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# Differential impacts of rainfall and irrigation on agricultural production in Nigeria: Any lessons for climate-smart agriculture?

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ABSTRACT

The rain-fed agriculture system is vulnerable to climate change impact. However, such impact may also vary by aggregate and sub-sectoral levels of agricultural production. The impact of climate change and variability on agricultural production would engender appropriate policies and practices towards a sustainable agricultural production system. We investigated the differential impacts of rainfall and irrigation on agricultural production in Nigeria, and drew lessons for climate-smart agriculture (CSA) in Nigeria. Using time series data that spanned 43 years and econometric analytical technique, we quantified the differential impacts of rainfall and irrigation on aggregate production and sub-sectors (all crops, staples, livestock, fisheries and forestry). Irrigation had positive and significant impact on aggregate agricultural production as well as all sub-sectors of agriculture. These findings suggest the need for the minimization of the impact of climate-induced production risks through CSA which would involve complementary development of more arable land areas under irrigation in Nigeria. Irrigation would also enhance complementary agricultural water management for the development of all the sub-sectors of agriculture, thereby enhancing food security and sustainable agricultural production under prevailing climate change and variability.

## 1. Introduction

The agricultural production system in Nigeria is predominantly rain-fed. In such a case, extreme rainfall patterns and/or variability becomes a critical production risk. The rain-fed agricultural production system is vulnerable to seasonal variability which affects the livelihood outcomes of farmers and landless labourers who depend on this system of agricultural production (Vermeulen et al., 2012). Climate change affects rainfall through rainfall variability which is conditioned by the hydrological cycle, and observable rainfall patterns. This situation, therefore, makes climate change an important consideration for sustainable agricultural production (Easterling et al., 2007). In the event of erratic rainfall, irrigated land area is insurance for rain-fed agriculture. Similarly, land areas under irrigation are predictors of resilience of agriculture to rainfall-induced vagaries and impact of climate change (Cassman et al., 2013). Hence, it is imperative to consider and analyse the long-term impact of rainfall and irrigation on agricultural production by sub-sectors. The analyses in this paper have implications for food security (availability, accessibility, and stability) and sustainable agricultural production in Nigeria, which is the most populous nation in Africa.

The impact of climate change occurs at multiple scales (global, regional and national) and sectors (including agriculture). The latest report of the Intergovernmental Panel on Climate Change (IPCC, 2015) attests to strong evidence of global climate change and impacts. Climate change and agriculture are inextricably linked (Nwanze and Fan, 2016; World Bank, 2015, 2008). The agricultural sector and its sub-sectors are increasingly showing a high level of vulnerability and impact. Climate change across Africa is exacerbated by low levels of adaptation and mitigation (IPCC, 2015; Montpellier Panel Report, 2015). Further evidence abound on the impact of climate change and variability on specific sub-sectors of agricultural production (crops, livestock, fisheries and forestry) from across other geographical scales and countries (Gourdji et al., 2015; Craparo et al., 2015). As a result of climate change, farmers are now making changes and building resilience to vagaries of climate change (Wood et al., 2014; Kristjanson et al., 2012).

The agricultural production risk imposed by rainfall variability may be a motivation or hindrance to investment in improved agri-

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cultural technology and climate resilient agriculture. Farmers who are unable to adapt to the changing climate may find alternative livelihoods or remain impoverished. Others may become resilient by developing alternative systems of production that will help them cope with the changing climate. This situation predisposes farmers to a pseudo choice-making process that is constrained by initial endowment or capacity to innovate so as to overcome vulnerability by becoming climate-resilient through appropriate adaptation and mitigation strategies. It has been noted that any strategy to adapt agriculture and food systems to a changing climate must therefore exploit the diversified means of climate resilient strategies (Vermeulen et al., 2012), including irrigation agriculture. Variability and extreme rainfall events have the potential to transform agricultural production systems (rain-fed or irrigated) and sub-sectoral diversifications of agricultural production (including crops, livestock, forestry and fisheries) as well as downstream production activities (like processing, marketing and off-farm activities) which could help to smoothen agricultural consumption and production along the value chain (Liverman and Kapadia, 2010; Nelson et al., 2009). The ability to circumvent the negative impact of climate and weather variability in agricultural production is an important consideration for climate-smart agriculture (CSA) and for maximizing its benefits of enhancing agricultural livelihoods and economic development.

CSA is an emerging concept and practice that seeks to adapt agricultural production to climate change and weather variability, while maintaining agricultural productivity, biodiversity and the ecosystem that sustains food security, livelihoods and economic development. CSA seeks to enhance productivity, water conservation, livelihoods, biodiversity, resilience to climate stress, and environmental quality (FAO, 2013, 2010; Neufeldt et al., 2011). The overall outcome of CSA is to improve agricultural livelihood incomes, promote food security and sustainable agricultural development by ensuring that agricultural production systems are best suited to respond to the challenges of climate change and variability. The resilience of agriculture to climatic changes and variability could boost agricultural production and broadly contribute to sustainable development (Nwanze and Fan, 2016).

Contextually, CSA in Nigeria implies enhancement of agricultural livelihoods and intensification, improvement of environmental friendly agricultural systems, and sustainability of supply of agricultural water and conservation through the expansion and management of irrigation in order to cope with the vagaries of rainfall variability, flooding, drought, low productivity, and food insecurity. This paper, therefore, draws lessons for CSA (including the social, economic, and technical/environmental barriers) based on the econometric analysis of differential impact of rainfall and irrigation on agricultural production in Nigeria.

The paper builds on emerging literature on the impact of climate variability on agricultural production (Ajetomobi et al., 2015; Craparo et al., 2015; Gourdji et al., 2015). It reveals the reliance of agriculture to climate change and variability (Schlenker and Lobell, 2010; Schlenker and Roberts, 2009; Guiteras, 2009; Kurukulasuriya et al., 2006), and expand literature on the long-term impact of rainfall-induced production risks and adaptation measures (irrigation) on agricultural production in Nigeria. We found motivation to expand on the understanding provided by anecdotal research at the community and household levels that provided insight into particular adaptation strategies and impacts of climate change on agricultural production (Ajetomobi et al., 2015; Below et al., 2012; Vermeulen et al., 2011). The empirical assessment of the impact of irrigation as an adaptation measure, and complementarity with rain-fed agriculture at aggregate and sub-sectoral levels of agricultural production under long-term climate change and variability remains unclear, at least for Nigeria.

The empirical analysis of the impact of rainfall as climate-induced agricultural production risks and irrigation as a measure of adaptation to climate change for aggregate and sub-sectors of agricultural production in Nigeria is important because policies aimed at building climate change resilience and food security are typically implemented at scales (national level) greater than the individual household and community (IPCC, 2015; Gourdji et al., 2013; Dell et al., 2013; Lobell et al., 2011a,b; Easterling et al., 2007). Therefore, this paper provides empirical findings of the impact of rainfall and irrigation on agricultural production using econometric techniques. It analysed the differential impacts of rainfall and irrigation on aggregate agricultural production and sub-sectors (crops, staples, livestock, fisheries and forestry).

## 2. Materials and methods

### 2.1. Type, measurement and sources of data

Time series data were extracted from joint databases of the Central Bank of Nigeria (CBN), National Bureau of Statistics (NBS), Nigerian Meteorological Agency (NIMET) and the Food and Agriculture Organization (FAO) of the United Nations in the Statistical Bulletin of the NBS. Supplementary data on occurrence of flooding of national emergency situations were obtained from various publications. The specific data extracted included: agricultural production indices (aggregate production, all crops, staples, livestock, fishery, and forestry), incidence or occurrences of flooding in a specific year, mean annual rainfall in millilitres, proportion of land area under irrigation and value of agricultural (food) imports in million US dollars. The indices of agricultural production is the relative level of the aggregate volume of agricultural production for all sub-sectors (aggregate, all crops, staples, fishery, livestock and forestry) for each year in comparison with the base period (base year = 1990) (http://faostat.fao.org/site/362/DesktopDefault.aspx?PageID=362) (NBS, 2008).

The dataset spanned 1970–2012 (that is, 43 years). Typically, the impact of climate change is considered over a long period of time (usually more than 30 years). This condition also satisfied the econometric properties of a large sample size required for the estimation of the generalised method of moments (GMM) econometric technique (Craparo et al., 2015; Gourdji et al., 2015; Hansen, 2012).

### 2.2. Analytical methods

Descriptive and inferential analyses (averages, standard deviations and correlations) were used to analyse the dataset to elucidate the variables. The estimation followed an autoregressive integrated moving average (ARIMA) model style. The GMM technique was used to estimate the parameters of the model that was used for estimating the impact of rainfall and irrigation on aggregate agricultural production and by sub-sectors. The choice of parameter estimation technique was informed because the ordinary least squares parameter estimation technique (regression) might result in biased estimation which is particularly linked to spurious regression and endogeneity problems. The issue that may cause spurious regressions is the possible existence of unit roots or non-stationarity of variables in the time series data analysis. This problem was handled by differencing while the problem of endogeneity of correlated independent variables (Fan et al., 2008) was resolved with the use of instrumental variables in the GMM estimation procedures.

Following Fan et al. (2008), and Arellano and Bond (1991), the GMM estimator was stated as an autoregressive (AR) procedure as:

$$\Delta y_{it} = \sum_{e=1}^{m} a_e \Delta y_{it-e} + \sum_{e=1}^{n} \beta_e \Delta x_{it-e} + \Delta \eta_{it} + \Delta u_{it} \quad (1)$$