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Impacts of small built infrastructure in inland valleys in Burkina Faso and Mali: Rationale for a systems approach that thinks beyond rice?

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ABSTRACT

The potential to increase agricultural production in inland valleys in West Africa has received a good degree of attention in both national development strategies and academic literature, and improving agriculture productivity in inland valleys has been an active area of donor engagement. Despite this attention, documentation of the degree to which benefits are enhanced through construction of built water storage infrastructure in such sites is somewhat scant. This paper examines evidence from eight inland valley sites with recently-built water retention infrastructure (4 in southwest Burkina Faso, 4 in southeast Mali) to determine how economic returns derived from agricultural production have changed through built infrastructure construction. Farmer interviews were undertaken at each site to identify costs and benefits of agricultural production before and after small built infrastructure construction. Overall results indicate that net present value increased substantially after built infrastructure was constructed. The results nonetheless highlight substantial variation in economic impacts across sites. A central variable explaining such variation appears to be the degree to which water retention is exploited for groundwater-based offseason cultivation. These findings will help development planners to better predict the degree and nature of change engendered by water storage projects in inland valley sites, and help to ground-truth grand statements about the development potential of this piece of natural infrastructure.

1. Introduction

Greater utilization of inland valleys (alternatively called "valley bottoms", "low lands" or "bas fonds") is considered central to achieving agriculture production and food security targets in West Africa (e.g., Giertz et al., 2006; Barbier, 2011). With low use relative to their potential (Andriesse et al., 1994; Delville et al., 1996; Kiepe and Rodenburg, 2013; Rodenburg et al., 2014), inland valleys have been recognized as important areas for expanding rice production in West Africa. Recognition of this importance has, in turn, led to a growing body of literature focused on the dynamics of rice productivity in inland valleys. Becker and Johnson (1999) sought to identify factors explaining variation in rice yield in a forest zone of Cote d'Ivoire. Erenstein et al. (2006) attempted to understand drivers of lowland use around four West African urban centers. Wakatsuki and Masunaga (2005) described how use of the "sawah" technique can help unlock the potential of *inland valleys* in West Africa. Issaka et al. (2009) identified change in rice production resulting from introduction of the *sawah* technique (leveled, bunded and puddled rice fields with water inlets and outlets) on experimental sites in Ghana, and Fasholo et al. (2009) and Nwite et al. (2008) examined similar issues in Nigeria. Several other authors (Oosterbam et al., 1987; Andriesse et al., 1994; Narteh et al., 2008; Giertz et al., 2006) characterized variation in types of *bas fonds* sites. Finally, Rodenburg et al. (2014) offered a methodology for selecting best-bet inland valley sites for development.

In addition to these studies on rice productivity in inland valleys, an additional body of literature has exposed critical nuances related to the profitability of rice production in West African inland valleys, and the importance of inland valley rice cultivation to income generation, overall economic welfare and countries' public financial resources. Katic et al. (2013) and Toure et al. (2013) analyzed the financial and economic profits and the effect of trade policies on performance of rice production in inland valleys in Ghana, Burkina Faso and Niger. Kolawole et al. (2011) examined the profitability of different sawah rice production models in inland valleys of Nigeria using a gross margin approach. Finally, Seck et al. (2010)

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compared the competitiveness of rice production for selected ecologies in Sub-Saharan Africa with domestic resource cost ratios.

While these studies mark important progress toward understanding how the agriculture potential of inland valleys can be tapped, there are at least three gaps in the body of literature that has been thus far produced. First, there appear no empirical before versus after studies that capture how economic benefits from the pre-existing natural infrastructure has been enhanced through construction of built water storage infrastructure in inland valley sites. Second, literature on agriculture production and economic returns in inland valleys is generally confined to main season rice production, which may fail to fully reflect uses of inland valleys that include multiple crops in multiple seasons. Finally, the studies referred to above appear geographically focused mainly in the ''forest zone'' of West Africa rather than more Sudano–Sahelian environments such as those of Burkina Faso and Mali.

This paper determines the effect of built water storage infrastructure on benefits derived from agricultural production in a set of 8 inland valleys sites in southwest Burkina and southeast Mali. Changes in benefits derived from use of inland valleys – considered from the perspective of farmers' income, overall society's welfare and public funds – are presented and analyzed. Agriculture production and economic returns from built infrastructure are analyzed not only in relation to main season rice production, but also include off-season crop production.

2. Background and methods

2.1. Background: Inland valleys

There are approximately 190 million ha of inland valleys in Sub-Saharan Africa (Rodenburg et al., 2014), and 85 million ha of inland valleys in West Africa specifically (Andriesse et al., 1994). As lowland areas where water naturally collects, West African inland valleys comprise an important piece of natural infrastructure. The benefits of such natural infrastructure are evidenced by the greater agricultural production that occurs in such sites relative to other portions of the ephemeral streams on which they are found. Tapping the potential of inland valleys is nonetheless often constrained by water availability, and it appears that their levels of production often vary between and within years as a function of rainfall.

Enhancing the natural benefits of inland valleys is widely recognized to hold much potential for increasing agricultural production and food security in West Africa—particularly given that less than 25% of such sites are currently cultivated (Andriesse et al., 1994; Delville et al., 1996; CAADP Pillar I, 2009). The Sikasso area holds particular potential for development, and many inland valley development projects in this region have been undertaken in recent decades (Ahmadi et al., 1999). While various combinations of measures can be utilized to increase the natural benefits that accrue from inland valleys, improving the reliability and availability of water – often through small water retention infrastructure (<1.5 m in height) – can be considered central to any combination. Construction of such built infrastructure, which prolongs surface water availability and increases groundwater infiltration, has indeed been an active area of donor engagement in Sahelian countries.

2.2. Study area: Southeast Mali and southwest Burkina

2.2.1. Study sites

This paper focused on eight sites. Four sites were located in southeast Mali, in which infrastructure development was supported by a USAID-funded project called Integrated Initiatives for Economic Growth (IICEM). Four sites were located in southwest Burkina, in which development was supported by a German-funded project called *Programme pour l'amenagement de Bas fonds dans le Sud-Ouest* (PABSO). Sites of focus were selected at random by the authors from the set of information on each project. Study sites were selected from a total of 15 IICEM sites in the Sikasso region of Mali, and a total of 45 PABSO sites in Burkina. The four sites in Mali are located in the Niger Basin, and the four sites in Burkina are located in the Volta basin. The precise locations of the eight sites are shown below (Fig. 1).

2.2.2. Climate

Climate across the 8 sites varies minimally (Table 1). Mean annual temperature ranges from 26.1 to 26.4 °C. While annual rainfall could be considered broadly similar across the 8 sites, rainfall is slightly higher in Malian sites. Rainfall is overwhelmingly concentrated in four months of the year (June–September), which spurs the need for water storage in the eight months during which precipitation is minimal.

2.2.3. Hydrology

All sites were located on ephemeral streams and appeared to manifest conditions typical of a wetter Sudan Savannah. River flow is very seasonal, primarily during and after the rainy season (June–September). Figures derived from project reports suggest runoff above sites to be typical of small tributaries (i.e., 6–9 million m^3/year). While precise data on water tables could not be obtained, it appears that groundwater was generally unable to be used for agriculture without built infrastructure.

2.2.4. Soils

In the Malian sites of Kouroumasso, M'Pegnesso and Zoloko, fine textured clay and silt prone alluvial soils offer opportunities for crop rotation of potatoes and rice. Clay soils are encountered in the plains of Gladié I. In the four Burkinabe sites, soils were found to be clay loom which is comparatively heavy and difficult to work on.

2.2.5. Market access

Examination of sites' degree of market access revealed some variation. With the exception of Gladie I, Malian sites were located less than 5 km from major roads. Sites in Burkina Faso, by contrast, averaged an 8 km distance to major roads (Table 2).

2.2.6. Project interventions

While both IICEM and PABSO projects centered on water infrastructure construction, both projects also included other components. IICEM consisted of three components: (1) construction of small dams and renovation of storehouses, (2) provision of credit facilities for procurement of seeds and fertilizer, and (3) capacity building through provision of business and literacy training. The PABSO project was also comprised of three components: (1) construction of small dams (2) complementary measures such as support to farmer organizations, training on marketing and conservation, and strengthening capacity in the areas of land titling and infrastructure maintenance, (3) facilitating rural credit.

2.2.7. Water infrastructure

The nature of water infrastructure varied somewhat between IICEM and PABSO sites. IICEM sites possessed a single dam structure, constructed from concrete, between 1.5 and 3 m in height and between 80 and 500 m in length. Each site had a manually operated gate, enabling water to be released downstream. PABSO sites, by contrast, possessed a terraced system of smaller (<1 m) dams nested along the beds of seasonal streams. Each PABSO site also possessed several manually operated gates to enable water