CABRI Agriculture Dialogue

Tools to assess value for money in agriculture

Case Study: Mali

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2014

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Acronyms and abbreviations

ASAP	Adaptation for Smallholder Agriculture Programme
DID	Difference in differences
FAOSTAT	Food and Agriculture Organisation of the United Nations Statistics
GDP	gross domestic product
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
MAFAP	Monitoring African Food and Agricultural Policies
NERICA	New Rice for Africa
NRIP	National Rural Infrastructure Programme
ON	Office du Niger
PSM	propensity score matching
RCT	randomised controlled trial
USAID	United States Agency for International Development
WACIP	West African Cotton Improvement Programme

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1. Introduction

Mali is a sub-Saharan country, the economy of which is based primarily on agriculture. The agricultural sector's performance and structure are important to policy-makers, as the sector employs 73 per cent of Mali's labour force and has accounted for more than a third of its gross domestic product (GDP) since 1992 (FAOSTAT 2013).

Agriculture is extremely vulnerable to environmental risks and climate shocks, such as drought, flooding and irregular rainfall patterns.

Mali has succeeded in reducing the incidence of hunger and poverty, but there is still room for improvement. Chronic food insecurity and malnutrition continue to be endemic throughout the country, and the situation was aggravated by the global fuel and food crisis of 2008, which led to a sudden increase in food prices.

Even with rapid urbanisation, nearly 70 per cent of Mali's population live in rural areas where poverty is more prevalent, and the vast majority of people rely on agriculture for food and income (IFAD 2011). Agriculture is potentially a key driver of the economy and the foundation for poverty-reduction initiatives.

Agriculture is extremely vulnerable to environmental risks and climate shocks, such as drought, flooding and irregular rainfall patterns (IFAD 2011). Only 12 per cent of the country's large irrigation capacity has been developed and crop yields remain far below potential (IFAD 2011). This has led to the implementation of various irrigation projects aimed at increasing the area under irrigation to boost crop production and increase farmers' income.

Most of Mali's agriculture is dominated by subsistence, rain-fed farming based around single households. Cotton is the main cash crop grown by households. The majority of rural inhabitants have limited access to land and suffer from low crop yields. Most farms are not equipped to adopt modern approaches such as good agricultural practices or the usage of high-yielding seed varieties, as the use of agricultural inputs and mechanisation is very limited. The government of Mali has instituted sector-wide reform of the cotton industry to increase production and income, with the ultimate goal of reducing poverty.

This case study highlights two agricultural initiatives to reduce poverty and food insecurity. We consider how the programmes were evaluated to quantifiably measure their impact and the benefits they achieved.

The rest of the case study is organised as follows. Section 2 presents background information on Mali. Section 3 provides a description of a cotton programme, with an overview of the programme's objectives and motives, and two independent evaluations of the programme. Section 4 describes an irrigation programme implemented in Mali, followed by two independent evaluations of the programme that use different evaluation techniques and data.

2. Background

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Mali is a developing country in north-western Africa with a population of 14.85 million (World Bank 2012). In 2010, 50.4 per cent of the population were reported to be living on less than $1.25 per day (World Bank 2012). The Malian agricultural sector is dominated by small family farms, which make up approximately 68 per cent of the sector (Angelucci et al. 2013). These smallholder farmers grew by 7.7 per cent in 2010, and contributed 37 per cent of the country's GDP in 2008 (Angelucci et al. 2013). The country has been facing growing imports since 1976, which has created a deficit in its agricultural trade balance. Cereals account for 80–90 per cent of the value of total agricultural imports, mainly to address food insecurity in Mali (Angelucci et al. 2013). Cotton accounts for over 90 per cent of total agricultural exports, but its value has declined steadily since 2003 (Angelucci et al. 2013).

Numerous programmes and organisations have collaborated to tackle some of the problems faced by this sector. Strengths of Mali's agro-industrial sub-sector include low unit labour costs in the textile industry, and a large potential market for special cotton fabrics. Cotton is Mali's largest non-food-based agricultural export. Mali's agricultural sector is heavily impacted on by drought and has various systemic problems. Despite the importance of cotton, the industry lacks appropriate technology and has a low rate of technology adoption. Less than 1 per cent of the country's cotton is actually processed in Mali, due to the low level of technology in the textile industry (Bass 2012). In Mali, growth in the rural sector is severely constrained by declining and erratic rainfall. Most crops produce low yields, except for rice in irrigated perimeters of the Middle Niger River Valley, which are managed by the Office du Niger (ON).[1] Limited water supply and low irrigation networks further exacerbate low productivity in rural areas. Mali faces high transport costs due to poor infrastructure and poorly organised value chains, which apply excessive margins to wholesalers and intermediaries, resulting in high and volatile food prices (Angelucci et al. 2013). This results in a disconnection between domestic, international and regional prices.

1 The Office du Niger is a semi-autonomous government agency in Mali that administers a large irrigation scheme on the Niger River located in the Ségou Region of the country.

Two commodities have received extensive government policy support: cotton and rice. Cotton is given importance as it is the country's main agricultural export, and rice is prioritised as it is the country's staple cereal. Yield increases in rice have been seen in recent years due to improved irrigation and the distribution of New Rice for Africa (NERICA) seed varieties.

The Malian cotton sector has also faced immense competition from cheaper imports and the distribution of second-hand clothes from high-income countries. Mali is a net exporter of cotton yarn and a net importer of cotton fabrics.

Mali has been unable to develop a viable textile industry, because it has been unable to manage a state-owned company profitably due to a lack of human capital and properly functioning institutions (Bass 2012). The Malian cotton sector has also faced immense competition from cheaper imports and the distribution of second-hand clothes from high-income countries. Mali is a net exporter of cotton yarn and a net importer of cotton fabrics. Yarn is exported to Mauritania, Burkina Faso, Côte d'Ivoire and China. Cotton fabrics are exported mainly to Mauritania. In 2008, 80 per cent of the cotton fabrics imported by Mali were from China (Bass 2012).

In 2012, a quarter of the government's agriculture-specific budget was devoted to rice (Angelucci et al. 2013). Spending has been centred on irrigation projects and input subsidies, which appear to have boosted production. However, rice producers have not received adequate price incentives. This is because policies, such as import taxes and low retail prices, have focused on protecting consumers rather than producers, especially during the recent food crisis.

Given the importance of rice as an urban staple, and the ability to grow the crop under irrigation, the Malian government considers rice a key part of the country's food strategy. Termed the 'Rice Initiative', the NERICA rice dissemination project and the development and cultivation of the lowland regions (also known as the *bas-fonds* in French) are policies that have been initiated due to the great value attached to rice and rice productivity. Rice is produced under various irrigation and production systems, ranging from the full-water-control irrigation systems of the Office du Niger to rain-fed and lowland systems in southern Mali. Increases in rice production have flowed primarily from significant increases in public-led investments in large-scale gravity-fed irrigation infrastructure, and from improving the enabling environment with a progressive withdrawal of the state from the direct marketing and processing of rice.

The Rice Initiative was implemented to increase local rice production by 50 per cent over the 2008/09 season. This increase in production was to be achieved through: the extension of irrigated areas; the rapid expansion of upland rain-fed rice, led by the introduction of the drought-resistant NERICA 4 variety; and the intensification and expansion of controlled flooding of lowland systems (OMA 2009). The project also provided farmers with seed and fertiliser inputs to increase productivity. Although initially aimed at rice productivity, the programme went on to provide subsidised inputs for maize, sorghum, millet and cotton. In this programme, small weirs or dams were built to improve irrigation in the lowlands region to take advantage of the potentially lower per kilogram cost of rice production there than in the full-water-control perimeters of the Office du Niger.

Several other agricultural sector programmes have been supported by international donors and the Malian government. The International Fund for Agricultural Development (IFAD) has implemented numerous projects in Mali. The organisation has planned and maintained projects that total over half a billion dollars. The new Adaptation for Smallholder Agriculture Programme (ASAP) facility, managed by IFAD, for strengthening the resilience of small farmers and rural communities vulnerable to climate change was mobilised in 2013. The World Bank is in the process of implementing the Agricultural Competitiveness and Diversification Project, which will be used to reinforce the competitiveness of targeted value chains through specific investments. It will aim to remove critical constraints from production to marketing, and to build organisational and institutional capacity in both the private and public sectors.

In the next two sections, the focus falls on two projects aimed at enhancing and developing Mali's agricultural sector: the West African Cotton Improvement Programme (WACIP); and the National Rural Infrastructure Programme (NRIP), with an emphasis on developing irrigation in the lowlands. The implementation and evaluation of these programmes will be discussed in detail.

3. The West African Cotton Improvement Programme

The WACIP was funded by USAID to improve the competitiveness of cotton production in selected countries of West and Central Africa. The programme targeted Benin, Burkina Faso, Chad and Mali. The programme began in 2006 and was originally scheduled to end in 2009. However, USAID extended the project through to 2012 as implementation of the project had not been completed.

The programme's goal of reducing poverty and hunger by increasing the incomes of cotton farmers and processors was to be achieved through improving the production of cotton and non-cotton crops, and increasing the value of cotton products.

The programme focused on solving a range of problems from improving the quality of cotton by introducing a genetically modified variety known as insect-resistant Bt cotton to developing an enabling environment for the propagation of policy and institutional reform.[2] The WACIP also aimed at reducing soil degradation by expanding the use of good agricultural practices, and established a regional training programme for the operators of cotton gins, also known as ginners.

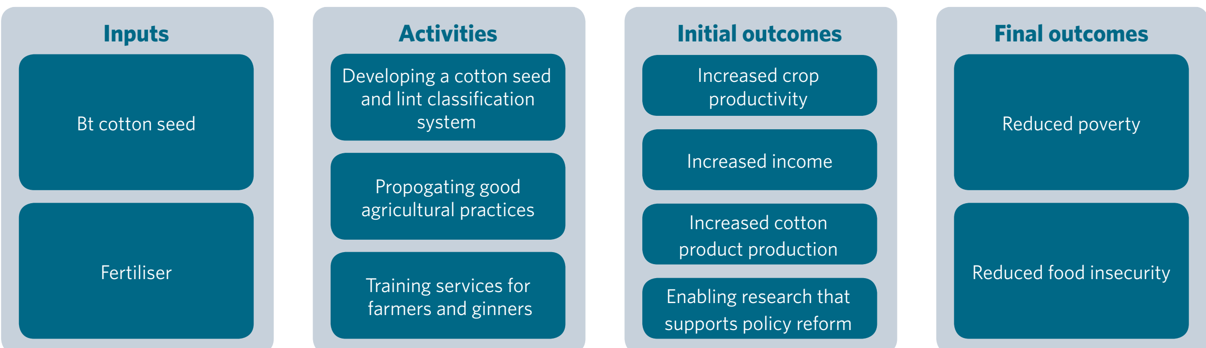
2 Bt cotton is a genetically modified variety of cotton that produces an insecticide that kills insects and other pests that feed on the crop. It is also known as insect-resistant cotton due to the Bt toxin produced by the crop.

The WACIP results chain depicted in Figure 1 provides a roadmap for how the desired progress towards the targeted development goal can be achieved. The results chain graphically represents a process from inputs and activities to intermediate outcomes and longer-term results, and summarises the mechanism through which the WACIP was implemented.

The WACIP pursued a number of programmes with substantial economic impact, including a set of programmes affecting farm income, training heads of farms by way of visits to demonstration plots of 0.5 or 0.25 hectares and reviewing the concrete results of the methods discussed. The farm heads subsequently trained their family members working on their farms. To increase the incomes of farmers, the project focused on several main challenges:

- use of recommended inputs and practices (fertiliser, pesticide, crop calendars, etc.);
- improvement in the use of credit for inputs, by training co-operative secretaries;
- longer-run programmes to improve soil fertility (part of developing better agricultural practices); and
- support for cotton research facilities to help them address cotton pest issues (and insect resistance), to improve their capabilities, communications and assistance to cotton extension services, and to further enable policy reform.

Figure 1: Results chain of the West African Cotton Improvement Programme



Overall, the programme was successful and indicated a substantial increase in income from cotton, and also substantial increases for the two food crops in the programme – maize and cowpeas. There was an extensive training programme, using the demonstration plots to offer well over a hundred farmers the opportunity of cultivating good agricultural practices.

The results chain aims to provide answers to the following questions:

- What are the inputs of the WACIP?
- What activities were conducted using these inputs?
- What are the intermediate outcomes?
- What are the final outcomes?

By looking at the results chain, one can conceptualise what to expect from an evaluation measuring the impact of the WACIP. We expect poverty and food insecurity to decrease (as farmers will have more income, food consumption will increase) and this will happen through increases in fertiliser usage and in agricultural productivity. Performance indicators based on the results chain can be selected, and impact evaluation questions can be formulated, such as what the impact of the WACIP is on household consumption. The results chain allows the evaluator not only to understand whether the programme was successful but also the reason behind its success or failure. If the WACIP failed to achieve its intended outcomes, was it because there was no change in agricultural practices? Was it because the change in practices did not lead to increases in productivity? The subsections that follow summarise two impact evaluations that seek answers to such questions.

3.1 Impact evaluation I: Randomised controlled trial

To evaluate the project, the WACIP implementing team, together with USAID, identified indicators that would measure the programme's performance at activity, initial and final outcome levels (Pomeroy & Diakite 2010). These included:

- output indicators that tracked programme outputs, such as people trained, organisations assisted, technologies adopted and policies analysed;
- outcome indicators, such as policy reforms adopted and changes in crop yields, that tracked progress towards the WACIP outcomes; and
- impact indicators that measured the level of achievement of overall project objectives.

The evaluation included an extensive monitoring system, visits to many test plots, and participation in training sessions by USAID evaluators. A survey was conducted of a random sample of 2 500 units from among farmers who participated in training programmes such as visiting demonstration plots to observe the methods, progress and outputs of the plots. The demonstration plots were run for two years, and a baseline was taken as the yields of the two previous years for the randomly selected farmers, compared to the yields in 2008/09 and 2009/10 after their exposure to the programme.

As the farmers were randomly selected, there was an experimental set-up to the design of the study, and the simple randomised controlled trial (RCT) methodology looking at differences over time between the trends in the treatment and control groups, provided an unbiased estimate of programme impact.

One of the programme's performance indicators was change in income. This information was at the level of the farmer. Selecting change in income as a performance indicator was suitable for the evaluation of many activities. To estimate increased incomes, yields of cotton, corn and cowpeas were taken for 2008/09 and compared with yields from the previous three years. The changes in yield showed a substantial increase in income (43 per cent for cotton, 7 per cent for maize and 153 per cent for cowpeas).

Table 1 provides estimates of the programme's impact on a number of other performance indicators. Results are grouped by crop type. Production, quantity sold and average sale price of all crops increased from the baseline to the post-intervention period. There was an opposite trend in the cost of inputs during the same period. More importantly, adoption of new technology led the cotton yield to increase by 12 per cent, the maize yield to increase by 14 per cent and the cowpea yield to increase by 25 per cent. These factors coupled with higher prices increased gross margins significantly for all three crops.

The findings of the study suggest that WACIP farmers in Mali gained nearly $14 million (+58 per cent) in additional net revenue with the implementation of the programme.

Exercise

- What problem do you see with reporting changes in outcome variables for the group of participants only and attributing these changes to the programme?
- What other method could have been used to get a better estimate of the programme's impact?

This survey and evaluation were conducted by USAID. USAID funded the programme and partnered with local extension organisations for the distribution of inputs and assistance with training sessions.

3.2 Impact evaluation II: Ex ante simulation

This impact evaluation studied the potential economic benefits to consumers and producers of adopting insect-resistant cotton and maize production technologies (Vitale et al. 2007). This was done by using an economic surplus model. An economic surplus model is a partial equilibrium model where the economy is characterised by a set of equations and parameters. Analysis is done by changing the value of the parameter of interest and studying how outcome variables

Table 1: Baseline and 2009/10 WACIP agricultural results				
Crop/Parameter	Unit	Baseline	2009/2010	% Change
Cotton				
Area	Ha	50 573	50 573	0%
Production	Kg	49 510 475	55 216 434	12%
Quantity sold	Kg	49 510 475	55 216 434	12%
Average sale price	$/Kg	$0.36	$0.38	5%
Purchased input cost	$	$6 126 027	$2 111 274	-66%
Yield	Kg/Ha	797	1 092	12%
Gross margin	$/Ha	$232	$371	60%
Net revenue	$	$11 752 756	$18 748 268	60%
Maize				
Area	Ha	47 928	47 928	0%
Production	Kg	78 575 111	89 678 489	14%
Quantity sold	Kg	48 614 365	40 355 320	14%
Average sale price	$/Kg	$0.20	$0.22	10%
Purchased input cost	$	$3 836 155	$978 645	-74%
Yield	Kg/Ha	1 639	1 871	14%
Gross margin	$/Ha	$247	$391	59%
Net revenue	$	$11 829 103	$18 750 622	59%
Cowpeas				
Area	Ha	2 845	2 845	0%
Production	Kg	1 004 617	1 259 084	25%
Quantity sold	Kg	486 716	610 000	25%
Average sale price	$/Kg	$0.52	$0.45	-13%
Purchased input cost	$	$7 143	$22 218	211%
Yield	Kg/Ha	353	443	25%
Gross margin	$/Ha	$180	$190	6%
Net revenue	$	$510 815	$540 173	6%
Net revenue (all crops)	**$**	**$24 092 674**	**$38 039 063**	**58%**

Source: Pomeroy & Diakite (2010)

change as a result of this shock to the economy. Different scenarios are considered to see how sensitive the results are to the assumed values of the parameters.

In this particular case, economic surplus was created through the introduction of new technology. The adoption of insect-resistant cotton and maize was expected to decrease production costs and increase market supply. Consumers were expected to enjoy surpluses due to lower cotton and maize prices, and producers were expected to benefit from the increase in sales. Of course, such an outcome depends on how fast and widespread the adoption of these new technologies is. Adoption rates for these new technologies were assumed to be endogenously determined within the model. In other words, the authors did not make any assumptions as to how fast and how widely these technologies would spread, but let the dynamics of the model determine adoption rates. One important factor here is the cost of the technology. If the technology is too expensive, farmers would be reluctant to adopt it, and this would reduce the potential benefits of the programme. This effect was incorporated into the model by simulating results under different levels of technology cost.

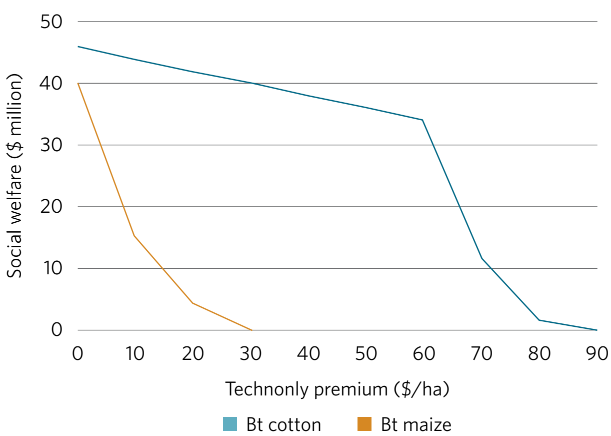
Exercise

- Do you expect consumers' surplus to increase or decrease as a result of an increase in technology cost?
- Do you expect producers' surplus to increase or decrease as a result of an increase in technology cost?

Data for the study were collected from various sources. Data on the regional aspects of the model, such as population, production areas, crop yields and market prices, were obtained from various statistical service departments in Mali. Data from farmer surveys were used to calculate certain parameters of the model. One important parameter that could not be obtained from Malian data was the increase in yield as a result of the adoption of insect-resistant maize and cotton. The estimate for this parameter came from another country, Burkina Faso, which had adopted these technologies earlier and where a field experiment had been conducted to measure the impact of insect-resistant maize on yield. The field trials found that cotton yields increased by 20 per cent in Burkina Faso. It was assumed that a similar impact would be observed in Mali.

Figure 2 shows the expected economic impacts of the adoption of insect-resistant cotton and maize in Mali. Economic surplus, measured by social welfare, was plotted against a technology premium, which is a measure of the cost of this technology. The first conclusion was that the expected economic surplus is reduced as the cost of adopting this technology increases. This is what was expected. Secondly, the adoption of Bt cotton seems to have a greater potential for increasing the economic surplus than does the adoption of Bt maize.

Figure 2: Economic impacts of the introduction of Bt cotton and maize in Mali



Source: Vitale et al. (2007)

Economic surplus is composed of two parts: consumer surplus and producer surplus. Further analysis revealed that the increase in consumer surplus was higher than the increase in producer surplus.

4. The National Rural Infrastructure Programme: Small dams for lowland (*bas-fonds*) regions

The objective of the National Rural Infrastructure Programme (NRIP) was to reduce poverty and improve the living conditions of the rural population in Mali, through building sustainable financial and environmental rural infrastructure including: irrigation infrastructure; rural transport infrastructure; safe drinking water supply; and sanitation facilities.

In 2005, the Malian government began increasing the number of dams in the lowlands region, in order to broaden water access for farmers. The programme was one of several dynamic water control measures for enhancing agricultural production and the diversification of revenue for rural people.

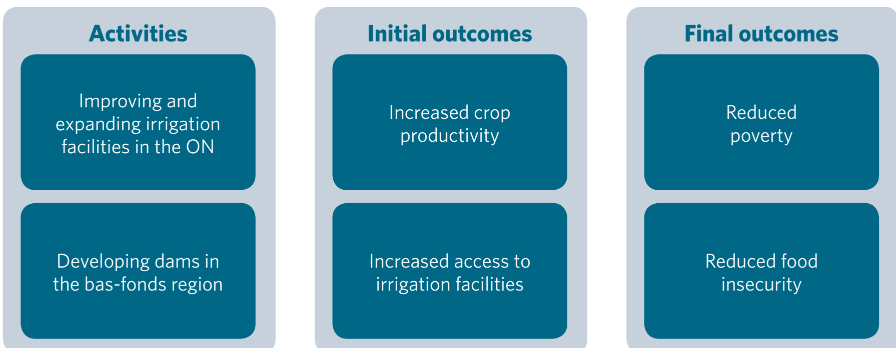
Under irrigation infrastructure the project's aim was to pilot new capital cost collection mechanisms and to promote private irrigation investment. The project also aimed to improve irrigation infrastructure management through beneficiary training, to promote cost reduction of irrigation development and to rehabilitate damaged irrigation perimeters and develop small-scale perimeters in poor areas.

The World Bank conducted beneficiary surveys in 2004 and 2007 to assess farmer expectations and monitor completed work. According to members of the zonal irrigation infrastructure management committees, the rehabilitated irrigated plots met farmers' expectations, and primary and secondary canals were well constructed and correctly maintained.

In 2005, the Malian government began increasing the number of dams in the lowlands region, in order to broaden water access for farmers. The programme was one of several dynamic water control measures for enhancing agricultural production and the diversification of revenue for rural people. The project aimed to expand the production of rice in lowland areas, where production costs were lower. At the time, USAID was looking into an intervention that would help Mali in its efforts to promote the construction of water infrastructure on marginal lands, including flood plains and lowlands, given the high potential of such infrastructure to increase rice production. The intended outcome of this project was to create climate-resilient agricultural production systems and to strengthen the most vulnerable agro-pastoral communities.

The results chain in Figure 3 assists us in thinking more analytically about causes and effects. By looking at the

Figure 3: Results chain of the National Rural Infrastructure Programme



results chain, one can conceptualise what to expect from an evaluation measuring the impact of the irrigation programme. Let us start by first developing the type questions we want answered. What was the impact of the irrigation programme on crop productivity? Did the programme increase access to irrigation? Was it successful in achieving its final outcome goals of reducing poverty and food insecurity? We expect poverty and food insecurity to decrease through increased crop productivity, due to improved access to irrigation facilities. Reducing farmer dependence on rain-fed crops and increasing crop diversity is expected to decrease food insecurity. Performance indicators can be selected and impact evaluation questions can be formulated on the basis of the results chain.

4.1 Impact evaluation I: Difference in differences with matching

Dillon (2008) uses three techniques to evaluate the impact of improved irrigation on poverty in northern Mali. The first is a difference-in-differences (DID) estimation. Secondly, propensity score matching (PSM) is used to arrive at more comparable treatment and control groups. Finally, DID is used along with matching as an additional robustness check. This study estimates the impact of access to irrigation on poverty, production and nutrient intakes.

Data were collected through field research, and included a multi-topic household survey in northern Mali, conducted in 1997–1983 and again in 2006. Estimates of the project impact derived from outcome indicators could contain either upward or downward bias. The differences between the control and treatment group's pre-treatment characteristics create this bias. For example, programmes allocated to highly productive areas to ensure programme success have pre-treatment characteristics of higher productivity to start with, creating an upward bias due to non-random placement. This selection bias implies that the distribution of observable and unobservable village and household characteristics between treatment (with irrigation) and comparison groups (without irrigation) may be statistically different.

Dillon (2008) starts with DID estimations. The DID is estimated by comparing the mean changes between treatment and control groups over two periods of time. The DID estimator controls for the treatment group's fixed effects (i.e. features of the group that do not change over time) through differencing. The DID estimator assumes that rates of change between the two groups would have been the same in the absence of development intervention. The results of the DID regressions are reported in Table 2.

Four performance indicators are used in these regressions, the first one being the consumption aggregate. Before the intervention, the consumption aggregate was higher for the control group. After the implementation of the programme, this was reversed: consumption in the treatment group was 71.9 units higher than in the control group. The increase in the differences from the pre- to the post-implementation period is the programme impact. In other words, the programme had a positive and a significant impact (at a 5 per cent confidence level) on consumption.

The same holds for agricultural productivity, daily household calories and daily household protein. The programme had a

Table 2: Difference-in-differences regression results

		1998			2006		Differences 1998–2006	
Variable	N	Mean	SD	N	Mean	SD		
Consumption aggregate (Real) (FCFAs)	227	482 729.0	346 558.0	246	541 155.0	294 436.0	65 225.0	*
With irrigation	81	427 961.0	343 826.0	82	589 107.0	299 357.0	160 755.0	
Without irrigation	146	513 144.0	345 494.0	164	517 178.0	289 891.0	12 226.0	
Difference with and without irrigation		-85 152.0			71 929.0		148 529.0	**
Agriculatural production (kg)	246	447.1	879.1	246	1 028.2	1 554.6	581.0	
With irrigation	82	589.9	958.5	82	2 472.5	1 845.2	1 882.6	
Without irrigation	164	375.7	830.5	164	306.0	605.2	-69.7	
Difference with and without irrigation		214.3			2 166.5		1 952.3	**
Daily household calories	228	5 307.4	301.0	228	5 096.9	208.4	-210.5	
With irrigation	59	4 398.1	387.0	59	6 234.8	474.8	1 836.8	
Without irrigation		5 624.9	380.5	169	4 699.7	220.0	-925.2	
Difference with and without irrigation		-1 226.8			1 535.1		2 762.0	*
Daily household protein (grams)	228	160.5	8.9	228	139.3	5.7	-21.1	
With irrigation	59	136.0	11.4	59	172.4	13.1	36.4	
Without irrigation	169	169.0	11.3	169	127.8	6.0	-41.2	
Difference in protein with and without irrigation		-33.1			44.6		77.6	**

Note: * and ** denote statistical significance at 10 per cent and 5 per cent confidence levels respectively.

Source: Dillon (2008)

positive and a significant impact (at either 5 per cent or 10 per cent) on all three measures of performance.

Exercise

- Discuss how each of the performance indicators below is related to this programme:
  - aggregate consumption;
  - agricultural production;
  - daily household calories; and
  - daily household protein.
- Using the results chain provided in section 4, describe the mechanism through which these performance indicators are affected by the implementation of the NRIP.

In order to ensure that the comparison group closely resembles the treatment group in baseline characteristics, the author uses a PSM technique for constructing the comparison group. Since PSM estimates are very sensitive to how exactly the matching is done, in this study, four different matching estimators (nearest-neighbour matching, matching with 10 closest neighbours, kernel and local linear matching techniques) were employed to check the robustness of matching results.

PSM matches households with similar observable characteristics in order to measure the impact of irrigation, varying only the treatment, which in this case is access to irrigation. The results from this method show greater estimated effects than those of the DID method. The study concludes that irrigation has a significant, positive impact on household.

Table 3 provides estimates of the programme impact when DID is applied to the matched sample. Qualitatively, all the results hold: the programme has a positive and significant impact on all four measures of performance. The estimates change in magnitude. But the sign and the significance of the coefficients do not change, leading to the conclusion that the results are robust in terms of different identification strategies; that is, several different ways of conceptualising and measuring the links in the results chain all point in the same direction, the success of the project.

Table 3: Difference-in-differences regression results with matching

Estimator Differences in the outcome variables (1998–2006)	N	Nearest neighbour matching (1)	Nearest neighbour matching (10)	Kernel Epanechnikov	Local linear matching estimator
Household consumption (FCFA)	98	738 148 (310 093)**	694 921 (274 938)**	739 050 (292 275)**	738 148 (318 645)**
Agricultural production (kg)	98	1 170 (367)***	1 591 (288)***	1 284 (341)***	1 888 (295)***
Daily total household calories	98	11 371 (4 862)**	10 494 (3 742)***	10 618 (4 230)**	11 371 (4 611)**
Daily total household protein	98	360 (141)**	326 (115)***	328 (126)**	361 (144)**
Livestock (in total livestock units)	98	6.6 (2.13)***	6.4 (2.07)***	6.2 (2.03)***	6.6 (2.19)***
Household composition					
Men	98	0.429 (0.483)	0.733 (0.364)**	0.625 (0.370)*	0.429 (0.444)**
Women	98	0.265 (0.585)	-0.139 (0.449)	0.106 (0.514)	0.265 (0.601)
Boys	98	-0.326 (0.548)	-0.237 (0.411)	-0.073 (0.439)	-0.327 (0.550)
Girls	98	-0.061 (0.587)	-0.112 (0.438)	0.187 (0.471)	-0.061 (0.605)

Note: *, ** and *** denote statistical significance at 10 per cent, 5 per cent and 1 per cent confidence levels respectively.

Source: Dillon (2008)

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