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Invest in small-scale irrigated agriculture: A national assessment on potential to expand small-scale irrigation in Nigeria

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ABSTRACT

Nigeria is faced with the daunting challenge to improve performance of its agriculture sector. Currently, crop production in Nigeria is predominantly rainfed; irrigation is perceived as an important means to boost agricultural productivity in the country. We estimated the potential of expanding small-scale irrigation in Nigeria, considering both biophysical and economic constraints. Under baseline conditions, the land area in Nigeria with investment potential for small-scale irrigation is estimated to be 1 million ha in dry-season and 0.65 million ha in rainy season, respectively. Further sensitivity analyses show that the estimated potentially irrigable area depends on input parameters such as irrigation cost, fertilizer application rate and farmers' risk aversion coefficient. These results reveal not only substantial potential of investing in small-scale irrigation in Nigeria, but also financial risks in the investment and importance of linking irrigation investment decisions to agricultural policies beyond irrigation to create coordinated strategy for agricultural development.

1. Introduction

Nigeria is the most populous country in Africa. Like many other Sub-Saharan countries, Nigeria has long been beset with poverty. According to the World Bank (2015), 46% of Nigerian people live in poverty. The prevalent poverty is also accompanied by high food insecurity. Titus and Adetokunbo (2007) found that the food insecurity incidence for the urban households is 49%. In another study, Akinyele (2009) reviewed evidence/knowledge from various sources on food and nutrition in rural Nigeria and concluded there is even more widespread food insecurity in rural areas: the malnutrition level of children is as high as 56 percent in a rural area of South West and 84.3 percent in three rural communities in the north. Addressing the challenges of poverty and food insecurity calls for boosting agricultural production in Nigeria. Agriculture is a main economic sector in Nigeria providing employment for 70% of population of the country. An increased agricultural productivity could not only improve food security, but also bring more income and enhanced well-being to Nigeria's large rural population.

Among various options for agricultural development in Nigeria, irrigation development is perceived as an important one. Currently, crop production in Nigeria is predominantly rainfed; the irrigated agriculture accounts for only 1% of cultivated area in the country (FAO AQUASTAT, 2017). This rainfed agriculture renders crop production in Nigeria vulnerable to climatic variability, both intra-annually and inter-annually. The intra-annual variability is characterized by the seasonality of rainfall. Nigeria has tropical climate with rainy and dry season(s) alternating with each other. Rainfed farming practices concentrate or are limited to months of the rainy seasons. When it comes to inter-annual variability, a large portion of agriculture in Nigeria is located in the Sudano–Sahelian region, which is historically prone to drought (Tarhule and Woo, 1997; Batterbury and Warren, 2001). As a natural phenomenon originating from inter-annual variability of precipitation, drought has huge impact on crop production and is linked to several famines in Nigeria's history (Van Apeldoorn, 1981; Olaniran, 2002). The development of irrigation may help remove these barriers imposed by climate variability on rainfed crop production and substantially benefit agricultural sector in Nigeria. Support for irrigation development has been embedded in the Agricultural Transformation Agenda (ATA) which guides current agricultural policies in Nigeria (FMARD, 2011).

This paper presents a study to assess investment potential of expanding irrigation in Nigeria. We focused on small-scale irri-

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gation. The existing irrigation systems in Nigeria consists of both small-scale and large-scale irrigation schemes. Small-scale scheme is the dominant one and accounts for more than 95% of the cropland area under irrigation in Nigeria (FAO AQUASTAT, 2017). The small irrigation schemes here refers to all irrigation developed under private ownership of smallholder farmers for harvesting water resources to augment water supply for crop production. It is in contrast to dam-based large-scale irrigation which use water in the reservoir behind the dams and are public financed. The implementation of small-scale irrigation may involve a collection of technologies, such as pulley-bucket, motor pumps and small reservoirs etc. Small-scale irrigation is viewed as a “bottom-up” or “grass-roots” approach to development (Kay, 2001), and has received much attention in recent years (Abric et al., 2011; de Fraiture and Giordano, 2014; Gebrehiwot et al., 2015). In Nigeria, the1960s and 1970s witnessed several initiatives to develop large-scale irrigation schemes, and these initiatives formed a part of Nigerian government’s effort to promote production of staple crops through introducing modern agricultural inputs and technologies (Abalu and D’Silva, 1980; Okolie, 1995; Shimada, 1999). However, these large-scale irrigation projects are generally perceived inefficient and ineffective. Only 20% of area equipped with large-scale irrigation is actually irrigated (Takeshima et al., 2010). The factors that lead to the failure of large-scale irrigation project include delayed construction, poor management, difficulty in recovering capital costs and less-than-expected water supply (Adams, 1991). Thus, there was a policy shift into small-scale irrigation since 1980s. As a demonstration of the shifted policy interest, on the Agricultural Transformation Agenda, priority is given to the rehabilitation of existing irrigation projects where reservoirs already exist rather than to constructing new irrigation reservoirs (FMARD, 2011), and in the World Bank’s three phases of the National Fadama Development Programme (Fadama I, II, and III), focus was made on providing financial support for farmers to acquire productive assets, such as irrigation pumps, for practicing small-scale irrigation (Nkonya et al., 2012). It is anticipated small-scale irrigation will constitutes main form of future irrigation development in Nigeria.

The rest of the paper is organized as follows: in Section 2, we describe the data and present the methods we used and developed for the study. The assessment results are reported in Section 3, and their policy implications and a few limitations of the study are further discussed in Section 4.

2. Data and methods

2.1. Small-scale irrigation expansion pathways in Nigeria

Irrigation practices by smallholder farmers in Nigeria and other Sub-Saharan African countries have been investigated in a number of studies. Characteristics of existing irrigators’ behavior revealed in these studies allow us to develop a vision on the future expansion pathways of small-scale irrigation in Nigeria, which underpins our analysis.

Specifically, using data collected from Living Standard Measurement Survey (LSMS) Takeshima and Edeh (2013) analyzed the topology of existing irrigated agriculture in Nigeria. They found that in Nigeria irrigation, mainly practiced at small scale, occurs in both dry season and rainy season. The identified major crops irrigated in the dry season are vegetable, rice and maize. This result is consistent with the observations from other Sub-Saharan Africa countries (Meinzen-Dick et al., 1994; Girma and Seleshi, 2007; Namara et al., 2011): irrigation helps extend crop production into dry season; farmers tend to use irrigation to cultivate high value or critical food crops to generate additional income. LSMS data, on the other hand, also show that in rainy season, in addition to vegetables, rice and maize, farmers also irrigate coarse grains (sorghums and millets) and legumes (e.g., cowpea and groundnuts). The economics behind rainy season irrigation is less understood, but the role of irrigation in increasing the resilience of rainy season farming has been well recognized (Fox and Rockström, 2003). That is to say, investment in irrigation may offers insurance against erratic and unreliable rainfall; farmers practice irrigation in prolonged dry spells to mitigate drought conditions and to maintain yields in drought years.

In view of the findings from Takeshima and Edeh (2013) and the different roles irrigation may play in crop production in Nigeria, we assumed two groups of crops (Table 1) which could be potentially irrigated by expanded small-scale irrigation schemes. We then estimated irrigation expansion potential associated with the two groups of crops separately using different approaches. The first group consists of dry-season vegetables, dry-season maize and dry- and rainy-season rice. We also include wet-season rice into this group considering intensive water requirement in rice production. It was assumed that irrigation will determine the cultivation scale of these irrigated crops. An optimization model was formulated to estimate the scale of irrigation expansion based on long-run cost benefit of irrigated crop production, by assuming irrigation expansion would maximizes net revenue received by farmers. The second group of crops include rainy season maize, vegetables, sorghum, millet, cowpea, groundnuts and other main crops cultivated in rainy season (sweet potato, yam and cassava). Given the supplemental nature of irrigation in rainy season crop production, it is important to account for variability of crop production induced by variable climate and farmers’ attitudes towards risks. It has shown that farmers are generally risk averse, and the risk aversion attitude is a factor influencing their decisions in agricultural technology adoption (Binswanger, 1980; Yesuf and Bluffstone, 2009; Brick et al., 2012; Nielsen et al., 2013). Risk analysis techniques were thus applied to estimate adoption rates of supplemental irrigation associated with crops in the second group.

2.2. SPAM, ex-ante irrigation map and SWAT

The main data sets we used in the study are listed in Table 2. Two major ones are the SPAM database and an ex-ante Nigerian irrigation site map developed by Taiwo et al. (2010). SPAM is an acronym for Spatial Production Allocation Model (You et al., 2014a). It is designed to downscale national and sub-national agricultural statistics for crop production to a 5 arc-minute (approximately 10 km × 10 km on equator) grid. SPAM database with global coverage has been created and is available at http://mapspam.info. In this study, an updated national SPAM database for Nigeria was developed. The SPAM-Nigeria estimates spatial distributions of cultivation area and yields of main crops in Nigeria circa 2006 (calculated as averages between 2005 and 2007 and a distinction between rainfed and irrigation system is made) and provides a baseline for our analysis (see Appendix I for more details on SPAM methodology and data in SPAM-Nigeria database).

Another data set, Taiwo et al.’s (2010) irrigation map shows the possible sites for the uptake of small-scale irrigation in Nigeria (Fig. 1). The input data used in creating this map include topography, climate, soil and a mosaic of high-resolution LULC (land use and land cover) remote sensing images (Landsat and Spot). Field survey work was also conducted to collect environmental attribute information on existing irrigation farms. Supervised learning algorithm was used to train a classifier to identify land with irrigation development suitability. The total area of these sites on this map amounts to 14 million hectares. A limitation of this mapping product is that no explicit consideration is given to such factors as water balance and economic viability, which may serve as key constraints for irrigation development. In our study, Taiwo et al.’s (2010) irrigation map was used as an ex-ante estimate of the upper bound