FARA

Unlocking the Potential of Agricultural Research and Development in the Highlands of East and Central Africa

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Unlocking the Potential of Agricultural Research and Development in the Highlands of East and Central Africa

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Acknowledgements

This book documents the proof of the Integrated Agricultural Research for Development (IAR4D) Concept that was developed by the Forum for Agricultural Research for Development in Africa (FARA). The IAR4D concept forms the basis for the Sub-Saharan Africa Challenge Programme (SSA CP), which is the only CGIAR Challenge programme that was implemented in a single region in the world. The SSA CP programme sought to facilitate agricultural research for development (ARD) to improve rural livelihoods, increase food security and support sustainable natural resource management throughout Sub-Saharan Africa. This goal was to be achieved by developing and implementing the IAR4D approach that overcame the shortcomings of the traditional approaches. The programme was challenged to conduct activities that would validate the IAR4D concept during its first phase.

The SSA CP programme implementation embraced an extensive partnership arrangement, which was unprecedented. It was implemented in the three sub-regions of Sub-Saharan Africa, namely West and Central Africa, Eastern and Central Africa and Southern Africa. Over 80 institutions participated in the programme, of which 55% were pure research based, while 45% were civil society organizations (NGOs, private sector groups, farmers' organizations and community based organizations). More than 243 researchers across the globe supported the programme implementation.

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Executive summary

The poor performance of traditional agricultural research for development (ARD) approaches is reflected in the low adoption rates of technologies, poor linkages among agricultural value chain actors and the pervasive unprofitability of farm enterprises in Sub-Sahara Africa (SSA). To enable agricultural research to play a more effective role in catalysing development, the Forum for Agricultural Research in Africa (FARA) proposed a new approach–Integrated Agricultural Research for Development (IAR4D).

The Sub-Saharan Africa Challenge Programme (SSA CP) was implemented in three Pilot Learning Sites (PLS) across the continent. SSA CP aims to reverse the underperformance of agricultural research in Africa by developing, testing and scaling out/up the IAR4D approach. Each of the PLS defined the domain within which the project's research sites are located and identified location for the allotment of the treatment using rigorous scientific methods. This report documents the proof of the IAR4D concept from the Eastern and Central Africa sub-region tagged the Lake Kivu (LK*)* PLS.

The Science Council (SC) of the CGIAR, with clearly defined outputs in mind, mandated SSA CP to commence on a proof of the concept to answer three vital questions regarding the validity of IAR4D's claims and its ability to deliver better outcomes as an R&D concept.

These questions were:

- Does IAR4D work?
- Does IAR4D deliver more benefits than the conventional R&D if given the same environment and resources?
- Can IAR4D be scaled up and out?

These questions formed the basis for the report. The report used the data collected from the baseline and midline surveys, which used the quasi experimental approach and two sets of counterfactuals, namely, the conventional, where traditional ARD was in existence, and the clean sites, where it was assumed there was no ARD at least two years prior to the commencement of IAR4D.

Using the propensity score matching (PSM) and double-difference methods (DDM) to control for project placement and self-selection biases, we found that IAR4D improved household assets of the participants; it also encouraged participation in research and facilitated the adoption of research outputs.

The PSM results indicated that the IAR4D participants were likely to be young married farmers from the Democratic Republic of Congo (DRC) who owned small-sized farms. Results further indicated that farmers at the conventional sites were likely to be women owning a few productive assets. Participants at the clean sites, on the other hand, were young farmers not frequently patronised by extension agents and more likely to be from Rwanda or Uganda. These results suggest that the IAR4D was targeted at the vulnerable groups (young farmers) whose household sizes were small and who had limited productive assets.

Does the IAR4D work as a concept?

The impact analysis provided an answer to this question. It revealed that IAR4D positively affects the income of the beneficiaries to the tune of $80 per participant. Further analysis showed that this amount conveniently lifts the participants out of the pre-set poverty of $1/day and translates to an income of $2.67 per day. The income of around 13,728 people in the PLS experienced considerable improvement during the period considered.

Does the IAR4D deliver more benefits than the conventional R&D methods?

Using various evaluation techniques like the matching method, the PSM and the double difference approach, it could be safely concluded that the IAR4D delivers more benefits than the conventional R&D method. The results, while confirming IAR4D's positive impact, revealed that under the same conditions, the conventional did not have a consistent and positive impact on the farmers.

The analyses also showed that the IAR4D positively impacts women's incomes (47%), food security (44%) and wealth distribution (119%). The results for these indices are consistently robust and reliable. The programme improved the income of 4,648 women and enabled 4,128 people to cross the food insecurity line in the PLS.

Household incomes improved substantially for farmers who participated in IAR4D and compared to the farmers at the conventional and clean sites, there was an average increase in incomes of 47%; this is unprecedented and well above the income returns from similar projects in the continent. For instance, the World Bank-sponsored Fadama II Project in Nigeria (which won the Bank's Regional Excellence Award) had an income impact rate of about 60 percent, a feat achieved after six years of operation.

Can the IAR4D be scaled up and out beyond the current area of operation?

The ex-ante analysis, in line with the impact assessment, suggests that the concept can be successfully scaled up and out with multiple potential positive effects on the beneficiaries. Results of the potential economic surplus model show that Rwanda could gain an estimated US$285 million, or US$8 million per year, by adopting the IAR4D approach in pepper production.

Sorghum production in Uganda had estimated gains of US$391 million – equivalent to US$11.2 million per year through IAR4D. The average annual producer and consumer surpluses are US$8.2 million and US$3.3 million respectively, with a rate of return of 37% and a benefit–cost ratio of 42 to 1. In Uganda, IAR4D generated an estimated gain of US$359 million – equivalent to about US$10.3 million per year. The average annual present producer surplus and present consumer surplus are about US$7.5 million and US$3.0 million, respectively. The benefits of potato cultivation in Uganda are the highest in the country and higher than what obtains for the same crop in the other two PLS countries.

The findings unambiguously indicate that the estimated benefits are much more sensitive to the expected adoption, than to changes in research and extension costs. Nevertheless, the estimates indicate that the production of all crops is socially profitable under the IAR4D approach. The results are consistent with earlier economic analyses, which showed that IAR4D was more productive, profitable and acceptable to farmers than the conventional research for development approach.

The ex-ante report on the LKKV PLS (Ayanwale et.al. 2011) confirmed that IAR4D recovered investment costs and was superior to both the conventional and the clean modes. The benefits varied by task forces (agro-ecological zones), with Rwanda gaining the least benefits of the three.

The project had a bigger impact on the poorest beneficiaries and could have greater impact in the future because of the lagged effect of the productive asset acquisition. A follow-up study is needed to capture the longer-term effects of productive assets and other changes that farmers experienced as a result of participation in the IAR4D. This study was conducted during an early stage of the project and does not capture its lagged impacts, especially the long-term benefits of productive asset acquisition and rural infrastructure development.

The key issues that need to be addressed in scaling up are: better targeting of poor and vulnerable groups, especially women; finding sustainable methods to promote development of rural financial services; and conscious inclusion of capacity building of IAR4D beneficiaries in efficient management of productive assets.

As for appropriate targeting, it may be recalled that, over the first two years of the project, the Gini coefficient of income for beneficiaries decreased by about nine percent compared with an increase for other categories of non-beneficiaries, indicating that the project helped reduce income inequality. In tandem, the project also raised the value of the poorest tercile's productive assets more significantly than for the other terciles. The non-significance of the impact on income for the other two terciles suggested appropriate targeting of the poor and vulnerable groups.

Chapter 1

Introduction

The performance of the agricultural sector is closely linked to research and development (R&D) inputs. In Sub-Saharan Africa (SSA), most countries have relied on the traditional agricultural and rural development (ARD) approach, which has not delivered the promised growth. The poor performance is manifest in the low adoption rates of technologies, poor linkages among agricultural value-chain actors and the pervasive non-profitability of farm enterprises. The substandard performance can be traced to the organization of R&D as a linear process. This configuration of ARD actors limits interaction with researchers and timely intervention in research process and direction. Integrated Agriculture Research for Development (IAR4D) was put forth as a solution to overcome the limitations of the traditional approaches for organizing ARD in SSA and to revive the agricultural sector.

IAR4D was designed to embed research within an innovation system comprising all the actors in an agricultural value chain. Within such a system – a network configuration – innovation does not follow a linear path that begins with research, moves through the processes of development, transfer, diffusion, adoption, production, and ends with successful introduction and use of new products and processes. Rather, it involves continuous feedback between different stages, thus drawing on the knowledge of all relevant actors at each stage. The network configuration facilitates timely interaction and learning and aims at generating innovations (rather than research products per se). In this regard, innovation refers to the activities and processes associated with the generation, product distribution, adaptation, and use of new technical and institutional/organizational knowledge. It therefore adds value to products of research, thus catalysing the achievement of development impact.

The IAR4D concept developed and adopted by the Sub-Saharan Africa Challenge Programme (SSA CP) is a functional perspective of FARA stakeholders. It defines operating principles and guidelines for stakeholders with diverse interests to come together to analyse the problem and develop solutions. When adopted, this approach is expected to lead to generation of technologies that are relevant to local conditions and are acceptable to local communities. It is defined as an action research approach for investigating and facilitating the organization of multi-institutional, multi-disciplinary actors (including researchers) to innovate more effectively in response to changing complex agricultural and natural resource management contexts in order to achieve a shared vision of rural development. It comprises a set of individuals and organizations working together around a developmental challenge and incorporating end-user concerns, requirements and capacities. It brings together stakeholders from research, extension, policy and markets to work with the end user in developing solutions that are mutually beneficial. It further strengthens the linkages and promotes interaction between ARD actors and helps develop solutions that benefit all the players.

The emergence of IAR4D presented an opportunity to address complex issues that require participation and contributions from a range of stakeholders with direct or indirect interest. However, implementing IAR4D has been challenging and to date there are no available guidelines or protocols on how to identify and involve stakeholders from different sections in constructive problem-solving exercises. Realizing IAR4D's potential to increase the adoption of agricultural technologies, SSA CP has initiated proof of concept research in three widely differing agro-ecologies in the western, eastern and southern Africa regions to assess its usefulness in generating deliverable public goods for the end-users, its superiority over conventional approaches and its applicability as a research approach to generate more user-friendly technologies.

'Sites' as part of the SSA CP research design and Innovation Platforms

The pilot learning site (PLS) for East and Central Africa, named the Lake Kivu Pilot Learning Site (LKPLS), was located at the borders of Rwanda, Uganda and the Democratic Republic of Congo (DRC). The three task forces within LKPLS worked closely on the interactions between agricultural productivity, natural resource sustainability, markets and policy themes. The interactions between these themes implied that the three taskforces operated in common sites and potentially with common partners.

IAR4D operations revolve around the successful establishment and operation of a multi-stakeholder problem-solving forum referred to as the Agricultural Innovation Platform (AIP). An AIP brings together multi-stakeholders for visioning, planning and implementation or application of new ideas, practices, services that arise through interaction, creativity, insight and empowerment with the aim of improving the existing situation/conditions around a common interest/challenge and thereby bringing about the desired change.

The research design asserted that each of the three task forces in LKPLS worked with four IPs, thereby totalling 12 IPs. Each IP was considered unique because the problem and entry-points differed for each task force even though some of the partners were the same. There were four IPs in each country while each task force established and developed at least one IP in each of the three countries, and two IPs in one of the three countries. Table 1 displays a sample framework for the task force site selection.

Some of the IPs are illustrated in Table 2. Table 3 provides further illustration.

Table 1: Example of organization of common sites in the Lake Kivu PLS

DRC Site 1	**DRC Site 2**
TF1 & TF2	TF2 & TF3
Rwanda Site 1	**Rwanda Site 2**
TF2 & TF1	TF1 & TF3
Uganda Site 1	**Uganda Site 2**
TF1 & TF2 & TF3	TF3

Note: TF = Taskforce.

Table 2: Bufundi Innovation Platform

Country	**Uganda**
IP Name	Bufundi
Entry point	Soil and water conservation
Focus enterprise/value chain	Potato
Location	Kabale District
Participating villages	Five parishes and their respective sub-parishes
Date IP initiated	14 November 2008
Partners:	
Farmers	Core IP members (individual and farmer group representatives)
Private sector	Uganda National Agro-Input Dealers' Association (UNADA), Equity Bank, Bufundi, Transporters, Joro Investment Ltd, Kampala Potato Traders Group
Policy makers	Local government (district, sub-county, local councils II – parish and I – sub-parish)
Researchers	National Agricultural Research Organization (NARO), Uganda, Makerere University, Uganda, Africa Highland Initiative (AHI), International Potato Centre (CIP), International Crop Research Institute for Semi-Arid Tropics (ICRISAT)
Extension	Kulika, National Agricultural Advisory Services (NAADS), Uganda
Training Institutions	Kyambogo, Kabale, Makerere, and Kenyatta Universities
Others	University network (University of Nairobi, Egerton, Jomo Kenyatta University of Agricultural Technology, Kenyatta University, Commonwealth of Learning)
Opportunities addressed	Improved seed potato, improved production, organized markets and improved potato sales to Kampala, collective action for soil and water conservation, improved soil fertility and yields; linked to financial credit institutions, e.g. SACCO
Sustainability issues	Local farmers' organization capacity building, information on markets, development of MoU, continued strengthening by ARD organizations, e.g. NARO, capacity building through student support.

Table 3: Isangano Gataraga IP

Country	Rwanda
IP Name	Isangano Gataraga
Focus enterprise/value chain	Irish potatoes
Location Participating villages	Gataraga Secto, Musanze District Ten
Date IP initiated	November 2009
Partners:	
Farmers	Core IP members (group representatives)
Private sector	Gataraga SACCO, input trader
Policy makers	Local authorities (executive secretary of the sector)
Researchers	Institute for the Study of African Realities (ISAR), International Centre for Tropical Agriculture (CIAT), Makerere, National University of Rwanda (NUR), Urugaga Imbaraga (National Farmers' Federation)
Extension	Public extension
Training Institutions	NUR, ISAE, Wageningen University Research
Others	-
Opportunities addressed	Clean potato seed production through positive selection, improved potato quality through harvest (dehalming) and post-harvest (washing) techniques
Sustainability issues	Local farmers' organization capacity building; collective value-added potato marketing

Table 4: Market development and productivity enhancement innovations for traditionally cultivated crops: sorghum (Uganda) and banana (DRC)

Country and IP	Interface challenge	Partners	Innovations	Outcomes
Bubare sorghum IP, Uganda	Market-technology-policy interface of low productivity of a crop that is culturally deeply entrenched; untapped market caused by unbranded, poor packaging of sorghum non-alcoholic porridge	IP farmers, private sector (Huntex, millers, grain traders, porridge makers, Muchahi SACCO), policy makers (Kabale LG, sub-county local govt.), researchers (Makerere, KAZARDI, AHI, ICRISAT), Extension (NAADS	Local government support for participatory evaluation of new market-preferred, line planted and fertilised sorghum varieties; market development using packaged and branded product	Increased knowledge of production practices, yield and income; diversified market, consumer acceptability, increased income by the processor (1200 litres of sorghum porridge (bushera) sold, generating Ug. Shs. 3 million per month equivalent to USD 1,500)

Country and IP	Interface challenge	Partners	Innovations	Outcomes
DRC Musangany – a banana IP	Market-value addition technology-policy interface of disorganized market and low productivity of a culturally deeply entrenched crop; banana caused by bacterial wilt, resulting in quarantining from Rwanda but able to sell wine and juice, though lacking clean planting materials	Farmers (IP members), private sector (GAP/ Pharmakina, researchers (Institut National pour l'Etude et la Recherche Agronomiques (INERA); TSBF, CIAT, Observatoire Vulcanologique de Goma (OVG), Extension (SYDIP, DIOBASS, ACF) Others: (microfinance-MECREGO,	Market development using packaged and branded product Kasiksi wine; organizing a banana traders' association in Bukavu; standardisation of packaging and pricing of banana varieties; linking of producers and traders; collective marketing of banana; facilitating access to clean material – community "greenhouse" macro-propagateur	Increased knowledge of production practices; diversified market; increased income

Governments, donors, and other practitioners in the development community are keen to determine the effectiveness of programmes with far-reaching goals such as lowering poverty or increasing employment. Any assessment of impact, which requires attribution of specific effects to specific interventions, faces formidable challenges (Ravallion, 2001). Measurement and attribution of impact on individuals is, in fact, among the most difficult and controversial aspects in the field of social science (Meyer, 2002). It is extremely challenging to observe the counterfactual corresponding to any change induced by a treatment or intervention (Cameron and Trivedi, 2005; Imbens and Wooldridge, 2009). Efforts to *create* the counterfactual are complicated by potential selection bias due to non-random placement of the intervention or due to self-selection of certain households in the treatment. To address selection concerns and create a credible counterfactual, social scientists increasingly use randomisation.

Chapter 2

Study area and data

The IAR4D approach was formally introduced to farmers in LKPLS in 2008. The three institutions or task forces that facilitated its adoption were CIAT in DRC, Institute for Agricultural Research in Rwanda, and National Research Organization in Uganda represented by the University of Makerere. They brought together various stakeholders at the IP level, encouraging them to plant key crops. Figure 1 displays the specific areas around Lake Kivu where the approach was initiated.

Country indicators

The three LKPLS countries have different administrative systems. Within Rwanda, there are four geographically based provinces (north, south, east, and west) and the City of Kigali, which are further subdivided into 30 districts, 415 sectors, cells and, finally, villages. In Uganda, the current urge to make the services more accessible to the people has resulted in an increase in the number of new districts from 17 (as of 1967) to 80 in 2009. The districts are further sub-divided into counties, sub-counties, parishes and villages. The sub-county is the smallest local government administrative and planning unit. Each sub-county has a community development officer, an agricultural, fisheries, forestry and primary health officer, mandated to provide technical backstopping in their various fields. These officers also form the sub-county technical planning committee and aim to establish a natural resource management committee under the local council system (at the village and parish levels) that will oversee the utilisation of natural resources. In Uganda, because of the various provisions at the sub-county,

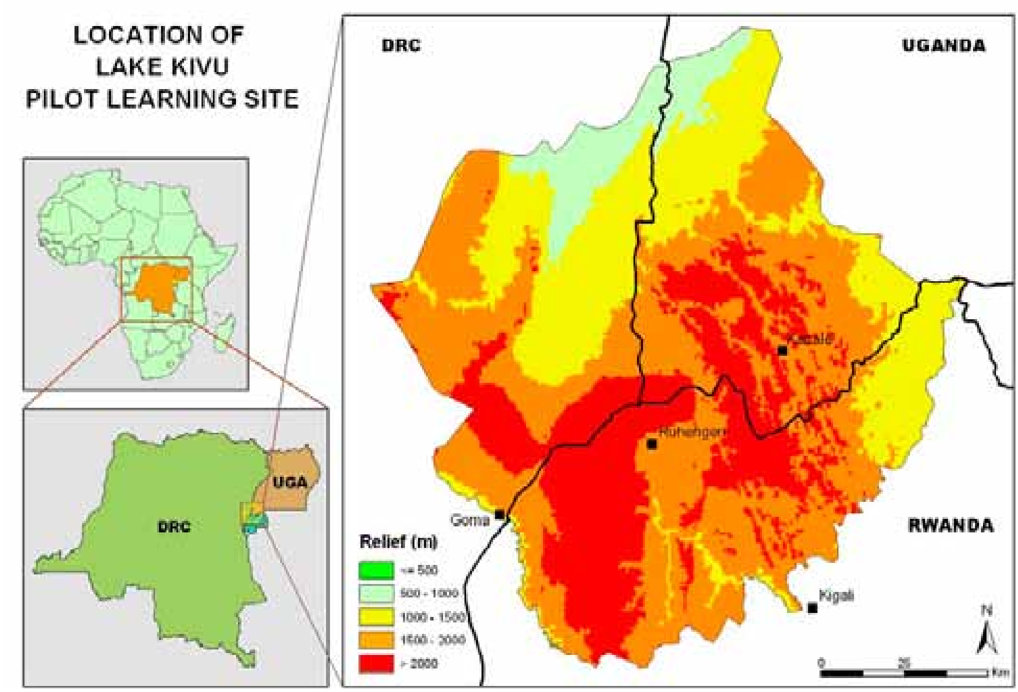

Figure 1: Location of the Lake Kivu Pilot Learning Site of the SSA CP

village and parish levels, stakeholders can share knowledge, thereby enhancing technology diffusion. Within DRC, the administrative hierarchy follows provinces, cities, communes and neighbourhoods (in urban areas) and provinces, territories, districts, groupements and villages (in rural areas). It should be noted that a site is located within the "sub-county" in Uganda, "sector" in Rwanda and "groupement" in DRC.

Data collection methodology for household survey

Research sites (districts/communes/local government areas) were allocated to IAR4D and non-IAR4D categories through stratified random sampling. The strata within which the randomisation was carried out consisted of three development domains delineating the combination of market access potential and agro-climatic potential. The task forces were spread across the IAR4D treatment sites, covering various strata, to investigate the performance of the approach across a wide range of conditions. Each IAR4D treatment site (district/commune/local government area) was associated with two counterfactual sites (conventional and clean) also randomly selected from the same stratum as the IAR4D site.

Criteria for site selection included:

1. Site characteristics and representativeness
2. Current state of IAR4D

3. Value of site for market research
4. Value of site for research on productivity enhancement
5. Value of site for research on natural resource management
6. Accessibility for operations

Each of these criteria was scored on a Likert scale of 1 to 5, the former being least preferred, depending on the criterion being evaluated.

A series of data collection instruments were developed for use. The core questions were the same for all the villages to facilitate cross-site and cross-border comparisons. The SSA CP's hypotheses were tested by comparing the outcomes in households within the IAR4D villages against outcomes realised by households in the conventional ARD and clean villages. The treatment communities consisted of IPs and farm households in the IAR4D sites, while the non-treatment communities consisted of similar organizations and households in the non-IAR4D sites.

Data was collected using pre-tested questionnaires and through observations from households in the IP and the counterfactual sites over 2008 and 2009. A total of 180 villages were sampled. From each of the treatment villages, ten households were randomly selected from a list of household names generated with the help of village leaders. At the end of each day, the completed questionnaires were checked for errors before being stored for subsequent entry into the database.

The information collected pertained to general household characteristics, land and asset ownership, use of agricultural technologies, production and marketing systems for both crops and livestock, constraints to production and marketing, social capital, resource endowment, access to credit, extension and training, food security situation and input access and costs at plot level.

Table 5: Sample size by country and by treatment

LKPLS Country	Clean	Conventional	IP	TOTAL	Share %
Uganda	270	276	268	814	34.5
Rwanda	235	223	294	752	31.8
DRC	260	342	194	796	33.7

Chapter 3

Methodological framework

Conceptual framework of the quasi-experimental Impact Assessment Approaches

Descriptive and inferential statistics were employed in the analysis of the data collected for this study. Panel data made up of the baseline and midline cross-sections of data with quasi-experimental design was also used . The quasi-experiment is preferred when randomisation is impractical or impossible and there is no control over extraneous variables. A quasi-experimental design was created when the probability that a subject would have been treated is used to adjust for the estimate of the treatment effect.

This report used propensity score matching (PSM) to estimate the effect of IAR4D on participants and non-participants. Propensity scores provide an alternative method to estimate the effect of receiving treatment when random assignment of treatments to subjects is not feasible. PSM refers to the pairing of treatment and control units with similar values on the propensity score, and possibly other covariates, and the discarding of all unmatched units (Rubin, 2001). It is primarily used to compare two groups of subjects but can be applied to analyses of more than two groups

To explain further, if PSM was used in a randomised experiment comparing two groups, then the propensity score for each participant in the study would be 0.50. This is because each participant would be randomly assigned to either the treatment or the control group with a 50 percent probability. In study designs where there is no randomisation, such as in a quasi-experimental design, the propensity score must be estimated. Propensity score values are dependent on a vector of observed covariates that are associated with the receipt of treatment.

Generally, if a treated subject and a control subject have the same propensity score, the observed covariates are automatically controlled for. Therefore, any differences between the treatment and control groups will be accounted for and will not be a result of the observed covariates.

Following the notation in the evaluation literature, let $D = 1$ if an individual is treated and $D = 0$ otherwise. We then define the outcome for a treated subject ($D = 1$) as Y_1 and the outcome for non-treated subject ($D = 0$) as Y_0. As will be discussed in equation 3.2, various matching methods such as kernel matching and the nearest neighbour matching methods were used to analyse the data. The essence is to explore impact assessment where it exists. Our goal is to identify the average treatment effect on the treated (i.e., the effect of implementing IAR4D on participants).

$$\Delta = E\,(Y_1 - Y_0||D = 1) = E\,(Y_1||D = 1) - E\,(Y_0||D = 1) \tag{3.1}$$

The first term on the right hand side of equation 3.1 is observable. However, the second term on the right hand side cannot be observed, i.e., what the project beneficiaries would have experienced had they not participated. Matching was used to estimate $E(Y_0/D = 1)$. For matching to be valid, certain assumptions must hold. The fundamental assumption underlying matching estimators is *ignorable treatment assignment* (ITA) (Rosenbaum and Rubin, 1983) or *selection on observables* (Heckman and Robb, 1985).

This assumption is represented by $(Y, Y)_{\perp} D||X^*,$ (3.2)

where X^* is a vector of variables that are unaffected by the treatment. This assumption states that, conditional on a set of observables X^*, the respective treatment outcome is independent of actual treatment status. In empirical work, X^* usually contains pre-treatment variables and time-invariant individual characteristics.

Since we are estimating the average treatment effect on the treated, condition (3.2) can be weakened to the following mean independence assumption involving only Y_0

$$E(Y_0|| X^*,D) = E(Y_0 ||X^*) \tag{3.3}$$

Counterfactual

What would have happened to the participants' group had they not participated? The key assumption of this framework is that individuals included in the treatment and non-treatment groups have potential outcomes in both states: the one in which they are observed and the one in which they are not observed (Rubin, 1978).

Propensity score is the probability of taking treatment given a vector of observed variables.

$$P(x) = Pr\,[D=1|X=x]$$

If we take individuals with the same propensity score, and divide them into two groups – those who were and were not treated – the groups will be approximately balanced on the variables predicting the propensity score.

Un-confoundedness assumption

This implies that the treatment (IAR4D beneficiary) is random conditional on some set of observed characteristics (X), which allows for "selection on observables". The common support assumption guarantees that each treated unit (a participant/beneficiary) can be matched with a corresponding control unit (non-participant/non-beneficiary). The average treatment effect is then calculated as the mean within-match difference in the outcome variable between the treated and untreated units. Unlike regression techniques, matching estimators do not impose any functional form restrictions, nor do they assume a homogenous treatment effect across populations (Zhao, 2005).

Methods of matching

Nearest neighbour matching

We now discuss the issue of which PSM estimator to use. Let N_1 be the number of participants and N_0 be the number of non-participants. The outcomes for the two groups can be written as $Y_1 = \{Y_{1i}\}_{i=1}^{N_1}$ *and* $Y_0 = \{Y_{0j}\}_{j=1}^{N_0}$ respectively. Consider member i of the participants' group, the simplest method of matching is to use nearest neighbour matching (with replacement). Here we approximate $E(Y_{0i} || D = 1)$ using Y_{oj}, the outcome for the member j of the non-participants' group, whose propensity score $\hat{P}(X_j^*)$ *is closest to* $\hat{P}(X_j^*)$. In nearest neighbour matching, the absolute difference between the estimated propensity scores for the control and treatment groups is minimized. The control and treatment subjects are randomly ordered. Then the first treated subject is selected along with a control subject with a propensity score closest in value to it. It is usually easy to understand and implement and more importantly, it offers good results in practice and has comparably fast running time on the computer. Nearest neighbour matching sometimes does not offer the best matching result.

Kernel matching

In this method, every treated subject is matched with the weighted average of the control subjects. The weights are inversely proportional to the distance between the treated and control group's propensity scores.

Justification

In order to make causal inferences, random selection of subjects and random allocation of the treatment to subjects is required. In observational or impact studies, random assignment to treatments is not possible. The primary limitation of an observational/impact study is that there may be random selection of subjects but not random allocation of treatments to subjects. When there is a lack of randomization, casual inferences cannot be made because it is not possible to determine whether the difference in outcome between the treated and control (untreated) subjects is due to the treatment or differences between subjects on other characteristics. Subjects with certain characteristics may be more likely to receive treatment than others. To put it simply, PSM is a quasi-experimental design that mimics a randomised experiment and makes it appear as if it is randomised design.

Limitations of quasi-experimental designs

- Selection bias may be substantial
- Comparison groups used to make counterfactual claims may have warped counters and failing factuals, leading to intolerably ambiguous findings.
- If the two groups do not have substantial overlap, then substantial error may be introduced.

Sample selection

The data used in this report was taken from baseline and midline surveys of about 1,800 households across LKPLS. The survey was conducted by task forces within SSA CP's framework supported by the Forum for Agricultural Research in Africa and its donors—including the European Union (EU), Department for International Development (DFID) (UK), and the governments of Italy and Norway.

The baseline survey was conducted from August to November 2008 and the endline survey was conducted from November 2010 to January 2011.

The sample frame was derived from different districts selected to represent the three basic areas of task forces in LKPLS. In each district, a sample of households was selected by taking a sample of district wards, followed by a random sample of villages within each ward, and then a random sample of households in each selected village. Finally, a household was retained in the sample if it belonged to one of the 180 villages selected within the clean, conventional or IP/action sites.

Baseline surveys for IP and community-level characteristics

Baseline surveys, field observations and focus group discussions were conducted to benchmark pre-treatment characteristics of IPs, site characteristics and baseline levels of outcomes predicted under the IAR4D approach: number, variety and time to develop innovations; knowledge and behavioural outcomes (adoption, input supply, input demand, volume of sales), including market outcomes (output supply and consumption demand) and productivity outcomes (yields, technical and allocative efficiency and profit); and impacts (incomes, livelihood assets and equity). Several indicators were used to measure outcomes based on the context. The questionnaires were designed for comparison within an IP over time and across IPs. To generate counterfactuals, surveys and field observations were conducted in the comparison sites and villages assigned to conventional and non-IAR4D-non-conventional treatments. Key players in the innovation systems, including public and private agricultural researchers, extension workers, leaders of farmers group, traders, dealers, lenders and key informants, were interviewed to benchmark the characteristics of innovation systems and baseline levels of outcomes just as it was done for the IP sites.

Baseline survey for household and village community characteristics

The same data collection tools were also used to collect data on household and village or community-level characteristics, and behavioural, efficiency, environmental and welfare outcomes. Surveys were used to track feedback, information diffusion, awareness and knowledge changes, adoption, and market effects of innovations and spillovers using the Miguel and Kremer (2004) approach.

Evaluation surveys

Follow-up evaluation surveys and qualitative assessment studies were conducted in the third year (2010) to assess the implementation process, document the intermediate steps of the research-to-impact pathway and conditioning factors, assess participants' subjective reactions to IAR4D, identify subgroups experiencing greater or lesser impact than the sample as a whole and measure changes in outcome at the levels of the IP, household, community and market. Follow-up surveys used the indicators utilised in the baseline surveys to measure outcomes.

Data analysis

Assessing the impact of any intervention requires making an inference about the outcome that would have been observed had the programme participants not participated. Following Heckman et al. (1997) and Smith and Todd (2001), let Y_1 be the mean of the outcome conditional on participation, that is, the treatment group, and let Y_0 be the outcome conditional on non-participation, that is the control group. The impact of participation in the programme is the change in the mean outcome caused by participation, which is given by:

$$\Delta Y = Y_i - Y_0 \qquad (1),$$

where Δ is the notation for the impact on a given household (1).

The fundamental problem of evaluating this individual treatment effect arises because, for each household, only one of the potential outcomes, either Y_1 or Y_0 and not both, can be observed. This leads to a missing-data problem, which is the heart of the evaluation problem (Smith and Todd 2001). The unobservable component in equation (1), be it Y_1 or Y_0, is called the counterfactual outcome. Measuring impact as the difference in mean outcome between all households involved in the project and those not involved, even when controlling for programme characteristics, may thus give a biased estimate of programme impact. Since one cannot estimate the individual treatment effects in equation (1) directly, one may need to concentrate on population averages to evaluate the impact of a treatment.

Two treatment effects are dominantly used in empirical studies. However, the most commonly used evaluation parameter is the "average impact of the treatment on the treated" (ATT), which focuses explicitly on the effect on those for whom the programme is actually introduced. In a random programme assignment, the expected value of ATT is defined as the difference between expected outcome values with and without treatment for those who actually participated in the treatment (Heckman et al. 1998b), which is given by:

$$\Delta Y_{ATT} = ATT\ (\Delta Y \mid X{:}Z = 1) = E(Y_1 - Y_0 \mid, Z = 1) = E(Y_1 \mid Z = 1) - E(Y_0 \mid Z = 1), \quad (2)$$

where Z is an indicator variable indicating whether a household actually received treatment or not: Z_i being equal to 1 if the household is a beneficiary and 0 otherwise. X denotes a vector of control variables.

Data on programme beneficiaries identify the mean outcome in the treated state $E(Y_1|X, Z = 1)$. The mean outcome in the untreated state $E(Y0|X, Z = 1)$ is not observed and a proper substitute for it has to be chosen to estimate ATT.

Various quasi-experimental and non-experimental methods have been used to address the bias problem (Heckman et al. 1998). One of the most commonly used quasi-experimental methods is PSM, which selects project beneficiaries and non-beneficiaries who are as similar as possible in terms of observable characteristics expected to affect project participation as well as outcomes. The difference in the outcomes between the two matched groups can be interpreted as the impact of the project on the beneficiaries (Smith and Todd 2001). We used this method to estimate the ATT for impacts of the IAR4D on the key outcomes of the project (that is, poverty/food security, factor productivity, market participation, awareness and adoption, and natural resource management).

The PSM method matches project beneficiaries with comparable non-beneficiaries using a propensity score, which is the estimated probability of being included in the project. Only beneficiaries and non-beneficiaries with comparable propensity scores are used to estimate the ATT. Those who do not have comparable propensity scores are dropped from the comparison groups.

One of the advantages of PSM over econometric regression methods is that it compares only comparable observation and does not rely on parametric assumption to identify the impacts of projects. However, PSM is subject to the problem of "selection on unobservables", meaning the beneficiary and comparison groups may differ in unobservable characteristics, even though they are matched in terms of observable characteristics (Heckman et al. 1998). Econometric regression methods devised to address this problem suffer from the problems previously noted. The bias resulting from comparing non-comparable observations can be much larger than the bias resulting from a selection of unobservables, although it cannot be said if this conclusion holds in general (Heckman et al. 1998).

In this study, we address the problem of selection on unobservables by combining PSM with the use of the double-difference (DD) estimator. The DD estimator compares changes in outcome measures (i.e. change from before to after the project) between project participants and non-participants, rather than simply comparing outcome levels at one point in time.

$$DD = (Y_{p1} - Y_{p0}) - (Y_{np1} - Y_{np0}), \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

where Y_{p1} = impact (e.g. income) on beneficiaries after the project started; Y_{p0} = impact on beneficiaries before the project started; Y_{np1} = impact on non-beneficiaries after the project started; and Y_{np0} = impact on non-beneficiaries before the project started.

The advantage of the DD estimator is that it nets out the effects of any additive factors (whether observable or unobservable) that have fixed (time-invariant) impacts on the outcome indicator (such as the abilities of the farmers or the inherent quality of natural resources), or that reflect common trends affecting project participants and non-participants equally (such as changes in prices or weather; Ravallion, 2005).

Thus, for example, if project participants and non-participants differ in their asset endowments (mostly observable) or in their abilities (mostly unobservable), and if those differences have an additive and fixed effect on outcomes during the period studied, such differences will have no confounding effect on the estimated ATT.

In principle, the DD approach can be used to assess project impacts without using PSM, and will produce unbiased estimates of impacts as long as these assumptions hold. However, if the project has differential impacts on people with different levels of wealth or observable characteristics, the simple DD estimator may produce biased estimates if participants and non-participant households differ in those characteristics (Ravallion, 2005). By combining PSM with the DD estimator, controls for differences in pre-project observable characteristics can be established. A bias could still result from the heterogeneous or time-variant impacts of the unobservable differences between participants and non-participants. For example, communities and households that had participated in ARD may have different responses to IAR4D than those in a clean environment because of the cumulative effects of social capital developed under the ARD, favourable or adverse experiences, or other factors. Such shortcomings are unfortunately inherent in all non-experimental methods of impact assessment (Duflo et.al. 2006). Although there is no perfect solution to these potential problems, we believe that the method adopted addressed these issues as well as could be possible in this case.

The standard errors estimated by the DD method may be inconsistent because of serial correlation or other causes that interlink errors. In ordinary regression models, serial correlation can result from unobserved fixed effects, but by taking first differences, the DD method eliminates that source of serial correlation. However, serial correlation still may be a problem if more than two years of panel data are used (Duflo et al. 2004). Since this study covers only two periods – before and after the project – serial correlation among multiple periods is not a concern. Another reason for the possible non-independence of the errors is clustering of the sample.

The propensity scores were computed using binary logit regression models. We estimated three probit models for three comparisons: (1) IAR4D beneficiaries compared with all non-beneficiaries, (2) IAR4D beneficiaries with conventional beneficiaries, and (3) IAR4D beneficiaries with non-beneficiaries in clean communities. The dependent variable in each model was a binary variable indicating whether the household was a beneficiary of the IAR4D project or not.

The explanatory variables used in computing the propensity scores were those expected to jointly determine the probability of participation in the project and the outcome. We focused on the determinants of income and productive assets when selecting the independent variables for computing PSM.

The independent variables used in the regression are summarized in Table 6.

Table 6: Variables used to compute propensity scores and their expected signs

Variable	Expected impact on participation in IAR4D	Why?	Expected impact on income and wealth	Why?
Gender of respondent (Male = 1; Female = 0)	-	IAR4D is gender friendly	-	Women are usually poorer than men
Household size	+	Larger families could be associated with poverty or other vulnerabilities that makes participation in IAR4D worthwhile	-	The larger the family, the poorer it is
Age of respondent	+/-	IAR4D supports both the young and old	+	Older respondents likely to be better off because of accumulation of wealth and experience over time
Level of education of respondent (years of formal education)	+	Some project requirements need a certain level of education	+	Education increases income opportunities, such as on-farm activities
Area of farmland cultivated (ha)	+/-	IAR4D concept encourages more area of land to be cultivated.	+	More area of land enables households to earn more income and more productive assets
Agro-ecological zone represented by country	+/-	The technologies promoted by IAR4D in each agro-ecology motivate participation	-	Some zones closer to urban centres have greater potential for membership than remote ones
Distance to nearest all-weather road	+	Closeness to urban centre encourages participation since products can be marketed easily	+	Access to improved roads increases income opportunities and reduces transaction costs
Value of productive asset	+	Same as for land area	+	Same as for land area

Variable	Expected impact on participation in IAR4D	Why?	Expected impact on income and wealth	Why?
Request	+	Respondents who make a request for innovation are likely to be responsive to new ideas	+	Those who desire new ideas are likely to have more income and wealth earned from implementing new ideas.
Agent	+	Respondents visited by extension agents have timely access to information and can make decisions incorporating new innovations.	+	New ideas bring new opportunities to earn income and wealth.

Source: SSA CP Data

Results and discussion

Impact of IAR4D on household income

The 2008 average income for treated (clean before intervention), conventional and the clean sites were \$170.41, \$193.26 and \$150.36 respectively. In this kind of scenario, the estimation of income is difficult, and we had to resort to the use of proxy in form of the productive assets owned by the participants before and after the intervention.

At midline, the average incomes were estimated to be \$604.32, \$517.49 and \$445.40 respectively The ATT was computed based on two alternative matching methods. The outcome variable was based on participant income per year measured in USD. The z-statistics were based on bootstrapped standard errors with 50 replications, which were used to verify whether the observed effect was significant or not.

The results show that the average income of the treated (IAR4D farmers) sample due to participation in the IP activities based on the PSM (ATT) was \$80.55 in the case of kernel ($p<5\%$). A comparative analysis shows that the IP farmers are better off (with higher household incomes) than the farmers in the two counterfactuals of conventional and clean sites. The ATT of the two counterfactual sites were neither positive nor statistically significant, suggesting little or no impact on the participants.

Estimation results of propensity scores

Estimation of propensity scores serves two purposes: (1) to determine the ATT and, (2) to obtain matched treated and non-treated observations. The results of the probit models are reported in Table 7.

Table 7: Probit regression of IAR4D participation (matched observations)

Explanatory variables	Treated (IAR4D)		Control (Conventional)		Control (Clean)	
	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
Gender (1 = male; 0 = female)	0.207	0.164	-0.381***	0.161	0.175	0.164
Age of respondent (yrs)	-0.256*	0.160	0.016	0.166	-0.285**	0.163
Education of respondent (yrs)	-0.012	0.082	0.105	0.082	-0.093	0.082
Household size	0.274**	0.114	0.165	0.117	0.124	0.117
Farm size	0.092**	0.047	-0.067	0.046	-0.021	0.047
Assets (productive)	0.059**	0.026	0.073***	0.026	0.014	0.026
Marketing district	-0.001	0.002	-0.001	0.001	0.001	0.001
Agent	0.087	0.149	-0.176	1.149	-0.342**	0.187
Request	0.016	0.015	0.003	0.016	0.020	0.016
Rwanda	0.276*	0.170	0.159	0.171	-0.442***	0.171
Uganda	0.402*	0.172	0.001	0.173	-0.422***	0.175
Constant	-0.966	0.658	-1.160	0.671	0.043	0.660
Sample size (n)	1716		1716		1716	
Pseudo R^2	0.009		0.009		0.039	
Prob > χ^2	0.039		0.035		0.160	
Log likelihood	-1085.71		-1080.46		-1079.23	

Source: SSA CP Data

Table 7 reveals that the participants in the IAR4D were most likely to be young farmers with family members and some productive assets, including reasonably sized farmland, and from Rwanda or Uganda. On the other hand, participants in the conventional module were most likely to be women with some productive assets, while those in the clean sites were likely to be young farmers without regular contact with extension agents. These results suggest that the IAR4D intervention's focus was more on the married youth, who constitute the vulnerable group in the project area.

These probit model results were used to compute the propensity scores that were used in the PSM estimation of ATT. Several methods can be used for selecting matching observations (Smith and Todd, 2001). We used both the kernel matching method (using the normal density kernel), which utilises a weighted average of "neighbours" (within a given range in terms of the propensity score) of a particular observation to compute matching observations, as well as the nearest-neighbour method, which uses a weighted average to improve the efficiency of the estimator (Smith and Todd, 2001). Observations outside the common range of propensity for both groups (i.e. lacking "common support") were dropped from the analysis. This requirement of common support eliminated about half of the total number of observations, indicating that many of the observations from various strata were not comparable.

Further testing of the comparability of the selected groups was done using a "balancing test" (Dehejia and Wahba, 2002), which tested for statistical significant differences in the means of the explanatory variables used in the probit models between the matched groups of the IAR4D participants and non-participants. In all cases, the test (balancing test) showed statistically insignificant differences in observable characteristics between the matched groups (but not between the unmatched samples), supporting the contention that the PSM ensures the comparability of the comparison groups (at least in terms of observable characteristics).

We used bootstrapping to compute the standard errors of the estimated ATT, generating robust standard errors because the matching procedure matched control households to treatment households “with replacement” (Abadie and Imbens 2006).

The project’s experimental design is such that it allows an examination of the intervention’s spillover effect by comparing the changes in the income of the participants with those of the non-participants living within and outside the project’s community. The homogenous results suggest that non-participants may have benefited from the project’s spillover, for example, they made use of the innovations and research findings made available to the participants. In addition, some services like storage facilities, shredding machines and employment were available to the participants as well as the non-participants.

It is likely that the project’s impact on incomes will be larger than currently captured because of the lagged effects of investments on productive assets, infrastructure and other project investments. Table 8 shows the homogenous impact of IAR4D on the participants’ income. The result shows that participation in IAR4D had a positive and significant impact on the beneficiaries at the 5 percent level. The quantum of the impact improved the beneficiaries’ condition about 48 percent from their baseline condition, while the counterfactual situations (both conventional and clean) were neither better nor statistically significant. If we assume a household size of eight, then we can safely assert that participation in the IAR4D has improved the income of about 13,728 people in the PLS.

IAR4D’s effect varied across the major agro-ecological zones of the PLS. The participating countries served as proxies for the various agro ecologies in the PLS. Given the configuration of the task forces in the LKKV PLS across the countries involved, we estimated the impact by country. The results show that the project had a significant impact (at $p < 0.10$) in both DRC and Uganda, with a percentage change of about 83 and 32 points respectively. In essence, the results revealed that the participants in DRC and Uganda were 83 percent and 32 percent higher than the baseline.

The vital importance of gender in development programmes has been stressed in recent times, primarily because of the acknowledged potential that women have in improving the overall welfare of the household and because they are usually the most vulnerable during an economic downturn. Table 8 reveals that participation in IAR4D increased the income of women participants by about 47 percent at the midline relative to the baseline condition. The result was positive and significant at the 5 percent level, showing that the programme is well targeted at women. By encouraging women, the project may have enabled them to catch up with men in terms of income and thus stabilise household welfare. Additionally, the income change for women participants was better than for the counterfactuals, for whom it was neither positive nor significant. The programme has improved the income of 4,648 women in the PLS. Hence, we can safely conclude that IAR4D is gender inclusive.

Table 8: Impact of IAR4D on household income across types of respondents

	Net real household income (US$)			% change due to participation in IAR4D
	Before IAR4D	After participation in IAR4D	ATT	
IAR4D (n = 1716)	170.41 (19.23)	604.32 (26.40)	80.55** (41.65)	47.27
Conventional (n = 283)	193.26 (15.16)	517.49 (40.21)	-57.22 (46.07)	
Clean (n = 171)	150.36 (13.22)	445.40 (26.52)	-23.03 (139.71)	
Agro-ecological zones				
DRC				
IAR4D n = 193	81.33 (16.87)	307.99 (42.29)	67.16* (51.00)	82.58
Conventional n = 285	76.91 (14.35)	210.39 (33.13)	-33.21 (49.15)	
Clean n = 281	51.35 (7.86)	204.72 (30.69)	-27.99 (49.00)	
Rwanda				
IAR4D n = 274	93.01 (8.70)	436.02 (43.92)	105.75 (101.28)	
Conventional n = 213	136.67 (23.37)	230.39 (33.13)	-76.68 (155.89)	
Clean n = 202	137.17 (15.61)	232.36 (104.74)	-29.16 (123.47)	
Uganda				
IAR4D n = 275	295.48 (45.41)	446.11 (47.26)	93.13* (65.11)	31.52
Conventional n = 276	257.06 (33.32)	276.07 (69.40)	-69.16 (74.59)	
Clean n = 274	261.62 (32.52)	318.90 (45.17)	-25.01 (61.06)	
Gender				
IAR4D n = 581	169.81 (13.39)	425.37 (29.28)	79.07** (43.19)	46.56
Conventional n = 647	201.76 (16.88)	352.73 (47.38)	-68.22 (54.78)	
Clean n = 647	163.25 (15.29)	276.52 (29.92)	-11.58 (41.34)	
Food security				
IAR4D n = 516	138.86 (10.94)	380.63 (27.12)	60.61** (35.41)	43.65
Conventional n = 656	158.26 (12.09)	285.96 (43.11)	-57.86 (50.86)	
Clean n = 630	133.11 (9.39)	214.88 (24.54)	-1.97 (40.41)	
Research				

	Net real household income (US$)			% change due to participation in IAR4D
	Before IAR4D	After participation in IAR4D	ATT	
IAR4D n = 78	450.80 (110.72)	-63.88 (17.07)	109.34 (237.03)	273.01
Conventional n = 78	379.86 (78.06)	-120.52 (33.84)	203.77 (241.92)	
Clean n = 78	-	-	-357.25 (287.24)	
Wealth distribution				
Tercile 1 (poorest)				
IAR4D n = 228	4.85 (0.43)	290.21 (37.19)	39.82 (30.71)	
Conventional n = 248	4.51 (0.41)	113.57 (30.44)	-42.51 (39.80)	
Clean n = 256	4.38 (0.41)	113.16 (33.78)	-1.56 (39.33)	
Tercile 2				
IAR4D n = 605	53.59 (1.64)	310.10 (25.45)	63.61** (34.79)	118.70
Conventional n = 605	58.28 (1.77)	160.08 (31.15)	-17.73 (51.68)	
Clean n = 605	57.28 (1.59)	159.87 (30.21)	-42.78 (40.62)	
Tercile 3				
IAR4D n = 238	439.94 (51.60)	603.11 (61.66)	121.81 (124.63)	
Conventional n = 267	299.49 (37.29)	359.60 (105.97)	-104.52 (144.36)	
Clean n = 243	202.66 (36.13)	388.17 (64.96)	-16.38 (107.48)	

ATT = $(Y_{p1}-Y_{p0})-(Y_{np1}-Y_{np0})$. “Before project” is the situation before IAR4D was introduced in 2008, while “after project” is two years after the project started in 2010.

“ATT” and the corresponding “%” refer to the change in measured household income resulting from participation in the IAR4D IP. % net change due to participation at the platform = $(ATT/Y_{p0})*100$.

* Significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

Essentially, one of the widely acknowledged shortcomings of agriculture in SSA was its inability to provide adequate food security. IAR4D's impact on food security shows that the participants were about 44 percent more food secure than those in the counterfactual sites. The former were more food secure, with a positive impact on food security, while the impact on the counterfactuals was neither positive nor statistically significant. In fact, the results show that 4,128 people were able to cross the food insecurity line in the PLS.

One of the main advantages of the IP is the free exchange of research ideas among all the stakeholders and the almost immediate adoption of the same by participants. Research ideas do not come from scientists alone, but also from indigenous sources. Table 8 shows that participation in research activities, while it improved the income of beneficiaries positively, was not statistically significant. This is very instructive, especially in regard to the potential of IPs in the IAR4D zones. The prompt generation and adoption of research ideas has not made IAR4D beneficiaries very different from their counterparts in the PLS.

We explored the impact of IAR4D on the income strata of the community. Table 8 reveals that the income of the beneficiaries in the lowest tercile (the poorest) increased by over 118 percent, indicating that the project had a positive and significant impact (at $p < 0.05\%$) on the beneficiaries. This is very important, suggesting that the project appropriately targeted the poor in the choice of beneficiaries. The scale of the impact also indicates the negative baseline conditions from which the beneficiaries started. The result also shows that both counterfactuals (the conventional and the clean) have not been significantly impacted by the project.

In summary, IAR4D has enabled beneficiaries to realise significant increases in their incomes. The study's research tools have enabled us to attribute, with considerable confidence, the income increases among the beneficiaries from participation in the project. IAR4D's impact was both positive and significant among the beneficiaries in the three participating countries. It should be noted that this study has been unable to capture the full impact of the project because the project had only operated for two years at the most in the PLS when impact evaluation was undertaken. Thus, our results do not capture the lagged impacts of the rural infrastructure, productive assets, and other project interventions.

IAR4D targets poor and vulnerable groups like women, youth, and the elderly, which is likely to reduce income inequality. The impact of this targeting was examined by considering the change in income inequality over the two years of the project. We computed the Gini coefficient of the income of the respondents for this objective. The results, which are displayed in Table 9, confirm

Table 9: Impact of IAR4D on income distribution

Treatment type	Gini coefficient at baseline	Gini coefficient at midline	% Gini coefficient change
All respondents	0.73	0.64	-0.09
IAR4D beneficiaries	0.73	0.64	-0.09
Conventional	0.73	0.65	-0.08
Clean	0.65	0.72	0.07
Gender	0.71	0.64	-0.07
DRC	0.79	0.67	-0.08
Rwanda	0.67	0.61	-0.06
Uganda	0.65	0.63	-0.03

Source: Data Analysis 2012

that the Gini coefficient of the beneficiaries decreased by about 9 percent, suggesting that the project contributed to reduction of income inequality. However, in the clean zone, there was an increase in income inequality by about 7 percent.

The largest decrease in income inequality was seen among the IAR4D beneficiaries, at around 9 percent, relative to an increase of 7 percent recorded for the clean sites. The results also show that there was a decrease in income inequality by 7 percent among the women, with a decrease of 8 and 9 percentage points when considered on a country basis. This indicates that there is a need for country specificity in the intervention. However, the result is consistent in that the income of the poorest increased more significantly than the middle and upper terciles.

Results of the ex-ante impact analysis of Lake Kivu PLS

In assessing the potential economic benefits from adoption of the IAR4D approach, we estimated the yield gains and the unit production cost reduction; defined the priority crops production for extrapolation to other areas; examined the adoption pathway; and used the economic surplus model to evaluate the potential economic impact. A sensitivity analysis was also undertaken to evaluate the robustness of the estimated benefits with respect to model assumptions and certain parameter values. Apart from the model assumption (closed economy), the analysis focused on assessing the effects of: (1) halving the expected adoption rates, and (2) doubling the extension costs.

The gross margin analysis indicated that, under a reasonable set of assumptions and using baseline data for the 2008 cropping season as well as the secondary data, if the technology had been available in the baseline year and priced appropriately (so that it would be adopted comprehensively) farmers in the PLS would have benefited by US$941 million in that year: US$158 million (17%) in Rwanda, US$424 million (45%) in DRC and US$359 million (38%) in Uganda.

As for benefits obtainable per hectare, pepper yielded the highest returns in Rwanda with a value of US$3816.72; cassava yielded US$833.69 in DRC and potato US$373 in Uganda. These estimates may be understated for several reasons. First, we used average values to generate the figures. It is clear that some countries would have obtained above average benefits, while below average benefits may have accrued to others. However, the nature of the technology and the prevailing environment determines the actual value of benefit obtained eventually.

Rwanda

The results of the potential economic surplus model show that stakeholders in Rwanda gained an estimated US $285 million over the reporting, equivalent to US$ 8 million per year, from the adoption of the IAR4D approach in pepper production. Out of which, producer surplus was about US$210 million (about 60 percent) – equivalent to annual benefits of about US$6 million with an internal rate of return of 34 percent. The estimated benefit: cost ratio of 30 to 1 in pepper production indicates that each dollar invested in IAR4D research and extension generates 30 dollars' worth of additional output.

When it comes to potato production, it generates estimated gains of US$353 million – equivalent to US$10 million per year – in potato production with an average annual producer surplus and consumer surplus of US$7.4 million and US$3.0 million, respectively; and research and extension yields a rate of return of 36 percent and a benefit: cost ratio of 37 to 1. Nevertheless, IAR4D appears to have the lowest potential for generating productivity gains in excess of the expenditure in plantain/banana cultivation compared with potato and pepper. It generates estimated gains of US$117 million – equivalent to US$3.3 million per year. The average annual producer and consumer surpluses are US$2.57 million and US$1.03 million, respectively, with the IAR4D approach research and extension yielding a rate of return of 25 percent and a benefit: cost ratio of 13 to 1.

DRC

The estimated gains from sorghum production in DRC through IAR4D was US$391 million – equivalent to US$11.2 million per year. The average annual present producer and consumer surpluses are US$8.2 million and US$3.3 million respectively, with a rate of return of 37 percent and a benefit: cost ratio of 42 to 1. However, with respect to cassava production, the IAR4D approach yields average annual present producer and consumer surpluses of about US$5.7 million and US$2.3 million respectively, with research and extension yielding a rate of return of 33 percent and a benefit: cost ratio of 28 to 1.

With regard to plantain/banana production, the results show that IAR4D generates high estimated gains of US$405 million – equivalent to about US$11.6 million per year. The average annual present producer and consumer surpluses are about US$8.5 million and US$3.4 million, respectively, with a rate of return of 37 percent and a benefit: cost ratio of 42 to 1.

Uganda

In Uganda, IAR4D generates an estimated gain of US$359 million – equivalent to about US$10.3 million per year. The average annual producer and consumer surpluses are about US$7.5 million and US$3.0 million, respectively. In sorghum production, the IAR4D approach to research and extension yields a rate of return of 36 percent and a benefit: cost ratio of 38 to 1. The findings show that IAR4D generates high estimated gains of US$932 million – equivalent to about US$26.6 million per year with respect to potato production. The average annual producer and consumer surpluses are about US$19.2 million and US$7.7 million, respectively. The results further demonstrate that, in potato production, the IAR4D approach research and extension yields a rate of return of 47 percent and a benefit: cost ratio of 97 to 1. The benefits from potato cultivation are the highest in the country and higher than what obtains for the same crop in the other two countries in the PLS.

The results also show that, in plantain/banana cultivation, IAR4D generates high estimated gains of US$599 million – equivalent to about US$17.1 million per year. The average annual present producer and consumer surpluses are about US$12.4 million and US$5.0 million, respectively, with the approach yielding a rate of return of 44 percent above its research and extension costs and a benefit: cost ratio of 64 to 1.

The findings unambiguously indicate that estimated benefits are much more sensitive to expected adoption than to changes in research and extension costs. Nevertheless, the estimates indicate that the production of all crops is profitable under the IAR4D approach. The results were consistent with earlier economic analyses, which showed that IAR4D was more productive, profitable and acceptable to farmers than the conventional R&D approach.

Conclusions and policy implications

The proof of concept exercise sets out three questions to establish IAR4D not only as a concept but also as a viable alternative to the traditional R&D (conventional) approach:

(i) Does IAR4D work as a concept?

The answer to this question lies in the homogenous result of the impact analysis, which confirms that IAR4D works and positively impacts the lives of the beneficiaries to the tune of US$80 per participant. The incomes of about 13,728 people in the PLS have improved consequent to its introduction.

(ii) Does the IAR4D approach deliver more benefits than the conventional R&D methods?

Using the matching methods as well as the PSM and double difference approach we can safely conclude that IAR4D delivers more benefits than the conventional R&D method. The results while confirming the positive impact reveal that, under the same conditions, the impact is not consistently positive on the non-beneficiaries in the conventional and the clean sites.

The analyses also show that IAR4D benefits women's income and research participation, especially those in the poorest segment of the community. The programme improved the income of 4,648 women and enabled 4,128 women to cross the food insecurity line. These results are consistently robust and reliable.

(iii) Can IAR4D be scaled up and out beyond the current area of operation?

The results of the ex-ante analysis, in line with the impact assessment analysis, suggest that the concept can be successfully scaled up and out with potentially multiple positive impacts on the beneficiaries. Anecdotal evidence suggests that neighbouring communities are eager to adopt this approach.

The IAR4D approach had been underway for nearly two years in the LKKV PLS, during which time the project realised significant positive impacts on household income, food security, gender, and research participation. Using propensity score and double-difference methods to control for project placement and self-selection biases, we found that IAR4D increased participants' income, improved household assets and encouraged participation in research as well as adoption of research outputs.

Household income gains were substantially higher for the IAR4D participants than for non-beneficiaries, with an average increase in real incomes of about 48 percent, which is not only better than the conventional and clean sites but also well above the achievement of similar projects in the continent.

This result is much in line with the ex-ante report on the LKKV PLS (Ayanwale et.al. 2010), in which the projected benefits of IAR4D not only surpassed the costs of investments but were also higher than both the conventional and clean modes. Furthermore, the benefits derivable vary by taskforces (agro-ecological zones), and Rwanda earned the least quantum of benefits of the three.

The project had a bigger impact on the poorest beneficiaries and could have a much greater impact in the future because of the lagged effect of the productive asset acquisition. Thus, a follow-up study is needed to capture the longer-term benefits of productive assets generated as a result of participation in the IAR4D programme and other changes like rural infrastructure development.

The key issues that need to be addressed in scaling up this success story include among others: better targeting of poor and vulnerable groups, especially women; finding sustainable methods of promoting development of rural financial services; and conscious inclusion of capacity building of IAR4D beneficiaries in efficient management of productive assets.

As regards appropriate targeting, it may be recalled that, over the first two years that the project operated, the Gini coefficient of income for beneficiaries decreased by about nine percent compared to an increase for other categories of non- beneficiaries. This suggests that the project contributed to the reduction in income inequality through targeting poor and vulnerable groups. Consistent with this, the project also succeeded in raising the value of productive assets of the lower tercile more significantly than for the other terciles. The non-significance of the impact on income for the other two terciles suggests appropriate targeting of the poor and vulnerable groups.

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Acronyms and abbreviations

ACFADP	Agricultural Development Programme
AEZ	Agro-Ecological Zone
AFAN	All Farmers' Association of Nigeria
AHI	Africa Highland Initiative
AIP	Agricultural Innovation Platform
ARD	Agricultural Research and Development
CBO	Community Based Organization
CGIAR	Consultative Group on International Agricultural Research
CIAT	International Centre for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Centre
CORAF	Conseil ouest et centre africain pour la recherche et le développement agricoles, West and Central African Council for Agricultural Research and Development
CP	Challenge Programme
CRST	Cross Site Research Support Team
DD	Double Difference
DDM	Double Difference Methods
DFID	Department for International Development
DIOBASS	Ecologie et Société est une association internationale engagée auprès des communautés de base dans leur transformation sociale et technique.
EU	European Union
FADAMA II	Second National Fadama Development Project of the Federal Ministry of Agriculture and Water Resources Nigeria
FARA	Forum for Agricultural Research in Africa
FEPSAN	Fertilizer Producers and Suppliers Association of Nigeria
GIS	Geographical Information Systems
GNP	Gross National Product
IAR	Institute for Agricultural Research (Nigeria)
IAR4D	Integrated Agricultural Research for Development
ICRAF	International Centre for Research on Agro-Forestry
ICRISAT	International Crop Research Institute for Semi-Arid Tropics
IFDC	International Fertilizer Development Centre
IFPRI	International Food Policy Research Institute
IITA	International Institute for Tropical Agriculture
ILRI	International Livestock Research Institute
INERA	Institut National pour l'Etude et la Recherche Agronomiques (DRC)
INRAN	Institut National de Recherche Agronomique de Niger
IP	Innovation Platform
IPG	International Public Good

ISAR	Institute for the Study of African Realities
ISFM	Integrated Soil Fertility Management
KAZARDI	Kachwekano Zonal Agricultural Research and Development Institute
KKM	Kano Katsina Maradi
KTARDA	Katsina State Agricultural and Rural Development Authority
LCRI	Lake Chad Research Institute (Nigeria)
LK	Lake Kivu
MDG	Millennium Development Goals
MLL	Maize Legume Livestock IP
MOU	Memorandum of Understanding
MTP	Medium-Term Plan
MTP	Medium-Term Plan 2009–2010
NAERLS	National Agricultural Extension Research Liaison Service (Nigeria)
NAPRI	National Animal Production Research Institute (Nigeria)
NARO	National Agricultural Research Organization (Uganda)
NARS	National Agricultural Research System
NGO	Non-Governmental Organization
NGS	Northern Guinea Savannah
NIHORT	National Institute for Horticultural Research and Training (Nigeria)
NRM	Natural Resources Management
NSS	National Seed Service
NUR	National University of Rwanda
OVG	Observatoire Vulcanologique de Goma (DRC)
PCU	Programme Coordination Unit
PLAR	Participatory Learning and Action Research
PLS	Pilot Learning Site
PLT	Pilot Learning Team
PM&E	Planning, Monitoring, and Evaluation
PSM	Propensity Score Matching
R&D	Research and Development
RPG	Regional Public Goods
SACCO	Savings and Credit Co-operative
SLL	Sorghum Legume Livestock IP
SRO	Sub-Regional Organization
SS	Sudan Savannah
SSA	Sub-Saharan Africa
SSA CP	Sub-Saharan Africa – Challenge Programme
TF	Taskforce
TSBF	Tropical Soil Biology and Fertility Program of the CIAT
UNADA	Uganda National Agro-Input Dealers' Association
ZMM	Zimbabwe Mozambique Malawi

About FARA

FARA is the Forum for Agricultural Research in Africa, the apex organization bringing together and forming coalitions of major stakeholders in agricultural research and development in Africa.

FARA is the technical arm of the African Union Commission (AUC) on rural economy and agricultural development and the lead agency of the AU's New Partnership for Africa's Development (NEPAD) to implement the fourth pillar of the Comprehensive African Agricultural Development Programme (CAADP), involving agricultural research, technology dissemination and uptake.

FARA's vision: reduced poverty in Africa as a result of sustainable broad-based agricultural growth and improved livelihoods, particularly of smallholder and pastoral enterprises.

FARA's mission: creation of broad-based improvements in agricultural productivity, competitiveness and markets by supporting Africa's sub-regional organizations (SROs) in strengthening capacity for agricultural innovation.

FARA's Value Proposition: to provide a strategic platform to foster continental and global networking that reinforces the capacities of Africa's national agricultural research systems and sub-regional organizations.

FARA will make this contribution by achieving its *Specific Objective* of sustainable improvements to broad-based agricultural productivity, competitiveness and markets.

Key to this is the delivery of five *Results,* which respond to the priorities expressed by FARA's clients. These are:

1. Establishment of appropriate institutional and organizational arrangements for regional agricultural research and development.
2. Broad-based stakeholders provided access to the knowledge and technology necessary for innovation.
3. Development of strategic decision-making options for policy, institutions and markets.
4. Development of human and institutional capacity for innovation.
5. Support provided for platforms for agricultural innovation.

FARA will deliver these results by supporting the SROs through these Networking Support Functions (NSFs):

NSF1/3. Advocacy and policy
NSF2. Access to knowledge and technologies
NSF4. Capacity strengthening
NSF5. Partnerships and strategic alliances

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