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Exploring the Potentials of Integrated Agricultural Research for Development in Southern Africa

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Acknowledgements

This book documents the proof of the Integrated Agricultural Research for Development (IAR4D) concept 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), the only CGIAR Challenge Programme that is restricted to a single region in the world. The focus of the SSA CP is to substantially facilitate greater impact from agricultural research for development leading to improved rural livelihoods, increased food security and sustainable natural resource management throughout Sub-Saharan Africa. The SSA CP aims to achieve this by developing and implementing the IAR4D approach, which overcomes the shortcomings of traditional paths taken by agricultural research and development. The CP was challenged to conduct activities that will lead to a proof of the IAR4D concept in its first phase.

The SSA CP implementation embraces extensive partnership arrangements that are unprecedented. The implementation was conducted in three sub-regions that constitute Sub-Saharan Africa: namely, West and Central Africa, Eastern and Central Africa, and the Southern Africa sub-regions. Over 80 institutions were involved in the implementation of the program. Of these 80 institutions, 55% were research-based institutions, while the other 45% were civil society organisations (NGOs, the private sector, farmers' organisations and community-based organisations). The SSA CP implementation rallied the inputs of more than 243 researchers across the globe.

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Executive summary

The acknowledged poor performance of traditional agricultural research and development (ARD) approaches reflected in the low adoption rates of technologies, poor linkages among agricultural value chain actors and the pervasive unprofitability of farm enterprises in Sub-Saharan Africa (SSA) led the Forum for Agricultural Research in Africa (FARA) to suggest the Integrated Agricultural Research for Development (IAR4D) approach. This approach enables agricultural research to play a more effective role in catalysing development. It embraces a broader system of agricultural innovation that facilitates interaction and enhances flow of knowledge among all key actors in agricultural systems and value chains.

The SSA Challenge Programme (CP) is being implemented in three Pilot Learning Sites (PLS) across the continent. These are the Kano-Katsina-Maradi (KKM) PLS in the West African sub-region; the Lake Kivu (LK) PLS in the East and Central Africa sub-region and the Zimbabwe-Mozambique-Malawi (ZMM) PLS for the Southern African sub-region. By applying IAR4D, SSA CP aims to reverse the underperformance of agricultural research in Africa by developing, testing (proving whether it works) and scaling out/up an approach for conducting agricultural research for development in Africa. FARA strongly believes that IAR4D overcomes the shortcomings of conventional approaches. Each PLS defines the domain within which the project's research sites are sampled. This book focuses on the Zimbabwe-Mozambique-Malawi (ZMM) PLS.

The Science Council of the Consultative Group on International Agricultural Research (CGIAR) mandated SSA CP to prove the validity of the claim that IAR4D is relatively better in delivery of development outcomes than conventional research and development (R&D) approaches. The proof of the concept was guided by the following three related questions:

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

After 2 years of experimenting with IAR4D, this report provides answers to the three important questions. Analysis in this report is based on two data panels, i.e., baseline data collected in 2008 and mid-line surveys collected in 2010. A quasi-experimental approach was used to compare selected indicators between the intervention villages and those in the two control

villages – conventional, which is the traditional ARD, and the clean sites where it was assumed there was no ARD, at least 2 years prior to the commencement of the IAR4D.

Using propensity score (PSM) and double-difference methods (DDM) as controls for project placement and self-selection biases, it was found that IAR4D improved productive assets of the participants, encouraged participation in research and facilitated the adoption of research outputs.

The PSM results indicate that participants in the IAR4D are likely to be young female farmers with small household sizes and a low level of productive assets. Results further indicate that farmers in the conventional sites are likely to be elderly, educated farmers. However, it was the gender of the participants that formed the most important determinant for farmers in the clean sites; in other words, those in clean sites are mostly women farmers. These results suggest that the IAR4D was targeted at vulnerable groups (young women) with a low level of education, small household sizes and small level of assets.

Does the IAR4D work as a concept?

The answer to this question came from the homogenous result of the impact analysis. The answer is yes! The IAR4D works and impacts positively on the lives of the beneficiaries to an average income of $211 per participant monthly. This figure lifted the participants well above the poverty level, considering their baseline conditions. The World Bank defined household spending of less than $1.00 per day as extremely poor (World Bank, 2005). Indeed, the programme improved the income of 1,688 persons in the PLS.

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

With the use of matching methods as well as the PSM and DDM approaches, it was safely concluded from the results that the IAR4D delivers more benefits than the conventional R&D method. The results, while showing the positive impact for the IAR4D, reveal that under the same conditions, the conventional and the clean do not impact consistently and positively on the non-beneficiaries.

The analyses also show that the IAR4D impacts positively on women's income (288%), research participation (2730%) and wealth distribution (6883%). These results are consistently robust and reliable. The incomes of 1,512 women improved as a result of the programme.

Incomes improved substantially more for the IAR4D participants than for non-beneficiaries in conventional and clean sites, with an average increase of about 270% in real incomes resulting from their participation, which is not only better than the conventional and clean sites but well above the achievement of similar projects on the continent. For instance, the World Bank-sponsored Fadama II project in Nigeria (winner of the Bank's Regional Excellence Award) had an income impact rate of about 60%, a feat achieved after six years of operations.

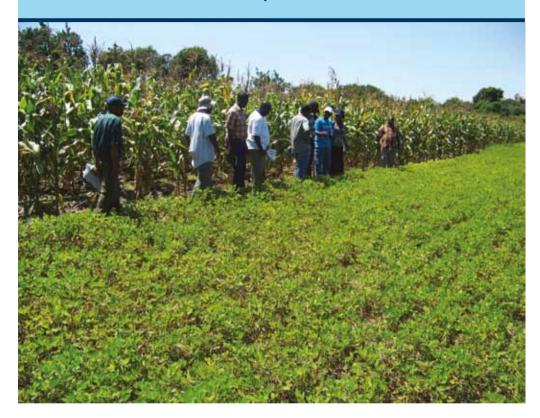## Can the IAR4D be scaled out and up beyond the current area of operation?

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. The result of the *ex ante* report on the ZMM PLS (Ayanwale et al., 2010) had confirmed that the projected benefits of IAR4D not only surpassed the costs of investments but was also superior to both the conventional and the clean modes. Further, the derivable benefits varied between task forces (representing agro-ecological zones), with Malawi showing the least quantum of benefits among the three countries involved in the PLS. This could be due to baseline conditions in Malawi and possibly due to a lower level of education and larger family sizes compared to the other countries involved in the PLS.

The project had a bigger impact on the poorest among the beneficiaries and could have much greater impact in future because of the lagged effect of the productive asset acquisition. Thus, 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 their participation in the IAR4D. As the study was conducted at an early stage of the project, it 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 this success story include amongst others: better targeting of poor and vulnerable groups especially of 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.

With regard to appropriate targeting, it may be recalled that over the first 2 years of the project's operations, the Gini coefficient of income for beneficiaries decreased by about 15% compared with an increase for other categories of non-beneficiaries. This suggested that the project contributed to the reduction in income inequality, possibly through targeting of the poor and vulnerable groups. Consistent with this, the project also succeeded in raising the value of productive assets of the poorest tercile 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

1.0 Introduction

Investing in agricultural research and development is critical to improving livelihoods of the resource-poor in Sub-Saharan Africa (SSA) as it is also necessary for the conservation of natural resources. The steady growth of agricultural research and development (ARD) in SSA has resulted in studies replete with cases of unsatisfactory performance of ARD initiatives (Adekunle et al 2013). These approaches are widely blamed for significantly contributing to the unsatisfactory performance of agriculture in improving the livelihoods of its end-users—especially the smallholder farmers. The poor performance of traditional ARD approaches is reflected in low adoption rates of technologies, poor linkages among agricultural value chain actors and the pervasive unprofitability of farm enterprises in SSA. The SSA Challenge

Programme (CP) questions the ability of research and development (R&D), which is structured as a linear process to influence important interactions between researchers, communities and other stakeholders in providing timely interventions.

Recognising the need to transform this configuration by embedding research within an innovation system comprising all actors in agricultural value chains, Integrated Agriculture Research for Development (IAR4D) was proposed. Within such a system—a network configuration — innovation does not follow a linear path that begins with research, moving through the processes of development, transfer, diffusion, adoption, production and ending with successful introduction and use of new products and processes; rather, it tends to involve 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*).

The structure of IAR4D concept implies that action from all the relevant stakeholders (private sector practitioners, policymakers, farmers, researchers, extension agents, credit providers, end-users, etc.) helps provide farmers with direct access to timely supply of agro-inputs, credit facilities and output markets. The innovation platform (IP) also provides direct benefits to all stakeholders involved. Financial institutions get interest through the provision of credit to farmers; seed companies and agro-dealers have a guaranteed market for their products and agro-processors in the IP purchase farmers' produce at competitive prices. This network of stakeholders guarantees the success of IAR4D to a reasonable extent. The system also ensures adoption of productivity-enhancing technologies that enable farmers to produce the quantity and quality of commodity demanded by the market.

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

The Zimbabwe-Mozambique-Malawi Pilot Learning Site (ZMM PLS) comprises north-east Zimbabwe, central Mozambique and southern Malawi. Agricultural systems in ZMM are predominantly mixed farming. In general, livelihoods are based on maize, tobacco, cotton, grain legumes, small ruminants, poultry and off-farm work activities. Over time, agricultural productivity has not been improving due to shortages of improved seed varieties, fertilisers and agro-chemicals and the high input to output price ratios. The region is facing significant decline in farm sizes, animal draught power and availability of farm labour due to human immunodeficiency virus infection/acquired immunodeficiency syndrome (HIV/AIDS). Soil fertility is also declining, yields are falling and smallholder farmers are reverting to extensive production practices. This is creating a self-reinforcing cycle of increasing land degradation, worsening poverty and food insecurity, which in turn only exacerbates the existing problem of land degradation. Drought and market volatility result in increased vulnerability, thereby reinforcing the vicious cycles.

The impacts of climate change (floods, droughts and unseasonal events) create challenges for the poorest communities due to their dependence on climate-sensitive economic sectors, such

as rainfed agriculture. Smallholder farmers have yet to recover from the impact of the 1991-92 drought; recurrent ones make it difficult for people to raise their standard and quality of life. These series of shocks have wiped out the smallholder farmers' savings and productive assets and thus increased their vulnerability and reduced their farm productivity.

The SSA CP seeks to reverse this downward trend in agricultural productivity and the worsening poverty levels among smallholder farmers. It adopts strategies designed to sustainably intensify and diversify from maize cultivation to higher value cash crops such as vegetables and livestock combined with increasing off-farm income-generating activities that have strong linkages to agriculture. Implementation of these strategies depends on productive and profitable technologies for improved soil fertility management, conservation of agriculture, integrated pest management (IPM), private sector investment for the development of viable input and output markets and farmers' collective action (institutions that encourage bulk buying, rotational savings, joint marketing, and rural microfinance). Diversification could also involve development of low-lying areas for irrigated or rainfed vegetable production. In the low population density areas, priorities include area expansion and intensification through zero tillage, conservation farming, grain/legumes integration, farmer-based multiplication of seeds and planting materials, and community-based land tenure reform.

The special economic environment in this PLS, especially in Zimbabwe, calls for concern. In the early 21st century, Zimbabwe's economic crisis deepened when the agricultural production plummeted, depriving the country of its traditional source of export revenue, while debt and inflation skyrocketed. The International Monetary Fund (IMF) suspended aid to the country due to the government's poor fiscal management, and Zimbabwe plunged into an economic meltdown. There was hyper-inflation as prices soared out of control, and consequently a thriving black market emerged. In January 2008, Zimbabwe reported an annual inflation rate of 100,000%. All these factors not only affected the economy but also development initiatives. They also have the potential to influence the development of the entire region where the ZMM PLS functions.

Objective of the ZMM PLS Project

The main objective of the ZMM PLS project is to test the effectiveness of IAR4D (proof of concept) in improving the performance of priority agricultural value chains through intensification and other technical and institutional innovations in high and low potential farming systems. There are three sub-projects designed to address the above challenges facing agriculture development in southern Africa and each of the three sub-projects work independently. Each of the three sub-projects that constitute the ZMM PLS project focuses on a specific value chain and is expected to deliver similar outputs. However, the activities of the sub-project differ based on the entry points and the specific context of each value chain.

The first sub-project is led by the Soil Fertility Consortium for Southern Africa (SOFECSA), hosted by CIMMYT. The guiding philosophy of SOFECSA is that 'Soil fertility is declining, yields are falling and smallholder farmers are reverting to extensive production practices'. Those

farmers' practices are resulting in mutually self-reinforcing mechanisms that increase land degradation, which in turn, accelerates poverty and food insecurity. Central to the SOFECSA project work is developing mechanisms for 'exiting the maize poverty trap', with integrated soil fertility management (ISFM) and effective market linkages as key entry points. Using IAR4D approaches, the project seeks to test, promote and evaluate innovations generated through multi-stakeholder partnerships. The first set of technologies being promoted are cereal and legume based technologies, which include cereal/using legume intercropping and cereal-legume rotation. The second set comprises fertiliser-based technologies that include mineral fertilisers only, organic fertilizers (as available) and their combinations with mineral fertilisers, and appropriateness of available fertiliser formulations. The last set of technologies includes those designed to help farmers adapt to climate change. These include promoting staggered planting dates for dry planting, early planting, and early planting. This is linked to improving efficiency of agricultural input and output markets, farmers' and marketing participants' skill development, development of farmers' and marketing participants' organisations, public agricultural research and extension organisations and private sector firms' capabilities to supply technology linked to market demand, micro-credits and making interventions to scale.

The second sub-project is led by the Tropical Soil Biology and Fertility Institute of CIAT (TSBF-CIAT). It aims to contribute towards establishing proof of the IAR4D concept by identifying the effectiveness of its platforms for resolving constraints on the development, dissemination and uptake of new conservation agriculture interventions linked to improved agricultural input and output markets, improved social capital that allows farmers to tap both internal and external community networks, thereby promoting access to sources of information, support and resources (e.g., links to traders, financiers, extension agents, and NGOs). The sub-project also examines the effectiveness of the IAR4D process in building the capacity of farming communities with relevant skills for rural development, increasing access to markets, improved postharvest handling and grain storage and diversification of production systems with high-value crops.

The project's work is premised on the understanding that decline in per capita food production that the Sub-Saharan Africa is experiencing is linked to falling soil fertility levels. According to Giller et al. (2009) conventional tillage, which is common in southern Africa, causes soil erosion and the loss of organic matter as these practices leave the soil bare and unprotected in times of heavy rain and intense heat. Conservation agriculture, which the project promotes, maintains and improves the soil structure with minimum disturbance of the natural soil ecology. Economic benefits include reduction in labour and energy use, less turnaround time and a reduction in production costs. Conservation farming relies on three main principles, which include minimal soil disturbance, permanent soil cover and crop rotation. Residue cover protects and feeds the soil fauna that produces and maintains an open pore system in the soil. Crop rotation ensures a more balanced extraction of plant nutrients from the soil and also ensures that the root system explores the soils to different depths.

The third sub-project is led by Bioversity International. It aims to contribute to establishing proof of the IAR4D concept by identifying the effectiveness of IAR4D innovation platforms

for resolving constraints on the development, dissemination and uptake of science-based practices in vegetable growing, harvesting, preservation, storage, transporting, packaging, processing and marketing. The sub-project investigates the impact of multiple-scale integration of interventions to strengthen the capacity of public and private sector organisations to undertake vegetable research and works with farmers to produce vegetables under improved soil and water management conditions, building the capacity of farmers to produce vegetables 'as a business', developing linkages with agricultural input and output markets, and stimulating demand for vegetables through promotions.

Each sub-project has established four IPs that are scattered across ZMM PLS. Table 1 shows the distribution of the IPs by country and sub-project.

Table 1: Distribution of Innovation Platforms by Country in the ZMM PLS.

	Conservation agriculture	Soil fertility	Vegetables
	IAR4D	IAR4D	IAR4D
Malawi	Balaka	Zomba	Zomba
			Thyolo
Mozambique	Barue	Barue	Barue
			Milanje
Zimbabwe	Murehwa	Makoni	
	Wedza	Wedza	
n	20	20	20

Chapter 2

2.0 The study area

The PLS chosen for the Southern African Development Community (SADC) sub-region consists of the transect, or a corridor, from southern Malawi through Mozambique to Mashonaland, East Zimbabwe, Manicaland (Nyanga Rural) and Manica (Barwe) in Zimbabwe. This site covers approximately 275,000 km^2 and has a total population of about 11.5 million. It encompasses different gradients when moving northwards from Zimbabwe to southern Malawi, such as low to high population densities and increases in average annual rainfall and the length of growing period. The PLS is characterised by a trans-boundary effect in which the three countries share similar farming systems (classified as mixed-maize systems), with livestock decreasing in importance as one moves from south to north.

The PLS provides a unique opportunity to explore how public-private sector partnerships and cross-border trade can be used to drive the sustainable intensification of crop and livestock production systems, thus alleviating food insecurity, raising household incomes, and encouraging a reinvestment in the natural resource base. The challenge is to develop and promote production systems, public-private sector partnerships and a regional capacity that capitalises upon existing commercialisation initiatives and the informal cross-border food crop trade.

The study area has a good potential for agricultural intensification. Major legume commercialisation initiatives are already ongoing in the three countries, driven by the National Smallholder Farmers' Association of Malawi (NASFAM) in Malawi, Mozambican Leaf Tobacco in Mozambique, and Reapers in Zimbabwe, with support from the respective national agricultural research and extension programmes, donor communities, international agricultural research centres (IARCs), and non-governmental organisations (NGOs) such as World Vision International and CARE. Major cross-border food crop trade played an important role in averting widespread food insecurity in this region in 2002 and 2003. SSA CP could capitalise on further high-potential opportunities in the PLS, such as:

- introducing improved varieties (meeting market trade demands at local, national, regional and international levels) of beans, groundnuts, pigeonpeas and chickenpeas throughout the PLS.
- introducing improved varieties (with higher yields, disease resistance, and enhanced nutritional value) of cassava, banana and sweet potato in more humid areas.
- improving inter-country controls of pests and diseases, harmonising regional bio-safety, food safety, quarantine and seed laws, and strengthening rapid-response networks.
- capacity building in biotechnology, especially in fields of tissue culture, diagnostics and molecular markers.

2.1 Socioeconomic environment of the PLS

Zimbabwe

From 1990 until 2000 when land reform began in earnest, a policy of economic structural adjustment was implemented by the Government of Zimbabwe. The main element of the structural adjustment programme with respect to agriculture was to follow a liberalised market policy for agricultural commodities and inputs, with market forces dictating prices.

The gross domestic product (GDP) declined from US$ 5.1 billion in 2000 to US$ 4.6 billion in 2004, while per capita GDP was US$ 350. The economy has been experiencing a negative real GDP growth of -8.1% per annum in the past 5 years. Inflation rates increased from about 56% in 2000, peaked at 384% in 2003, and then declined to about 133% at the end of 2004. Unemployment is currently estimated to be over 70%. Goods and services exports, as a proportion of the GDP, have increased slightly from 29.4% to 36.3% between 2000 and 2004.

The current account balance has remained negative throughout this period. This negative economic performance has been ascribed to poor export performance, largely due to poor performance of the agricultural sector. Normally, agriculture contributes 18-20% to the GDP of Zimbabwe, with crop production accounting for about 62% and the balance contributed by livestock production.

The social conditions in Zimbabwe have deteriorated in tandem with the economic performance. The levels of both urban and rural poverty have increased over the past few years. The country had to import maize to augment local production due to a drought that affected most countries' "breadbaskets" in the region. The recent political strife, combined with the economic instability and drought, has left many in the country vulnerable.

An estimated 70% of the population lives in poverty, with rural areas facing the brunt of poverty. Around 85% of the adult population is literate. HIV/AIDS is taking a devastating toll on the population, with an estimated 24.5% of adults infected.

Zimbabwe has a literacy rate of about 85%, although there are gender imbalances, especially in rural areas. Women tend to be less educated than their male counterparts.

Mozambique

Following Mozambique's independence in 1975, the Government of Mozambique took over farms that had been abandoned by colonial farmers to maintain production, based on the socialist central planning paradigm. The complete chain, including production, financial providers, transport, and marketing, was managed directly by the Government at the national level. The weak institutional capacity and the civil war aggravated the situation as the infrastructure was destroyed and populations were displaced, only to become refugees in safer urban areas and neighbouring countries.

In 1987, the Government adopted a stabilisation and structural adjustment programme with the objective of re-establishing production and improving incomes by creating an economy based on private initiative and market forces. With the advent of peace in 1992, millions of displaced persons returned to their homes and farms to restart their livelihoods. The restarting process was not easy: the infrastructure had been destroyed, the farms had remained fallow for over a decade, and the returnees did not bring any start-up capital. However, since 1992, the economy has been registering significant growth, particularly in the agricultural sector. Domestic production of food-grains increased from 56% to 78%, while food aid decreased from 44% to less than 5% between 2001 and 2004.

Mozambique has achieved annual economic growth rates of around 8% in real terms, with agriculture contributing 30-32% of this growth. Democracy and peace were strengthened. With stability and reforms, the GDP per capita grew to US$ 230 in 2000, significantly improving incomes compared to the levels 5 years earlier. Nevertheless, these achievements have not resolved social and economic problems.

Analysis of data from the Household Survey of Inquérito aos Agregados Familiares (IAF) of 1996/1997 has provided a detailed profile of poverty in Mozambique. Nearly 70% of the population lives in absolute poverty and there are notable urban-rural and regional imbalances. The IAF data also permitted an identification of the main determinants of poverty in Mozambique, namely:

- Slow growth of the economy until the beginning of the 1990s
- Low levels of education of working age household members, particularly of women
- High dependency rates in households
- Low productivity in the family agricultural sector
- Lack of employment opportunities within and outside of the agricultural sector
- Poor infrastructure, especially in rural areas

Malawi

Malawi's population of about 11 million was, in 2003, among the poorest in the world. It has a per capita income of about US$ 170 per annum and 60% of the population lives in poverty. About 89% of Malawi's poor are in rural areas and agriculture is their key source of income. Most of the poor are in the Southern Region (49%), followed by the Central Region (40%), and the Northern Region (11%). Agriculture is the mainstay of the economy in Malawi. Depending on the climatic conditions and other factors, agriculture contributes to about 37% of the GDP, employs over 80% of the country's labour force, accounts for over 90% of the foreign exchange earnings, and supplies more than 65% of the raw materials needed by the manufacturing sector. Three main crops dominate the agricultural exports of Malawi, namely, tobacco, sugar cane and tea, which contribute 59%, 11%, and 10%, respectively, of the total export earnings. Other important export commodities with inherent potential for expansion include coffee, cotton, rice, paprika (*Capsicum anuum*), groundnut, cassava, chili (*Capsicum frutescens/*Malawian *Kambuzi*), cut flowers, sunflower, soybean, bean, and pigeonpea. On the other hand, cereals (such as maize), roots and tubers provide a major share of the food basket for the majority of Malawians.

The current estimated population of Malawi has grown to 12.5 million. About 45% of the population is under 15 years of age and 85% live in rural areas. The average population density is 110 persons per square km. The Southern Region is the most densely populated, while the Northern Region is the least densely populated. At the current population growth rate of 3.2% per annum, Malawi's population is expected to double by 2018. Life expectancy is 35 years. The indigenous population of Malawi is composed of many ethnic groups, the largest being the Chewa and the Nyanja, who live mainly in the Southern and Central Regions, the Yao and the Lomwe in the South, and the Tumbuka, the Tonga, and the Nkhonde in the North.

National literacy stands at 40% for females and 72% for males. Women are key workers and producers at both household and national levels. They are farmers, income earners, traders, and family caretakers. Women represent two-thirds of the full-time farming population.

Malawi faces huge challenges in achieving the Millennium Development Goals (MDGs) of "reducing poverty and hunger by half" by 2015. The country needs sustained investments to increase agricultural productivity and improve the effectiveness of agricultural investments. Raising agricultural productivity and diversifying its agricultural base to improve value-addition is the key to reducing widespread food insecurity and increasing rural incomes.

Thus, all three countries transected by the PLS have been going through one economic transformation or the other and are threatened by unstable political conditions within the region. The attendant implication of this is also felt on the agricultural development of the economy.

Chapter 3

3.0 Methodological framework

3.1 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 a quasi-experimental design, were employed in this study. The quasi-experiment is implicated when randomisation is often impractical or impossible and when there is no control over extraneous variables. A quasi-experimental design is created when a 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 are 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% 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 the treated ($D = 1$) as Y_1 and the outcome for non-treated subject ($D = 0$) as Y_0. As will be discussed in Section 3.2, various matching methods such as kernel matching and the nearest neighbour matching methods were used in the analysis of the data. The essence is to explore impact assessment where it exists. Our goal was to identify the average treatment effect on the treated (i.e., the effect of implementing the 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 $E(Y_0 D=1)$. However, 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).

$$\text{This assumption is represented by } (Y,\ Y) \perp D // X^*, \tag{3.2}$$

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

$$E(Y_0 // X^*, D) = E(Y_0 // X^*) \qquad (3.3)$$

Counterfactual. What would have happened to the participants' group had they not participated? The key assumption of this framework is that individuals selected into 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 weren't treated – the groups will be approximately balanced on the variables predicting the propensity score.

Unconfoundedness Assumption. This implies that the treatment (IAR4D beneficiary) is random conditional on some set of observed characteristics (X). This 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).

3.2. Methods of matching

3.2.1 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 $Y_0 = \{Y_{oj}\}_{j=1}^{N_0}$, 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 $\hat{P}(X_i^*)$. In nearest neighbour matching, the absolute difference between the estimated propensity scores for the control and treatment groups is minimised. 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. It is usually easy to understand and implement and, more importantly, it offers good results in practice and has comparably fast running time when run in a computer. Nearest neighbour matching does not at times offer the best matching result.

3.2.2 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.

3.3 Justification

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 treatment to subjects. When there is a lack of randomisation, 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. In simple language, PSM is a quasi-experimental design that mimics a randomised experiment and makes it appear as if it is a randomised design.

3.4 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 were taken from a baseline and midline survey of about 1,800 households across ZMM PLS. The survey was conducted by task forces within the framework of the SSA CP supported by the Forum for Agricultural Research in Africa (FARA) and its donors—including the European Union (EU), the Department for International Development (DFID) of the United Kingdom, and the governments of Italy and Norway.

Our data comes from the baseline study of the FARA-sponsored project undertaken in cooperation with the national agricultural research institutions (Chitedze Research Station in Malawi and IIAM in Mozambique). The baseline study involved a cross-sectional survey of 718 households spread across the Southern Malawi and Central Mozambique during 2007/08 cropping season.

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 the ZMM PLS. In each district, a sample of households was selected by taking a sample of district wards; a random sample of villages within each ward; and 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), 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, which were different according to 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—such as public and private agricultural researchers, extension, farmer leaders, traders, dealers, lenders and key informants—were interviewed to benchmark characteristics of innovation systems and baseline levels of outcomes for the IP sites.

Baseline survey for household and village community characteristics

Baseline surveys, observations and focus group discussions were conducted to collect data on household- and village-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 and other methodologies.

Evaluation surveys

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

3.5 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, i.e., treatment group, and let Y_0 be the outcome conditional on non-participation, i.e., control group. The impact of participation in the programme is the change in the mean outcome caused by participating in the programme, which is given by

$$\Delta Y = Y_i - Y_0 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(1)$$

where Δ is the notation for the impact for 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 there will never be an opportunity to estimate individual treatment effects in (1) directly, one may need to concentrate on population averages for the impacts of a treatment.

Two treatment effects are dominantly used in empirical studies. However, the most commonly used evaluation parameter is the so-called 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 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 $E\,(Y_1 \mid X, Z=1)$. The mean outcome in the untreated $E\,(Y0 \mid X, Z=1)$ 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., 1998a). 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 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 (i.e., poverty/food security, factor productivity, market participation, awareness and adoption as well as 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 observations 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 that the beneficiary and comparison groups may differ in unobservable characteristics, even though they are matched in terms of observable characteristics (Heckman et al., 1998a). 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 "selection on unobservables," although they could not say whether that conclusion holds in general (Heckman et al., 1998a).

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.

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

where Y_{p1} = outcome (e.g. income) of beneficiaries after the project started; Y_{p0} = outcome of beneficiaries before the project started; Y_{np1} = outcome of non-beneficiaries after the project started; and Y_{np0} = outcome of 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 those 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 are different 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 nonparticipant 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 clean environments because of the cumulative effects of social capital developed under the ARD, favourable or adverse experiences under ARD, or other factors. Such shortcomings are unfortunately inherent in all non-experimental methods of impact assessment (Duflo et al., 2006). Although no solution to these potential problems is perfect, we believe the method we have used addressed these issues as well as possible under the circumstances.

The standard errors estimated by the DDM may be inconsistent because of serial correlation or other causes of a lack of independence among the errors. In ordinary regression models, serial correlation can result from unobserved fixed effects, but by taking first differences, the DDM eliminates that source of serial correlation. However, serial correlation still may be a problem if more than 2 years of panel data are used (Duflo et al., 2004). In this study, because we used only two periods, before and after the project, we do not have any concern about serial correlation among multiple periods. 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 is 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 to participate in the project and the outcome. We focused on the determinants of income and productive assets when selecting the independent variables for computing the PSM.

The independent variables used in the regression are summarised in Table 2.

Table 2: Variables used to compute Propensity Scores and their expected signs

Variable	Expected impact on participation in IAR4D	Why?	Expected sign 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

Variable	Expected impact on participation in IAR4D	Why?	Expected sign on income and wealth	Why?
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 life cycle
Level of education of respondent (years of formal education)	+	Some project requirements need certain level of education	+	Education increases income opportunities, such as on-farm activities
Area of farmland cultivated (ha)	+/-	IAR4D concept encourages the cultivation of a larger area of land	+	A larger area of land enables households to earn more income and more productive assets
Agro-ecological zone	+/-	The technologies promoted by IAR4D in each agro-ecology motivate participation	-	Some zones closer to urban centers have more potential of membership than remote ones
Distance to nearest all-weather road	+	Closeness to urban centre encourages participation since products are easily marketed	+	Access to improved road increases income opportunities and reduces transaction costs
Value of productive asset	+	Same as for land area	+	Same as for land area

Source: Data Analysis, 2012

Results and discussion

Impact of IAR4D on household income

The 2008 average income for treated (clean – before intervention), conventional and the clean sites were $ 79, $ 35, and $ 48, respectively. As stated earlier, the economic condition that prevailed during the period of intervention in the three countries was quite deplorable. For instance, the Zimbabwean currency lost value on a daily basis for almost half a year. The Mozambicans were just getting out of a protracted period of civil war while the Malawians faced economic challenges. These situations made the estimation of household income difficult, and we had to resort to the use of proxy in the form of the productive assets owned by the respondents before and after the intervention.

At midline, the average incomes were estimated to be $18, $15, and $11, respectively (Table 4). The ATT was computed based on two alternative matching methods. The outcome variable is respondents' income per month measured in US dollars. 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 $211.32 in the case of kernel (p<1%) matching method. A comparative analysis shows that the IP farmers are better off (with higher income) than the farmers in the two counterfactuals of conventional and clean sites.

Estimation results of Propensity Scores

The importance of estimation of propensity scores is twofold: first, to estimate the ATT and, second, to obtain matched treated and non-treated observations. The results of the probit models are reported in Table 3.

Table 3: 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)	-0.773**	0.402	0.130	0.382	0.940**	0.505
Age of respondent (yrs)	-1.481***	0.450	1.163***	0.430	-0.145	0.448
Education of respondent (yrs)	0.053	0.235	0.400**	0.231	-0.194	0.241
Household size	-0.489*	0.287	0.239	0.266	0.028	0.294
Farm size	0.091	0.204	-0.256	0.201	0.323	0.219
Assets (productive)	-0.155*	0.088	0.053	0.083	0.002	0.088
Type of Household [dummy] (Monogamous Marriage)	0.253	0.332	-0.248	0.302	0.269	0.329
Type of Household [dummy] (Divorced male headed household)	-0.435	0.888	-0.728	1.192	0.744	0.893
Constant	6.507	1.876	-5.633	1.816	-2.116	1.879
Sample size (n)	279		279		279	
R^2	0.078		0.037		0.037	
Prob > X^2	0.001		0.114		0.160	
Log likelihood	-158.955		-169.699		-153.412	

Source: SSA CP Data

The results of the probit regression presented in Table 3 show that the participants in IAR4D are most likely to be young women with a small family size and low level of productive assets. However, participants in the conventional module are mostly educated, elderly farmers while those in the clean sites are mainly women. This result suggests that the IAR4D intervention was properly focused on the vulnerable groups (young women) 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 are possible for selecting matching observations (Smith and Todd, 2001). We used the kernel matching method (using the normal density kernel), which uses a weighted average of "neighbours" (within a given range in terms of the propensity score) of a particular observation to compute matching observations. Unlike the nearest-neighbour method, using a weighted average improves 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 statistically 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, that 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).

Table 4: Impact of IAR4D on household income across types of respondents

	Net real household income (US$)		ATT	% change due to participation in IAR4D
	baseline	midline		
IAR4D (n=211)	-78.29 (16.64)	18.01 (17.78)	211.32*** (76.58)	269.91
Conventional (n=283)	-34.66 (27.10)	15.46 (18.10)	-121.74 (90.48)	
Clean (n=171)	-47.74 (32.58)	11.73 (17.06)	-19.77 (78.89)	
Agro-ecological zones				
Conservation Taskforce	0.91 (17.46)	142.99 (430.83)		
IAR4D n=254	0.18 (0.18)	102.79 (41.51)	211.32*** (57.13)	23221.97

Conventional n=254	0.00 (0.00)	88.44 (33.42)	11.50 (36.11)	
Clean n=254	1.40 (1.40)	40.31 (42.98)	-25.04 (38.49)	
Zimbabwe				
IAR4D N=190	-87.17 (23.19)	-60.39 (18.29)	245.05*** (91.95)	281.11
Conventional n=279	-146.24 (31.94)	-110.12 (52.48)	-258.94 (204.77)	
Clean n=169	-187.53 (49.70)	-84.08 (27.95)	-54.35 (112.86)	
Mozambique				
IAR4D n=279	-91.36 (20.35)	-33.60 (22.93)	289.61** (141.52)	316.99
Conventional N=279	-128.85 (28.53)	-184.40 (89.58)	-166.85 (187.19)	
Clean n=189	-75.56 (21.65)	-240.40 (67.79)	-145.21 (147.91)	
Malawi				
IAR4D n=190	-114.58 (32.74)	-49.52 (14.29)	155.72* (105.47)	135.91
Conventional n=279	-138.26 (33.89)	-131.91 (45.34)	-64.37 (97.61)	
Clean n=169	-167.30 (38.83)	-57.10 (32.52)	174.55 (140.28)	
Gender				
IAR4D n=189	-80.00 (22.04)	-77.21 (20.79)	230.79*** (72.41)	288.49
Conventional n=281	-152.93 (34.12)	-93.95 (28.57)	-152.36 (99.45)	
Clean n=169	-161.51 (36.78)	-90.71 (33.97)	-20.65 (81.49)	
Research	**114.83 (387.34)**	**135.84 (578.16)**		
IAR4D *n=169*	-93.92 (27.59)	-63.88 (17.07)	256.42*** (112.17)	273.01
Conventional n=250	-135.35 (49.29)	-120.52 (33.84)	-140.31 (166.84)	
Clean n=144	-155.38 (78.84)	-124.09 (38.84)	-27.20 (153.49)	
Wealth distribution				
Tercile1 (poorest)				
IAR4D	3.59 (3.59)	85.12 (16.91)	247.12*** (92.65)	6883.56
Conventional	0.00 (0.00)	31.13 (36.88)	-137.19 (134.14)	

Clean	0.19 (0.19)	28.25 (50.30)	-99.81 (113.76)	
Tercile2				
IAR4D	2.78 (2.15)	135.67 (64.34)	-18.02 (203.32)	
Conventional	0.00 (0.00)	120.67 (46.47)	-30.47 (150.59)	
Clean	0.15 (0.30)	95.97 (41.16)	55.37 (138.30)	
Tercile3				
IAR4D	3.48 (3.48)	67.82 (18.70)	228.79** (104.82)	6574.43
Conventional	0.00 (0.00)	27.50 (63.50)	-294.84** (149.89)	
Clean	0.15 (0.29)	44.86 (68.52)	85.19 (145.21)	

ATT = $(Y_{p1}-Y_{p0})-(Y_{np1}-Y_{np0})$. "Before project" is the situation before the IAR4D in 2008, while "After project" is 2 years after the project started in 2010.

"ATT" and the corresponding "%" refer to the change in measured household income resulting from participation in the Innovation Platform (IP) of the IAR4D. % 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.

The experimental design of the project allows an examination of spillover effect of the IAR4D by comparing the changes in income of the participants with those of non-participants living within and outside the communities with the project. The homogenous results suggest that non-participants may have benefited from spillover of the project. For example, non-participants used the innovations and research knowledge made available to the participants. In addition, some services made available to participants could also be available to non-participants. Examples of such services include the storage facilities, shredding machines and employment opportunities made available to non-participants.

It is likely that the impact of the project on incomes will be larger than those currently captured because of lagged effects of investments on productive assets, infrastructure, and other project investments. The results in Table 4 show the homogenous impact of the IAR4D on the participants' income. They indicate that participation in IAR4D had positive and significant impact on the beneficiaries at the 1% level. The quantum of the impact ensured the beneficiaries were about 270% better off than the baseline condition, while the counterfactual situations (both conventional and clean) were neither better nor statistically significant. Further, the programme improved the income of at least 1,688 people in the PLS.

The effect of the IAR4D varied across the major agro-ecological zones of the PLS. However, we had access to data from only two of the agro-ecological zones and the results show that the project had significant impact (at p< 0.10) at the conservation task force level. Indeed, the results revealed that participants at the conservation task force were 23220% better than they were at the baseline. Given the configuration of the task forces in the ZMM was spread across three countries, we estimated the impact by country. The results show that the IAR4D made

significant impact in the three countries relative to the two counterfactuals. For instance, the impact of the IAR4D on the participants was highest in Mozambique where the impact on participants was about 317% higher than their baseline conditions, followed by the impact on participants of Zimbabwe (281%) and of Malawi (136%). All these figures were statistically significant at the acceptable levels.

Given the vital importance of gender issues in development programmes in the recent times, basically because of the acknowledged potential that women have in improving the overall welfare of the household and the fact that women are usually the most vulnerable in cases of economic downturn, the results in Table 4 show that participation in the IAR4D increased the income of women participants by about 288% at the midline relative to the baseline condition. The result was positive and significant at the 1% level, showing that the programme is well targeted at women. By encouraging women, the project may have enabled the women participants to catch up with men in terms of income and thus stabilise household welfare. In addition, the income changes for the participants are better than for the counterfactuals, which were not significant. Indeed, the programme improved the income of 1,512 women in the PLS. Hence, IAR4D is gender friendly.

One of the main advantages of the IP is the free exchange of research ideas from all the stakeholders and the almost immediate adoption of those ideas by the participants. Research ideas do not come from the scientists alone, but also from indigenous sources aimed at addressing the acknowledged challenges confronting the stakeholders at the IP. Results from Table 4 show that participation in research activities improved the income of beneficiaries positively and significantly (at p<0.01) by about 273%. This is very instructive, especially with regard to the potential of IPs in the IAR4D zones. The prompt generation and adoption of research ideas definitely pays the beneficiaries of the IAR4D.

We explored the impact of the IAR4D on the income strata of the community. The results show that the beneficiaries in the lowest tercile (the poorest) increased their income by over 6800% indicating a positive and significant (at p<0.01%) impact of the project on the beneficiaries. This is very important, suggesting that the project appropriately targeted the poorest of the poor in the choice of beneficiaries, leading to the huge impact. The huge impact also accentuates the very negative baseline conditions the beneficiaries started from. The result also shows that both counterfactuals (the conventional and the clean) do not have a significant impact. This indicates that IAR4D had an immediate impact on poverty reduction among the poorest households.

In summary, the IAR4D has caused beneficiaries to realise significant increases in income. Using the PSM and DD methods, our results allowed us, with considerable confidence, to attribute the income increases among the beneficiaries to participation in the project. In this PLS, the impact of IAR4D was both positive and significant across agro-ecological zones and among the beneficiaries in the three participating countries. It should be noted that the full impact of the project cannot be said to have been captured by this study because the project had only operated for 2 years at the most in the PLS. Thus our results do not capture the lagged impacts of the rural infrastructures, productive assets, and other project interventions.

Table 5: Impact of IAR4D on income distribution

Treatment type	Gini coefficient at baseline	Gini coefficient at midline	% Gini coefficient change
All respondents	0.88	0.84	-0.04
IAR4D beneficiaries	0.99	0.84	-0.15
Conventional	0.91	NA	NA
Clean	0.87	0.99	0.12
Gender	0.87	0.83	-0.04
Zimbabwe	0.89	0.97	0.08
Mozambique	0.86	0.99	0.13
Malawi	0.88	NA	NA

Source: SSA CP Data

The IAR4D targets the poor and vulnerable groups such as women, youth, and the elderly. This action is likely to reduce income inequality. The impact of this targeting was examined by considering the change in income inequality over the 2 years of the project. We computed the Gini coefficient of income of the respondents with this objective. The results are displayed in Table 5. Indeed, the results from the table show that the Gini coefficient of the beneficiaries decreased by about 4%, suggesting that the project contributed to reduction of income inequality. Income inequality was reduced in the intervention area as shown by the value of the Gini coefficient being 15%; however, in the clean zone, there was an increase in income inequality by about 12%.

The largest decrease in income inequality is among the IAR4D beneficiaries, showing a figure of about 15% relative to an increase of 12% recorded for the clean sites. The result also shows that there was a decrease in income inequality of 4% among the women, but increase of 8% and 13% points when considered on country basis. This indicates that there is a need for country specificity in the intervention activity. 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 the ZMM

The study estimated the likely economic impact of the IAR4D concept in the ZMM PLS of the SSA CP. The study estimates what would have been the impacts in a specific recent past if the IPs were in place, was operated and priced such that the cost per innovation would be similar for a particular counterfactual site.

To assess the potential economic benefits arising from the adoption of the IAR4D approach, we estimated the yield gains and the unit production cost reduction, defined the socioeconomic domains of 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 of the IAR4D concept. Moreover, a sensitivity analysis was 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 results obtained from the analyses of the data suggests that if the technology had been available at the baseline year and priced appropriately so that it would be adopted comprehensively, farmers' benefits in the PLS would have been US$382 million in that year. This sum is shared as US$61.75 million to Zimbabwe, US$145 million to Mozambique and US$174 million to Malawi.

Tomato yielded the highest benefit per hectare in all the countries with a value of about US$3060 in Zimbabwe and Mozambique and US$ 2174 in Malawi. Maize and groundnut yielded US$31.34 and 42.10 in Zimbabwe, respectively, and US$ 66.00 and 25.41 in Mozambique, respectively, while the figures for Malawi are US$ 69.88 and 115.62 respectively. On all fronts, it seems farmers in Malawi obtained more benefits from the concept among the three countries in the PLS.

The results of the potential economic surplus model shows that in Zimbabwe tomato production yields the highest annual gain of US$17.92 million split into US$ 12.80 million and US$ 5.12 million for present producer surplus and present consumer surplus respectively. It yields a rate of return of 42% and a benefit to cost ratio of 66 to 1. Maize production yields the next highest annual gain of US$ 6.16 million split into US$ 4.59 million and US$ 1.84 million for present producer surplus and present consumer surplus respectively. It produced a rate of return of 31% and a benefit cost ratio of 23 to 1. The average annual present producer surplus and present consumer surplus for groundnut were US$ 3.04 million and US$ 1.22 million respectively, with a rate of return of 26% and benefit to cost ratio of 15 to 1.

In the same vein, in Mozambique, tomato production yielded the highest gain among the three crops considered, producing an annual present producer and consumer surplus of US$ 10.59 million and US$ 4.24 million respectively, and a rate of return of 40% and benefit to cost ratio of 54 to 1. Maize production produced an annual present producer and consumer surplus of US$ 11.19 million and US$ 4.48 million respectively, as well as a rate of return of 41% and benefit to cost ratio of 58 to 1. Groundnut yielded an average annual present producer and consumer surplus values of US$ 7.97 million and US$ 3.19 million respectively, as well as a rate of return of 375% and benefit to cost ratio of 41 to 1.

The results obtained for Malawi showed that maize production yielded the highest benefit with the present annual producer and consumer surplus figures being US$ 5.98 million and US$ 2.39 million respectively. The rate of return is 34% and benefit to cost ratio of 30 to1. The benefits obtained from tomato production follows that of maize with the average annual present producer consumer surplus figures being US$ 3.39 million and US$ 1.39 million, respectively, and a rate of return figure of 28% with benefit to cost ratio of 17 to1. The average annual present producer and consumer surplus figures for groundnut are US$ 2.49 million and US$ 0.99 million respectively, with a rate of return figure of 24% and benefit to cost ratio of 12 to 1.

The results obtained are sensitive to the expected adoption rates but much less so to the research and extension costs. Altogether, production of the crops is socially profitable under the IAR4D option in the PLS. Hence, efforts should be made to encourage the adoption of the IAR4D option using extensive participatory approach.

Chapter 5

Conclusions and policy implications

The proof of concept exercise set out with three questions to establish the IAR4D not only as a concept but as a viable alternative to the traditional R&D (conventional) which will take Africa's agriculture to the desired level where the research outputs will be of benefit to the remote and immediate environment as well as improve the livelihood of rural farmers in Africa.

These three questions are:

Does the IAR4D work as a concept?

The answer to this question is in the homogenous result of the impact analysis. The answer is yes! The IAR4D works and impacts positively on the lives of the beneficiaries to an average of

US$211 per participant monthly. This figure lifted the participants well above the poverty level, especially when the baseline condition was taken into consideration. Indeed, the programme improved the income of 1,688 persons in the PLS.

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

With the use of matching methods as well as the PSM and DD approach, we can safely conclude from the results that the IAR4D delivers more benefits than the conventional R&D method. The results, while showing the positive impact for the IAR4D, reveals that under the same conditions, the conventional and the clean do not impact consistently positively on the non-beneficiaries.

The analyses also show that the IAR4D impacts on women's income, research participation and especially on the poorest segment of the community. The programme improved the income of 1,512 women in the PLS. These results are consistently robust and reliable.

Can the IAR4D be scaled out and up 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 indicates the eagerness of neighbour communities to join in!

The IAR4D concept had been on ground for about 2 years in the ZMM PLS, during which the project realised significant positive impacts on household income, food security, gender, and research participation. Using PSM and DDM to control 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 incomes improved substantially more for the IAR4D participants than for non-beneficiaries in conventional and clean sites, with an average increase in real incomes resulting from participation of about 270%, which is not only better than the conventional and clean sites but well above the achievement of similar projects on the continent.

This result is much in line with the *ex ante* report on the KKM PLS (Ayanwale et al. 2010) in which the projected benefits of IAR4D not only surpassed the costs of investments but was also superior to both the conventional and the clean modes. Furthermore, the benefits derivable vary by task forces (agro-ecological zones) in the sense that the Sahel savanna zone gave the least quantum of benefits of the three.

The project had bigger impact on the poorest beneficiaries and could have 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 effects of productive assets and other changes that farmers experienced as a result of their participation in the IAR4D. This study was conducted at an early stage of the project and may not adequately capture its

lagged impacts, especially the long term benefits of productive asset acquisition and rural infrastructure development.

Key issues that need to be addressed in scaling up this success story include: 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.

In regard to appropriate targeting, it may be recalled that over the first two years the project operated, the Gini coefficient of income for beneficiaries decreased by about 15% compared with an increase for other categories of non-beneficiaries. This suggests that the project contributed to the reduction in income inequality, probably through targeting of poor and vulnerable groups. Consistent with this, the project also succeeded in raising the value of productive assets of the poorest 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

ADP	Agricultural Development Programme
AEZ	Agro-ecological zone
AFAN	All Farmers' Association of Nigeria
ARD	Agricultural research and development
ATT	Average impact of the treatment on the treated
CBO	Community based organisation
CGIAR	Consultative Group on International Agricultural Research
CIAT	International Center for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Centre
CORAF/WECARD	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 method
DFID	Department for International Development
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 Suppliers Association of Nigeria
GIS	Geographical information systems
GNP	Gross national product
HIV/AIDS	Human immunodeficiency virus infection/acquired immunodeficiency syndrome
IAF	Inquérito aos Agregados Familiares/Household survey (Mozambique)
IAR	Institute for Agricultural Research (Nigeria)
IARCs	International agricultural research centres

IAR4D	Integrated Agricultural Research for Development
ICRAF	World Agroforestry Centre (formerly International Centre for Research on Agroforestry)
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
IFDC	International Fertilizer Development Center
IFPRI	International Food Policy Research Institute
IIAM	Institute of Agricultural Research (Mozambique)
IITA	International Institute for Tropical Agriculture
ILRI	International Livestocks Research Institute
IMF	International Monetary Fund
INRAN	Institut national de la recherche agronomique du Niger
IP	Innovation platform
IPG	International public goods
IPM	Integrated pest management
ISFM	Integrated soil fertility management
KKM	Kano Katsina Maradi
KTARDA	Katsina State Agricultural and Rural Development Authority
LCRI	Lake Chad Research Institute (Nigeria)
LK	Lake Kivu
MDG	Millenium Development Goals
MLL	Maize Legume Livestock IP
MoU	Memorandum of Understanding
MTP	Medium Term Plan 2009-10
NAERLS	National Agricultural Extension Research Liaison Service (Nigeria)
NAPRI	National Animal Production Research Institute (Nigeria)
NARS	National agricultural research system
NGO	Non-governmental organisation
NGS	Northern Guinea Savanna
NIHORT	National Institute for Horticultural Research and Training (Nigeria)
NRM	Natural resources management
NSS	National Seed Service
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 method
R&D	Research and development
RPG	Regional public goods
SADC	Southern African Development Community
SLL	Sorghum legume livestock IP
SRO	Sub-regional organisation
SS	Sudan Savanna
SSA	Sub-Saharan Africa
SSA CP	Sub-Saharan Africa Challenge Programme
TF	Task force
TSBF	Tropical Soil Biology and Fertility Institute of CIAT
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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