PABRA
Pan-Africa Bean Research Alliance
Better Beans for Africa

Food security and common bean productivity:

Impacts of improved bean technology adoption among smallholder farmers in Burundi

SDC FLAGSHIP PROJECT
END LINE REPORT 2020

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Executive Summary

In 2015, the Pan-Africa Bean Research Alliance (PABRA) programme of the Alliance of Bioversity International and the International Center for Tropical Agriculture (ABC) started implementing the project: **"Improving bean productivity nutrition, incomes, natural resource base and gender equity for better livelihoods of smallholder households in sub-Saharan Africa".** The project was financially supported by the Swiss Agency for Development and Cooperation (SDC), with complementary funding from Global Affairs Canada (GAC).

Burundi was selected as a flagship country for the project together with Zimbabwe, to develop a vibrant bean sub-sector in these two countries characterized by high productivity, increased bean consumption for food, nutrition security and increased bean trade with active involvement of women in the value chains. During the project launch in 2015, these two countries were emerging out of crisis. Burundi had suffered domestic political upheavals while Zimbabwe had experienced economic breakdown that ensued after land reforms.

The crises caused significant decline in bean production. The project aimed to improve food security, nutrition, income and gender equality of smallholder farmers through increased bean productivity. It also aimed to enhance nutrition, knowledge and gender integration, focusing on three overarching objectives:

i. Strengthening seed production and delivery systems, engaging both public and private-sector partners and using various seed delivery options, and promotion of released high Fe (Iron) and Zn (Zinc) bean varieties for wider adoption.

ii. Supporting nutrition initiatives linked to biofortified bean varieties, and nutrition information; while integrating gender.

iii. Supporting capacity building of researchers, development partners, value chain actors and farmers to enhance relevant skills.

This report assesses short and medium-term outcomes of project interventions in Burundi. Work presented in the report is based on two rounds of surveys conducted in July, November and December 2019. For the surveys, 805 households were interviewed from 63 Collines (the smallest administrative unit in Burundi and the equivalent of a village) that were selected to represent bean growing households in the country and support rigorous evaluation of the project outcome. The project implementation sought to collaborate with a diverse set of actors, from researchers, extension personnel, NGOs, private seed and input suppliers and agro-dealers farmer organizations, to facilitate uptake of technologies at scale. For this reason, the method of randomly assigning households into intervention and non-intervention groups done under the experimental methods of impact assessment was not possible. Similarly, the plan to collect a baseline survey was constrained by political challenges, delaying the project commencement. In the absence of the above, this report uses a multinomial endogenous treatment regression—to control for observable and unobservable differences between different adopter categories and ensure unbiased estimates of impacts of technology adoption. Then, we use matching methods of program evaluation—specifically inverse probability-weighted regression-adjusted estimators—to construct a comparison group by "matching" treatment households to comparison group households on their food security, based on observable characteristics. The study also used descriptive analysis to examine the access to technology and skills from capacity building component.

Our findings show that the project was effective in building partnerships and leveraging partner programs to disseminate improved varieties across a wider geographical scope. By the time of the survey, implementation had reached 78 (72%) out of 108 communes; 43% of these communes being primary sites receiving intensive intervention while 31% of the communes were satellite sites with low intervention intensity. A novel feature of this effort was the growth of seed production and access by farmers. The project was able to expand the number of seed producers in communities and reduce the distance within which farmers could access improved seed. Consequently, farmers were able to increase their yield, contributing to food security. Results demonstrate that households adopting the new bean varieties harvested 40% more beans per hectare compared to what they would have harvested had they not adopted them. This enabled them to enjoy higher food consumption even during lean seasons. This result highlights the importance of beans in filling the food supply gap, helping households meet food needs, and further implies that beans can be relied upon to reduce hunger. This notwithstanding, food insecurity persists during months of lean seasons for a significant proportion of households, pointing to the need for continued efforts to enhance bean productivity.

While the project was successful in increasing bean yields among adopters, average yield is still much lower than on-farm trial and on-station yields. This means that it is still possible to improve food security and nutrition in the country through bean production intensification. This study explored this possibility using a stochastic production frontier. Results demonstrate that both scaling out improved bean varieties, agronomic inputs and capacity building show great promise in closing yield gaps. Closing efficiency yield gaps through intensification of capacity building initiatives alone could increase bean yield by 47%, enabling the country to produce sufficient quantities to meet in-country bean demand. The capacity building component targeting women for education on bean management and nutrition worked well. More women than men benefited from the training and demonstrated satisfaction with the knowledge acquired. Study findings also indicate that majority of women trained under the flagship have used the information to change a number of practices on their farms. Moreover, some women reported gaining confidence that they could speak up during group meeting in the presence of men. However, the scope of nutrition education remains limited, as the project supported development of nutritious products for women entrepreneurs, and this scope could be expanded.

List of Acronyms

ABC	Alliance of Bioversity International and International Centre for Tropical Agriculture
ATET	Average Treatment of the Treated
BIF	Burundi Franc
CAPI	Computer Assisted Personal Interviewing
CAPAD	La Confédération des Associations des Producteurs Agricoles pour le Développement
CRS	Catholic Relief Services
DNA	Deoxyribonucleic Acid
ENAB	Enquête Nationale Agricole du Burundi
FAO	Food and Agriculture Organization
GAC	Global Affairs Canada
HFIA	Household Food Insecurity Access Scale
HFIAS	Household Food Insecurity Access Scale
HDDS	Household Dietary Diversity Score
HHS	Household Hunger Scale
ICM	Integrated Crop Management
IFAD	International Fund for Agricultural Development
INEAC	Institut national pour l'étude agronomique du Congo belge
ISABU	Institut des Sciences Agronomiques du Burundi
ISTEEBU	Institut de Statistiques et d'etudes Economiques du Burundi
IPWAR	Inverse Probability Adjustment Regression
MDDS	Minimum Dietary Diversity Score
MDD-W	Minimum Dietary Diversity for Women of Reproductive Age
METEM	Multinomial Endogenous Treatment Effects Model
NGO	Non-Governmental Organization
OLS	Ordinary Least Squares
PVS	Participatory Varietal Selection
PSM	Propensity Score Matching
PICS	Purdue Improved Crop Storage
SDC	Swiss Agency for Development and Cooperation
TLU	Total Livestock Units
UCODE	l'Union pour la Coopération et le Développement
WVI	World Vision International

1.0 Introduction and Background Information

1.1 Introduction

Burundi is a landlocked country in the Great Lakes region of Central-Eastern Africa. The country's economy depends on the agricultural sector. The sector contributes around 40% of the GDP, employs 84% of the labor force and contributes to over 95% to the food supply (PND, 2018). Despite its importance, the agricultural sector is constrained by high population pressure on land, progressively leading to soil fertility depletion and expansion into marginal lands (Cochet, 2004). This is eroding the country's capacity to produce enough food for the country's growing population. The country's per capita agricultural production has declined for years, with obvious implications on food and nutrition security (Baghdadli et al., 2008; WFP, 2014). In 2010, the country's food deficit was estimated at 470,000 tons (cereal equivalent) per year, with almost 75% of the population being food insecure (MINAGRIE, 2011) and 58% of the population chronically malnourished. The deficit in food nutrients is acute for protein and lipids, where only 40% and 22% of daily needs are fulfilled respectively (MINAGRIE, 2008).

Common bean is a staple crop for food security in Burundi. According to national statistics (ENAB, 2018), common bean occupies 599,139 hectares of land, shared between bush cultivars (366,061 hectares) and climbing cultivars (233,078 hectares) per year. This is equivalent to approximately 45% of the total harvested area per year (ENAB, 2018). The crop is cultivated everywhere in the country except for the few agro-ecological regions where there is acidic soil. In terms of volume produced, bean production ranks third after banana and sweet potato production.

Common bean is vital for nutritional security of Burundian households, providing 50% of proteins and approximately 20% of calories in the diet. Moreover, the crop is important for staggering food supply: with edible leaves, pods, green grains and dry beans—thus a strategic food security crop. Per capita, bean consumption is the highest in the region, estimated at 50 kilograms per year (Ntukamazina et al., 2017). Beans also contribute to household cash income, for those who produce surplus to sell.

The importance of the common bean in the food and nutrition security of Burundi was recognized as early as the 17th and 18th centuries (ISABU, 2016), when it was introduced in the country from Angola (Baert, 1994) to complement sorghum (Sorghum spp) and finger millet (Eleusine coracana). Its introduction was a response to persistent decline in the two cereal crops (Cochet, 2004) as their cultivation expanded into marginal lands to cope with population pressure. Common bean has a short growing cycle and can produce twice or three times per year in a mixed cropping system (Cochet, 2001)—compared to sorghum and finger millet with longer gestation periods.

After realizing the importance of common bean production in the country, the government of Burundi initiated research in 1933 to increase bean productivity with the introduction of some varieties of Guatemalan origin (Devos et al., 1983)[1]. However, it was not until 1979 that the bean research program was established at Institut des Sciences Agronomiques du Burundi (ISABU). A few years later, in 1984, the Alliance for Bioversity International & International Center for Tropical Agriculture (ABC) designed and implemented a regional program for bean improvement in the Great Lakes Region, and Burundi participated. As a spinoff of this program, the Pan-Africa Bean Research Alliance (PABRA) was born in 1996, with the African Bean National Research Institutes as members and ABC as a coordinating entity. The aim of PABRA is to accelerate research in the region, while developing the capacity of researchers in national programs to increase yield and reverse

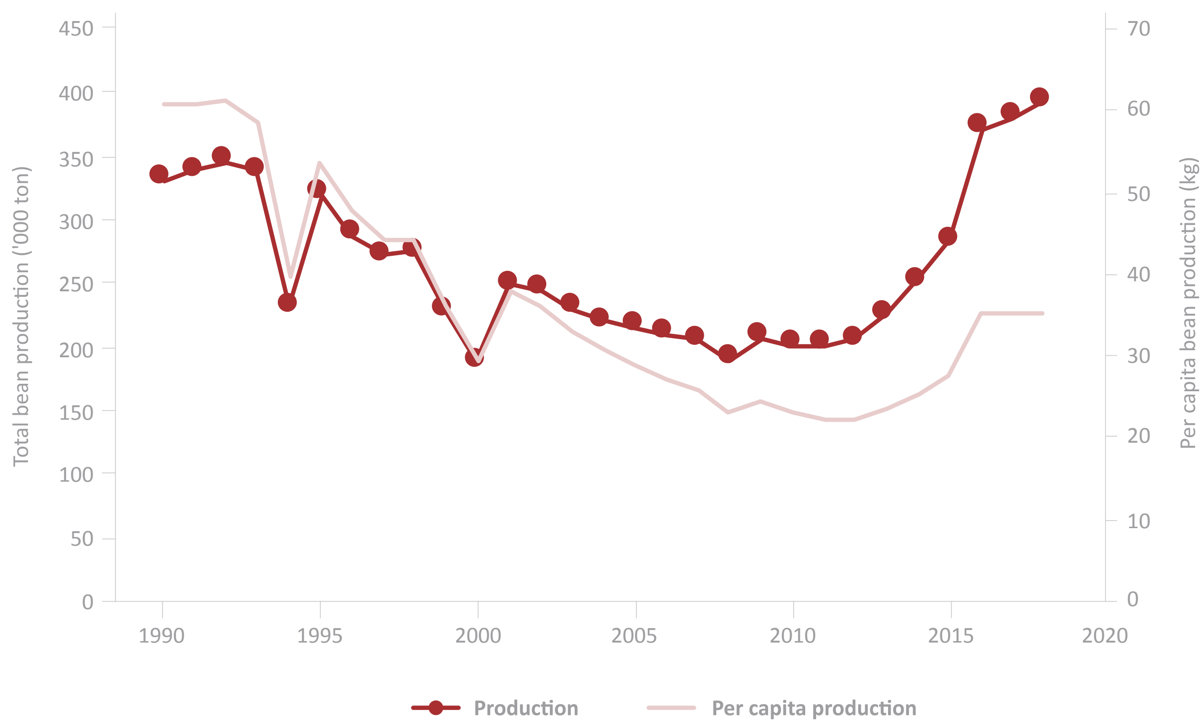
1 From 1933 to 1962, INEAC led essays of several varieties as well as the bean tests in the research stations of Gisozi and Moso. Over the same period, two varieties (i.e. Colorado, Bayo, mixed Mexico and Cuarentino) were disseminated around the two research stations (Berti, 1985).

declining trends in bean production observed in the early 1990s. Consequently, younger programs were able to receive germplasm developed in other member countries or by ABC, evaluate it and release varieties in their own countries. Under the same arrangements, ISABU of Burundi had released 22 varieties between 1994 and 2013, just before the flagship project started in 2015.

This investment in Burundi is reflected in common bean production trends that have steadily increased since 2008, to 393,233 tons in 2018–the highest ever in the history in the country. This growth saw a recovery from a decline in the 1990s and early 2000s, following political instability in the country (Figure 1)[2]. The growth in bean production has been slower than population growth (Barampanze and Ndikumana, 1994; ISTEEBU, 2016). Figure 1 shows that annual per capita bean production of about 35 kilograms in 2018 was below the level of 60 kilograms per person per year in the 1990s. As well as high population pressure on land that limit the expansion of area under bean production, the use of low yielding technologies is also a factor. In the last two decades, growth in the area allocated to bean production has been modest (1.3% per annum) while the population grew above 2% per annum (FAO data, 2018). Thus, high-yielding technologies are necessary for accelerating productivity growth in Burundi.

In this context, Burundi was selected as a flagship country under the project: **"Improving food security, nutrition, incomes, natural resource base and gender equity for better livelihoods of smallholder households in sub-Saharan Africa".** The project goal is aligned to the Burundian national objective of improving food security, nutrition, incomes and gender equality of smallholder farmers. The project sought to increase access to quality seed of improved, high-yielding and market demanded bean varieties together with complementary crop management practices for enhancing bean yields. The aim is to increase access to nutritious bean products for food, and improve linkages to profitable markets for higher household income. The flagship project in Burundi was implemented between 2015 to 2020.

FIG 1 Bean production and per capita available trends 1990-2017 *(Source: FAO data, 2019)*



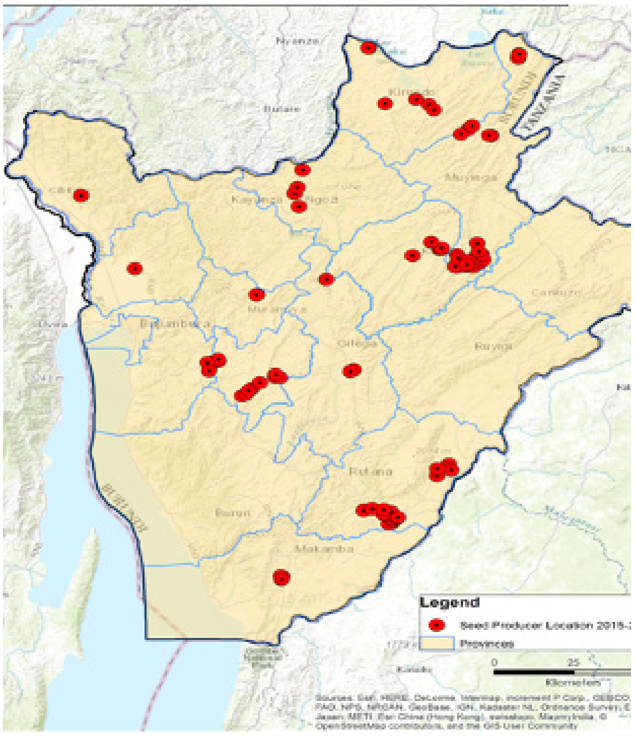
2 When the country experienced conflict during 1990 and 2005, bean production grew at negative rate, declining from 1.5tons per hectare to about 0.9 tons per hectare: a 60% decline.

Approximately 13 high-yielding bush and climbing bean varieties were disseminated among smallholder farmers[3], based on diversified seed systems facilitated through public-private partnership arrangements using participatory processes: field demonstrations, field days, participatory varietal selection. Partners included NGOs, other international initiatives and private seed producers. Varieties were bundled with crop management practices (i.e. in agronomy, post-harvest handling) and value addition guided by 20 years of PABRA experience in other countries with similar conditions. These interventions sought to strengthen formal and informal links between actors to facilitate the flow of new varieties while creating awareness among farmers, training and catalyzing seed multiplication. Consequently, the number of private seed producers increased from about 15 in 2014 to 55 by 2018 in different provinces of the country; positively influencing access to improved seed varieties.

The project developed various channels and approaches to deliver seed and Integrated Crop Management (ICM) to 198,164 bean-growing households through partnerships with different NGOs including CARE International, the International Fund for Agricultural Development (IFAD), Catholic Relief Services (CRS), World Vision International (WVI), La Confédération des Associations des Producteurs Agricoles pour le Développement (CAPAD), Appui au Développement Intégral et à la Solidarité sur les Collines (ADISCO), and l'Union pour la Coopération et le Développement (UCODE). The project aimed to improve smallholder knowledge on nutrition and gender integration, and reached 78 (72%) out of 108 farmers' communes; 43% of the communes being primary sites receiving intensive intervention, with 31% of the commune sites receiving low intensity intervention. This means that about 23% of the communes did not receive any intervention from the flagship project, thus classified as control groups.

This is the first study to measure the ex-post impacts of PABRA research in Burundi, exploring different dimensions of food security

FIG 2 Seed producers from 2015 to 2017 in different communes in Burundi



and nutrition adequacy, which is the ultimate goal of PABRA and that of the Burundian government. The study used descriptive analysis to examine the characteristics of bean farmers, access to technology and skills from capacity building components and econometric methods to analyze the adoption behavior of promoted technologies and their associated impacts. Results show that the project effectively disseminated varieties across a wide geographical scope while leveraging partnerships along the value chains. The project also was effective in enhancing the knowledge of farmers, especially empowering women and strengthening the capacity of private actors in up-stream value chains. As a result, the project increased access and use of improved bean varieties and associated crop management practices; increased bean yield and contributed to food security. However, a significant proportion of households remain vulnerable to food insecurity during months of lean season; requiring continued efforts to enhance their quality of life.

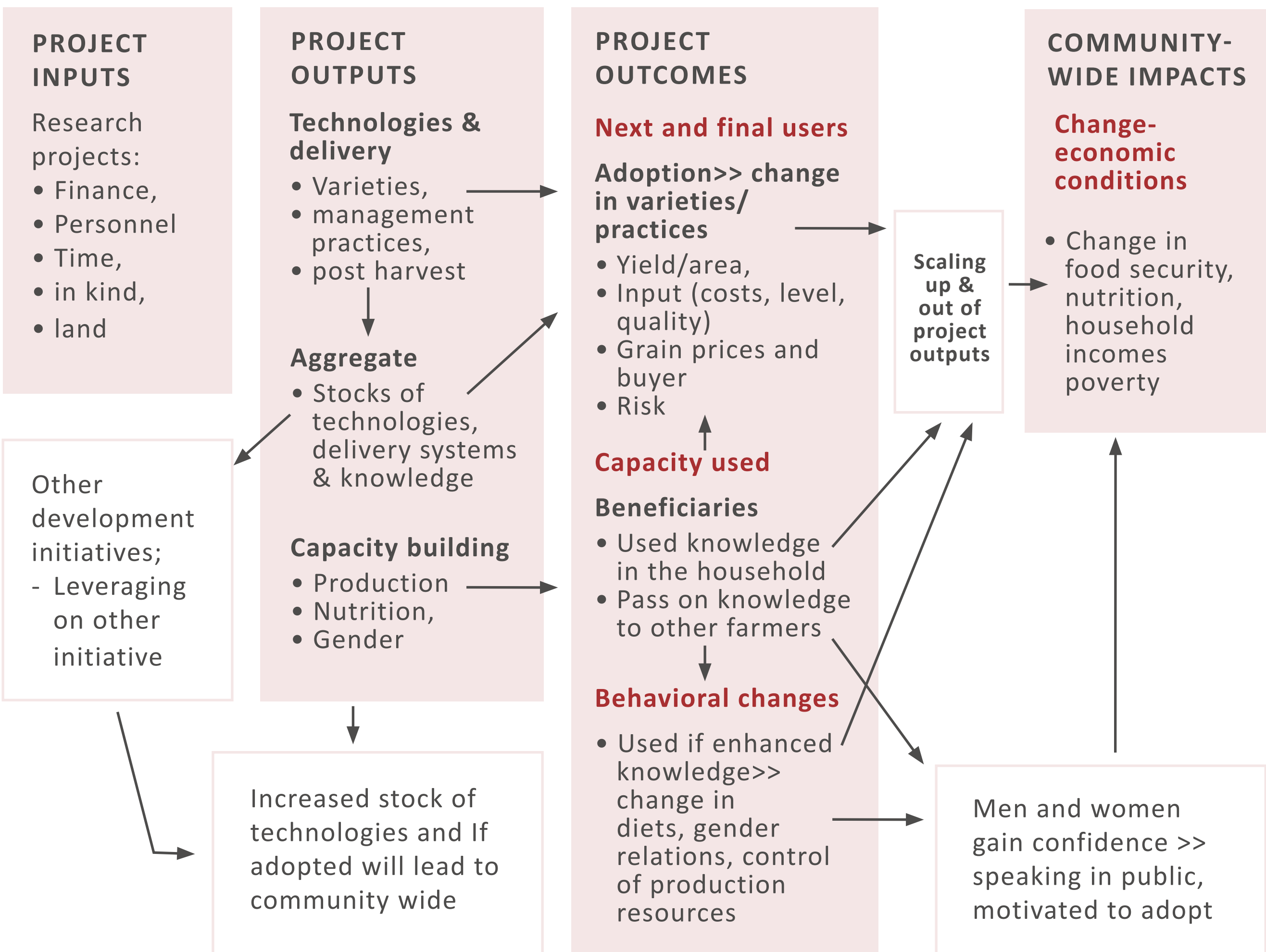
3 Namely, MAC44, RWR2245, CODMLB003, MUHORO, RWV1129, GSZ611, MUSENGO, MUKUNGUGU, VCB81013, GASILIDA, IZO2015110, KATB1 and A

2.0 Methods and Materials

2.1 Study Design and Theory of Change

The study design began with a two-day workshop with the ISABU team, to review the project performance based on output and dissemination of technology and information to farmers. The project was evaluated by logically linking the interventions to bean production challenges, achievements in terms of outputs and geographical scope of coverage. The workshop participants also assessed the contributions of other initiatives that leveraged the investments under the SDC project and integrated them into impact pathways mapped in figure 3. The same workshop discussed and agreed on the study objectives for impact assessment. Figure 3 demonstrates the flagship technical investments in varietal development and delivery; market linkages; integrated crop management practices (ICM); nutrition and gender equality linked to the overall goal to improve food security; nutrition of the smallholder bean growing households and ultimately reducing poverty via a chain of causal pathways. At the farm level, if farmers have access to improved seed, ICM and modern post-harvest handling techniques; and are trained in nutrition and gender supported by ISABU in partnership with NGOS; and if they adopt all or components of these technologies, they will raise their bean yields, in turn increasing bean volumes available for home consumption, sale or both, ultimately increasing food security. The flagship project may influence household

FIG 3 SDC flagship project interventions' impact pathways

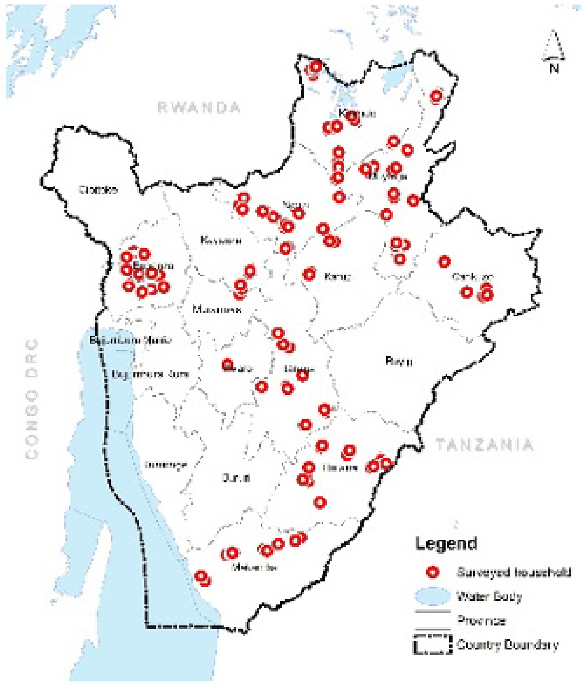


food and nutrition security through increased gains in yield and better access to market, and through increased awareness on nutrition delivered through gender responsive nutrition education in the flagship intervention. Data used in the analysis indicates that there was access to nutritional education under the flagship project reached relatively modest households compared to education on bean production. Thus, we focus on increased access to technological packages and training in bean production as the major pathways the flagship delivered impacts on food and nutrition security.

2.2 Data Sources and Measurement of Impact Variables

Data used for the study was collected from bean-growing households through a survey implemented in July 2019 by ISABU in collaboration with ABC. A total of 805 households were selected from 63 Collines and interviewed in two rounds. The sample of households was selected based on a stratified sampling method, with their probability of being chosen proportional to the number of Collines in the commune. The first round of the survey was conducted in July 2019 and elicited information on household level variables such as farm and household characteristics (housing characteristics and assets, social networks); production data including farmer knowledge and adoption of research derived varieties; inputs and bean harvests; market participation, and general household composition. The first round also gathered information on food items categorized into 12 groups consumed by the entire household within 7 days prior to the interview. For each food group, respondents provided information on the number of days it consumed the food during the 7 days of recall. From this data, we constructed the food consumption score, by summing the number of days that the household consumed each food group[4], multiplying by the weighted frequencies, and summing across groups to obtain a single proxy indicator. The household

FIG 4 Surveyed households



dietary diversity score is computed as the number of food groups consumed by the household.

The second survey occurred in November and December 2019 and gathered information on two dimensions of food and nutrition security: the food consumption by women of reproductive age data in 24 hours, and then on 7 day recall for the entire household. Food groups were disaggregated further into food items, distinguishing nutrient rich foods from others and their consumption by women in reproductive age (15-65 years) as the reference group based on 24 hours of recall. Based on the data from the food consumed by women of reproductive age, a minimum dietary diversity score for women of reproductive age was constructed. A Minimum Dietary Diversity for Women of Reproductive Age (MDD-W), a dichotomous indicator developed and validated as a proxy of micronutrient adequacy by Food and Agriculture Organization (FAO) was used (Herforth et al., 2016). Women's dietary intake was assessed based on qualitative 24-hour recall. Food items from each of the 10 predefined food were: 1) cereals: white roots and tubers, and plantains; 2) pulses: beans, peas, and lentils; 3) nuts and seeds; 4) dairy; 5)

4 Namely staples, pulses, vegetables, fruit, meat and fish, milk and dairy, sugar and honey, oils and fats.

meat, poultry, and fish; 6) eggs; 7) dark green leafy vegetables; 8) other vitamin A-rich fruits and vegetables; 9) other vegetables; and 10) other fruits.

The second dimension was on food insecurity conditions experienced by the household using the standard 9 questions that capture the occurrence of the condition in the previous 4 weeks (30 days) followed by questions on the frequency of occurrence for each condition. Then, responses to these questions were used to construct measures of food security such as household food insecurity and access scale (HFIA) score and household hunger scale following the formula recommended by FAO. In each round of the survey, data were collected using structured household and community level questionnaires by a team from ISABU who have good knowledge in French and Kirundi and have extensive experience in the bean production context of Burundi. The survey team were trained for 5 (five) days on how to ask the questions and use mobile devices in data collection that were programmed in both English and French languages. Prior to the actual survey, the questionnaires were translated from English into French, uploaded onto the mobile devices and pre-tested on selected farmers. A community questionnaire was administered to key informants–village leaders and elders–to gather information including access to information, seed, seed distribution programs, credit, roads, and market infrastructure and cultivar changes, and agro-climatic shocks.

3.0 Descriptive Analysis of Technology Access, Farmers' Satisfaction and Utilization

3.1 Farmers' Adoption of Improved Varieties

New improved bean varieties need to be accessible to communities before they can be adopted. The survey included questions on the type of varieties grown, their names, year the variety was first known and planted on the farm and quantity of seed planted in season B of 2019. For each variety grown, a handful of seed sample was obtained from the farmer, labeled with a code aligned to the household identifier provided from the Computer-Assisted Personal Interviewing (CAPI). These samples are still undergoing DNA analysis to validate reported variety identification. This report uses farmer reported variety identification. Table 1 shows a high prevalence of improved varieties use across surveyed farms[5]. Approximately, 72% (574) of households cultivate different improved bean varieties, and 70% (559) cultivate traditional landraces—thereby 42% of the farms grow both landraces either in separate or on the same plots (Table 1). A typical bean farmer plants about 26 kilograms of seed of different cultivars; 13.6 kilograms (44%) of which are of improved varieties and 12 kilograms of the landraces.

Bean growers maintain high varietal diversity both within the same plot and at farm level. On average, a bean plot is cultivated with two varieties, but farmers can grow up to 11 varieties, mixing improved and local varieties in the same plot. About 18% of bean plots were cultivated with a mixture of landrace[6] and improved varieties. The rest 41% (404) of the plots were exclusively planted with traditional varieties and another 41% (406) of the plots

TABLE 1 Percentage of adopters, adoption intensity and types of bean grown

VARIABLE	OBSERVATION	MEAN	STD. DEV.
Percentage of household			
Variety local	799	69.96	45.87
Variety improved	799	71.84	45.01
Extent of adoption			
Quantity of seed improved planted (kg)	1,120	13.56	21.12
Quantity of seed local planted (kg)	1,121	12.11	20.33
Allocation of bean plots by variety type (%)			
Land races only	992	40.7 (404)[NB]	
Improved variety only	992	40.9 (406)	
Landrace +improved mixed	992	18.4 (182)	

NB figures in brackets are the absolute number of plots

5 To ensure that variety identification is based on accurate information, seed samples were collected for each plot planted by the farmer in season B, for further identification using DNA finger printing tools that are more reliable for variety identification.

6 According to Nahimana (1991), the mixtures of varieties are composed, among others, of several traditional cultivars that have naturally been selected by farmers based on different criteria: the adaptability to climate conditions, good organoleptic qualities, the tolerance of some insect/pests and diseases and the good integration in the traditional mixed cropping system.

planted with pure improved varieties. While different farmers may partially adopt new crop varieties for different reasons, such as the need for varietal diversity; experimentation or matching variety with soil characteristics (Bellon and Taylor, 1993), bean growers in Burundi, traditionally grow variety mixtures. They cultivate pure stands of improved varieties for the market or when experimenting with the variety before incorporating it in the mixture grown for home consumption (Goderis, 1995).

Both men and women are likely to adopt improved varieties as full adopters or partial adopters. Results also reveal no correlation between the adoption of improved varieties and the sex of the plot manager or the household type. Both men and women bean farmers adopt improved varieties at the same rate. However, female farmers living in female-headed households (divorced) and those that are single are more likely to access seed of improved varieties from grain market. Project interventions have greatly influenced access to improved seed, enabling high levels of adoption. For example, among the adopters, the majority (74%) learnt and planted the varieties for the first time between 2014 and 2019 (Figure 5), reflecting high access to improved seed varieties in the last five years of the project. Among the adopting farms, improved varieties are replacing landraces. For example, when asked which varieties they recently stopped growing, most of the adopters (95%) mentioned a landrace.

3.2 Farmers' Satisfaction with Variety Performance

The high adoption of improved varieties reflects their good properties relative to the traditional local varieties. During the survey, farmers were asked to rate the importance of each trait when choosing a variety to grow. Responses were provided on a five-point Likert scale; where one was low importance or performance and 5 extremely important. For each trait, a follow-up question sought to elicit information about the farmers' evaluation of major varieties. If a trait received a low-performance yet high-importance rating, breeders need to improve the level of that trait. The overall rating of a "satisfaction value" is calculated by multiplying the performance and the importance value (Ferguson et al., 2005). To evaluate the effect of crop improvement research on meeting farmers' preferences, we compare the satisfaction levels of the currently grown variety with that of a variety the farmer stopped growing recently. As expected, farmers reported higher satisfaction from the varieties they are currently growing compared with varieties

FIG 5 Year the curent variety was first known and planted by the current adopters

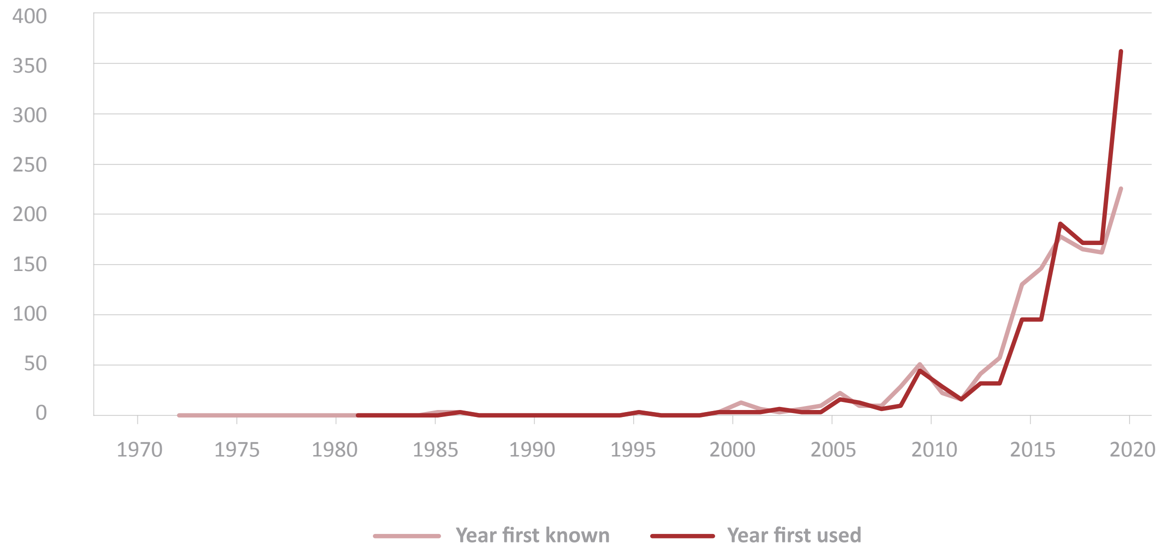
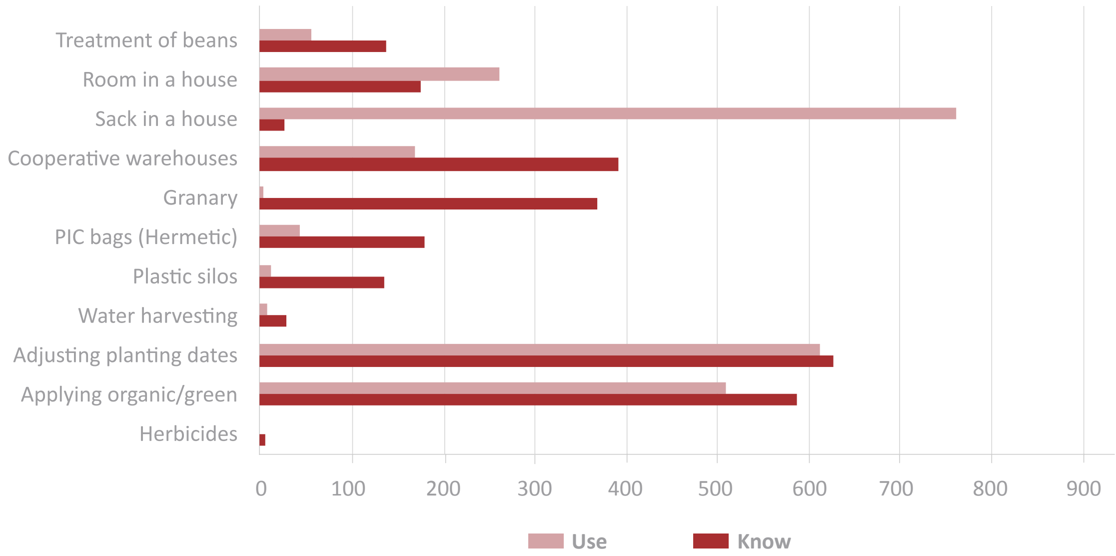


FIG 6 Number of farmers who are aware and use management practices



they stopped growing recently. The average satisfaction rating for all 23 traits was 31 for currently grown varieties and 20 for varieties recently replaced, resulting in 11 extra points for satisfaction. This result means that varietal improvement research was effective in meeting farmers' trait preferences.

There was no statistically significant difference between men and women when rating satisfaction with the performance of Flagship varieties. The lack of gender difference is the success of participatory variety selection process that helps integrate men and women preferences into varietal development.

3.3 Access and Use of Recommended Management Practices

Disseminated together with improved varieties, were good agronomic inputs and climate-smart management practices. Results show that the majority of farmers have accessed information on the recommended pre and post-harvest bean management practices. Notably, they know about the importance of adjusting the planting calendar in response to weather information, use of organic or green manure to manage soil fertility and existence of storage

TABLE 2 Comparison of farmers' satisfaction for currently major variety and recently dropped variety

	MALE		FEMALE		ALL		DIFF (MEN-WOMEN)
	MEAN	SD	MEAN	SD	MEAN	SD	
Change in satisfaction (overall)	12.6	12.7	12.5	12.7	12.5	12.7	-0.1 NS
production traits	4.0	4.0	4.0	4.0	4.0	4.0	0.0 NS
markets	4.4	4.6	4.3	4.6	4.4	4.6	-0.1 NS
consumption	4.2	4.6	4.1	4.6	4.2	4.6	0.0 NS

NB: NS denotes not statistically significant at 10%

warehouses provided by cooperatives (Fig 6). Post-harvest techniques, notably use of PICS bags, warehouses and plastic silos, all promoted under the project, are still in their early stages of diffusion and few respondents knew about them. Only 181 (22.5%) respondents out of 807 knew about PIC bags, while 394 (49%) knew about cooperative warehouses.

Compared to pre-harvest techniques, use of recommended post-harvest methods remained low even among those who were aware of them (Fig 6). As with varieties, we examined farmers' perception towards these management practices using a 3-point scale; whereby 1 represents low and 3 high satisfaction. For pre-harvest management techniques, the levels of satisfaction was in the range of 60-80%, which is fair to good performance and explains high use rates (Table 3).

The technique of adjusting planting dates is perceived by farmers as highly effective and low-cost, but for a good number of farmers, the technique increases labor perhaps because they lose flexibility in post-planting activities. Organic manure is effective and not labor intensive, but the technique is costly for the majority of farmers, thus lowering their satisfaction. Post-harvest storage technologies such as PICS bags and warehouses were used by few farmers because the supply is still low and thus costly. For example, a 100 Kilogram PICS bag costs 8.500 BIF ($4.7). To increase the adoption of PICS bag, the Government of Burundi has subsidized access to PICS bag which has lowered their price to 5.800 BIF (=$3) a 100 Kilogram PICS bag (MINEAGRIE, 2019).

3.4 Farmers' Access to Capacity Building and Utilization of Knowledge

Sex disaggregated data were analyzed to examine how men and women benefited from project training. At the time of survey in November 2019, about 20% of surveyed households had benefited from training in at least one of the flagship topics. Among those, 70% were represented by women and 30% were men. This is because PABRA puts emphasis on women's big role in bean management. The NGOs providing most of the training also focus

TABLE 3 Farmers' satisfaction with selected management practices

	OBS	MEAN	SD	MINI-MUM	MAXI-MUM	% SATIS-FACTION
Pre-harvest tech						
Applying organic/green manure	511	6.31	1.19	3	9	70.06
Adjusting planting date	614	7.21	1.59	3	9	80.17
Water harvesting techniques	9	5.78	1.09	4	7	64.20
Post-harvest[NB]						
Plastic silos	12	2.75	0.45	2	3	91.67
PICS bags (Hermetic storage bags)	45	2.82	0.49	1	3	94.07
Granary	4	2.50	0.58	2	3	83.33
Cooperative warehouses	170	2.90	0.34	1	3	96.67
Sack in the house	764	2.32	0.58	1	3	77.18
Room in a house	263	2.53	0.54	1	3	84.28
Treatment of beans	56	2.59	0.53	1	3	86.31

NB: Levels of satisfaction based on only the technical effectiveness of the technique.

on women. Access to capacity building among women farmers under the project grew rapidly to 2018, when 43% of the women participated, with only 22% accessing it for the first time while about 20% of the women had previously been trained (Figure 7A). Similar trends were reported among men: their access grew positively from the first year of project and reached a peak in 2018 (Figure 7B).

FIG 7A Among those trained, year when Women (%) accessed training under the flaship project in Burundi 2015-2019

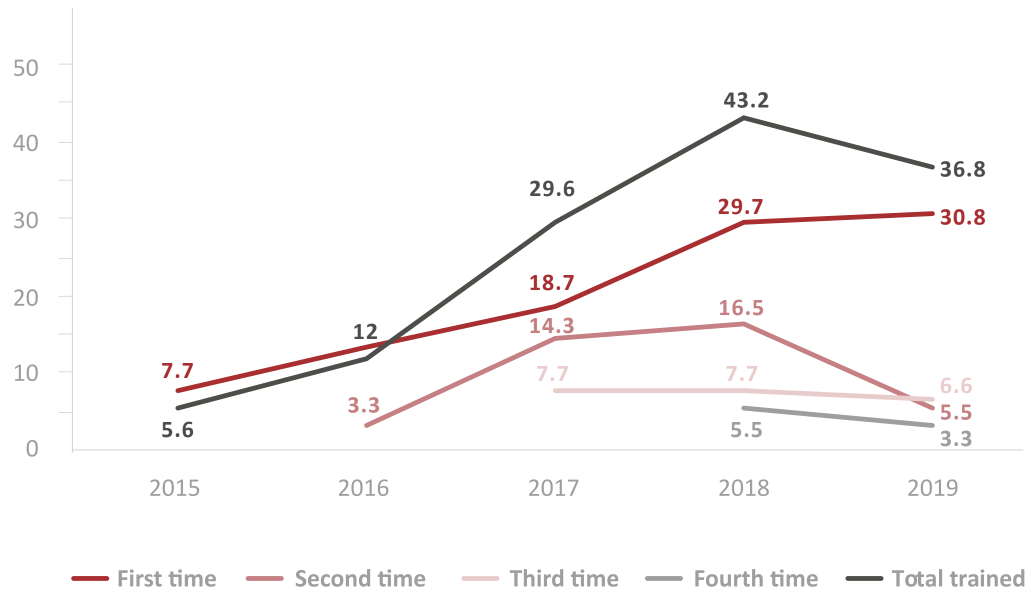
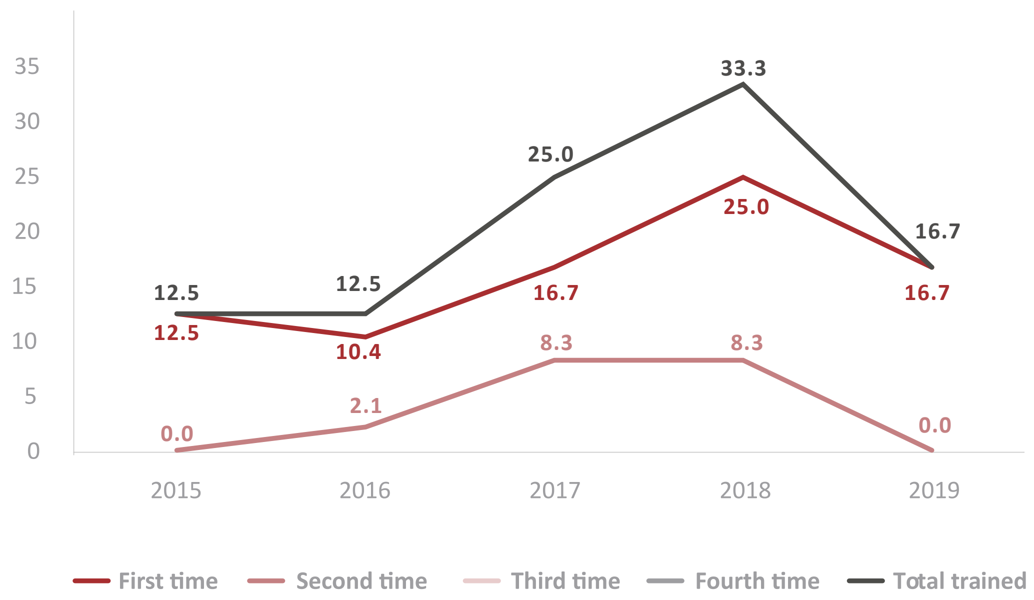
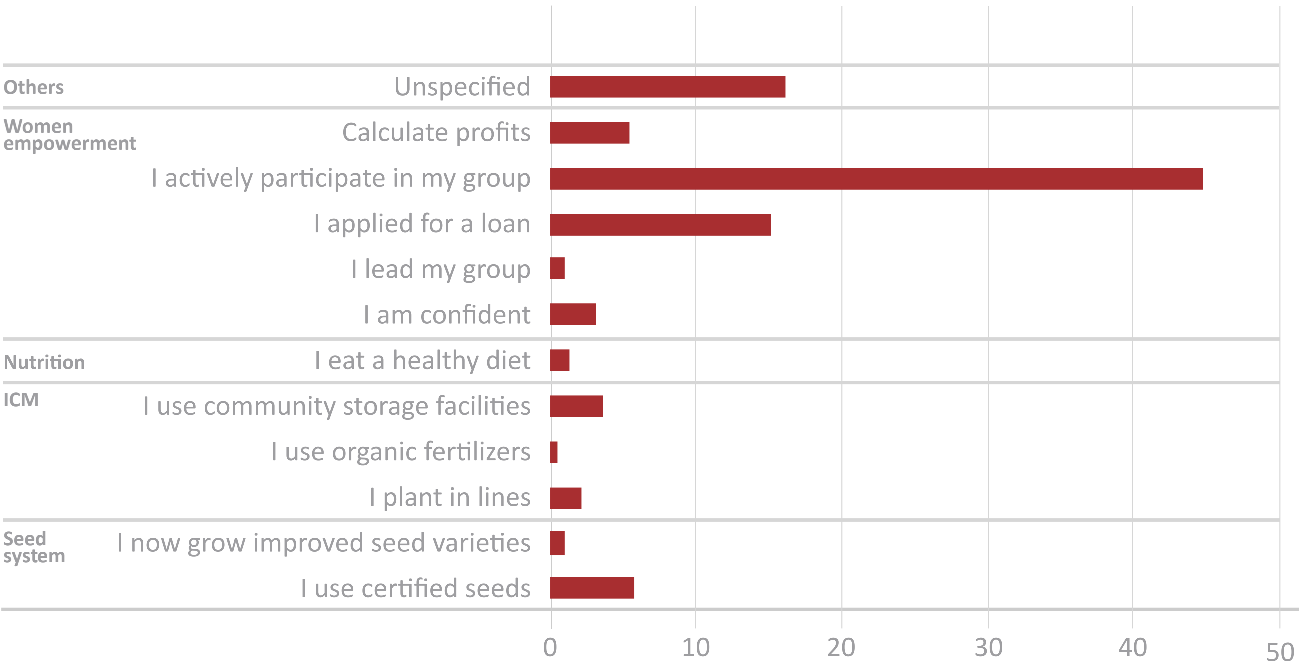


FIG 7B Among those trained, the year when Men(%) accessed training under the flaship project in Burundi 2015-2019



Partnerships played an important role in scaling out capacity building efforts. Out of total training lessons accessed by women, NGOs organized and delivered 52%, while ISABU directly managed 18%. Also noteworthy, is that 95% of responses suggested that women utilized the knowledge they acquired from the training; 61% of responses show that changes were made in ICM; while 21.5% were in seed quality and about 8.5% of the changes contributed to women empowerment (Figure 8).

FIG 8 Percentage of women responses showing changed practice/behavour as result of training



4.0 Farm Level Performance of Improved Bean Technology

4.1 Descriptive Analysis of Yield from Improved Varieties

It is crucial for us to assess whether the project was able to improve bean productivity. Estimating the effect of improved variety adoption on bean yield in the context of high variety diversity and partial adoption can be challenging. As described in earlier sections and confirmed by the data used in the analysis, some farmers adopt partially by mixing new variety seeds with landraces. To account for partial adoption when modeling the effect of improved bean variety adoption on bean yield, we measure adoption at plot level and define adoption as a choice of; 1) planting improved variety only; 2) partially mixing of improved and landraces in the same plot; and 0) no adoption when landraces only are cultivated in the plot. Thus, adoption of improved variety is defined as a multivalued treatment variable, with yield as the outcome variable.

We computed bean yield as the quantity of grain in kilograms, harvested from each kilogram of seed planted in season one of 2019. Quantity of seed planted is a proxy for area, because in small scale mixed cropping systems such as those in Burundi, it is easier for farmers to recall amounts of seed planted than when asked about the size of bean area (Sperling and Munyaneza 1995; Katungi et al., 2018). Out of 1,992 plots surveyed, 45-50% had a portion of the bean crop harvested fresh, i.e. before dry and ready for final harvest (Table 4). Among the plots harvested fresh, the percentage harvested fresh varies from 0.001 to 80%, with an average of 13-16%. A comparison of fresh harvest across different categories of plots defined by level of adoption, did not reveal statistically significant differences. Thus, the adopters and non-adopters of improved varieties behave in the same way towards fresh harvest. We ruled out any possible systematic bias in yield estimates linked to fresh harvesting. During interviews with farmers, each respondent was asked to estimate the portion of bean crop that was harvested fresh and the quantity harvested dry. Based on responses, the fresh harvest was converted into dry equivalent before computing yield.

TABLE 4 Percent of bean harvested fresh and the average quantity for grain harvested per one kilogram of seed planted

		LOCAL VARIETIES ONLY	IMPROVED VARIETIES ONLY	IMPROVED VARIETIES + LOCAL
What bean in this plot was harvested fresh?		45.63	45.67	50.5
If yes, percent of harvest that was fresh	Mean	14.80	17.77	15.85
	SD	15.80	12.82	11.48
Use of fresh harvested	Consumption	100	97.39	99.35
	Sold		2.61	0.65
Seed multiplication ratio	Mean	9.85	11.47	10.83
	SD	4.93	6.13	5.15

NB figures in brackets are the absolute number of plots

Table 4 shows that adopters outperform non-adopters in terms of the quantity of bean harvested from each kilogram of seed planted in season B 2019. In the 2019 Season(b), farmers that planted improved varieties obtained higher seed multiplication ratios compared to those who planted landraces. The seed multiplication ratio was 1.62 kg (16.4%) higher for full adopters than it was for non-adopters (Table 4). Improved bean varieties produced the highest seed multiplication ratio of 11.5 kg when planted in separate plots compared with when mixed with landraces (10.8 kilograms). More specifically, bean yield was higher on plots that were planted with only improved varieties (variety type=1), followed by plots that were cultivated with improved and local variety mixtures (variety type=2). The descriptive bivariate analysis, however, can easily under estimate or overestimate yield advantage of improved varieties if adopters are systematically different from non-adopters. For example, adopters might also be decision makers with higher education or capable of using fertilizer. Thus, their yield would still have been higher than that of non-adopters even without planting improved varieties. Conversely, adopters might have planted improved varieties on highly degraded soils that undermines the yield advantage of improved varieties if not controlled for in the analysis. To address these concerns in the analysis, we conduct an econometric based multivariate analysis to predict bean yield for each plot, and determine the yield attributable to the adoption of improved varieties.

4.2 Econometric Estimation of Improved Variety Adoption and its Effect on Yield

We presume that at the time of planting beans, a farmer compares the three adoption options and makes his/her choices to maximize the expected utility. The farmer's choice of adoption category is influenced by household and farm characteristics, plot-specific attributes, as well as location specific factors. Thus, farmers may self-select into the adoption option, depending on their characteristics, adopt some beans which may also influence yield. The decision to adopt and yield might as well be influenced by same factors that remain unobservable to the researcher. A multinomial endogenous treatment effects model (METEM) developed by Deb and Trivedi (2006a, 2006b) has been used in recent impact studies to analyze joint technology choice and its impact on outcomes such as yield (Manda et al., 2015). We follow these studies in applying METE as a two-stage estimation procedure to analyze the effect of improved variety adoption on bean yield in Burundi.

In the first stage, the mixed adoption is specified as a multinomial selection model, while the impact of adoption on yield is estimated using OLS with selectivity correction in the second stage. We apply a maximum simulated likelihood estimation method to account for potential selection on observable and unobservable variables in the estimation of a multinomial endogenous treatment regression model, to ensure consistent and unbiased estimates. Following the recommendation of Deb and Trivedi (2006a) also followed by previous studies that have used METE, we add instrumental variables in the first stage even if the fitted parameters could be identified without adding an exclusion restriction variable (Manda vet al., 2015; Konje et al., 2018). An index of the physical access to seed in the Colline is constructed and included as the instrumental variable. A falsification test was conducted and results show that index of the physical access to seed in the Colline is positively and significantly associated with the use of improved varieties by farmers, but does not directly influence bean yield among non-adopters. Based on results, the selected instrument does not influence the yield obtained by non-adopters—thus validating instruments. The empirical model specification, description of explanatory variables, and the presentation and discussion of the determinants of improved variety adoption are detailed in annex 2.0 while this report provides a brief summary of the important determinants of improved variety adoption behavior and estimated yield effects.

4.2.1 Model Diagnostic Results

The second stage results from a multinomial endogenous treatment regression are presented in Table 5. The model diagnostic test results show that the hypothesis that all the regression coefficients of the variables in the multinomial endogenous treatment regression model are jointly equal to zero rejected. The Wald test statistics ($\chi2$= 330.2) was significant at less than 1%[7]. The factor loadings (lambda) are also significant, which support our assumption that adoption of improved varieties might be correlated with the unobservable heterogeneity in the yield function. The negative sign of the lambda (λ) means that unobservable factors that influence adoption of improved varieties are also likely to be associated with a lower yield.

4.2.2 Summary of Determinants of Improved Bean Variety Adoption

Several factors influence the adoption pattern of improved bean varieties in Burundi. The likelihood of planting an improved variety was positively associated with the physical access to seed for both full and partial adoption, membership in farmer groups and soil fertility of the plot. The likelihood of adopting improved climbing bean varieties is higher on soils of average fertility than it is on plots that have good soil fertility. Adoption of a mixture reduces as one moves from good to poor soil fertility plots. This means that farmers wait to first observe a decline in productivity before adopting intensification technologies like climbing beans. Adoption of improved varieties also varies across agro-ecological environments. Farmers located in villages prone to drought and excessive rainfall are less likely to adopt improved varieties; but increases the probability of mixing improved varieties with landraces in the same plot. This is perhaps because high rainfall may be associated with high disease pressure that motivates farmers to mix improved and landraces as a risk management strategy.

4.2.3 Effect of Improved Variety Adoption on Yield

A comparison of the estimates from the OLS regression under the assumption of exogeneity with results from METE, shows a downward bias in the estimated effect of improved variety adoption when an endogeneity problem is ignored in the estimation (Table 5). As earlier noted, this bias suggests that adoption is likely to be higher among farmers with prior lower yields due to unobservable factors. After controlling for possible unobservable factors, by application of a multinomial endogenous treatment effects estimation, results show that planting improved bean varieties increases yield by 40 percent, which is of larger magnitude. The result is consistent for both bush and climbing bean and comparable to the estimated effect of the improved bean use on yield in neighboring countries of Uganda and Rwanda (Larochelle et al., 2015), where most of the varieties released in Burundi have come from the PABRA germplasm exchange. We find that farmers that cultivate a mixture of improved bean varieties and landraces, i.e. partial adopters, also achieve higher yields than what they would have obtained without improved varieties in the mixture. Specifically, adding improved varieties into the mixture of landraces within one plot increased yield by 27% compared to what it would have been if only the landraces were grown (Table 5). However, the magnitude of the effect is smaller, which implies that mixing improved varieties and landraces, could minimize potential losses in case of risk occurrence, and is likely to lead to loss of some yield gain from full adoption.

Other factors influencing bean productivity in Burundi include quality of staking materials, household characteristics and provinces. Better-educated and well-off households in terms of wealth and household assets harvest greater volumes of beans than the poorer or lower educated ones. As part of climbing bean improvement, research has also promoted the use of quality staking materials, recommending staking length of about two meters. Results show that for one additional unit increase in the length of stake, yield increases by 3%. However, about 27% of farmers continue to use stakes below two meters, undermining the productivity of climbers. This means that this group can increase their yield by an average of 1.5% if they followed the recommended staking. Finally, consistent with the country production statistics, bean yield varies across geographical zones, being higher in Kirundo, Muyinga, Karunzi, and Ngozi compared to Gitega. Kirundo and Muyinga consist of soils considered very rich in fertility and of optimal PH for bean production while Gitega is in the Bututsi natural regions that are considered unfit for bean production.

7 P-value=0.0001

TABLE 5 Multinomial endogenous treatment effect estimation of the impact of improved variety adoption on bean yield

	MULTINOMIAL ENDOGENOUS TREATMENT REGRESSION MODEL						ORDINARY LEAST SQUARES REGRESSION OLS FOR EXOGENOUS ASSUMPTION)		
	LOG YIELD ALL SAMPLE			LOG YIELD CLIMBING BEAN ONLY					
Variables	Coef.	Std. Err.	P>z	Coef.	Std. Err.	P>z	Coef.	Std. Err.	P>t
Improved only	0.399	0.091	0	0.420	0.133	0.002	0.222	0.082	0.007
Mixture	0.270	0.090	0.003	0.274	0.119	0.022	0.110	0.080	0.172
Log family labor	0.178	0.057	0.002	0.125	0.059	0.034	0.184	0.030	0
Dummy fertilizer	0.099	0.080	0.214	0.142	0.116	0.219	0.131	0.081	0.108
Dummy organic fertilizer	-0.039	0.070	0.578	0.134	0.103	0.196	-0.015	0.072	0.83
Log rainfall	0.838	0.711	0.239	1.060	0.811	0.191	0.740	0.777	0.341
Log altitude	-0.063	0.318	0.842	0.180	0.349	0.606	-0.071	0.289	0.806
Log of age	-0.061	0.110	0.582	-0.273	0.151	0.07	-0.069	0.118	0.559
Dummy sex of Household head	-0.084	0.098	0.392	0.006	0.134	0.962	-0.117	0.096	0.221
Length of staking				0.032	0.010	0.002			
years of school	0.034	0.010	0.001	0.012	0.012	0.325	0.034	0.010	0.001
Household wealth index	0.187	0.046	0	0.201	0.058	0.001	0.195	0.046	0
Total livestock physical unit	0.007	0.002	0	0.082	0.030	0.007	0.008	0.004	0.031
Soil quality type (base=sandy									
_Loamy	-0.003	0.098	0.976	-0.114	0.158	0.472	0.004	0.087	0.963
_Clay	0.082	0.067	0.223	0.127	0.094	0.179	0.077	0.077	0.317
Province (base=Gitega)									
Kirundo	0.686	0.193	0	0.592	0.310	0.056	0.641	0.175	0
Makamba	-0.209	0.204	0.306	-0.112	0.234	0.631	-0.202	0.176	0.253
Muyinga	0.505	0.161	0.002	0.710	0.207	0.001	0.487	0.153	0.002
Rutana	0.121	0.160	0.447	0.367	0.209	0.079	0.123	0.148	0.404
Bubanza	0.280	0.203	0.169	0.426	0.306	0.164	0.243	0.180	0.178
Ngozi	0.416	0.162	0.01	0.610	0.198	0.002	0.346	0.139	0.013
Cankuzo	0.229	0.234	0.328	0.146	0.347	0.673	0.200	0.209	0.339
Karuzi	0.498	0.188	0.008	0.596	0.213	0.005	0.407	0.198	0.04
Kayanza	0.314	0.219	0.152	0.550	0.277	0.047	0.293	0.225	0.193
Mwaro	0.281	0.206	0.172	0.450	0.263	0.087	0.280	0.343	0.414
dummy if climb type	0.121	0.062	0.052				0.122	0.070	0.082
_constant	-4.151	3.926	0.29	-7.010	5.371	0.192	-3.257	4.282	0.447
/lnsigma	-0.249	0.058	0	-0.260	0.072	0			
/lambda_improved variety only	-0.206	0.049	0	-0.282	0.093	0.003			
/lambda_improved + landrace mixture	-0.183	0.061	0.003	-0.224	0.066	0.001			
Sigma	0.779	0.046		0.771	0.055				
Number of observations	754			383			754		
Number of observations							F(25,728)		5.62
Wald chi2(71)	330.2			315.81			Pvalue		0.0001
Log pseudo likelihood	-1631.7			-822.57			R-squared		0.162
P-value	0			0			Adj. R_squared		0.133
							Root MSE		0.837

4.2.4 Profitability of Smallholder Bean Growing and Market Participation

In this section, we analyze the profitability of improved bean varieties to evaluate whether the yield gains from their adoption were high enough to offset the increase in production costs. Table 6 compares economic benefits of bean growing groups distinguished by varieties grown as improved vs local. Although it does not mean causality, results show that farmers growing improved varieties receive 61% higher net income per one kilogram of seed planted than those growing local varieties. However, the total variable costs are 13% higher for improved varieties, and the variable costs per unit of output per kilogram is 0.7% higher for improved varieties than the local cultivars. These results suggest that although improved varieties have a yield advantage over local varieties, their production cost is slightly higher, as improved varieties often incur more labor, especially in terms of harvesting, drying or threshing (Shiferaw et al. 2008). In terms of returns on investment, improved varieties are 15.8% more profitable than local varieties. For one Burundi Franc (BiF) invested in cultivating one kilogram of improved varieties, the farmer obtains 1.37BiF while a non-adopter receives 1.18 BiF[8] (Table 6). Disaggregating the data by seed access and comparing returns on investment with and without seed access constraints, results show profitability of improved varieties drops by 18.5% when the adopter faces constraints to access, while that of local varieties decreases by 9.4% (Table 6).

TABLE 6 Economic benefits of improved varieties based on one kg of seed planted

	LOCAL (0)		IMPROVED (1)		ALL SAMPLE COMBINED		DIFF (1-0)	P-VALUE
	Mean	SD	Mean	SD	Mean	SD		
Number of observations	335		762		1109			
Yield (kg/kg seed)	9.85	4.93	11.47	6.13	10.66	5.66	1.62	0.001
Revenue (BiF/kg of seed)	8733.79	5338.06	10649.41	5990.17	9706.05	6037.82	1915.62	0.001
Seed price (BiF/kg)	1209.72	1039.12	1312.62	1313.80	1203.70	1062.74	102.90	0.801
Production cost (BiF/kg of seed	4951.15	5443.23	5589.53	4753.99	5059.57	5327.88	638.38	0.612
Grain price (BiF/kg)	880.79	268.65	950.85	283.05	911.51	276.79	70.06	0.004
Variable production cost/kg of output)	541.14	448.91	545.11	475.89	518.35	439.83	3.97	0.413
Net income	3665.59	6777.28	5105.25	6265.48	4588.54	6908.18	2231.5	0.0001
Returns of investment ROI	1.18	1.46	1.37	1.51	1.32	1.47	0.187517	0.0457
ROI under no seed access constraint	1.26	1.44	1.38	1.47	1.39	1.45		
ROI under seed access constraint	0.80	1.55	1.33	1.66	0.98	1.54		
Diff								
Yield under no seed access constraints	9.98	5.10	11.85	6.36	10.89	5.81		
Yield under seed access constraints	9.12	3.79	10.00	4.93	9.56	4.71		
Diff	0.86	1.09	1.85	1.43	1.33	1.10		
yield in kg/Ha asuming seeding rate of 70	689.71875		803.0358		746.3946			

8 The investment costs do not include family labour.

5.0 Impact of Improved Variety Adoption on Household Diets and Food Security

Food security is a multi-dimensional condition defined as “access by all people at all times to sufficient food for an active, and healthy life” (World Bank 1986). Implicit in this definition are three important dimensions of food security: food availability, access by all households and individuals and its intake in sufficient quantities and quality. In poor rural farming communities, food is relatively widely available either on-farm or via social networks immediately after harvest, and dwindles later in the season. In this section, we assess changes in the food and nutrition security of households in the flagship project. Assessing the causal effect of the flagship project on food security of Burundian bean growing households is challenging for two reasons. First, we lack baseline information to compare household food security before and after the intervention. Second, we can only observe food security of benefiting households, but we cannot observe the food security of the same households if they had not benefited. What confounds this problem further, is the fact that adopting technologies is a voluntary decision made by individual farmers who might be systematically different from those who chose not to adopt. Thus, our ability to estimate impacts of improved bean technology adoption on household welfare lies in the proper identification of bean growing households who are similar to adopters (i.e. the treated group) but did not adopt (i.e. control group) the said technologies.

We follow the treatment effects framework and estimate Average Treatment of the Treated (ATET) using an Inverse Probability Adjustment Regression (IPWRA) method that was developed by Robins and Rotnitzky (1995) and Van der Laan & Robins (2003). Compared to the commonly used Propensity Score Matching (PSM) techniques for impact evaluation, IPWRA allows for the specification of the outcome model to control for any confounding factors. Put simply, suppose we are interested in the effect of the flagship intervention on household food consumption frequency. The IPWRA allows us to include other factors that may influence food consumption frequency in the outcome model, which might also influence adoption decisions. By doing this, time-invariant covariates can be included in the outcome model, thus making it unnecessary to ensure a balance of the covariates in the first stage model. Thus, the name, doubly robust estimator, but this property requires that at least one of the models is correctly specified (Woodridge 2010).

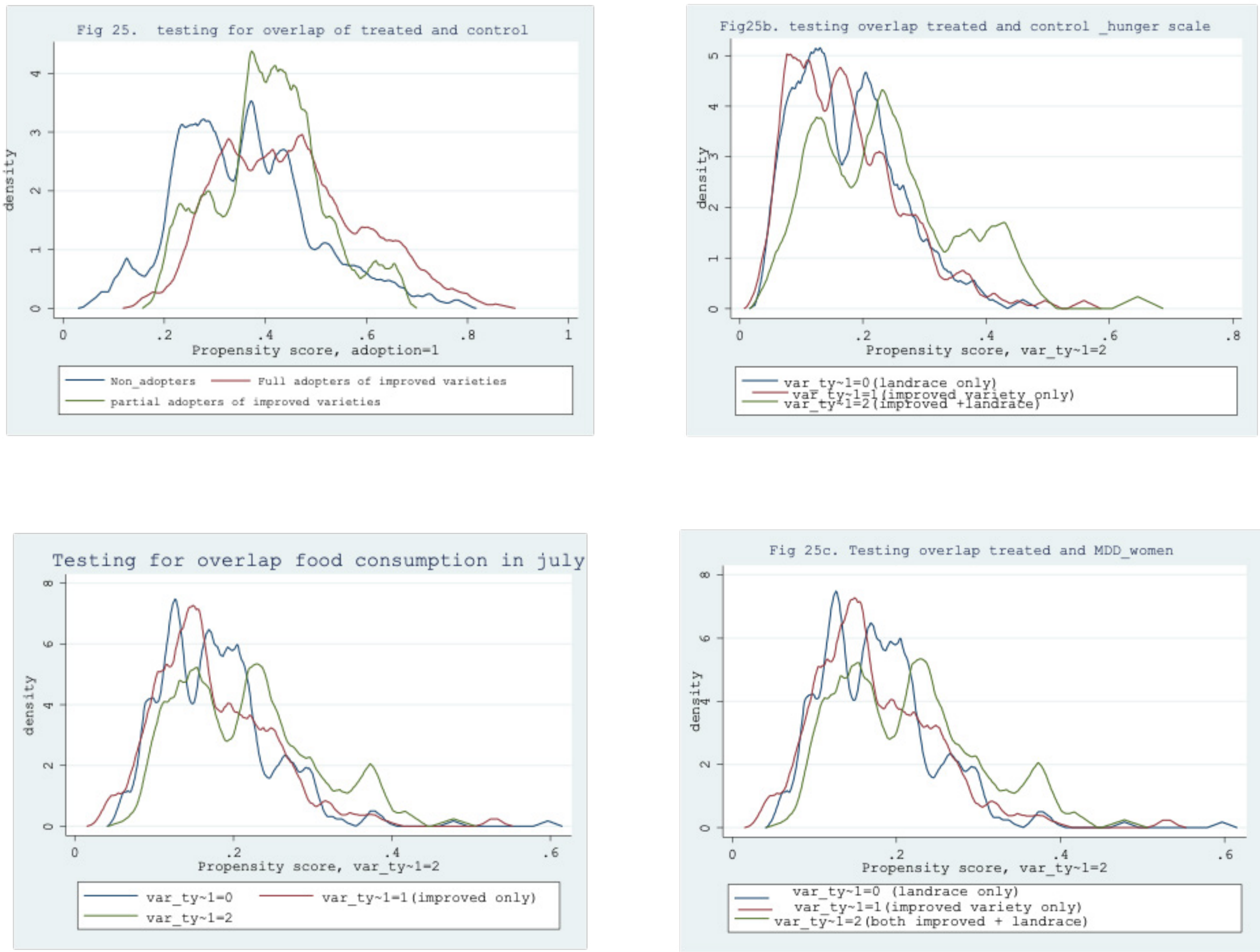
The IPWRA is implemented as a three-step estimation procedure. In the first step, the probability that the individual is treated (i.e. belong to adoption level j) is estimated, and the propensity scores predicted. The inverse of the probability that each observation is in the treatment or control group is used to re-weight the sample in the second step. The resulting sample, in which the distribution of covariates is independent of the treatment, ensures that the requirement of weak confoundedness is satisfied. In the third step, the expected outcome is estimated for each observation using a weighted outcome model that includes some of the observable characteristics used to estimate the treatment model and additional information.

For empirical estimation, we define an adopting household of the flagship project technology, as one which, at the time of the first round of the survey in July 2019, identified itself as using either improved bean varieties only, or both improved and landraces. In the survey data we use for this analysis, households fall into 3 categories: 0 = grow landrace only; 1=grow improved varieties only and 2 = use improved varieties in a mixture with landraces. Thus, improved variety adoption is essentially a multivalued variable hypothesized to influence food security of adopters according to the option they choose.

Explanatory variables included in the first stage estimation as predictors of technology choice included household socio-demographic (household size, age, sex of decision-maker), and economic characteristics (wealth index, physical livestock units, cropped land size); proxies for market access (distance from the village center to tarmac road) attributes of the agro-ecological conditions (rainfall, soil acidity (PH), slope) and dummies for provinces. These factors can also influence food security and are thus used in the outcome model.

The IPWRA does not control for biases that may stem from unobservable differences between the treated adopters and untreated individual non-adopters. To minimize potential biases that may emanate from this weakness, we include in the treatment model, variables that proxy for vulnerability to production risks, such as experience with drought and subsequent loss of seed, environmental stresses, physical access to seed, plot characteristics and managerial capacity, such as education, experience, ability to read, social capital. A similar strategy was used by Smale et al. (2018) when they estimated the impact of improved sorghum varieties in Mali. Finally, we test for the overlap in our data by plotting the propensity scores for treated and control observations on graphs to examine the overlap of the distributions. Figure 9a-c shows that these distributions do, in fact, overlap.

FIG 9 Testing overlap of treated and control subsamples for common support



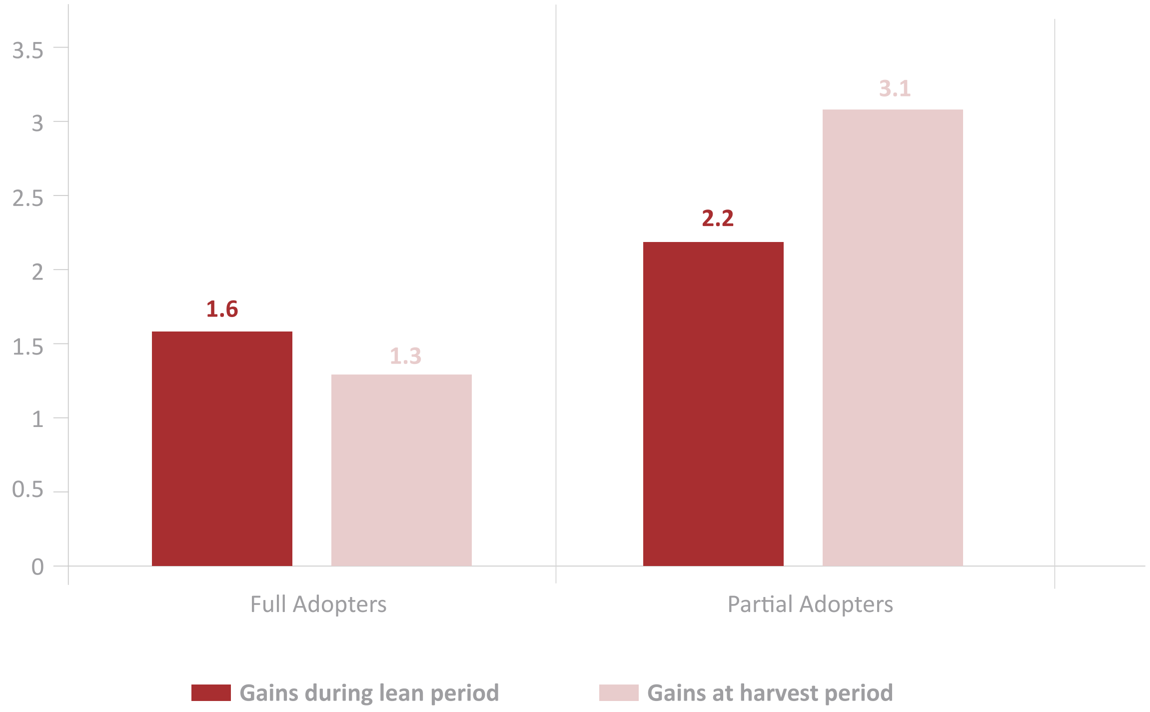
5.1 Econometric Results and Discussion

Tables 7 and 8 report the results from the IPWRA estimation of the impact of improved variety adoption on food security indicators using data collected immediately after harvest (July 2019) and in November-December 2019, months when households are vulnerable to food shortage (full description of the food security data is reported in Annex 1.0). The impact estimates of improved variety adoption on all indicators of the household food security were positive, as we expected. But only the estimates on food consumption score and minimum dietary diversity for women were statistically significant. In July, which falls within the harvesting of season B crops, households that shifted all their bean area from landraces to improved varieties, enjoyed 1.7% higher food consumption. Likewise, households that planted both improved varieties and landraces consumed food 3.7% more frequently than they would have if they had not adopted at all. The estimated effect was significant at 11% and 1% for full adopters and partial adopters respectively (Table 7). In other words, households that fully shifted from landraces to improved varieties would have an average food consumption score of 80.5 instead of 81.8 if they did not adopt. Similarly, for households that adopted partially, their average food consumption would have been less by a score of 3.7, equivalent to being 80.4 instead of observed 83.5 food consumption score during the period. Thus, the impacts at harvest observed were greater for households that adopted partially because this group also have larger landholdings compared with the households that adopted fully.

TABLE 7 Average treatment effects of the adoption of improved varieties household food consumption, hunger and micronutrient adequacy

ATET	COEFFICIENT	SD	ATET EFFECT (%)	P-VALUES
Log Food consumption score (July/Aug 2019)				
Improved varieties only	0.017	0.011	1.65	0.117
Variety mixture (local + Improved) only	0.037	0.014	3.69	0.008
Log Food consumption score (Nov/Dec 2019)				
Improved varieties only	0.035	0.021	3.45	0.097
Variety mixture (local + Improved) only	0.049	0.024	4.93	0.043
Household food insecure (Access) index				
Improved varieties only	-0.022	0.062	-2.15	0.727
Variety mixture (local + Improved) only	0.054	0.091	5.40	0.552
Minimum dietary diversity score for women of reproductive age				
Improved varieties only	0.415	0.144	4.61	0.004
Variety mixture (local + Improved)only	0.202	0.173	2.24	0.244

FIG 10 Gains in food consumption score by adopting households at harvest and during lean season, 2019



Nevertheless, the food consumption of households that fully shifted their bean area from landraces to improved varieties, show more resilience during lean seasons—when food consumption drastically reduces, as compared to those that adopted partially. Using data collected during lean seasons, results show that the impacts of adopting improved varieties are larger during the lean season; when the food situation is generally worse. The estimated effect was about 3.5% for full adopters, but only significant at 10%; while it was nearly 5% for partial adopters and significant at 5% (Table 7). Overall, the effect translates into a gain in food consumption score of 1.3 (1.6) for full adopters and 3.1 (2.2) for partial adopters at harvest time and during lean seasons respectively (Figure 10).

In the second pillar of food utilization, we evaluate whether the project has had any impact on the quality of diets using the Minimum Dietary Diversity for Women (MDD_W)[9] of reproductive age measured based on 24 hours of recall, gathered during the month of the lean season[10]. Results in Table 7, reveal that shifting from landraces to improved variety seed increased the MDD_W for women of reproductive age by 0.42 points (equivalent to 4.6% increase). Results further show that during the months of lean season, shifting from landraces to improved varieties was positively associated with consumption of nut seed, eggs, vitamin-rich fruits, and other vegetable, while negatively associated with consumption of dairy products. Since these are highly nutritious foods, we interpret the result as plausible that adopting improved bean varieties increased the intake of nutrient dense food by farming families in Burundi.

In terms of vulnerability to food insecurity, results demonstrate that households that entirely shifted from landraces to improved varieties were 3.2 percent points less likely to go the whole day and night without eating. Also for the same period, farming households that partially shifted from landraces to improved varieties were 13 percent points less likely to worry about insufficient food. Taken together,

9 MDD is commonly used as a proxy for nutrient adequacy.

10 Households report the food items consumed by a reference woman in the household in the 24 hours prior to the interview.

TABLE 8 Average treatment effect of improved bean variety on the probability of consuming nutritious foods in 24-hour recall and household food insecurity

	IMPROVED VARIETIES				PARTIAL ADOPTER			
	COEFFI-CIENT	SD	ATET EFFECT (%)	P-VALUES	COEFFI-CIENT	SD	ATET EFFECT (%)	P-VALUES
Nut seed	0.092	0.028	9.24	0.001	0.03	0.03	3.09	0.352
Dark green vegetables	0.078	0.032	7.76	0.016	0.05	0.05	5.19	0.265
Other vitamin rich fruits/ vegetables	0.119	0.040	11.87	0.003	0.15	0.06	15.19	0.007
Household insecurity								
Worry about not having enough food	0.027	0.037	2.73	0.466	-0.128	0.050	-12.78	0.010
Go the whole day without food	-0.030	0.017	-2.96	0.088	0.004	0.026	0.36	0.888

these results confirm the significant impact of improved variety adoption to reducing household vulnerability to food insecurity. Other factors influencing food security in the study area were access to non-agricultural income and the size of landholdings (Appendix 1). Access to non-agricultural income and arable land generate a total effect of 0.13% on food consumption frequency among non-adopters, which is double the effects the two have on food consumption among households that have entirely shifted to improved varieties (0.065%). However, in terms of hunger, adoption of improved varieties is associated with a small reduction, while access to non-agricultural income and arable land seems more important. The two combined explain 3.4% reduction in hunger (on a hunger scale of 0-5) compared with a reduction of 0.43% from full adoption of improved varieties. Approximately, 10% of households had experienced moderate to severe hunger in a month before the survey in November/December. Among the hungry households, half were non-adopters, and about 31% were households that had entirely shifted from landraces to improved varieties on very small sized plots. Thus, this category of households requires yield-gain higher than the average of 40% for them to reduce hunger.

6.0 Conclusions and Lessons for Future Interventions

This study assessed the performance and impacts of the SDC flagship project, whose goal was to improve household food security, incomes and nutrition in the country. The project sought to increase access to quality improved seed of new high-yielding and preferred bean varieties, together with complementary crop management practices for enhancing bean yields, access to nutritious bean products for food and better linkages to profitable markets for higher household incomes. In the context of low access to non-agricultural income and high population pressure on land in Burundi, adoption of land intensification technology is critical to achieve food security.

Study results show that the project effectively disseminated improved varieties, reached the targeted numbers across a wider geographical scope while leveraging partnerships along the value chains. The project was effective in enhancing the knowledge of farmers, especially women, on bean production and empowerment as well as strengthening the capacity of private actors along the value chain. As a result, utilization of improved technology increased, raising the bean yield among adopters. The results on food consumption frequency indicate that - for improved seeds – that technology adoption leads to increased food security access through higher yields, but the scale of adoption matters. Farmers that entirely shift from landraces to improved varieties, thus increasing the scale of adoption, are likely to achieve and sustain increased food consumption frequency across seasons. Our findings also show that the impact of improved variety adoption is greater among households with diets made of less than 6 out of 12 food groups, and among adopting households, drops slower than that of non-adopters in lean seasons.

Our findings also demonstrate that adopting households benefited through increased availability of beans through their own production for consumption and sale. Households adopting improved varieties consume and sell more quantities of beans per season. From the income obtained from bean sales, households were able to access other food, such as eggs and nut seeds taught during trainings, thus positively influenced the Minimum Dietary Diversity for Women (MDD-W) among these households. Additionally, the finding that participants were significantly less likely to go a whole day and night without eating, highlights the importance of beans in filling the food supply gap by helping households meet food needs, and further implies that beans can be relied upon to smooth household food supply throughout the year.

Despite this progress in ensuring food security contributed by the flagship, food insecurity persists. There are significant proportions of households that remain vulnerable to food insecurity during lean seasons. Based on these findings, we summarize lessons learnt and examine potential for scaling out the successes to raise bean yield and reduce food insecurity. We have learnt that the challenge of food insecurity in Burundi emanate from low production due to lack of sufficient land for agriculture and subsequent land degradation. Farmers wait until their productivity declines before adopting soil land intensification technologies like climbing bean. Given the importance of common bean in food security[11], occupying 45% of cropped land per year, its greater productivity growth countrywide is central to food security. Next, we evaluate the potential of the scaling out the two dimensions of the flagship interventions on food security in Burundi.

11 It matures quickly, can be stored until the next planting season and is grown in all the three seasons.

Strategy One: Scaling Up Dissemination of Improved Bean Varieties

First, we examine the potential of scaling up the adoption of improved bean varieties to expand the area occupied by improved varieties that are high-yielding and climate smart. Although the adoption of improved bean varieties is impressive, nearly half of the bean area remains planted to landraces with low-yielding capacity. Results from the study have shown that shifting one hectare of land entirely from landraces to improved varieties would give households about 275 kilograms more on harvest, which would give the country approximately 164,763 tons of additional production. Expanding cultivation of improved varieties in bean producing areas will bring 97,210 tons extra non-adopting production, raising per capita bean production from 35 to 43 kilograms per year, closing the demand gap between production and per capita consumption of 45 by 80%. However, for this strategy to be a success, there is a need to understand why farmers opt to mix improved varieties with landraces instead of planting only improved varieties.

The study has taught us that mixtures are popular in areas that receive heavy rainfall because of high risk of crop failure. Thus, breeding should continue to prioritize traits such as resilience to biotic stresses associated with heavy rainfall and promote climbing bean types that are relatively less affected by heavy rainfall.

Strategy Two: Enhancing Farmers' Agronomic Managerial Abilities through Capacity Building

Lessons from the capacity-building component of the flagship demonstrated that there is a potential to improve use of good agronomic practices if farmers know about the techniques and their associated benefits. We estimate an endogenous stochastic production frontier to assess the productivity and efficiency yield gap . Results from this analysis indicate an efficiency yield gap of 47% equivalent to a gap of 349 kilograms per hectare, and an average technical efficient yield of 1,095.4 tons per hectare. In other words, if all farmers are trained in good crop management practice such as seeding rate, planting and weeding time; have access to climate-smart information and tools, their bean yield would grow from the current average of 746.4 to 1,095 kilograms per hectare, without changing the inputs. Approximately 42% of plots were performing on half or less of their capacity than could have been realized with the same inputs. Thus, we conclude that strengthening farmers' managerial abilities could increase yields by 349 kilograms per hectare with same inputs. By closing efficiency gaps, the country could increase bean production by 87. 805 tons per year and 7.3 kilograms per person. As a result, per capita production could increase from 35 to 42 kilograms per hectare. Farmers' literacy; membership in farmer organizations or platforms, and household wealth, were found to reduce inefficiency, while distance from water source increases it.

Policy Implications

Our findings have several implications important for policy. First, the findings clearly imply that the design of nutrition sensitive projects concentrating efforts in equal measures on scaling up agricultural components; distribution of improved quality seed and conducting campaigns on nutrition awareness will have an effect on nutrition-related outcomes. Results have shown high potential to increase bean productivity through improved varieties, managing soil fertility, and fertilizer application as they are available. However, for higher impacts, soil testing and matching fertility management options to soil quality is necessary. Benefits from organic and inorganic fertilizers are higher on sandy and clay soils while loamy soils are good and can produce good yields even without fertilizers.

Secondly, geographical targeting of interventions is necessary for effective performance. For example, disaggregating the data showed that efficiency yield gaps are higher in some geographical provinces –Ngozi, Gitega & Kayanza–popular for climbing bean growing; and less in those that mainly concentrate on bush growing—Kirundo, Muyinga and Rutana—for reasons that climbing bean growing is more complex than growing bush beans. Also, inefficiency tends to increase among farmers that have adopted three seasons for beans compared to farmers who grow beans in two seasons. Thus, as farmers intensify production over time and space, they need new tools to manage intensification.

Finally, if intervention packages contain elements of nutrition education and gender equality, food insecurity prevalence is further reduced two-fold, with households consuming more nutritious food. This study has also demonstrated that, through capacity building, the flagship has contributed to women empowerment.

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APPENDIX 1 Inverse probability weighted regression adjustment estimates for food consumption, household hunger and minimum dietary diversity score for women of reproduction age:

	LANDRACES ONLY		IMPROVED VARIETIES ONLY		IMPROVED + LAND-RACES MIXTURE	
	Robust		Robust		Robust	
	Coef.	se	Coef.	se	Coef.	se
Log of food consumption score						
Log cropped land	0.019	0.016	0.012	0.010	0.010	0.017
What the last 7 days normal days	-0.071	0.081	-0.104***	0.037	-0.228^	0.134
Number of crops at beginning of season B						
one crop	0.028	0.065	0.103***	0.021	0.058^	0.034
Two or more crops	0.073	0.055	0.102***	0.027	0.055	0.054
Log of non-agricultural income	0.077***	0.019	0.049***	0.007	0.036**	0.014
credit	-0.050	0.044	-0.023	0.020	-0.004	0.033
Wealth index	0.026	0.031	0.031***	0.012	0.033	0.025
Log of the quantity of seed planted	-0.004	0.023	-0.002	0.010	-0.008	0.026
Does a village have market center	-0.155**	0.073	0.006	0.021	0.045	0.042
Distance (km) to market	0.000	0.000	0.000	0.000	0.000	0.000
Log of distance to source of water	-0.005	0.016	-0.007	0.007	0.017	0.016
Number of people in the household	0.018	0.012	-0.001	0.004	0.004	0.007
Log of slope	-0.058	0.046	-0.021^	0.012	-0.032^	0.019
Log of average monthly rainfall	-0.095	0.147	0.034	0.101	0.211	0.164
Constraints accessing chemical fertilizer? 1=yes	0.031	0.046	-0.011	0.021	0.055^	0.031
Village off activity is casual labor? 1=yes	-0.022	0.033	-0.046**	0.020	0.030	0.036
Constant	3.404***	1.042	2.922***	0.720	1.926	1.159
HH hunger score						
Log cropped land	-0.094	0.062	-0.082***	0.031	0.067	0.059
What the last 7 days normal days	0.419***	0.112	0.268***	0.069	0.696***	0.156
Number of crops at beginning of season B						
One crop	-0.443***	0.124	-0.315***	0.087	-0.465***	0.151
Two or more crops	-0.636***	0.144	-0.440***	0.081	-0.380**	0.178
Log of non-agricultural income	-0.104***	0.041	-0.060**	0.027	-0.206***	0.054
Credit	0.174	0.131	-0.027	0.071	0.182	0.166
Wealth index	-0.189***	0.069	-0.193***	0.047	0.010	0.090
Log of the quantity of seed planted	0.105^	0.057	0.013	0.034	-0.030	0.071
Does a village have market center	0.456***	0.128	0.146^	0.081	-0.255**	0.117
Distance (km) to market	0.000	0.001	0.000	0.001	0.001	0.001
Log of distance to source of water	-0.026	0.039	-0.045	0.031	-0.063	0.064
Number of people in the household	0.061***	0.024	0.043***	0.017	-0.010	0.033
Log of slope	0.088	0.070	-0.096**	0.044	0.000	0.084
Log of average monthly rainfall	-1.048**	0.497	-1.323***	0.450	-0.078	0.547
Constraints accessing chemical fertilizer? 1=yes	0.022	0.111	-0.100	0.083	-0.009	0.146
Village off activity is casual labor? 1=yes	0.125	0.104	0.162**	0.074	-0.129	0.124
Constant	7.886	3.553	10.124	3.233	3.446	4.021

	LANDRACES ONLY		IMPROVED VARIETIES ONLY		IMPROVED + LAND-RACES MIXTURE	
	Robust		Robust		Robust	
	Coef.	se	Coef.	se	Coef.	se
Minimum dietary diversity score- women						
Log cropped land	-0.011	0.108	-0.112	0.081	-0.022	0.197
What the last 7 days normal days	0.681	0.550	-0.563	0.330	-1.284^	0.698
Number of crops at beginning of season B						
One crop	0.418^	0.236	0.259	0.207	0.168	0.315
Two or more crops	0.249	0.380	0.615**	0.299	0.989**	0.500
Log of non-agricultural income	0.352***	0.074	0.535***	0.082	0.140	0.144
credit	0.152	0.250	0.089	0.205	0.098	0.301
Wealth index	0.167	0.142	-0.381***	0.144	0.067	0.182
Log of the quantity of seed planted	-0.008	0.110	0.100	0.108	0.040	0.204
Does a village have market center	0.269	0.219	-0.114	0.237	0.289	0.349
Distance (km) to market	0.001	0.001	0.007***	0.002	-0.001	0.001
Log of distance to source of water	-0.169**	0.084	-0.022	0.073	0.101	0.108
Number of people in the household	0.006	0.048	0.001	0.046	0.000	0.075
Log of slope	0.236	0.139	-0.010	0.111	0.105	0.179
Log of average monthly rainfall	-0.313	1.114	0.121	0.998	2.526	1.585
Constraints accessing chemical fertilizer? 1=yes	0.206	0.189	-0.272	0.211	0.237	0.250
Village off activity is casual labor? 1=yes	-0.284	0.213	-0.326	0.205	-0.082	0.264
Constant	1.637	8.131	-1.778	7.045	-13.511	12.283