum	3,317	11,237	1,052	1,780	990
Millet	3,368	19,282	1,052	1,622	1,147
Cowpea	785	5,302	1,052	2,483	5,415
Ground nut		1,282			
Soyabeans					1,074
Cassava			1,621		16,346
Yam			1,088		2,691
Cocoyam		860	560		13
Sugar cane			132		5,473
Banana			213		2,840
Mango	226				883
Acha					572
Tomato	226				2,329
Pepper	2,532	4,051	213		2,362

Source: Authors' calculation based on LSMS data.

Notes: [a] Figures in the table are obtained using sample weights and may be subject to large standard errors. For mixed cropping plots, the area for each crop was divided equally by the number of crops grown.

[b] Some information is missing, as not all irrigators reported their system.

Table 4.3—Crop and irrigation method (ha): Postplanting survey[a,b]

	1: Divert stream	2: Bucket	3: Hand pump	4: Treadle pump	5: Motor pump	6: Gravity
Rice	20,371	8,048	777	296	16,212	0
Maize	1,669	847	8,446	2,137	9,861	
Sorghum	1,555	7,450	714	1,592	456	
Millet	1,597	14,206	714	1,453	394	
Cowpea	368	4,887	719	1,888	2,289	
Ground nut		1,052				
Soyabeans					513	
Cassava	28,218	11,806	1,300		8,530	
Yam	1,341	4,004	883			
Cocoyam	50			5,111		
Sugar cane	1,543	6,592	116		4,248	151
Banana	927	6,874	0	50	1,057	
Mango		2,947		755	264	
Acha				1,373		
Tomato	68	2,809		755		
Pepper	1,187	1,900	109	1,396	1,379	

Source: Authors' calculation based on LSMS data.

Notes: [a] Figures in the table are obtained using sample weights and may be subject to large standard errors. For mixed cropping plots, the area for each crop was divided equally by the number of crops grown.

[b] Some information is missing, as not all irrigators reported their system.

According to Table 4.1, a diverse set of crops were irrigated; these crops include rice, maize, coarse grains (sorghum, millet), legumes (cowpea, ground nuts, soyabeans), and vegetables (peppers, tomatoes). Irrigation of these crops, including rice, is typically small scale, with the typical size of the irrigated plot being less than 1 ha. Irrigated crops and seasons are somewhat related. In Table 4.1, we assess whether each crop is mostly irrigated in the rainy season or the dry season, using information from the PP and PH surveys. In general, most irrigation seems to be carried out in the rainy season rather than the dry season, except for vegetables and some rice or maize. Coarse grains and legumes are mostly irrigated in the rainy season. Cereals (rice and maize) are also irrigated in the rainy season, though some dry season production is observed. Overall, although the figures need to be interpreted carefully, because sample size is small, most of the irrigated area in Nigeria is for rice, maize, coarse grains and legumes, and vegetables.

Irrigation practices are also diverse in terms of water sources and irrigation methods (Tables 3.2 and 3.3, respectively), both of which are also correlated with irrigated crops. Common sources of irrigation water include surface sources, such as rivers or streams, and groundwater sources, such as wells and boreholes (Table 3.2). Although rice and maize are mostly irrigated from rivers, streams, lakes, or ponds, coarse grains and legumes are mostly irrigated from groundwater sources. Popular water-application methods include diverted stream and motorized pump, as well as manual water-lifting devices, such as buckets, hand pumps, and treadle pumps (Table 3.3).

Different water sources and irrigation methods lead to differences in water-extraction costs, as well as in water application capacity, though it is difficult to obtain the exact differences in water extraction costs and irrigation efficiency (Takeshima, Salau, and Adeoti 2010). Regarding the irrigation methods, diverted stream may require the least labor for conveying water, though construction and maintenance of a waterway, such as a canal, may incur substantial costs. The water-extraction capacity of motor pumps compared with manual pumps (hand or treadle) is, in theory, roughly proportional to the ratio of the horsepower of the motor pump, which is typically 2–7 HP in Nigeria (Takeshima et al. 2010), to the horsepower of human labor, which is typically about 0.1 HP (Awulachew, Lemperiere, and Tulu 2009). Thus, a 2-HP motor pump can irrigate approximately 1.2–2.0 ha in 12 hours, assuming 50 percent irrigation efficiency (Awulachew, Lemperiere, and Tulu 2009; personal communication with farmers in Nigeria), whereas most of the manual pumps can irrigate only about 0.1 ha in 12 person-hours. The differences among all the manual water-extraction methods (bucket, hand pump, or treadle pump) may be small. Thus, use of irrigation methods may be associated not only with the area irrigated but also with the cost of manual labor.

Sales patterns also differ across key irrigated crops. Table 4.4 summarizes how each of the irrigated crops is sold. As expected, most of the rice or vegetables irrigated are for sale. One striking feature is the paucity of maize or coarse grain irrigators selling their crops. For example, only 10 percent of rainy season maize irrigators sold their maize. Note that this does not seem to be because maize is mixed with other irrigated crops, as there appear to be substantial irrigators growing single crops of maize. Similar patterns are observed for coarse grains and legumes; however, the significant majority of sorghum and millet irrigators give out their harvests as gifts. In some irrigated plots, other crops, such as rice or vegetables, are also irrigated, grown, and sometimes sold. There are, however, many plots in which none of these crops are sold.

Table 4.4—Share of farmers selling harvested crops grown on irrigated plots (rainy season)

	% selling harvest	% giving harvest as gift
Maize	10	32
Rice	69	
Vegetables	81	
Sorghum/Millet	20	73
Legume	19	33

Source: Authors' calculation based on LSMS data.

Typology of Farm Households and Irrigators: Results of Cluster Analysis

Major Types of Farm Households and Irrigators in Nigeria

Tables 4.5–4.8 summarize the main characteristics of each farm household type as identified through the cluster analysis. Sample weights are used to calculate the proportions of farm households falling into each type, as well as the relevant sample statistics. We classify farm households into six types in the South system and six types in the North system. We choose to use six types for each because this number of types seems to better capture the potential clusters, based on the aforementioned statistical criteria. In addition, the values of each variable in Tables 4.7 and 4.8 are often statistically significantly different across types. Tables 4.5 and 4.6 provide brief descriptions of each type in both the South and the North systems, whereas Tables 4.7 and 4.8 present more detailed characteristics of each type.

Table 4.5—Typology of farm households (South)

Type	Characteristics	Major crops	Share (%)[a]
1	Very small scale, Low input intensity, Income and asset poor, Low literacy, Female head	Root crops, maize	33
2	Very small scale, Suburban, Low input intensity, Medium income and asset level, High literacy	Cassava	7
3	Very small scale, Low input intensity, Medium asset level, High literacy	Root crops, maize	40
4	Small-to-medium scale, Low input intensity, High dependency on agricultural income	Sorghum, root crops, cereals	8
5	Small-to-medium scale, Medium input intensity, Active engagement in nonfarm income-earning activity	Cocoa	8
6	Medium scale, Remote, Asset wealthy, Active engagement in nonfarm income-earning activity, Facing higher agricultural wage, High input intensity, High tractorization, Some irrigation	Rice	4

Source: Authors.
Note: [a] The share is among the sample used in the analysis.

Table 4.6—Typology of farm households (North)

Type	Characteristics	Major crops	Share (%)[a]
1	Small scale, Large livestock assets, Low literacy, Low-to-medium input intensity, Some animal traction, Some irrigation	Maize, sorghum	16
2	Small-to-medium scale, Remote, Poor, Low input intensity, Some tractorization, High agricultural wages, High dependency on agricultural sales	Maize, sorghum	8
3	Small scale, Poor, High literacy, Medium input intensity, Some animal traction, Some tractorization	Maize, rice, sorghum	7
4	Small scale, Poor, Low agricultural wages, High literacy, Low-to-medium input intensity, Some animal traction, Some irrigation	Coarse grains, legumes	39
5	Small scale, Income and asset poor, Low literacy, Low input intensity, Some animal traction, Some irrigation	Coarse grains, legumes	27
6	Very small-scale, High literacy, Low agricultural wages, Good market access, High input intensity, Some irrigation, Some tractorization	Rice, vegetables, coarse grains	3

Source: Authors.
Note: [a] The share is among the sample used in the analysis.

Table 4.7—Key characteristics of each type (South)[a]

	Farm household types					
	1	**2**	**3**	**4**	**5**	**6**
Number of observations	315	58	415	73	64	28
% share among sample farmers[b]	33	7	40	8	8	4
Main crop[c]	*c*	*c*	*cm*	*syc*	*a*	*r*
Subcrop[c]	*ym*		*y*	*rm*	*c*	
Real wage (daily wage / kg of maize)	10	13	10	13	14	18
Population density (per km^2)	290	500	320	106	292	79
Distance to 20,000 town (minutes)	2.1	2.5	1.8	3.5	1.6	3.8
% on alluvial soil	9	100	13	0	0	3
Rainfall risk (std. in mm)	256	266	272	155	199	142
Distance to nearest dam[e]	1.3	2.2	1.4	0.6	0.5	0.4
Distance to river[e]	0.016	0.016	0.016	0.017	0.017	0.017
Household size	4	5	6	6	4	7
% female	46	12	11	2	17	1
% literate	3	47	93	40	59	65
Household assets, excluding land (USD)	68	242	388	347	156	779
Livestock assets (USD)	0	0	19	130	0	133
Expenditure on nonfood consumption goods (USD per capita per year)	46	74	91	44	83	144
% with nonfarm income source	30	50	65	25	80	84
% owning some plots	14	13	16	10	44	55
% taking out credit/loan	18	24	25	35	17	38
% using irrigation	0	8	1	1	5	17
Rainfed area (ha)[d]	0.2	0.3	0.2	1.4	1.0	2.3
Total area (ha)[d]	0.2	0.3	0.2	1.4	1.0	2.6
Fertilizer cost (USD/household)[d]	0	0	0	0	0	93
Seed cost (USD/household)[d]	0	0	0	0	0	0
Chemical cost (USD/household)[d]	0	0	0	20	13	56
% hiring harvesting labor[d]	21	9	17	37	62	72
% with crop sales (excluding gift)[d]	71	29	70	92	99	90
% with crop sales (including gift)[d]	75	45	75	95	99	90
% using animal traction[d]	0	0	0	0	0	0
% using tractors[d]	1	0	1	2	2	98

Source: Authors.

Notes: [a] Figures in the table are median within each type, except the figures in percentage, which are adjusted for sample weights.

[b] % shares are adjusted for sample weights.

[c] Crop (*c* = cassava, *m* = maize, *r* = rice, *s* = sorghum, *y* = yam, *a* = cocoa). Main crop is grown by more than 50 percent of households in each type, and subcrop is grown by more than 33 percent.

[d]These are for production between January 2010 and August 2010, due to data limitation.

[e]These distances are Euclidean distances.

Table 4.8—Key characteristics of each type (North)

	Farm household types					
	1	**2**	**3**	**4**	**5**	**6**
Number of observations	185	109	76	463	369	34
% share among sample farmers[b]	16	8	7	39	27	3
Main crop[c]	*ms*	*ms*	*mr*	*sgl*	*sgl*	*rl*
Subcrop[c]			*s*			*sgv*
Real wage (daily wage / kg of maize)	13	17	14	8	8	8
Population density (per km^2)	129	119	133	164	153	109
Distance to 20,000 town (hours)	3.0	3.0	2.8	2.4	2.4	2.4
% on alluvial soil	1	4	11	5	4	17
Rainfall risk (std. in mm)	160	142	159	141	142	140
Distance to nearest dam[e]	0.46	0.45	0.40	0.43	0.54	1.30
Distance to river[e]	0.017	0.017	0.017	0.017	0.017	0.017
Household size	7	7	7	6	6	7
% female	2	3	2	1	1	0
% literate	7	85	88	91	5	57
Household assets, excluding land (USD)	189	317	511	287	134	305
Livestock assets (USD)	533	73	144	453	533	453
Expenditure on nonfood consumption goods (USD per capita per year)	35	70	64	38	33	58
% with nonfarm income source	46	66	73	63	51	85
% owning some plots	37	40	24	23	19	10
% using irrigation	7	2	9	2	2	90
Rainfed area (ha)[d]	0.7	0.7	0.7	0.6	0.8	0.2
Total area (ha)[d]	0.7	0.7	0.7	0.6	0.8	0.5
Fertilizer cost (USD/household)[d]	47	32	53	30	0	60
Seed cost (USD/household)[d]	0	0	0	0	0	0
Chemical cost (USD/household)[d]	0	11	30	0	0	21
% hiring harvesting labor[d]	59	23	76	75	44	98
% with crop sales (excluding gift)[d]	60	71	71	57	56	61
% with crop sales (including gift)[d]	89	83	92	82	82	90
% using animal traction[d]	70	5	68	72	47	56
% using tractors[d]	6	0	37	4	3	10

Source: Authors.

Notes: [a] Figures in the table are median within each type, except the figures in percentage, which are adjusted for sample weights.

[b] % shares are adjusted for sample weights.

[c] Crop (*m* = maize, *r* = rice, *s* = sorghum, *l* = millet, *g* = legumes, *v* = vegetables). Main crop is grown by more than 50 percent of households in each type, and subcrop is grown by more than 33 percent.

[d] These are for production between January 2010 and August 2010, due to data limitation.

[e] These distances are Euclidean distances.

In the South (Tables 4.5 and 4.7), the largest groups are very small-scale cassava producers, which can be further categorized into two groups based on their asset and literacy levels. Their production has low input intensity in terms of fertilizer, seed, and chemical expenditure per hectare. Other types are root crop (cassava and yam) producers who also grow maize or sorghum in a small-scale manner with low input intensity. Two other types in the South are classified into cocoa producers and medium-scale intensive producers who typically grow rice; the total farm sizes of these two types are typically larger than 1 ha. Medium-scale intensive producers use the highest input expenditure per household, with typically USD 90 and USD 56 being spent per year for fertilizer and agrochemicals per household, respectively. Their production is fully tractorized, and they typically have additional income from nonfarm self-employed business. Medium-scale intensive producers are asset wealthy, and the medium-scale intensive producers in the South have distinct characteristics from other types of farmer, operating in remote areas where land is possibly abundant but labor is relatively expensive.

In the North (Tables 4.6 and 4.8), the most common types of producers are coarse grains and legumes, as well as maize producers, agropastoralists, and small-scale intensive producers. The coarse grains and legumes systems can be further classified into two types: one with higher literacy and slightly more intensive production, and the other with low literacy and low input intensity. The medium-scale maize and sorghum system consists of the poorest farmers, whereas the small-scale subsistence system is found among medium-income households in suburban areas. The remaining types can be classified into a maize and sorghum group with rainfed rice production and a commercial irrigated rice system.

The share of irrigators within each type of farm household and their key characteristics provide interesting insights into how irrigation might or might not affect farm households' behaviors. A higher share of irrigators within each type of farm household may indicate that irrigation is an important determinant for household characteristics such as production input intensity, whereas a lower share may indicate the opposite. Characteristics of types of households with a higher share of irrigators are somewhat different from other types of farm households in both the South (Table 4.7) and the North (Table 4.8). In both regions, irrigation use is typically associated with rice production, and to a lesser extent with vegetables and other grains.

In the South, groups with a higher share of irrigators (cocoa producers and medium-scale intensive producers) are found closer to major dams, whereas in the North, they are found more on alluvial soils, indicating that the potential for irrigation is partly determined by the proximity to dams or soil type (Table 4.7). In the South, these two groups, especially medium-scale intensive producers, use modern inputs intensively, often hire harvesting labor, operate in remote areas near households that are relatively asset endowed, and have nonfarm income sources. However, the share of tractor users in medium-scale intensive producers is more pronounced than the share of irrigators. Realizing high returns from irrigation in the South, therefore, seems to require sufficient mechanization, economies of scale in production, availability of modern inputs, and sufficient capital. Irrigation in the South may also typically make sense only for crops like rice, which requires intensive water control even during the rainy season, but not for other crops that may grow relatively well under rainfed conditions.

In the North, a high share of irrigators is found among small-scale intensive producers that mainly produce rice or vegetables. However, some fraction of irrigators is also found in sorghum, maize, and legume producers (Table 4.8). Characteristics of small-scale intensive producers indicate that irrigation for rice and vegetables in the North may provide a high return from smaller plots through input-intensive production, if labor is cheap. Unlike in the South, tractorization does not seem a requirement for irrigation in the North. For other groups growing sorghum, maize, and legumes, shares of irrigators are low, indicating that irrigation is mostly supplementary and may not affect the behaviors of these households. However, the share among all irrigators falling into these groups may be high due to the large share of these groups among all farmers. For example, although shares of irrigators are only 4 percent in Types 4 and 5, they account for two-thirds of farm households in the North. Therefore, in the North, although irrigation may affect the production behaviors of small-scale rice and vegetable growers, substantial shares of irrigation used in maize, sorghum, and legumes may have relatively small effects.

Use of irrigation is also associated with the gender of household head in the South and to a lesser extent in the North. Farm household types in which more female-headed households are found are less likely to use irrigation. For example, in the South, Type 1 households, which are both income and asset poor and which grow root crops and maize in a less input-intensive manner, are most commonly represented by female-headed households; use of irrigation by this type of household is almost nonexistent. Similarly, in the North, although female-headed households are generally rare across all household types, they are particularly rare among Type 6 households, which use irrigation most widely. Although its causes need to be empirically investigated in future studies, this pattern is consistent with observations in Nigeria that adoption by female-headed households of modern farm production technologies, including irrigation pumps, tends to be lower than that in male-headed households (Takeshima and Yamauchi 2012), partly due to challenges in access to finance (Okojie et al. 2009).

Results Among Irrigators

Tables 4.9–4.11 summarize the results from cluster analyses applied to irrigators in Nigeria. Irrigators in the data seem to be classified roughly into (1) labor-intensive diverted stream (LIDS) irrigators; (2) tractorized irrigators; (3) coarse grains and legumes irrigators; and (4) dry season irrigators. We name the types in this way for illustrative purposes; these classifications are not exclusive. For example, among LIDS irrigators, a few irrigators also use other irrigation systems. However, they are classified into LIDS irrigators because of the similarity in their characteristics—that is, because of the prevalence of their use of diverted stream in Type 1, the name "diverted stream irrigators" is used to illustrate their representative characteristics. Similar implications apply to other irrigator types. Each type is largely associated with particular crops irrigated. Irrigated crops for coarse grains and legumes irrigators are self-evident. LIDS and tractorized irrigators typically irrigate rice, and dry season irrigators typically irrigate vegetables.

Table 4.9—Typology of irrigation households[a]

Irrigator types	Major crops irrigated	Key characteristics	Share (%)
1. Labor-intensive diverted stream irrigators	Rice	Small scale, labor abundant with low real wage, better market access *North Central*	33
2. Tractorized irrigators	Rice	Commercial; largest irrigated area, though still small scale; input intensive, with heavy tractor uses *South East*	2
3. Coarse grains / legumes irrigators	Coarse grain, Legume (occasionally rice)	Rainy season irrigation, suburban, subsistence, small scale, some intensive use of fertilizer, animal traction *North West*	33
4. Dry season irrigators	Vegetables (occasionally rice)	Semisubsistence; small scale; intensive use of fertilizer, seed/chemicals, animal traction; relatively labor endowed, with low wage *North East / North West, South West*	33

Source: Authors' estimations.
Note: [a] The share is calculated based on the sample weights among the sample used in the analysis.

Table 4.10—Water source and systems in each type (rainy season)

Irrigator types	Water source	System
1. Labor-intensive diverted stream irrigators	Stream	Diverted stream
2. Tractorized irrigators	Stream	Diverted stream
3. Coarse grains / legumes irrigators	Borehole, Stream	Motor pump, some hand or treadle pump
4. Dry season irrigators	Stream	Motor pump, some treadle pump

Source: Authors' assessment based on cluster analysis.

Table 4.11—Irrigator typology characteristics

	Irrigator household types			
	1	2	3	4
Number of observations	36	4	30	37
% share among sample farmers[b]	33	2	33	33
Major irrigated crops[c]	*r*	*r*	*sl*	*v*
Major rainfed crops[c]	*s*	*cmy*	*g*	
Real wage (daily wage / kg of maize)	9	31	10	9
Population density (per km^2)	73	269	146	127
Distance to 20,000 town (hours)	3.0	3.2	2.4	2.4
% on alluvial soil	4	100	0	42
Rainfall risk (std. in mm)	141	243	149	149
Distance to nearest dam[e]	0.44	1.20	0.98	1.40
Distance to river[e]	0.017	0.013	0.017	0.017
Household size	8	6	7	7
% female	0	25	0	3
% literate	40	50	32	74
Household assets, excluding land (USD)	294	420	146	423
Livestock assets (USD)	144	9	520	173
Expenditure on nonfood item (USD per capita per year)	65	68	36	53
% with nonfarm income source	71	50	73	83
% owning some plots	13	0	29	19
% taking out any credit/loan	46	0	66	46
% using diverted stream[d]	65	100	9	2
% irrigating dry season	21	0	40	70
% irrigating dry season only	19	0	3	55
Irrigated area in rainy season (ha)[d]	0.3	0.3	0.5	0.0
Total area (ha)[d]	0.9	0.5	0.6	0.4
Fertilizer cost (USD/household)[d]	53	30	53	17
Seed cost (USD/household)[d]	0	22	4	0
Chemical cost (USD/household)[d]	21	233	24	0
% hiring harvesting labor[d]	88	50	69	58
% with crop sales (including giving out as gift)[d]	92	50	88	82
% with crop sales (excluding giving out as gift)[d]	74	50	56	73
% using animal traction[d]	39	0	78	36
% using tractors[d]	17	100	4	5

Source: Authors.

Notes: [a] Figures in the table are median within each type, except the figures in percentage, which are adjusted for sample weights, except the figures in percentage.

[b] % shares are adjusted for sample weights.

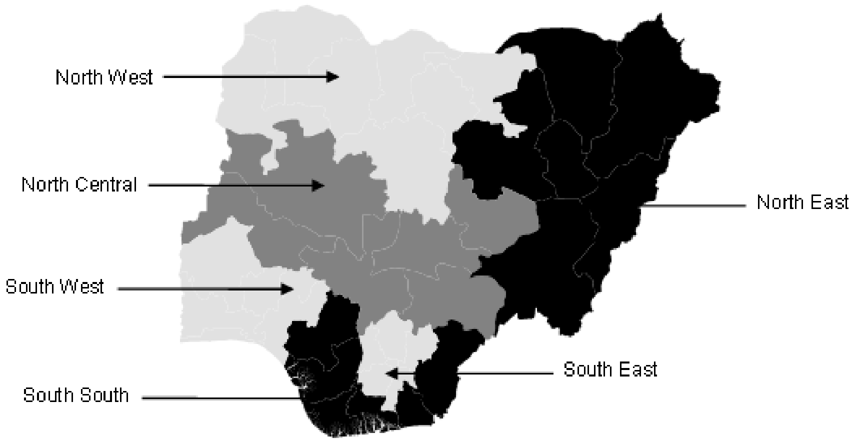
[c] Crop (*c* = cassava, *m* = maize, *r* = rice, *s* = sorghum, *l* = millet, *y* = yam, *g* = legumes, *v* = vegetables, *a* = cocoa, *p* = plantain, *o* = orange). Main crop is grown by more than 50 percent of households in each type, and subcrop is grown by more than 33 percent.

[d] These are for production between January 2010 and August 2010, due to data limitation.

[e] These distances are Euclidean distances.

Certain patterns seem to emerge in the characteristics of each type of irrigator. For example, LIDS and tractorized irrigators mainly consist of commercial rice irrigators, who tend to operate on the largest scale among all types of irrigators (though they are still small scale in terms of absolute plot size). These two types of irrigators are typically found in the North Central and South East regions (based on six geo-political zones of Nigeria shown in Figure 4.1), and their production is characterized by intensive use of modern inputs, such as fertilizer, improved seeds, and agrochemicals, as well as the use of tractors (possibly for land preparation) and hired labor. They also tend to source water from surface water sources (rivers or streams) and to then divert flows to their plots. Canal irrigation of this type is commonly observed in many public irrigation schemes in Nigeria (Table 4.10).

Figure 4.1—Six geopolitical zones in Nigeria



Source: Authors.

Coarse grains and legumes irrigators are typically found in the Northwest region. Their production is smaller scale, and their intensity of modern input use is relatively modest, though some growers show a relative intensive use of animal traction and hired harvesting labor. These irrigators rely mostly on groundwater sources, such as wells or boreholes, mostly extracted manually using hand or treadle pumps—though there are a few cases in which motor pumps are used (Table 4.10). Noticeably, one-third of these farmers give out most of their harvests as gifts, instead of selling.

Dry season irrigators are typically found in the Northeast and Northwest, but also in the Southwest. Vegetable irrigation in the Southwest appears to be increasing, particularly in urban areas such as Lagos (FAO 2012). Similar to coarse grains and legumes irrigators, these irrigators rely mostly on groundwater sources, such as wells or boreholes, mostly extracted manually using hand or treadle pumps—though there are a few cases in which motor pumps are used. These irrigators are typically more educated and asset endowed, and they tend to cultivate slightly larger areas than other irrigators, though their input intensity is relatively modest.

As discussed earlier, female-headed households are rarely found among irrigators (except the Type 2 irrigator households, in which one household among the four identified has a female head). This indicates that supporting females through irrigation technologies in Nigeria is generally challenging, regardless of which irrigable crops are promoted.

Profitability and Constraints of Irrigation for Key Crops

The typology of irrigators discussed in the previous section indicates that crops are highly correlated with different irrigator types. This suggests that irrigation of each crop is conducted in distinctive ways and that choosing different crops to irrigate involves changing production practices. It also suggests that the set of resource constraints faced by farmers may determine the profitability of irrigation for each crop. This section compares the profitability of irrigated and rainfed systems for key crops, mostly drawing on the descriptive statistics of the LSMS data and literature on production costs and input uses. Key crops are rice, vegetables (pepper, okra, onion, tomato), and sorghum, many of which are strategic crops for which value chain development is prioritized under the Agricultural Transformation Agenda (ATA) plan.[1] Such crop-based comparisons can be informative when trying to understand where irrigation makes sense for these crops. Key aspects for making this decision are differences in the types of inputs, which account for

[1] This includes the Rice Transformation Implementation Plan 2012, the Action Plan for Sorghum Transformation in Nigeria, the Plan for the Maize-Soybean Transformation in Nigeria, and the Mechanization Plan for Agricultural Transformation Agenda.

the large share of production costs. Table 4.12 summarizes the costs and uses of certain inputs for rice, vegetables, and sorghum in irrigated and rainfed systems, as calculated from the LSMS data. Because some of the key inputs, such as certain labor costs, are not available from LSMS data, Tables 4.13–4.15 present costs and uses of inputs from irrigated or rainfed systems as reported in the literature from Nigeria and neighboring countries.

Table 4.12—Cost and uses of certain inputs (LSMS postplanting data)[a]

	Rice			Vegetables		Sorghum	
	Irrigated	Irrigated: tractor users	Typical rainfed	Irrigated	Typical rainfed	Irrigated	Typical rainfed
Number of obs.	*56*	*15*	*309*	*11*	*223*	*21*	*1,200*
Number of crops grown on the irrigated plot	*1*	*1*	*3*	*2*	*3*	*3*	*3*
Fertilizer (USD/ha)	87	92	24	46	3	120	3
Seeds (USD/ha)	0	0	0	11	0	0	0
Herbicide (USD/ha)	52	84	6	0	0	12	0
Pesticide (USD/ha)	0	19	0	0	0	0	0
Harvesting labor (USD/ha)	75	88	0	18	0	22	8
Total area (ha)	0.4	0.4	0.4	0.26	0.16	0.56	0.51
Yield	3.3	4.2				1.0	1.2
Mechanization pattern							
% of plots using animal traction or tractor	46	—	46	40	14	71	59
% using animal traction	20		31	30	14	71	54
% using tractor	27	—	16	10	1	0	5

Source: Authors' calculation based on LSMS postplanting data.
Note: [a] Figures are medians of the samples in each category. Vegetables here include any of pepper, okra, onion, and tomato.

Table 4.13—Key cost components for irrigated rice in selected locations in Nigeria (USD/ha)

	Lake Gerio Irrigation Project	Kano River Irrigation Project	Duku Irrigation Scheme
	Jamala, Shehu, and Garba (2011)	Enplan Group (2004)	Akanbi, Omotesho, and Ayinde (2011)
State	Adamawa	Kano	Kwara
Year	Year unknown	2003	2006
Exchange rate (USD 1 =)	N150	N130	N130
Fertilizer	200	212	120
Herbicide / Insecticide	32	71	8
Seed	27	15	41
Machine			221
Labor	671	245	472
Total variable cost	1,186	780	862
Gross revenue	1,803	962	1,648
Gross margin	617	182	786

Source: Authors' calculations based on Jamala, Shehu, and Garba (2011); Enplan Group (2004); and Akanbi, Omotesho, and Ayinde (2011).

Table 4.14—Key cost components for irrigated vegetables in Sokoto state (USD/ha)

	Tsoho and Salau (2012)	Adewumi, Omotesho, and Bello (2005)
State / year	Sokoto / 2009	Sokoto / 2004
Exchange rate (USD 1 =)	N150	N120
Crops	Pepper, tomato, okra, and so on	Tomato
Seed	165	53
Fertilizer	102	74
Chemicals	58	29
Irrigation cost	180	144
Fuel	*168*	*109*
Pump maintenance	*12*	*35*
Labor	766	699
Family	*521*	*514*
Hired	*245*	*185*
Total variable costs (including imputed family labor cost)	1414	1,028
Gross revenue per hectare	2,570	1,243
Gross margin	1156	215

Source: Authors' calculations based on Tsoho and Salau (2012) and Adewumi et al. (2005).

Table 4.15—Key cost components for irrigated or rainfed sorghum in the Republic of Niger and in Kaduna state in Nigeria (USD/ha)

	Irrigated	Rainfed	Rainfed	
	Anders et al. (1984)		Baiyegunhi and Fraser (2009)	
	Republic of Niger		Kaduna state	
			Small– medium scale (~ 5 ha)	Large scale (~ 5 ha)
Seed	15	9	3	5
Fertilizer	54	0	71	50
Chemicals	0	0	0	0
Tractor use	46 (plowing)		48	
Postharvesting	96	2		
Irrigation cost	77	–	–	–
Labor[b]	282	318	283	110
Other (tools)	0	17		
Total variable cost	574[a]	346	322	165
Yield	2.50	0.65	1.50	0.84
Gross revenue	1,476	414	369	207
Gross margin	902	68	47	42

Source: Authors' calculations based on Anders et al. (1984) and Baiyegunhi and Fraser (2009).

Notes: Assuming US$1 = 300 West African CFA Franc (FCFA) in 1983, and US$1 in 1983 is US$2.3 in 2012 adjusting for inflation.

[a] Including imputed labor costs.

[b] This is based on the assumption of US$3 per day, which is similar to the daily wage in northern Nigeria.

Rice and Vegetable Irrigation

Irrigated rice production is typically monocropping (that is, the median number of crops grown is one) and is rarely mixed with other crops; this is different from rainfed rice production (Table 4.12). Irrigated rice production, in particular, is associated with higher costs of fertilizer, herbicide, harvesting labor, and tractor use compared to rainfed rice. The median yield in irrigated rice systems in LSMS data is 3.3 tons/ha; for tractor-using rice irrigators, it is 4.2 tons/ha. The amounts in Table 4.13, though varying in numbers, generally suggest similar trends. Thus, irrigated rice production in Nigeria is generally characterized by intensive uses of fertilizer and labor or mechanical power.

Vegetable irrigation in Nigeria is generally characterized by small plot sizes (Table 4.12). Use of fertilizer and chemicals is relatively low, even under the irrigated system. Seed costs are relatively higher, compared with rice or sorghum, possibly indicating the importance of the use of improved vegetable seeds in irrigated systems relative to farmer-exchanged seeds or recycled seeds, which are possibly more common for irrigated rice and sorghum. Irrigated vegetable production in various locations is also characterized by high labor inputs—these inputs are similar to those for irrigated rice but higher than those for irrigated sorghum. Similar to irrigated rice production, irrigated vegetable production is more sales oriented and input intensive, particularly of labor and seed.

The profitability and production costs for irrigated vegetables still leave some questions about why dry season irrigation seems to be used mostly for vegetables, rather than for sorghum or rice (though some rice is irrigated in the dry season), as indicated in Table 4.1. One reason could be that although the water requirement is high for vegetables, the high profitability of vegetables justifies the high irrigation costs. In addition, in some suburban areas, labor may be relatively more available as compared with during the rainy season, creating a more suitable environment for labor-intensive vegetables as compared with sorghum. Dry season vegetable irrigation may also be more common than rice irrigation, possibly because less fertilizer is needed (an unavailability of fertilizer is thus less constraining), though this needs further investigation in future studies.

Sorghum Irrigation

Although rice and vegetables are some of the major irrigated crops in West Africa, partial irrigation or water control is also used for other grains in Nigeria, such as sorghum, millet, and legumes (Adebayo 2003; Oguoma and Ikpeze 2008). In parts of northern Nigeria, it is also perceived that irrigation would "improve yield from traditional rainfed crops such as millet, sorghum, groundnut, and cowpeas" (Sokoto-Rima River Basin Development Authority (1980, p. 8), cited in Mitchell [1994]). These crops are grown either as single crops under irrigation or with other irrigated crops. In addition, as was shown in Table 4.4, most crops grown under irrigation are for consumption and gift, rather than for sale. As shown in Table 4.1, much of the irrigation of coarse grains and legumes is observed only in the rainy season, when it is used primarily to supplement the rainfall shortage or uncertainty.

The figures in the LSMS data (Table 4.12) and those in the literature (Table 4.15) on production costs for sorghum under irrigated and rainfed systems indicate potential key differences between sorghum irrigation and rice or vegetable irrigation. First, certain inputs, such as fertilizer, are used more intensively under irrigated systems, as compared with under rainfed systems. Fertilizer cost for irrigated sorghum is comparable to that for irrigated rice or vegetables. However, other inputs used under irrigation are still relatively lower when compared with the irrigation of crops such as rice or vegetables. For example, the labor cost for irrigated sorghum is relatively low compared to vegetable irrigation. The labor cost is and also not substantially higher than the labor cost for rainfed sorghum. This is possibly because irrigation is used to supplement during times of rainfall shortage and because the irrigation water requirement for sorghum is low. Sorghum irrigation tends to involve slightly larger plot sizes than plots for irrigated rice and vegetables, though the former are still as small as 0.5 ha. Thus, one hypothesis is that profitability of sorghum irrigation may depend relatively more on fertilizer and land availability than on labor, as compared with rice or vegetable irrigation.

Unlike for rice or vegetables, the economics of irrigated sorghum is less clear. Understanding its economics is important, however, because the popularity of sorghum irrigation indicates that better access to irrigation water will not automatically lead to irrigation of rice or vegetables. Following are some hypotheses that may be worth testing in future studies to understand the popular use of irrigation for sorghum (and millet and legumes). First, irrigated sorghum creates less-profit but also less costly-cost than irrigated vegetables and rice. Second, rainy season irrigation is predominant for sorghum, whereas dry season irrigation of either sorghum or other crops is rare. Moreover, most sorghum irrigators do not seem to irrigate rice or vegetables as well as sorghum, even though the use of irrigation for sorghum could indicate better access to irrigation water and thus higher potential for irrigated rice or vegetables. More evidence is needed to see whether this is because of the high input price (in particular, the high agricultural wages for labor) needed for rice and vegetable irrigation, or because of the insufficient water availability for rice and vegetables (both of which require more water than sorghum). Similarly, dry season irrigation of sorghum or other crops, such as rice and vegetables, is rare among rainy season irrigators of sorghum, possibly because access to an irrigation source in the dry season is highly limited—thus, there is not enough water for any of the crops, including sorghum.

As mentioned in the previous section, another important aspect of sorghum irrigation is that most irrigators do not sell their crops as harvest but rather give them out as gifts. The fact that few irrigators of sorghum sell surplus indicates that its profitability is currently low, while its irrigation is less constraining because manual pumps (bucket, hand pump, and treadle pump) are sufficient for irrigating sorghum (see Table 4.3). However, those who receive sorghum as gifts may face either higher irrigation costs, possibly due to remoteness of their plots from a well or borehole, or high opportunity costs. In addition, for many sorghum irrigators, the sorghum market may be distant, so that selling (buying) sorghum outside the area is not profitable for irrigators (buyers).

Although the irrigation of sorghum (together with millet and legumes) is a major farming type in Nigeria, current patterns of irrigation of this crop may have a limited impact on the marketed supply of sorghum. Irrigation's potential for contributing to the development of the sorghum value chain under ATA is unclear. Further studies are needed to assess (1) under what conditions irrigation may be important for transforming sorghum production and (2) how promoting current types of irrigated sorghum production may help the welfare of farmers.

5. DISCUSSIONS

Irrigation is often considered a critical input for agricultural transformation in developing countries like Nigeria. This report provides a brief picture of the types of Nigerian farm households that use irrigation, major types among those irrigator households, and the implications of irrigation potentials in Nigeria. Although more rigorous analyses are needed in future studies, the findings in this report suggest potential roles and limitations of irrigation for realizing agricultural transformation and poverty reduction in Nigeria.

Farm households in Nigeria are diverse in terms of resource endowments and production behaviors, and irrigators are concentrated in relatively few types of households. Such patterns indicate that the adoption of irrigation technology is still confined to specific production environments and is defined by agroecological characteristics, access to urban areas, asset endowments, and nonfarm income sources. Irrigation is adopted together with entirely new production practices that are characterized by input intensity.

Irrigation is used in different production systems in the North as compared with in the South. In the South, irrigation seems to make sense only under highly commercial, tractorized production of certain crops, like rice, and on medium-size land—except for small-scale vegetable irrigation in urban areas, which appears to be in the minority. In the North, where more irrigation takes place, irrigation is playing a more diverse role. For example, use of irrigation is associated with input-intensive production by the more commercial-oriented, labor-intensive, and machine-intensive production of rice and vegetables. In the North, irrigation is also used by less labor-intensive and machine-intensive productions of sorghum, maize, millet, and legumes within the community, where the harvest is given out as gifts, potentially for social capital investment. These gifts may also address the failure of output market for these crops, possibly due to high transaction costs.

Challenges exist in scaling up the existing irrigation of each crop. Although irrigation seems important in the intensive production of rice and vegetables, tractorization often seems to be an important precondition in the South, whereas cheap labor may need to be available in the North. In addition, choice of irrigated crops, water sources, irrigation methods, and irrigation seasons all seem highly correlated, suggesting that irrigation in Nigeria only makes economic sense for each crop with specific levels of water use given the level of aridity and rainfall and the cost of extracting water. Such specificity indicates the challenges in scaling up existing irrigation of each crop through increased production area or production intensity (through switching from one-season to semiannual irrigation), even though the greatest potential for irrigation may often exist in areas where irrigation is currently practiced because of agroecological and hydrological conditions. Policies promoting the value chain development for certain crops will have to build on such specificity of the conditions that make irrigation of each crop profitable, unless public support can drastically change the irrigators' resource constraints so that the entire cost structure changes, which is often quite challenging.

Future studies are needed to assess whether our interpretations of the economics behind the observed patterns and typology of irrigation systems and aforementioned important policy implications are correct. In particular, future studies should investigate in more detail the selected types of irrigation systems identified in this report, their profitability, and their cost structures, including the opportunity costs of various resources. The research should also consider how various policies that affect the prices of inputs, crops, and irrigation would alter farmers' behaviors.

APPENDIX: CLUSTER ANALYSIS METHOD

We combine the hierarchical method and *K*-mean method in the following way. First, we conduct hierarchical clustering using Ward's minimum variance method to obtain a first approximation of a solution. Second, we use the mean of j from the first step solution as a starting point for the subsequent *K*-mean method. In the *K*-mean method, we use Gower (1971) dissimilarity measure, which is appropriate for our data, in which the variables j contain both binary and continuous data.

We conduct a statistical test to determine whether the number of clusters we select is better than any small number of clusters. For each K cluster identified through the cluster analysis, we calculate the between- and within-cluster variances for each variable j. Following Siou et al. (2011), between-cluster variance for j is defined as

$$V_{\text{between-cluster } K,j} = \frac{1}{K-1} \times \sum_{i=1}^{K} \left(\bar{x}_{ij} - \bar{\bar{x}}_j\right)^2,$$

where $\bar{x}_{ij}$ is the sample average of variable j within cluster i, and $\bar{\bar{x}}_j$ is the average of $\bar{x}_{ij}$. In other words, $V_{\text{between-cluster } K,j}$ is variance of within-cluster mean of j,

$$V_{\text{within-cluster } K,j} = \frac{\sum_{i=1}^{K}(n_i - 1) \times s_{ij}^2}{\sum_{i=1}^{K}(n_i - 1)},$$

where n_i is the number of observations within cluster i, and s_{ij}^2 is the sample variance of variable j within cluster i.

According to Siou et al. (2011), the greater ratio of $V_{\text{between-cluster } K,j}$ to $V_{\text{within-cluster } K,j}$ indicates better clustering with respect to variable j. Siou et al. (2011) presented the natural log transformation of the ratio for each j. We calculate the statistic

$$\sigma_K = \sum_j \ln\left(\frac{V_{\text{between-cluster } K,j}}{V_{\text{within-cluster } K,j}}\right),$$

which proxies clustering performance across all j. Greater σ_K indicates that the cluster solution better identifies distinct farm household types across all dimensions of their characteristics. Table A.1 summarizes σ_K corresponding to our corresponding cluster analysis results in Tables 4.7, 4.8 and 4.11. In both South (Table 4.7) and North (Table 4.8), clustering into six types is better than clustering into any fewer number of types, and for irrigators (Table 4.11), clustering into four types is better than clustering into any fewer number of types.

Table A.1—Cluster analysis statistics (σ_k) for different number of clusters

Regions	Number of clusters				
	2	3	4	5	6
South (Table 4.7)	–131.785	–97.169	–79.573	–67.717	–66.333
North (Table 4.8)	–188.304	–133.073	–100.168	–97.696	–89.603
Irrigators (Table 4.11)	–115.049	–86.791	–50.826		

Source: Authors.

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