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Rainfall variability adaptation strategies: An ex-ante assessment of supplemental irrigation from farm ponds in southern Burkina Faso

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ABSTRACT

This study assesses the economic value of supplemental irrigation as a rainfall variability adaptation strategy in a small catchment in south-western Burkina Faso. The bio-economic model built for the catchment maximises net cash income by optimally allocating land, labour, water and capital. Yields vary according to soil type, agricultural practice and the type of rainy season. We introduced farm ponds as an adaptation strategy – called supplemental irrigation – for grain crops during long dry spells in the rainy season. Simulation results show that supplemental irrigation can be cost effective and increase incomes, particularly during years with poor rainfall. However, in this catchment, gains from supplemental irrigation are limited because labour and capital are constraints on pond implementation.

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1. Context and issues

Agricultural production in sub-Saharan Africa is mainly rain-fed and as such is particularly vulnerable to rainfall variability, such as long dry spells. African rainy seasons experience recurrent dry spells, as described in many climate-related studies (Modarres, 2010; Barron, 2004; Barron et al., 2003; Sivakumar, 1992). These dry spells are important factors in crop failures, depending on when they occur during the cropping season, and their duration and frequency (Barron et al., 2003).

This variability has a direct impact on the primary production, diets and monetary incomes of rural families and food supply (Failler, 2014; Badolo and Kinda, 2014). Farmers have developed strategies to counter this rainfall variability. Soil and Water Conservation (SWC) techniques such as zaï, half-moons and stone bunds help concentrate water and fertilizer around crops' roots (for more details, see Zougmoré et al., 2014)

These techniques are rendered ineffective when dry spells, sometimes exceeding two weeks, are too long (Roose, 1993; Sultan et al., 2013). Furthermore, some SWC techniques have been found to be barely cost effective for individual farmers, as grain yield increases do not necessarily cover labour inputs and construction costs. For example, it has been shown that in central Burkina Faso, yield increases do not cover the cost of constructing stone bunds in the community because of the large amount of labour required to collect and transport the stones from their original locations to the fields (Barry et al., 2008). The construction of stone bunds was found to be profitable when the investment costs were reduced by providing free transportation of stones.

With the projected increase in the occurrence of extreme weather events, there should be a focus on techniques that increase production while reducing the impact of rainfall variability. Supplemental irrigation from farm ponds has long been identified as a production technique that should reduce such uncertainties and ensure better food security. Supplemental irrigation is implemented during dry spells in the rainy season to prevent crops from suffering excessive water stress. Sané et al. (2008) described the characteristics of such dry spells. In Burkina Faso, the implementation of supplemental irrigation depends on farm size, available water resources, and technical and financial considerations (Narayan et al., 2008; CNID-B, 2009). Many authors have shown supplemental irrigation's potential to minimise risks and increase crop yields in sub-Saharan Africa. Dugué (1986) tested supplemental irrigation from small farm ponds in northern Burkina Faso and assessed how it could secure production, especially in years with poor rainfall. Fox et al. (2005) have shown that the use of farm ponds and supplemental irrigation can be cost-effective in rain-fed agriculture in Kenya, Tanzania and Burkina Faso. In 2005, the National Agricultural Research Institute (INERA) in Burkina Faso tested supplemental irrigation on

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sorghum production in Saria under a Sudanese climate (average annual rainfall of 750 mm) and in Sabouna under a Sahelian climate (average annual rainfall of 400 mm). Compared to hand tillage (with hoes), the trial showed that supplemental irrigation has more of an effect on grain yields in the Sahel while tied ridges were more efficient under the Sudanese climate (Somé and Ouattara, 2005). The variability (long dry spells) of current rainfall in the Sahel does not allow SWC techniques to be more efficient than supplemental irrigation. However, the authors found that deep ploughing with animal power was an important element that allowed yield gains with supplemental irrigation. Also, the Burkinabe National Committee on Irrigation and Drainage (CNID-B, 2009; Coulibaly et al., 2011) has conducted supplemental irrigation tests in the Sourou Valley on 200 ha of maize over a period of three years (2008–2010). Yields were above 4 tonnes per hectare and increased by between 230% and 300%, providing a significant return on investment. In Burkina Faso, the National Programme on Climate Change Adaptation Strategies (PANA) has incorporated supplemental irrigation in its priority project.

Drawing on the experience of a pilot project, Burkina Faso's Ministry of Agriculture launched a 'maize garden' development project mainly in the Sahelian and Sudano-Sahelian agro-climatic zones in 2012. Several thousand farmers were given subsidies of US$ 163 to dig farm ponds of 300m^3. Farmers dug a total of 3000 farm ponds and, though the impact of the project still has to be evaluated, the Burkina Faso government has initiated another pilot project to promote supplemental irrigation. This project seeks to add thousands of new small ponds collecting runoff water to secure around 2500 ha throughout the country.

Most of the studies reviewed were limited to measurements of yields and agronomic impact but did not quantify the economic impact of supplemental irrigation at the farm scale. Supplemental irrigation has been tested in northern Burkina Faso, but not in the more humid southwest. The southwest region is the most favourable for agricultural production in the country and is increasingly marked by strong spatial and temporal rainfall variability, thereby affecting production choices and farmers' incomes. These rainfall disruptions are becoming recurrent, causing a high risk of food insecurity.

The purpose of this study is to assess the economic impact of building farm ponds for supplemental irrigation in southwest Burkina Faso. Using a bio-economic model, we compared a baseline scenario to a scenario with supplemental irrigation in which farmers in the catchment dig farm ponds to irrigate their crops during long dry spells in the rainy season. We quantified the impact of the technology on catchment incomes. After an in-depth description of the study area, we present the model built to test the technology (Section 2) and discuss the results (Section 3).

2. Method

2.1. The study area

This study was conducted in the village of Pontièba located in the municipality of Dano in southwest Burkina Faso (Fig. 1). The average annual rainfall is 850 mm and the rainy season extends from May to October. It is followed by a dry and cold season from November to January and then a dry and hot season from February to May. The length of the growing period is quite variable, ranging from 70 to 100 days. The number of dry days within the growing season has increased significantly, indicating a change in rainfall distribution.

The farming system in the village of Pontièba is typical of the Dano catchment area. The main rainfed crops include maize, sorghum, millet, cotton and, to a lesser extent, cowpea, groundnut and sesame. Sorghum, cotton and maize are grown in the best soils; millet and sorghum are grown on shallower soils and maize in home gardens. Cowpea is usually grown in combination with a cereal. Rice is grown in flooded lowlands during the rainy season. In lowlands with a low flood risk one can also find maize. In irrigated areas, farmers grow rice during the rainy season and vegetables during the dry season, but not necessarily on the same plots.

Hand tillage (with traditional hoes) is commonly used for soil preparation and weeding. Only 20% of households in the catchment area use animal traction. Sowing and harvesting are manual.

The traditional SWC techniques are not common in the catchment and fallowing soils is becoming rare. In the mid-1990s the average fallow period was about six years, but this has dropped to three years today (DPASA, Ioba, 2013). The use of organic fertilizers depends on the quantities of manure available and usage is still very low because the region is not livestock-oriented. Inorganic fertilizer use is low because of the difficulties obtaining credit from banks. Fertilizers are mainly applied to cotton, as the cotton company distributes inputs on credit (fertilizers, seed and pesticides), with the cost of these inputs deducted from the revenues generated after harvest.

2.2. Sampling and data collection

Data about the Pontièba farms in the catchment come from several sources. A survey of a sample of 100 households randomly selected in the village of Pontièba by Yili (2006) was conducted in two phases in order to describe the farmers' activities and constraints, and generate data that can help aggregate and parameterise the catchment model. In the first phase, the author identified the characteristics of the households in the area (family size, labour, consumption expenditures, capital, etc.). The catchment is composed of about 300 households with an average of 6 people per household. Cereals such as sorghum, maize and millet are the most consumed. Grain demand per individual per year is estimated at 200 kg according to the standards of the Ministry of Agriculture. In the second phase, the survey focused on land use with plot identification using a Global Positioning System (GPS).

Yields, prices and climate data (long-term records: 1981–2013) available for Dano and the surrounding provinces from the Ministry of Agriculture and the Burkina Meteorological Department served to estimate average crop yields and prices. Finally, we held two focus group discussions (FGDs), the first with selected farmers and the second with local agricultural technicians to cross-check the data on yields and prices and discuss some aspects of the cropping patterns and the model.

The irrigated area of Pontièba, from the common reservoir, covers about 25 ha or about 2% of the surface area of the catchment (about 13 km^2). The reservoir located upstream has a capacity of 300,000 m^3. When it is full, it allows rice and two successive crops to be irrigated: usually, rice during the rainy season, and then maize or vegetables during the dry season. Dry season production is not always possible because the size of the catchment area means that the reservoir is not completely filled every year. Therefore, the irrigated area varies between 17 and 25 ha, depending on the water available in the reservoir after the rainy season.

2.3. Formulation of the model

The model used in this study is a bio-economic optimisation model that seeks to represent the interactions between a stock of natural capital and the economic activity supported by it (Pacini et al., 2004). In our case the natural stock is the stock of water in the reservoir. Bio-economic models help describe the combination of activities that maximise income and as such are more likely to be implemented by farmers. They are ex-ante assessment tools (Torkamani, 2005; Pacini et al., 2004; Hazell and Norton, 1986) that help test some key innovations, in our case supplemental irrigation.

We have chosen not to represent animal breeding in the model because the region is not livestock-oriented. Given the relative isolation of the area, we have also chosen not to include off-farm activities.

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