Australian Government

Australian Centre for International Agricultural Research

Final report

Project	Identifying socioeconomic constraints to and incentives for faster technology adoption: Pathways to sustainable intensification in Eastern and Southern Africa (*Adoption Pathways*)
project number	FSC/2012/024
date published	October 12, 2016
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approved by	NA
final report number	FR2019-55
ISBN	978-1-925747-31-7
published by	ACIAR GPO Box 1571 Canberra ACT 2601 Australia

Contents

1 Acknowledgments

The Adoption Pathways project was made possible by an international collaboration involving funding from ACIAR; with this funding the International Maize and Wheat Improvement Center (CIMMYT) was able to convene research teams from the project countries. Project research teams included: Ethiopian Institute of Agricultural Research (EIAR), Egerton University in Kenya, Lilongwe University of Agriculture and Natural Resources (LUANAR) in Malawi, Eduardo Mondlane University in Mozambique and Sokoine University of Agriculture in Tanzania. Other partners in the project were Queensland University in Australia, University of Life Sciences in Norway and the International Food Policy Research Institute (IFPRI) in the USA. We are grateful to ACIAR and the people of Australia for the generous funding and wish to thank all team members from the participating institutions for their dedication to accomplishing this project. We wish to acknowledge the thousands of farmers who participated for their patience in answering detailed survey questions for multiple rounds during the project. We acknowledge the role played by public sector extension and administrative officers, enumerators, graduate students and colleagues from the project institutions whose support and contributions helped make this project a success.

2 Executive summary

The Adoption Pathways project was conceived to work toward answering several questions relating to sustainable agricultural intensification in Eastern and Southern Africa. To deal with the existing food security and resource scarcity challenges, the farming systems of Africa need to be grounded in a strong knowledge-base concerning the economic, social, and environmental necessities for sustainable growth of these farming systems. This will involve identifying and understanding important drivers or critical enablers of technology adoption, particularly those that will enable smallholder farmers to reduce production risks, conserve resources and improve profits.

Examining the conditions outlined above involves answering critical questions such as: What are the drivers/impediments of adoption of multiple sustainable agricultural intensification (SAI) practices under different social, institutional, agro-ecology and market conditions? Does adoption of SAI practices, including new varieties, lead to positive impact for productivity, incomes, food security and nutrition? Does adoption of SAI practices serve as coping strategies to climate-induced production risks? Can SAI, including new varieties and production methods, help men and women smallholder farmers equally? What would be better ways to package the evidence and provide support services for smallholder farmers to implement SAI practices?

The Adoption Pathways project was part of a portfolio of projects that has contributed to the broader theme of sustainable intensification research led by CIMMYT and made possible by the contribution of several teams from national and international research groups brought together by funding from the Australian Centre for International Agricultural Research (ACIAR). The project was undertaken in the five Eastern and Southern African countries of Ethiopia, Kenya, Malawi, Mozambique and Tanzania.

The project has produced substantial outputs that can enrich existing agricultural information, build new knowledge and enable policy makers, donors and programs to enact research-based decisions that can drive technology adoption and improve livelihoods of smallholder farmers, including women. A summary (see Appendix 1 for details) of these outputs include:

1. Gender disaggregated three wave panel data set (2010/11, 2013, 2015/16), building on a legacy dataset collected under a related ACIAR funded project (SIMLESA) is now being developed covering close to 5000 households in each data wave across the five project countries.
2. Several empirical evaluations of the gender gaps in technology adoption, food security and market access have been completed and published.
3. Human and institutional capacity development activities were accomplished, including 9 PhD and 11 MSc students who based their research on Adoption Pathways project data.
4. Studies on the impacts of SAI practices on downside risks, food and nutrition security, crop income and agrochemical use have also been published.
5. These results have been shared in various policy forums including annual project meetings.

In order to achieve its full impact in the coming years; we propose that new projects and initiatives be established based on the work of the Adoption Pathways project. These should focus on capacity building for the analysis of panel datasets, continued study of intrahousehold input allocation and sharing of agricultural output and scaling up the findings from this project to influence next generation of sustainable agriculture policies.

3 Background

The core pillars of the agricultural Green Revolution relied on improved varieties and fertilizers, as well as massive public sector support for irrigation and fertilizer subsidies. In Sub-Saharan Africa (SSA), a more balanced approach to agricultural intensification must deliberately focus on better agronomic practices, natural resource management and agro-ecosystem health. Without these supportive pillars, it is unlikely that SSA's rain-fed, capital-deficient production systems, which also face a number of resource degradation challenges, can truly enter a sustained intensification pathway. Since fertilizer and seed-based intensification is capital-intensive, there is limited hope that the spectacular success witnessed in Asian production systems in the 1960s can be replicated in SSA without a major rethink. At the heart of this rethink is the need for investments in soil conservation and erosion control – replenishing soil nutrients and moisture conservation are prerequisites in SSA. This rethink should be accompanied by concomitant and massive investments in fertilizer, seed supply and value chains.

The success of cereal-centric and water and fertilizer intensive systems of the green revolution came at considerable costs in terms of unsustainable subsidies, excessive fertilizer and water use and pollution. To avoid these costs in the emerging farming systems of Africa, we need to improve our knowledge base on the economic, social, and environmental necessities for the sustainable growth of African farming systems. This involves a two-part effort:

- First, a strong pillar of research in agricultural sciences (involving many disciplines) to support an intense effort to produce critical knowledge.
- Second, sharing the knowledge that helps understand the puzzles of farming with smallholders, and trialing new approaches on their fields to learn what works better, and why.

The pathways to sustainable agricultural intensification (SAI) may involve two segments. The first pathway will lead farmers to adopt new knowledge and tools to help them cope better with what they do now and help them find what they could do better later. This would only lead to an intermediate outcome. The second and more lasting adoption-to-impact pathways would lead farmers to long-term adoption/adaptation – paving ways to increased production, profitability and improved livelihoods.

This second pathway involves identifying and understanding important drivers or critical enablers of technology adoption: ways to reduce risks and improve profits from farming. Addressing issues of knowledge transfer through better extension, improving credit markets, and identifying infrastructure needs and/or policy directions to make those support services possible would take time and resources. And, it would involve asking several pertinent questions:

- What are the drivers/impediments of adoption of multiple sustainable agricultural intensification (SAI) practices under different social, institutional, agro-ecology and market conditions?
- Does adoption of SAI practices, including new varieties, lead to positive impacts for productivity, incomes, food security and nutrition
- Does adoption of SAI practices serve as coping strategies to climate-induced production risks?
- Can SAI, including new varieties and production methods, help men and women smallholders equally?
- Do existing agricultural policies (e.g. subsidy) trigger adoption of SAI practices and improve households' welfare?

- What would be better ways to package the evidence and provide support services?
- And, how would this new knowledge help develop new policy directions?

The Adoption Pathways project was conceived to work toward answering the above questions. It is part of a portfolio of projects that contribute to the broader theme of sustainable intensification research led by the International Maize and Wheat Improvement Centre (CIMMYT) and made possible by the contribution of a dedicated team from national and international research groups brought together by the Australian Centre for International Agricultural Research (ACIAR). The project is undertaken in the five ESA countries of Ethiopia, Kenya, Malawi, Mozambique and Tanzania.

Rapid population growth in sub-Saharan Africa taken together with soil fertility declines and climate disruption has resulted in widespread food insecurity and malnutrition (Pretty et al. 2011). Sustainably increasing food supplies and improving nutrition security therefore needs to happen in an environment where many farmers are still using capital deficient production methods. Traditionally, efforts at sustainable intensification have focused mainly on physical soil and water conservation practices. Greater recognition of the need to provide economic benefits to farmers (to invest in more sustainable practices) has recently turned attention toward more integrated approaches based on the principles of conservation agriculture. Despite increasing efforts to promote integrated practices for improving productivity through conservation agriculture, there is a lack of data on adoption patterns of the various technologies used by smallholders, as well as a weak evidence-base on farmers' incentives and socioeconomic conditioning factors that hinder or accelerate investments in environmentally friendly agricultural technologies.

The Adoption Pathways project has conducted research to provide data, research evidence, information and policy guidance on how to put African agriculture on a more sustainable and productive path, primarily by seeking the means to intensify and diversify maize and legume production systems and conserve the limited resources available to smallholder farmers. These limited resources include land, labour, water and soil nutrients. The outputs from this project can produce information that decision makers can use to design programs that encourage a sustainable intensification of maize-based systems in East and Southern Africa.

In this regard, this project reaffirmed existing knowledge regarding the significant capacity and institutional constraints that prevent policy makers from taking advantage of the increased volume of micro-level household and farming systems data – which may undermine the impacts of this project. To mitigate the risks presented by these constraints, a variation of this project was approved to pilot a specific policy engagement process in Ethiopia.

In addition to these challenges, there is lack of innovative mechanisms for enabling policy makers to take advantage of micro-level household and farming systems data for improved policy-making, investment and targeting.

Improved use of household and local micro level information will aid in the design of workable pro-poor policies, which could drive increased technology adoption, productivity improvements and sustainable intensification. However, lack of longitudinal and high quality farm household datasets from key maize-based farming systems has been a long-term constraint in conducting policy-relevant research in sub-Saharan Africa (SSA).

In the African setting, there are no long-term datasets on the same villages and households for analysis of trends, changes in livelihood strategies, adoption dynamics and understanding of the drivers of change in farming systems. Therefore, governments, donors and other research and development organizations must be willing to support future longitudinal studies in the selected representative villages. The efforts to generating long-term panel datasets are something we hope will endure beyond the Adoption Pathways project. We envisage that there will be continued commitment from development and research organizations, as well as universities in the region, to sustain and institutionalise these efforts.

There is increasing evidence that the development opportunities and intensification pathways for African farmers are increasingly conditioned by underlying socioeconomic factors (e.g., social differentiation, gender relations, market access, and institutions), the heterogeneity in the production environment and agro-ecological conditions, recurrent climatic shocks (droughts, variability, extreme events, etc.), and market risks (Pender et al. 1999; Dixon et al. 2001; Dorward et al. 2005; Barrett 2008; Pretty et al. 2011).

Despite increased demand for policy-relevant information by African governments and development partners to facilitate investments in SAI, there is limited knowledge on the process of intensification over time, the dynamics of smallholder production process, or the resource use and technology adoption that leads to sustainable productivity growth while sustaining the environment. The overall incentive structure conducive to investment in sustainable practices may depend on several factors (Dixon et al. 2001. Pretty et al. 2011). They include: a) technology characteristics that fit farmers' production goals and their profitability (economic criterion); b) technology characteristics that enhance the farm resource base and thus maintain or improve land productivity (environmental criterion); and c) intra-household and distributional effects of investment benefits (social criterion). Understanding of these and other issues to support policy development require good time-series data and the capacity to analyse this data using appropriate econometric and modelling tools. Such data are also needed to understand the effect of farmers' livelihood strategies and SAI investments on managing climate-induced production risks and its contribution climate change adaption. Evidence on the relationship between SAI investments, livelihood strategies and famers' risk coping strategies is important for developing effective interventions and supporting policy instruments.

Gender-based technology adoption and food security gaps have also been of long-standing concern in many countries in Africa. Gender inequalities and lack of attention to female participation in agricultural development contribute to low productivity, and high levels of poverty and under-nutrition. The 2012 World Development report warned that the failure to recognize the roles, differences and inequities between men and women poses a serious threat to the effectiveness of agricultural development (World Bank 2012). While there is now a growing literature on gender differences in adoption of technologies and agricultural productivity (e.g., Quisumbing 1996; Peterman et al. 2011 and references therein), most of it is partial both in terms of its methodological treatment and geographical coverage while focusing primarily on chemical fertilizer and improved seeds. Most of these studies use gender as one of the determinants of technology adoption and agricultural productivity, often using male-and female-headed households as a proxy for gender. The Adoption Pathways project intended to improve the body of knowledge on adoption and gender by generating data at both the household and intra-household level to allow for more detailed analysis of intrahousehold gender gaps in agricultural outcomes.

In order to improve on past studies on adoption, which focused on individual households using micro level cross-sectional data, the Adoption Pathways project was meant to provide multi-year panel data sets that could be used to improve on the existing adoption literature. In particular, extant adoption studies have generally failed to recognize imperfections in markets, institutions, policy settings and the complex social and gender relations and roles in agriculture (Reardon et al. 1999; de Janvry and Sadoulet 1991; Doss and Morris 2001). These shortcomings limit the extent to which these studies can be used to inform policy.

A particular contribution of the Adoption Pathways project relates to the conceptualization of how farmers adopt multiple options available to them. While past research has focused on adoption and impact of component technologies in isolation, farmers typically adopt multiple technologies as complements, substitutes, or supplements in seeking to adapt to overlapping constraints. In addition, technology adoption decisions are path dependent;

the choice of technologies adopted most recently by farmers is partly dependent on decisions made in previous periods and earlier technology choices. Analysis made without controlling for decision-relevant market imperfections and technology interdependence in complex farming systems and dynamics of adoption is likely to bias the results. The Adoption Pathways project had one of its implied aims to correct for this situation.

The focus of the Adoption Pathways project has been relevant to the five project countries since all of them report low levels of adoption of SAI technologies and identify constraints related to farm level profitability of the proposed technologies, production risk, trade-offs in using labour and other resources (e.g., stover), gender issues, weak extension services and access to information and credit, high input costs, discretionary government intervention in maize pricing, and weak infrastructure and value chain linkages. Further analysis to unravel factors explaining the observed farmer adoption behavior is identified as a strategic need, which is addressed by this project.

The focus on sustainable resource management is consistent with the continent-wide initiative called the Comprehensive Africa Agricultural development Program (CAADP). The adoption of sustainable agricultural practices should contribute to sustainable land management by reducing soil mining and degradation processes on currently cultivated land in maize systems, and reducing the pressure to expand production to fragile eco-regions. Sustainable land management is Pillar 1 of the four pillars of CAADP. The Adoption Pathways project was also understood to align with the Australian government's research and development strategy and priorities for the Africa region. Having worked in Africa for 30 years, ACIAR still contributes more than 20 percent of its resources to this region. The research and development strategy in this project is not only based on the principle of strong alignment with strategies and priorities of national, regional and global development efforts in Africa, but it also builds on and leverages existing programs and partnerships.

4 Objectives

4.1 Objective 1: Enhance the technology adoption process by generating knowledge and panel data on how markets, assets, institutions, gender relations, risk and time preferences and technology policies constrain or facilitate adoption.

This objective was meant to address the lack of representative panel data from key farming systems because of the view that previous adoption studies remained partial both in terms of technology coverage (often focusing only on fertilizer and seeds) and in terms of methodological treatments relying on static approaches to adoption. Moreover, a concern was that previous adoption studies often did not take a holistic approach in assessing factors affecting technology uptake and diffusion as they often dealt with single technology adoption. In terms of gender analysis, most of these studies did not take into account the non-unitary nature of decision making within the household. By generating gender-disaggregated data and conducting systematic analysis of determinants of joint sustainable agricultural intensification (SAI) adoption decisions, this objective was meant to contribute in close these gaps.

The main outputs that were envisaged to come out of this objective include:

- Gender-disaggregated longitudinal household, plot and village level data collected, documented and shared publicly.
- Technology choice and resource allocation decisions and trends in farm productivity, profitability, institutions, markets, assets, and policies, including the gender aspects and relations analysed and documented for target countries.
- Key socioeconomic factors (including markets, policies, assets, institutions, and infrastructure, risk and time preferences) that influence technology adoption identified and documented.
- Gender-technology gaps and the underlying causes in maize based systems identified.

4.2 Objective 2: Advance the understanding of how farmers' livelihood strategies and SAI investments interact and influence vulnerability and farm household adaptation to climate variability and change.

This objective was motivated by the fact that the sub-Saharan Africa is likely to bear a huge burden from climatic change. Farming systems in the region are at the core of dealing with these changes. Sustainable intensification via the use of improved technologies was seen as presenting significant opportunities to raise crop yields and increase farm outputs beyond subsistence levels. As was stated in the project document, the promotion of these technologies amongst resource poor smallholders requires not only demonstrating the technical feasibility but also understanding their economic viability and social acceptability considering farmers' livelihood strategies and their needs to cope with external shocks such as climate variability and change. Due to paucity of data, the effect of farmers' livelihood strategies and SAI investments on managing climate induced production risks and its contribution to climate change adaptability has not been sufficiently explored. Such understanding and evidence on the relationship between SAI investments, livelihood strategies and famers' ex ante and ex post risk coping strategies is important for developing effective interventions and supporting policy instruments.

Key outputs of this objective include the following:

- Livelihood strategies of farmers (men and women) across farming systems understood and risk coping strategies to climate shocks identified.
- Whole farm system tools for dynamic risk analysis developed to evaluate options for reducing vulnerability to climate induced risk.
- Adaptation options that reduce vulnerability to climate shocks and enhance livelihoods evaluated and identified.

4.3 Objective 3: Generate evidence on the socioeconomic impacts of adoption of multiple and complementary technologies on different groups of farm and non-farm households using econometric and household/village economy models.

Technological progress among smallholder farmers can only occur when the benefits and impacts of new practices and farming methods are unambiguously clear. From the societal point of view, these direct impacts should translate into economic and social wellbeing. This is the reason a broader analysis was required of both the direct and indirect effects of the technologies under consideration in the project. Investments by farm households in new crop varieties, inputs and agronomic technologies [are generally expected to] give rise to a number of direct and indirect beneficial welfare impacts mediated through changes in intra-household resource reallocation as well as through economy-wide effects such as output prices (especially for the locally-traded commodities whose yields have increased); input prices (especially agricultural wages); and changes in rural non-farm employment attributable to local linkages between the nonfarm and farm sectors. While the general presumption is that direct impacts of technological change dominate overall impacts on the poor in Africa (de Janvry and Sadoulet 2001), evidence from other parts of the world suggest that indirect price impacts can be substantial as well (Renkow, 1993; David and Otsuka, 1994). It is desirable for assessment of the poverty, food and nutritional security impacts of technology adoption to be able to consider these indirect effects (rather than ignore them ex ante on the assumption that they are inconsequential). This objective was designed to use econometric models, flexible farm household models and micro-economy wide models to analyse impacts of adoption on selected outcome variables in a sub-set of target countries depending on the availability of data and local capacity.

The main outputs that were outlined in the project document are as follows:

- Appropriate tools for technology and policy impact analysis developed.
- Household level, gender and social distributional impacts of adoption of improved technologies identified.
- Resource use dynamics and intensification pathways determined using farm household models.
- Rural farm/non-farm linkages and the local price and wage/employment related effects of technology assessed using village economy-wide models for Malawi and Ethiopia.

4.4 Objective 4: Enhance the capacity for gender-sensitive agricultural technology policy research and communication of policy recommendations to facilitate adoption of maize system innovations.

This objective was meant to establish a strong evidence base on gender disaggregation (by systematically including sex-disaggregation panel data) utilizing new tools and methods. Moreover the use of these new tools were meant to help in strengthening the capacity of National Universities (NUs) and NARIs and other organizations to address gender systematically in their surveys and other data strategies. The work with NUs and NARIs and others to apply tools of gender analysis to interpreting this data will strengthen capacity for gender analysis. The results of this analysis will provide recommendations on how agricultural policies can ensure that women as well as men can benefit from SAI investments. Several communication outputs will be generated to target immediate users and end-users. For example, we will design and develop a project website linked to the SIMLESA website, develop and share policy briefs and posters that flesh out the key actionable policy messages, facilitate national and regional policy dialogue and advocacy for adoption of key research outputs/findings, organize country-specific farmers' workshops to share results and get feedback from them, and organize annual national and regional workshops to share and discuss findings with stakeholders.

Shaping the policy agenda through the results of agricultural research-for-development has typically been challenging. One particular challenge has been how research agencies can effectively engage policy makers to jointly undertake decision making based on micro-level evidence – an area that needs particular attention to enhance the impact of the project. An additional challenge is the generally limited domestic capacity and institutional mechanisms to use the volumes of micro-level household and farming systems data for improved policy making, investment planning and targeting. To enhance agricultural technology policies and targeting, the capacity and institutional mechanisms will be developed for policy makers. Policy makers need to be able to better use micro-data for improved policy decision-making. Integrating micro evidence in the policy process will be enhanced to cater for priority needs and ensuring a high policy influence from the continuing research outputs.

Main Outputs include:

- Enhanced national capacity for sex-disaggregated agricultural policy analysis and research.
- Enhanced capacity of stakeholders and national partners in risk analysis, adoption, and impact assessment.
- Policy recommendations communicated to policy makers and partners for faster technology adoption and inclusive impact by narrowing gender-technology gaps.
- Increased capacity and institutional mechanisms for policy makers to use micro-data.

5 Methodology

5.1 Overview:

The main methodological approach to the Adoption project was to develop multi-wave panel datasets building on a 2010 series of baseline surveys conducted in the five project countries. The use of non-experimental micro econometric impact evaluation has also been widely used in the project. Finally, the use of household and dynamic risk modelling has also been used to understand macro level drivers (e.g. fertilizer subsidies) on input use and household decision-making under climate, biotic, market and idiosyncratic risks. These methods are detailed briefly below.

5.2 The generation of panel data sets:

The core implementation methodology in this project was to collect multiple rounds of data to build on SIMLESA data and to facilitate the use of panel data analysis – thus moving beyond the longitudinal data for adoption and impact analyses. The main source of data was farm household surveys designed to achieve representation in terms of natural, socio-economic and farming systems variability across the five project countries. The sampling design for the surveys was based on the SIMLESA project. The 2010 data collected by national project partners and CIMMYT under the SIMLESA project across 508 districts formed the baseline data on which further data collection and analysis has been undertaken. The topics covered such aspects as technology adoption in the context of intra-households input and market access (Objective 1), studies on the impact of SIMLESA technologies on risk and time preferences and livelihood strategies to facilitate the adoption of SAI technologies (Objective 2), the evaluation of technology adoption on different groups of farm households (Objective 3).

Therefore, building on the 2010 baseline data, two more rounds of data collection were implemented in 2013 and 2016. The 2010 villages from which baseline data were collected were considered the **sentinel sites** in the sense of being used for long-term monitoring purposes in the project. The data collection exercises were based on structured surveys originally designed for the 2010 on baseline SIMLESA survey.

In the 2013 and 2016 rounds, the 2010 instrument was modified and expanded to collect in-depth panel datasets on gender roles and relations, household vulnerability, and ex-ante and ex-post risk coping strategies. In order to capture fully the items on gender that were outlined in the project proposal, the baseline SIMLESA survey instrument was expanded to collect in-depth data on gender roles and relations, household vulnerability, and ex-ante and ex-post risk coping strategies. The data collection efforts were done through strong collaboration between teams from the national institutions and CIMMYT. National partners were instrumental in coordinating and leading much of the data collection efforts in the target countries. National partners were responsible for coordination with local government offices, recruitment of field personnel and supervision of field data collection and quality control. Table 1 summarizes the amount of data and their locations that were collected under the Adoption Pathways and SIMLESA 2010.

Table 1: Data Sets Gathered in Adoption Pathways Project

Country	Districts			Villages			Households		
SIMLESA Program	**2010**	**2013**	**2016**	**2010**	**2013**	**2016**	**2010**	**2013**	**2016**
Ethiopia	9	9	9	60	60	60	900	865	833
Kenya	5	5	5	88	88	88	613	535	496
Malawi	6	6	6	230	230	230	896	752	612
Mozambique	4	3	**3**	**70**	61	**61**	510	394	373
Tanzania	4	5	5	60	60	60	701	551	587
Sentinel Sites	**28**	**28**	**28**	**508**	**499**	**499**	**3620**	**3097**	**2901**
Non-SIMLESA									
Ethiopia	30	29	30	133	133	133	1557	1410	Not done in 2015
Malawi	10	10	9	207	207	207	1029	820	585
Sub-total	40	39	39	340	340	340	2586	2230	585
Total	**68**	**67**	**67**	**848**	**839**	**839**	**6206**	**5327**	**3486**

For some of the objectives, international partners in collaboration with national partners took the lead in advanced analysis of data and model simulations proposed under Objectives 1-3. For example, under Objective 2, there was analysis of household models by NMBU to identify the ramifying and equity issues around the Malawi subsidy program. These models were based on mathematical programming and included within season and between season rainfall variability making it suitable to assess the vulnerability of existing farming systems to climate induced risks.

IFPRI was instrumental in the construction of the Women Empowerment in Agriculture Index (WEAI) and for leading an experimental elicitation of farmers' risk and time preferences, household specific risk-aversion indices. The University of Queensland has been instrumental in developing a dynamic risk model for analyzing risk and its impact on technology adoption and livelihood choices.

Collaborations with ongoing projects were also instituted. The Adoption Pathways project was closely linked to the SIMLESA and the data, information and knowledge generated by this project are freely available to SIMLESA scientists and national stakeholders. Some tangible linkages between the Adoption Pathways and SIMLESA projects include the following:

- The outputs from SIMLESA project will serve as an input for the pathway project, particularly for the modeling work.
- Data related to the sustainability such as soil erosion and soil fertility and economic data (e.g. crop yield under varying management) with and without SIMLESA technologies will be made available from SIMLESA project.
- The Pathway project will also feed SIMLESA with systematically and rigorously analyzed information and knowledge that will facilitate technology targeting. This

will include information on constraints and drivers of technology adoption for different socioeconomic groups and technology impacts under different scenarios.

Several policy briefs drawing on the lessons from Adoption Pathways research have been produced and shared at the most recent SIMLESA annual meetings. These briefs will assist SIMLESA to scale up its key messages. The Association for Strengthening Agricultural Research in East and Southern Africa (ASARECA) has featured to of these briefs in their policy communications.

5.3 Econometric Models for Analyzing Technology Adoption and Impact Analysis:

Econometric analysis of baseline data collected by SIMLESA and CIMMYT in 2010 formed the basis to characterize the adoption of SIMLESA related technologies, and **identify constraints to adoption** by different groups of households. Using non-experimental approaches, the SIMLESA baselines data were used to perform impact evaluation methods on relevant outcomes. For the most part, cross-sectional econometric estimation methods were the main analytical approaches used to examine how markets, assets, institutional and infrastructural factors and gender relations promote or hinder technology adoption and dis-adoption. The types of technologies analyzed were those promoted by SIMLESA project such as: improved seed varieties, fertilizer, maize-legume intercropping, maize-legume rotations, conservation agriculture practices, organic manure, and use of different types of modern inputs, among others. A number of state-of-the-art non-experimental econometric impact evaluation methods were used to assess the impacts (see impact indicators below) of technology adoption at household and farm level for different social groups (e.g., male-and female-head of households).

The methods used in this area of analysis employed some of the most recent approaches to non-experimental impact evaluation. The methods used in these analyses were meant to deal with some of the challenges in impact evaluation related to selection bias and creating *artefactual* counterfactuals, a necessity in observational studies. Under objective 1, specifically, analysis of gender technology adoption gaps and the underlying causes were undertaken using endogenous (and exogenous) switching regressions as well as Oaxaca-Blinder decomposition methods to understand gender gaps in input use, market access and food security.

Some of the potential left hand side (or dependent) variables used in the econometric impact analysis included changes in:

- Income
- Crop productivity
- Per capita consumption expenditures
- Marketed surplus of maize
- Food security
- Anthropometric measures (children under 5)
- Poverty
- Risk and vulnerability
- Asset accumulation (e.g. livestock, land, farm equipment, etc)
- Income diversification indices (crop-livestock, farm, non-farm)
- Investment in children's education and family health

The right hand side variables (or explanatory variables) included technology adoption (status or level) and characteristics of plots, farms, and households and relevant village/farming system level fixed effects. Specific plot level data (including plot characteristics such as use of conservation and other investments, input and output data, for all plots of households and repeated over time) where key technologies are introduced through (preferably, randomized) experiments will complement the household level analysis. The plot level effects may also be aggregated and analysed at household level over time to capture not only production and income effects but also savings and investment effects.

5.4 Household modelling:

The use of household modelling was used to study policy issues in relation to technology adoption such as those used by UMB. The importance of these models was that they allowed for the use of variables for which there would have been insufficient variation in the survey data, such as input and output prices, or variables that are endogenous and where good instruments are lacking. Similarly the use of household models and economy-wide models allowed the UMB and UQ teams to study both the direct effects of aggregate policy variables and dynamic risk considerations for technology use. Household models were built using legacy and more recent data from farm and household in 2006, 2007 and 2009 and these were used to calibrate crop production activities for the models. Some of the results from this work were presented in Holden and Lunduka (2010), which showed that increases in maize productivity were attributable to increased fertilizer intensity. At the same time, maize area shares of the farms appear to have declined in this period. The findings in these analyses are integrated into the household models. This means that the models aim to capture the evolutionary logic of the system and put less emphasis on the cross-sectional variation in many of the underlying variables such as land quality and socio-economic characteristics other than those explicitly included in the models.

In terms of the dynamic risk profit maximization, household models were developed to take into account the shortcomings of the classical profit maximization within African smallholder farming contexts. The profit maximization model is actually underpinned by very restrictive institutional context (rules, regulations, norms and beliefs) in which decisions are made. The focus, therefore, is more with the outcome of those decisions for the efficiency of the firm, but disregards how a firm reaches its decisions that underpin performance. The approach serves little in understanding adaptation when markets fail, where, among others, there is large divergence between prices paid and prices received. The resulting lack of trade induces behaviors seeking self- sufficiency in food production and labor supplies, meaning poorer households with large families. These situations distort opportunity costs, encourage farmers' subjective valuations, and prolong the continuation of traditional practices, resembling low-input low output production systems (Arslan and Taylor, 2009).

Therefore the ***state contingent production model*** was developed by the UQ team (with collaboration from the UMB team) to deal with the fact that farm production is highly contingent upon the environment. issues related to ex ante risk management, inseparability of production and consumption decisions, missing markets, Bayesian learning, heterogeneities in returns to resources (conditioned by among others gender norms) and loss aversion were considered in developing the household state contingent risk models.

This conception that people act according to perceived states of nature by choosing alternatives that minimize exposure allows for possible substitution across states of nature, where all production problems under uncertainty can be viewed as multi-input, multi-output production systems. These approaches allow for the realities of farmer decision-making where they are recognized to actively respond to alternative states of nature by changing their inputs to influence the final output based on past experiences and knowledge, in order to meet a desired objective function. The benefits of a state contingent approach are that it allows for production and decision-maker uncertainty to be treated separately. This separation removes the blurring of ambiguity found in other decision analysis systems where production and management inefficiency cannot be separated (O'Donnell and Griffiths, 2006). Furthermore, other indirect effects are measured taking into account the fact that farm households pursue livelihood strategies which typically include multiple activities beyond staple food production, and that various linkages exist between the farm and non-farm economies. To explore the use of village economy models, we plan to first do a diagnosis of the rural economies using comprehensive survey data, secondary data and qualitative understanding of the agro-ecosystems (including risks), local institutions (including cultural norms), household preferences and needs, and the policy context.

Overall, the combination of market imperfections and policy interventions on a large scale can lead to substantial general equilibrium effects as an outcome of adoption of new technologies and their related policy programs (such as input subsidies). The Adoption Pathways project has therefore used econometric, household models to estimate the direct and indirect impacts on technology adoption in Malawi and Ethiopia. Largely this was because there was data on social accounting matrices.

6 Improvements against activities and outputs/milestones

Objective 1: Enhance the technology adoption process by generating knowledge and panel data on how markets, assets, institutions, gender relations, risk and time preferences and technology policies constrain or facilitate adoption.

No.	Activity	Outputs/ Milestones	Completion Date	Comments
Output 1.1	**Gender-disaggregated longitudinal household, plot and village level data collected, documented and shared publicly**			
Activity 1.1.1	Critical review of literature on technology and agronomic management practice adoption to gain an understanding of knowledge gaps	Review materials compiled / organized and summarized in a Working Paper	Dec 2012	Reviews done for journal and working papers listed in Section 10.2
Activity 1.1.2	Develop standardized survey instruments and survey methodology for establishing sentinel sites (to generate long-term panel data) that includes a module that will focus on intra-household gender gaps in knowledge about preference for technologies, knowledge of technologies, and influence over adoption decisions	Survey instruments ready for field implementation; Data management, utilization and sharing protocol/policy developed	Nov 2012 Dec 2012	Instruments available. Standardized for 5 project countries
Activity 1.1.3	Conduct longitudinal surveys at the village, household, individual (gender disaggregated) and plot level in five* SIMLESA countries in two additional rounds	Enumerators and supervisors selected and trained Survey instrument pretested Longitudinal data at households, individuals, plots, and villages collected.	Nov 2012 May 2013- First round May 2015-	Longitudinal data available for all 5 project countries as of May 2016

No.	Activity	Outputs/ Milestones	Completion Date	Comments
			second round Molested	
Activity 1.1.4	Develop experimental methodology to elicit risk and time preferences that may shape technology use decisions.	Experimental protocol developed Experimental approaches applied in Ethiopia and Kenya Two working papers on factors influencing risk aversion and time preferences	February, 2013 June 2013 Dec 2013	Completed in collaboration with IFPRI
Activity 1.1.5	Complete data entry/cleaning and develop a comprehensive database using appropriate software and database management tools, and make it accessible to partners and users.	Data entry personnel trained on data entry Longitudinal data for five countries available for use by research team	July 2013 (1st round) July 2015 (2nd round) -December 2013 (1st round) - December 2015 (2nd round)	Data are being uploaded into Dataverse for Public access for 2010-2013 and for later public access of 2016 data in mid-2018
Output 1.2	**Technology choice and resource allocation decisions and trends in farm productivity, profitability, institutions, markets, assets, and policies, including the gender aspects and relations analysed and documented for target countries.**			
Activity 1.2.1	Analyse survey data to generate descriptive statistics and describe role of gender in adoption of agricultural technologies.	Research report produced for each country and shared with stakeholders Data posted on project website and available for public use after two years of data collection	April 2014 (1st round) April 2016 (2nd round) May 2016	Five papers covering gender topics published
Activity 1.2.2	Cross-country comparative analysis on adoption of technologies and welfare indicators	Descriptive synthesis report produced	May 2014 (1st round) May 2016 (2nd)	Paper published in 2015 in *Land Use Policy*

No.	Activity	Outputs/ Milestones	Completion Date	Comments
	using descriptive statistics			
Output 1.3	**Key socioeconomic factors (including markets, policies, assets, institutions, infrastructure, risk and time preferences) that influence technology adoption identified and documented**			
Activity 1.3.1	Econometric analysis on the influence of factors (incl. assets, institutions, policies, risk, time preferences) on multiple technology adoption using cross-sectional and panel data	Two working papers documenting the impact of these variables on multiple technology adoption completed using cross-sectional data	December 2012 - first working paper March 2016 second working paper	Several papers published in *Land Use Policy, Technological Change and Forecasting, Journal of Agricultural Economics and Ecological Economics*
Output 1.4	**Gender-technology adoption gaps and the underlying causes in maize based systems identified**			
Activity 1.4.1	Econometric analysis of the gender technology adoption gaps in adopting agricultural technologies and the underlying causes	Two working papers on gender technology gap and underlying causes of gap completed	March 2013-first working paper March 2016 second working paper	Effect of gender analysed in published papers (see List in Section
Activity 1.4.2	Cross-country analysis of the gender technology adoption gap and the underlying causes	A cross-country synthesis and comparison paper on the gender technology gap and underlying causes of gap completed	May 2016	Results summarized in Project Synthesis Report (See Appendix $$) shared at the May 2016 Final Project Workshop

PC = partner country, A = Australia

Objective 2: Advance the understanding of how farmers' livelihood strategies and SAI investments interact and influence vulnerability and farm household adaptation to climate variability and change.

No.	**Activity**	**Outputs/ milestones**	**Completion date**	**Comments**
Output 2.1	**Livelihood strategies of farmers (men and women) across farming systems understood and risk coping strategies to climate shocks identified**			
Activity 2.1.1	Review and synthesize available studies on rural livelihood strategies and ex-ante and ex-post coping strategies to climate risk, relevant to target countries.	A working paper on risks, adaptation needs, and livelihood strategies drafted	Nov 2012	Paper on risk coping strategies in Malawi under review in *Climate Risk*
2.1.2	Analyze survey data to identify farmers' ex-ante and ex-post risk coping strategies to manage climate risk.	Two working papers on ex-ante and ex-post risk coping strategies of farmers developed	Dec 2013	Paper on risk coping strategies in Malawi under review in *Climate Risk*
Activity 2.1.3	Econometric analysis of factors influencing livelihood strategies of rural men and women using cross sectional and panel data	Two working papers on the determinants of major livelihood strategies of rural women and men completed	June 2014	Working paper produced by UMB and UQ teams as summarized on page 15 and 16 of Project Synthesis Report (Attached)
Output 2.2	**Whole-farm system tools for dynamic risk analysis developed to evaluate options for reducing vulnerability to climate induced risk**			
Activity 2.2.1	Consult partners and the literature to select modelling approaches to incorporate climate change and variability risk in farming system models.	Modelling strategy for simulating risk management and adaptation options identified (a state-contingent farm household model)	Dec 2012	Paper on risk coping strategies in Malawi under review in *Climate Risk* Paper on effect of SIPs on risk published in *Journal of Agricultural*

No.	Activity	Outputs/ milestones	Completion date	Comments
				Economics
Activity 2.2.2	Develop, calibrate and validate dynamic risk models.	Initial base model tested and evaluated	April 2013	Advanced Model developed by UQ team.
Activity 2.2.3	Develop a version that can be used by local partners for whole farm risk analysis	Analytical tool with examples made available to users on CD	Jan 2015	Advanced Model developed by UQ team.
Output 2.3	**Adaptation options that reduce vulnerability to climate shocks and enhance livelihoods evaluated and identified**			
Activity 2.3.1	Identify potential adaptation options for further assessment using coping strategies and the dynamic risk model.	Initial adaptation options identified and incorporated into the dynamic risk model	Feb 2013(4)	Advanced Model developed by UQ team.
Activity 2.3.2	Evaluate the tradeoffs and interactions between SAI investments and risk and vulnerability for managing climate risk	One working paper (with country case studies) on effect of SAI investments and livelihood strategies for enhancing adaptation to climate risk developed	June 2015	*Paper on risk coping strategies in Malawi under review in Climate Risk* Paper on effect of SIPs on risk published in *Journal of Agricultural Economics*

No.	**Activity**	**Outputs/ milestones**	**Completion date**	**Comments**
Activity 2.3.3	Develop policy implications of adaptation options to climate variability and change	One working paper on cross-country synthesis of interactions between SAI investments and livelihood strategies and viable adaptation options completed	Mar 2016	Paper on risk coping strategies in Malawi under review in *Climate Risk* Paper on effect of SIPs on risk published in *Journal of Agricultural Economics*

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Objective 3: Generate evidence on the socioeconomic impacts of adoption of multiple and complementary SAI technologies on different groups of farm households using econometric and household/village economy models.

No.	**Activity**	**Outputs/ Milestones**	**Completion Date**	**Comments**
Output 3.1	**Appropriate tools for technology and policy impact analysis developed**			
Activity3.1.1	Identify critical climatic, environmental, market and cultural characteristics in each study site through review of theoretical and empirical literature, as well as available primary/secondary data (including SIMLESA baseline reports).	Key agro-environmental-climatic constraints and factors that are crucial for technology adoption behavior identified	December 2012	Reviews done for household modelling by UMB team
Activity 3.1.2	Identify technology access and promotion programs (other than SIMLESA) and policies in	Technology promotion programs and policies that directly or indirectly affect	December 2012	Paper on impact of credit, extension and subsidy on technology adoption under review in *Journal of*

No.	Activity	Outputs/ Milestones	Completion Date	Comments
	each study site that affect household adoption directly or indirectly (e.g. such as input subsidy programs, credit programs, productive safety net programs, land reform programs that affect tenure security)	the relevant technologies, their adoption and their impacts in the study sites identified		*Agriculture and Food Economics (JAFE)*. See Project Synthesis Report (Attached)
Output 3.2	**Household level, gender and social distributional impacts of adoption of improved technologies identified**			
Activity 3.2.1	Analyse impacts of adoption using econometric models on selected outcomes	Impact estimation methods identified Two impact working papers developed based on cross sectional	Nov 2012 December 2015	Several papers published in *Technological Change and Forecasting* (1), *Ecological Economics* (2), *Food Security* (1), *World Development* (1) and *Journal of Agricultural Economics* (1)
Output 3.3	**Resource use dynamics and intensification pathways determined using farm household models.**			
Activity 3.3.1	Develop flexible farm household models (static/dynamic, bio-economic) based on farm typologies.	Farm household model developed and analysis completed	August 2013	Working paper produced by UMB as summarized in the Project Synthesis Report (Attached)
Activity 3.3.2	Conduct policy simulations to evaluate alternative policy options enhancing wider adoption and impact of technologies	Identify policy options and technology promotion programs for impact evaluation Two working papers summarizing the	October 2013 May 2014	Paper on impact of credit, extension and subsidy on technology adoption under review in *Journal of Agriculture and Food Economics* (*JAFE*). See page 12 of Project Synthesis Report

No.	Activity	Outputs/ Milestones	Completion Date	Comments
		results of the simulations completed (one for Ethiopia and one for Malawi)		(Attached) Role of subsidies analysed and published in *Forum For DevelopmentStudies*
Output 3.4	**Rural farm/non-farm linkages and the local price and wage/employment related effects of technology assessed using village economy-wide models for Malawi and Ethiopia.**			
Activity 3.4.1	Develop social accounting matrices (SAMs) for two representative areas/ regions/ villages, one in Ethiopia and one in Malawi and estimate key parameters for the model	SAM constructed for representative villages in Malawi and Ethiopia	June 2014 Malawi SAM Feb 2015 Ethiopia SAM	Working paper produced by UMB as summarized on page 15 of Project Synthesis Report (Attached)
Activity 3.4.2	Develop micro economy-wide models and calibrate to SAM	Model specified and calibrated to SAM in GAMS	June 2014	Working paper produced by UMB as summarized on page 15 of Project Synthesis Report (Attached)
Activity 3.4.3	Conduct policy simulations to evaluate the impacts of alternative policy options through direct and indirect effects	Policy scenarios identified and simulations conducted	May 2015	Lead: UMB (Malawi and Ethiopia) with support from NUs, NARIs, CIMMYT and other partners
Activity 3.4.4	Assess impacts of policies that aim to enhance adoption of climate-smart technologies	Policies identified and policy simulations run Two working papers summarizing the results of Activities 3.4.1 to	June 2015	Paper on impact of credit, extension and subsidy on technology adoption under review in *Journal of Agriculture and Food Economics* (JAFE). See page 12 of Project Synthesis Report

No.	Activity	Outputs/ Milestones	Completion Date	Comments
		3.4.4 completed (one for Ethiopia and one for Malawi)		(Attached) Paper on the role of information, credit and extension in Malawi under review in *Climate Risk*

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Objective 4: Enhance the capacity for gender-sensitive agricultural technology policy research and communication of policy recommendations to facilitate adoption of maize system innovations

No.	Activity	Outputs/ Milestones	Completion Date	Comments
Output 4.1	**Enhanced national capacity for sex-disaggregated agricultural policy analysis and research**			
Activity 4.1.1	Conduct practical non-degree training on gender integration and analytical tools.	A training workshop on gender integration and gender analysis completed	March 2013	Training completed
Output 4.2	**Enhanced capacity of stakeholders and national partners in risk analysis, adoption and impact assessment**			
Activity 4.2.1	Conduct practical training on cross-sectional and panel data analysis and methodologies and tools for modelling and analysis of dynamic adoption decisions.	A training manual and modules for technology adoption decision and impact analysis developed A Training workshop for project partners on cross-sectional and panel data analysis completed	June 2013 March 2014	One training done in Addis Ababa in October 2014 Training conducted on household modelling in 2013

No.	Activity	Outputs/ Milestones	Completion Date	Comments
Activity 4.2.2	Conduct training on impact assessment methods including econometrics, economy wide models and bio-economic household modelling.	A Training workshop for national partners on impact assessment methods completed	March 2014	Training conducted on household modelling in 2013
Activity 4.2.3	Conduct practical training on risk assessment, risk modelling and tradeoff analysis	One training workshop on data risk assessment completed	February 2013	Training conducted on household modelling in 2013
Output 4.3	**Policy recommendations communicated to policy makers and partners for faster technology adoption and inclusive impact by narrowing gender technology gaps**			
Activity 4.3.1	Design and develop project website.	Project website designed and developed 8 Policy briefs, 10 peer-reviewed papers and 4 workshops and meetings outcomes published on the project website	August 2012 December 2012-May 2016	Project website designed but is not updated TBD
Activity 4.3.2	Develop and share policy recommendations (based on objectives 1-3 outputs) for enhancing farmer technology adoption.	8 Policy briefs produced both in English and in local languages to share key lessons and experiences from results across countries	Year 2-4 (2013-2016)	Twelve (12) policy briefs, 8 in July 2014 and 4 in May 2016 were published widely shared and distributed in the region.
Activity 4.3.3	Facilitate national and regional policy dialogue and advocacy for adoption of key research outputs/findings	25 R & D partners and development practitioner trained in policy advocacy and dialogue	March 2013 Year 2-4 (2013-2016)	This activity was not conducted

No.	Activity	Outputs/ Milestones	Completion Date	Comments
Activity 4.3.4	Organize country-specific farmers' workshop to share results and get feedback from farmers	Feedback and results sharing workshops organized with farmers in each partner country	Nov 2014 - first workshop March 2016 - second workshop	This activity was not conducted
Activity 4.3.5	Organize policy workshops to share and discuss findings with stakeholders to facilitate use of new evidence and approaches for technology targeting, adoption in Eastern and Southern Africa.	4 workshops organized along with SIMLESA regional meetings 7 Papers by researchers presented (from all objectives) (2014-5 papers + 2016 6 papers)	Year 2-4 (2013-2016) This activity will be combined with SIMLESA annual meeting which is held every year in March	Policy workshops organized as part of annual project meetings
Activity 4.3.6	Support PhD student field research in household bio-economic, farming systems and risk management modelling.	Two PhD students recruited and begin studies (Yohannis and Ali) Two PhD students graduated	Jan 2013 May 2016	PhD students have successfully completed.
Activity 4.3.7	Establish participatory low-cost M&E system through discussion with the project partners and staff.	Functioning common M&E system established based on SIMLESA project experience	December 2013	An M&E document was prepared and shared with CIMMYT M&E manager and ACIAR
Output 4.4	**Increased capacity and institutional mechanisms for policy makers to use micro-data (First variation)**			
Activity 4.4.1	Develop a needs assessment framework to identify needs and constraints in terms	A report documenting a framework/guideline to identify priority needs for strengthening policy capacity and	Dec 2015	Two needs assessment workshops held in Addis Ababa under

No.	Activity	Outputs/ Milestones	Completion Date	Comments
	of capacity, institutional and policy engagement mechanisms for linking micro level information to policymakers.	institutional mechanisms		the leadership of EIAR economists.
Activity 4.4.2	Apply needs assessment framework in Ethiopia through multi-level consultative process.	Country case report documenting priority needs for strengthening policy capacity and institutional mechanisms	Feb 2016	Two needs assessment workshops held in Addis Ababa under the leadership of EIAR economists. A one-day policy summit held in June 2016 in Addis Ababa Ethiopia
Activity 4.4.3	Strengthen capacity of selected key policy stakeholders to use micro-data through dialogue, training and support and explore promising institutional mechanisms.	Capacity of at least 1 key policy stakeholder at each of the 3 different levels in Ethiopia strengthened (local; regional; and national) and at least 1 promising/ appropriate institutional mechanisms tried	Apr 2016	At a one-day policy summit held in June 2016 in Addis Ababa Ethiopia, proposals presented on how to build capacity for data use in policy making.
Activity 4.4.4	National workshop in Ethiopia with development partners including policy makers to (i) validate need assessment findings; (ii) review and validate capacity building and institutional mechanisms opportunities; (iii) identify priority/demand driven research areas; (iv) explore	High level policy workshop held and a workshop report	May 2016	Three workshops (two involving high level policy people from Federal and Regional government Ministry of Agriculture) held. A final international policy summit in June 2016 in Addis Ababa Ethiopia,

No.	Activity	Outputs/ Milestones	Completion Date	Comments
	scenarios; and (v) identify and prioritize institutionalization options.			
Activity 4.4.5	Finalize needs assessment framework and synthesize findings and implications for national and other regional partners	A report documenting a framework/guideline and synthesis of findings within regional context (including comparative analysis)	May 2016	Findings synthesized in four policy briefs on Ethiopia that were presented to the State Minister of Agriculture together with high officials from the MoA in Ethiopia in July 2016. See attached Report.

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7 Key Results and discussion

Summary of Lessons from Adoption Pathways Research

Adoption of composites of farming practices lead to the best outcomes for yields, incomes, and risk and climate adaptation

An overarching theme of the Adoption Pathways project was to identify *socio-economic incentives to faster adoption of agricultural technology adoption*. A key incentive to technology adoption is impact on yields, underlying resource base, costs of production and overall; profitability. From a number of published research results under this project, there was evidence that most of the practices studied were have the potential to deliver positive impacts. A paper by Kassie, Jaleta and Mattei (2014)[1] shows that when improved seeds are used in combination with reduced tillage, crop rotations and legume intercrops, maize-derived incomes improved by as much as 170% in Malawi and 67% in Ethiopia (see also Hailemariam et al., 2013) – the message being that the implementation of composites of technologies has led to the highest incomes. Similar results were found for impacts on risk with *simulated risk premiums* lowest on plots where crop diversification was practiced under minimum tillage plots. Generally, the published results on the impacts of the sustainable agricultural practices show that appropriate promotion of better agronomy, fertilizer use and crop varieties should be done as a wholesome package and not one element at a time. The package approach should be used in adaptive research, extension messaging, policy support and public investments. In each case, specific packages suitable for particular locations and groups of farmers should be researched on disseminated and supported. Nevertheless, the application of packages of technologies can be a challenge for farmers. In order to successfully progress towards a more complete adoption of multiple combinations of practices a number of information and resource constraints have to be overcome. Our research shows a large role for information, extension and adaptive research to improve farm management and produce evidence on where and when such benefits would occur. In the paper by Marenya et al. (2015a), the farmer-to-extension staff ratio was found to predict adoption of minimum tillage in Ethiopia, Kenya, Malawi and Tanzania. The paper by Mulwa et al. (2015) showed that one of the key factors that drive farmers' decisions to adopt the adaptation practices is information. Various sources of extension information significantly inform adoption decisions. Key among these were government extension and information accessed through the media. Awareness of climate change and measures to mitigate its effects was thus depicted as a key hurdle in the adaptation process. The study also identified access to credit as a key impediment to adaptation. However, it also emerged from the study that credit constrained households were still able to adopt these beneficial practices when provided with climate change related information. The (Mulwa et al. 2015) paper therefore identified lack of information as one of the most important impediments to climate change adaptation among farming households.

These results have important policy implications. There is need for clearly designed policies to disseminate climate change information to farmers. The same should incorporate deepening of extension access with information on the appropriate adaptation strategies. Important also was the need for fostering credit markets for easy accessibility and affordability by the farmers. These specific policies geared towards overcoming information and resource constraints would lead to high adoption of crop varieties adapted to changing growing conditions and the implementation of agricultural practices that stabilize yields thus enabling farm households to successfully respond to climate change.

[1] All citations are research papers from Adoption Pathways project.

Due to poor market access, food security and nutrition depends on production and crop diversification at the household level

Even when research and extension systems have evidence that improved varieties are superior in terms of yield, their impact on household welfare cannot be taken for granted. Furthermore, malnutrition and food insecurity are key development challenges in sub-Saharan Africa (SSA), causing disease, poor health and mortality. Promoting diversification of agricultural food production to enhance nutrition and alleviate micronutrient deficiency (while improving and or maintaining natural resource base) is essential. This is particularly true where farmers have limited opportunities for specialization and constrained access to diversified diets through local food markets.

Efforts were made in the Adoption Pathways project that evaluated the impact of improved maize varieties on food security and other welfare indicators, finding strong empirical connections between welfare and the area planted under improved varieties. **The empirical association of better varieties and food security outcomes suggests that *without* income and market mediated food access, self-production remains the only realistic guarantor of food security.** The empirical studies associating food security with intensity of adoption (acreage) of improved varieties suggests that own-farm production offers one of the most important opportunities among other alternative routes to food security in rural areas. A recently completed paper (Kassie et al. 2015c) showed significant effect of adoption of maize-legume diversification and modern seeds on child stunting, per capita consumption of calorie, protein, and iron and diet diversity. These effects were especially manifest when modern seeds and maize-legume diversification occurred simultaneously. The impacts of adoption of combination of SAI practices (cropping systems diversification - legume inter-cropping and rotation and improved maize seeds) on household nutrition was such that there was a 27 percent, 29 percent, 50 percent and 7 percent increase in Kcal, protein, iron and diet diversity respectively. These results confirm the need to strengthen smallholder diversification in the face of limited access to diverse diets through local food markets (see Synthesis report in Appendix 1).

Social capital is an important co-determinant of technology adoption

A variety of social capital indicators were found to be important for the adoption of SIPs. These included factors such as membership to various economic interest and social groups, availability of friends or relatives who could provide support in times of need, and acquaintances in positions of importance, power or influence. The message from this is that opportunities to build the social capital of farming communities, and formalizing and supporting farmers' groups was important to create networks of information exchange, market access and resource mobilization.

An example of the influence of social capital was found in a paper that examined the role of social capital found that the more traders the household head reported knowing, the less likely he/she was to have adopted CA in Ethiopia and Tanzania. This appears to indicate that those already having a strong market orientation (having interactions with or knowing many traders) and already intensifying their production by using higher amounts of fertilizers and having more successful farms, may find the opportunity costs of the experimentation and adaptive process needed for CA to be too high, and therefore fail to commit to CA practices adoption. Those who belonged to a farm association were more likely to have adopted CA practices. Related results from adoption models using data from Adoption Pathways and related ACIAR-funded SIMLESA[2] project data also found that a variety of social capital indicators were important in predicting the adoption of many CA

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[2] Sustainable Intensification of Maize Legume Systems in Eastern and Southern Africa, is one of the ACIAR projects implemented in East and Southern Africa by National Partners and CIMMYT and in collaboration with Adoption Pathways project.

based and related production practices. In Ethiopia, Kenya and Malawi, the results consistently showed that farmers belonging to groups (having some social capital) were more likely to have more diversified cropping patterns. They were also more likely to try new minimum tillage methods, improved maize varieties and adopt soil and water conservation methods. Moreover social groups are apparently conducive to the participation of women in agricultural innovation process. The takeway from this is that opportunities to build the social capital of farming communities, and formalizing and supporting farmers' groups, are important opportunities to create networks of information exchange, market access and resource mobilization. The influence of public goods on adoption was found in the strong positive association between extension contacts, and farmers' perceptions of these services on probability of adoption of various CA based practices. The positive association and ability to find support from non-relatives suggests the influence of social connectivity as a predictor of agricultural technology adoption through information or resource flows and other mutual support systems (Marenya et al. 2015a).

To support sustainable intensification, Investments in public goods and smallholder support programs are needed

The influence of public goods on adoption was found in the strong positive association between extension contacts, and farmers' perceptions of these services on probability of adoption of various sustainable intensification practices (SIPs). Where farmers had favorable views of extension workers, there was also a greater chance that these farmers would adopt various improved practices. Moreover, the extension staff to farmer ratio was also a strong predictor of adoption of SIPs. Strengthening agricultural extension services and expanding the space of agricultural advisory services to include multiple players should be a policy priority.

Equitable Support for Smallholder Farmers: Malawi has one of the highest population densities in East and Southern Africa. In the absence of alternative economic opportunities, many households can remain stuck in an endless poverty trap of low agricultural productivity and low incomes. The government of Malawi has in recent years implemented large-scale fertilizer and seed subsides in an effort to boost maize production and avoid food crises. A major feature of the subsidy programme was to target households with reasonable amounts of land. In a study that looked at the equity aspects of this programme, the conclusion was reached that there was a risk of ignoring the equity issues arising from the fact that near-landless or landless households also need to be supported and constitute some of the most vulnerable rural populations. To rectify this situation, the study suggests that, since fertilizer is a land augmenting technology, the subsidy need not ignore those with limited land. If this kind of inclusion is not possible, then safety net employment programs should be put in place to reach those with little or no land who may not benefit from input subsidy program. Otherwise a large portion of poor rural households may miss out on these public programs, perhaps reducing the effectiveness of the agricultural support program.

Learning from Farmers' Risk Management Practices: The University of Queensland research team, in close collaboration with the CIMMYT and national partners in Ethiopia, developed a novel tool – a farm household decision analysis model that captured the reality of decision making by poor farm households in a semi-arid area of the Central Rift Valley of Ethiopia. The model incorporates farmers' well-known tendencies for risk aversion and the safety-first approach to ensuring family food security in determining options to improve their livelihood attainments, while working within tight resource constraints and limited opportunities for trade-linked exchange. Initial results from the Central Rift Valley region of Ziway, Ethiopia, indicate that farmers have limited ex post risk management measures, and hence they tend to discount potential gains more heavily and prefer farming methods or systems that are more like the status quo (tried and tested). While those with access to irrigation and markets can improve income significantly through diversified farming systems involving multiple cropping, staggered planting and the use of improved varieties and practices, maize-legume farming systems appear to be the solution for more risk averse farmers who have limited abilities for risk mitigation. It is unlikely that the majority of farmers who own less than 0.9 ha of land will find full self-sufficiency of family food requirements from a family farm, unless intensive multi-crop farming systems can be supported with irrigation, making the farm less sensitive to variation in climate.

Subsidies or Extension: which should receive greater attention?: In a policy simulation study, the role of alternative policies such as input subsidy policies, investments in agricultural extension and access to markets in predicting the adoption of minimum tillage and mulching as components of SIPs was analyzed. Using data from 2,700 households in Ethiopia, Kenya, Malawi and Tanzania, and controlling for household and farm level factors, the simulated probabilities of adoption of minimum tillage and mulching were carried out based on varying levels of extension to farmer ratio, credit availability and government expenditures on input subsidies.

For example, in some of the scenario simulations, simultaneously increasing extension staff to farmer ratio (EFR) and reducing subsidies (SER) in Malawian and Tanzanian cases, the probability of adoption declined by 2% (Tanzania) and 14% (Malawi). In simulations where EFR was increased with no credit availability, the compensatory effect of high extension even with a lack of credit was demonstrated. This was achieved by setting the EFR at the highest (Ethiopian) level, and making the credit-constraint variable to be 100 percent binding. The results showed that in all cases (except Ethiopia), predicted adoption increases from these results indicate that increases in the reach of extension systems and availability of information can make up for lack of credit and go a long way in enabling adoption even under severe credit limitations, independent of other factors.

The predictive power of input subsidies in predicting the adoption of the SIPs studied implied that lowering costs of complementary inputs (fertilizers, seeds, herbicides, and equipment) is central in encouraging adoption of SIPs. Considering that subsidies are essentially ways to reduce prices of inputs, diverse options for structurally lowering input-output price ratios should be of much policy interest. Second, investing in agricultural extension systems and increasing the number of extension personnel (increasing the extension personnel to farmer ratio, for example) and expanding the reach of publicly funded extension systems (among other complimentary providers) is a crucial element in the success of adoption of SIPs.

Dealing with gender gaps goes beyond observed variations in household surveys

Gender gaps that disadvantage women in technology adoption, food security and market access were observed both between and within households. The need to devise positive interventions to facilitate equal access to resources and rectify social impediments to gender equality was confirmed. Study findings are presented with the understanding that a household is an institution composed of unique individuals with complex social and economic interrelationships.

Gender Gaps in Fertilizer Use: Fertilizer is a critical input for sustainable intensification. Without soil nutrient replenishment through recycling and fertilizer applications, any efforts at sustainable production will fail. In a paper that examined fertilizer use within households (Marenya, Kassie and Tostao, 2015), there was statistical evidence that jointly managed plots had greater fertilizer application (except in the case of non-food cash crops where joint management is associated with lower fertilizer application rate). Although the association between joint management and greater fertilizer application rates was important, it showed that, broadly, **more research is still needed on intra-household input, land, and crop output and income allocation**. It is still necessary to establish why joint management is related to higher fertilizer application rates. Assuming that there are underlying reasons for why fertilizer use is higher under joint management, we are still left to wonder about sharing rules within the household. Whether the increase in fertilizer use is due to the pooling of resources remains an empirical issue that requires examination. Consequently and all else equal, greater fertilizer use should lead to higher yields. Whether the observed association between joint management means that household per capita consumption or crop incomes will also increase will depend on the sharing rules within particular households. These rules will determine whether the higher crop yields (or income therefrom) on jointly managed plots are available to all members of the household equally or not (Browning et al., 1994; Ghosh and Kanbur, 2008). It is also not clear whether harvests from jointly managed plots are essentially communal resources under men's control. An example of this phenomenon is reported by Braun (1989), who describe an irrigation scheme in Gambia that was meant to increase rice yields, commercialize the crop, and increase women's incomes because rice was a "woman's crop". However, when rice yields and incomes increased, men took an interest in the rice crop and the crop subsequently became a "communal crop under the control of men," rather than a "private crop under the control of women" (see Alderman et al. 1995, p. 9).

This raises the critical issue of bargaining power. In cooperative collective household models, household members can arrive at Pareto-efficient allocations via bargaining or engaging in strategic repeated games. The equilibrium allocation depends on various "threatpoints" or fall-back positions of the members concerned. If the social, legal, and economic environment provides the household members (especially women) with creditable fall-back positions, such as divorce, legal recourse or social sanctions, then it may be possible to achieve an equitable sharing of joint production. Without such bargaining power, inequitable intra-household allocation is likely to be the outcome. The ubiquity of inequalities in intra-household allocations – such as reported in Udry et al. (1995), Quisumbing (1996), Udry (1996), and Doss (2001) – lends weight to this particular concern about inefficient household sharing. Joint management would work well under the assumption that the benefits from additional production would be available to all household members on an equitable footing. That, however, remains an empirical assumption subject to further testing.

The caveats above suggest that if women have little control over the proceeds of jointly produced crops, then a more appropriate solution to improving women's access to and control of agricultural inputs is to target plots that are *ex ante* managed by women within the households. The precondition for the success of this approach will be that women have access to land and plots on which they can exercise autonomy. Where land is limited and further intra-household subdivision and reallocation is not possible, the alternative would be to encourage joint management and the equitable sharing of crop yields and proceeds. As this study shows, analyzing input use at the sub-household level is important because it can generate data that can help inform programs/policies for increasing input use for both women and men, both at the aggregate level and within households.

Gender gaps in Market Access: Determinants of the gender differences in agricultural productivity have received more empirical attention than aspects of market participation. Using data from Ethiopia, a published research paper under the Adoption Pathways project showed that women-led households (WLHHs) were more than twice as likely to be net buyers of maize compared to men-led households (MLHH). Additionally, MLHHs were more likely to be net sellers than WLHHs by 16.5 percentage points. Taking account of resource endowments, the research showed that the net buyer and net seller participation gaps between WLHHs and MLHHs would be substantially reduced by approximately 74 percent and 65 percent, respectively. Approximately another 26 percent (net buyer) and 35 percent (net seller) remained to be explained by coefficient and interaction effects. These coefficient and interaction effects represent those aspects that explain these gaps, but which do not find explanation from the observed regression controls. The greater portions of the gaps in the various market participation categories (net buyer, self-sufficient, net seller) were accounted for by these kinds of effects.

The results explaining gaps in the amounts of maize sold were more consistent with the resource endowment explanations of gender gaps. For example, farm size, number of livestock, availability of credit, membership in farmers' organizations, and indicators of fertilizer use were the variables that contributed significantly to the endowment effects in the equation explaining the differences in the quantity of maize sold between WLHHs and MLHHs.

The results imply that where they exist, closing the gaps between the two household types in market participation will require a two-pronged approach. First, there is a need for policies aimed at addressing gender differences in agriculture to pay attention to closing structural differences (that are not explained by resource endowments) that give men an apparent advantage in the initial discrete decision to participate in maize markets. Second, the need for ensuring equal access to resources between these two household groups was confirmed. In either case, the significance of farm size, membership in farmer groups and proximity to markets in explaining these gaps call for special attention to women in terms of positive policy interventions and investments to tackle these deficiencies.

Gender Gaps in Food Security: A research paper examined the reasons why women-led households (WLHHs) were more likely to be food-insecure than men-led households (MLHHs). The study was based on subjective food security assessments as provided by the household heads. The results suggest that WLHHs were more food-insecure and less endowed with several important resources. This had important repercussions for their welfare, including their food security. The results showed that about 10 percent of the WLHHs suffer from chronic food insecurity, compared with 5 percent of WLHHs. About 58 percent of the MLHHs are food-secure (break-even and food surplus are combined into food-secure), compared with only 43 percent of the WLHHs.

The econometric results confirmed that WLHHs were, in general, more likely to be food-insecure than MLHHs. However, we find that this cannot be explained by the differences in observable characteristics alone. A decomposition technique relying on exogenous switching treatment effect regression showed that even under baseline conditions where MLHHs and WLHHs are made more similar in returns to their characteristics, WLHHs still had less probability of food security because of gender differences that reduce their capacity to make full use of those demographic profiles. This indicates that there are important gender-specific factors that make WLHHs less food-secure than their MLHH counterparts, despite both groups having similar observed characteristics. These results have important policy implications. They imply that, although some of the gender differences in food security could be addressed through policy interventions, important differences – presumably linked to gender-specific social norms and differences in the way male and female farmers are treated by others – would still remain.

Still, the paper showed that traditional policy interventions are still needed to address some of the gender imbalances in fairly short order. The results concerning the determinants of food security suggest that WLHHs' food security increases with farm size, hence the need to do land reforms that increase women's access to land. The results showing the importance of social capital networks (the number of traders that farmers know within their vicinity, and their membership of farmers' groups) suggest that policies and programs to support formation of farmers' groups targeting women should be encouraged. With respect to the social capital network, policymakers should continue to work on strengthening female farmers' groups by providing financial support and training. These institutions can effectively provide smallholder WLHHs with access to inputs, market outlets, and credit and information that can reduce the transaction costs they face. To the extent that gender-specific norms drive part of the difference in food security, the paper suggests that panel data analysis would help show whether or not these norms change over time, shedding light on an important policy issue.

8 Impacts

8.1 Scientific impacts – now and in 5 years

There are three aspects to which the Adoption pathways project has contributed to the science and literature on technology adoption, it constraints and enablers. The first aspect refers to the productivity in terms of publications that we released in the course of this project. The second and third aspects refer to the methodological and conceptual contributions made by these published works to the science in the area of better understanding technology adoption and gender gaps respectively. We summarize these below.

Publications Record

As of April 2016, researchers associated with the project managed to publish 13 peer-reviewed journal papers, 33 working papers (several of which were under review in peer review journals) and 8 policy briefs. The proposal document had promised at least 10 peer-reviewed papers and 7 policy briefs based on peer-reviewed papers would be produced from the project when the project is finished. These papers covered a variety of topics such as:

- Gender gaps in technology adoption, food security and market access
- Cross country empirical studies on the adoption of sustainable agricultural intensification practices.
- Impacts of sustainable intensification practices (SIPs) on downside risks, food and nutrition security, crop income and agrochemical use
- Gender based intra-household differences in input use and implications for gender equitable agricultural input access
- Household level nutritional impacts of crop diversification
- Farm level ex-ante and ex-post adaption strategies analysis in Malawi
- Comparative study on the importance of agricultural extension staffing densities and input subsidies on the adoption of SIPs
- Household level nutritional impacts of crop diversification

Insights into the Complexities of Gender Gaps in Agriculture

The Adoption Pathways work on gender gaps in agriculture has considerable potential for impact. In this body of research, the project team endeavored to uncover the role of unobserved heterogeneities in shaping gender-based outcomes in technology adoption, food security and market access. Specifically, the realization that the mere measurement of the levels of resource gaps is not enough to explain these gender gaps in agriculture (whether these gaps are measured as technology adoption gaps or other welfare outcomes). There is need to articulate the role of quality of resources (more technically referred to as "returns" in gender gap analysis). This set of studies also shows advancement in gender analysis in agriculture in ways that have so far been rare in agricultural economics research in developing countries. The point being that simply leveling the playing field with regard to quantities of resources (such as land) without also looking further to see if other factors related to whether there are residual “returns to resources" gaps may be insufficient to close gender gaps in agriculture.

A fundamental question that arises with regards to empirically determining what lies behind gender gaps is whether gender is simply an intercept shifter or whether heterogeneous effects imply that when studying gender differences, the gender variable can *actually be seen as a slope shifter*. In the literature, it is often acknowledged that gender differences in observed characteristics and "returns"[3] to those characteristics make the identification of gender effects difficult by just using a gender dummy variable. However, failure to distinguish between the causal effect of gender and the artefacts of implied heterogeneity in econometric analysis could lead to misleading policy prescriptions. For example, if gender is simply an intercept shifter (and no more), then simply leveling the playing field with regard to resource access (and other enabling factors) will rectify the gender gap in terms of technology adoption or other outcome of interest.

If other factors come into play such that even if both men and women appear to be on an equal footing there remain productivity and other performance differences, then policy attention should go beyond simply increasing resource allocation to women (for example). These "other factors" range from unequal access to educational opportunities, to gender-based discrimination and subtle social norms that constrain the participation of women and other groups that are unfairly marginalized from the development process.

Using the Oaxaca-Blinder like decomposition approaches, several scientific papers produced within the Adoption Pathways project have shed much light on of aforementioned subtle and unobservable factors that lie behind gender gaps in agriculture. The gaps could be in input use and technology adoption as found by Marenya, Kassie and Tostao, 2015 in Mozambique, where plots managed by women have less fertilizer applied on them controlling for plot quality and other household characteristics. The existence of food security gaps where households led by women were consistently found to have lower household food security in Malawi and Kenya (Kassie et al., 2015b; Wagura, Kassie and Shiferaw, 2014; Kassie, Wagura and Jasper, 2014)) or market access where Marenya et al. 2015 found that WLHHs had a much lower chance of participating in maize markets as net sellers of maize. The main message from this body of work is that focusing on closing the gender gap in rural farming communities is important. Equally crucial is giving due recognition to factors that may negatively affect the welfare of women farmers and women led households. This is crucial even if some of the intractable issues are difficult to directly observe or quantify even though their effects are critical.

The contribution of the Adoption Pathways project has been to empirically analyze the extent to which differences not accounted for by observable endowment factors can explain gender gaps in agriculture. This has important policy implications. For instance, if after women receive equal access to resources their agricultural outcomes are still worse than that of their male counterparts, then policy research and implementation should shift toward efforts to identify, understand and rectify the sources of these disparities not observable in typical household surveys, in addition to making sure that men and women have equal access to resources.

Insights into Complexities of Technology Adoption Using New Methods

An outstanding aspect of the scientific enquiry in the Adoption Pathways project has been the consistent empirical finding from a number of studies, which have demonstrated that agricultural technology adoption decisions among smallholder farmers are best characterized by multivariate models. This has presented a major refinement of the most common models of agricultural technology adoption which have mostly presented the decision to adopt a particular farming practice (new seed variety, resource conservation or an agronomic practice) as a discrete choice model but with one choice variable (one technology) in the decision making econometric specification. While both this univariate approach and the multivariate framework both rely on discrete choice models motivated

[3] By "returns" we mean that even if women and men are similar in most observable respects, the outcome (input use, market access or food security) can be different because the scope for profiting from, say, credit or land access can be less for a who face unobserved obstacles.

by the random utility theory, the single technology framework fails to account for the multiplicity of practices that farmers have to apply simultaneously in order to achieve the best outcomes from any one agricultural technology or practice.

This result represents a considerable methodological (and even conceptual) advance in helping researchers in agricultural economics to better represent farmers' decisions in ways that recognise the real world complexities with which farmers have to contend. That this seemingly obvious concept has been missing and continues to be absent in the vast majority of adoption studies is surprising. As the summary of results have shown, the best outcomes from the use of improved maize varieties are achieved when concomitant (and complimentary) practices such as timely and proper tillage and weed control, as well as adequate application of soil nutrients through fertilizers (organic or inorganic), are applied simultaneously. In fact, it is arguable that the continued underperformance of new maize varieties in East and Southern Africa can partly be explained by the failure of agricultural scientists to develop these varieties in the context of multiple constraints that farmers have to manage and the failure of extension systems to present new technologies as "composites" of practices rather that discrete standalone parts. The focus on modelling adoption studies as a joint decision-making process, given that farmers have to apply "composites" of practices is important in properly informing agricultural research and extension policies and effective extension packages for farmer education. The research in the Adoption Pathways project has demonstrated that the best outcomes in terms of yields, incomes and risk reduction at the plot and household levels are related to simultaneous adoption of a variety of agricultural practices. The research in this project has therefore shown that this "package approach" should be the centrepiece of sustainable agricultural intensification – where better crop yields are achieved by applying a package of technologies that improve crop yields while also conserving and protecting critical agricultural resources.

Data Sets as Public Goods: The project has contributed to lasting scientific impacts through partnerships with advanced research institutes and national universities in the target countries. Unique scientific contributions of the project included 1) the developing of well-structured panel datasets in sentinel representative mixed maize systems, and 2) major methodological advances in adoption, adaptation and impact analysis by developing appropriate modelling tools. The rigorous and scientific evidence from econometric analysis of panel datasets, and using household and bioeconomic modelling approaches, will improve the collective understanding among the agricultural development community of how socioeconomic and farming system dynamics, as well as external factors such as climate variability and policies, shape the adoption process and hence adaptation to production risks faced by smallholder farmers. These data will also help in the understanding of farmers' incentives to invest in and adopt complementary SAI practices that will ultimately determine the intensification pathways to increase food security and enhance resilience of livelihoods in the face of climate variability and change. Availability of such policy-relevant knowledge will progressively enhance functionality and effectiveness of food security projects in the Africa.

The panel datasets will ultimately serve as a public good to be used by the academic and research community to further advance the knowledge frontiers and generate policy relevant results for several years. These will form a unique international public good for understanding farmer technology choice, resource allocation patterns and adoption decisions in the maize based farming systems in Africa. This capability will enhance the overall effectiveness of sustainable intensification projects, such as SIMLESA and AfricaRising, and fill the current knowledge gaps on what kind of policies and institutional innovations would be needed to accelerate technology adoption and diffusion.

8.2 Capacity impacts – now and in 5 years

The project's achievements illustrate how with the support of institutions from the North, scientists and institutions in the South can contribute high quality scientific work of international repute. The Adoption Pathways project shows the great impact that universities and research institutes in advanced economies can have by making training and collaboration opportunities available for nationals from low income regions. Building capacity of national partners in the collection and analysis of gender-disaggregated data, using advanced econometric techniques to conduct adoption constraints analysis, and developing/using the tools of modelling, was a major objective of this project. Several hands-on non-degree trainings were conducted on gender, impact evaluation and household modelling.

8.3 Community impacts – now and in 5 years

Using policy days during the project annual meetings, policy and consultative seminars and workshops, we estimate that in the period of the variation at least 100 senior officials (including the vice chancellors of the four African universities participating in this project) and policymakers from the five project countries have been exposed to the core messages emanating from this project. At the final project meeting, a policy summit was organized and the main messages from this project were discussed at length. The issue of integrating household survey data and research results into policy formulation and decision-making process was discussed with a high level team from the Ministry of Agriculture in Ethiopia including the Federal State Minister of Agriculture.

We believe that the Adoption Pathways project will have community-wide impacts primarily through policy influence which will then be used to guide future focus of socioeconomic research and define extension messages for educating farmers to empower them to change their technology-adoption behavior. When the messages from this project finally influence research, extension and development policy, better understanding of adoption and impact pathways for new technologies and identification of accelerators and impediments of adoption will emerge. This will primarily benefit smallholder producers whose improved agricultural practices will enable them to have improved food security, higher productivity, more stable production and greater incomes from enables by improved production and marketable surpluses.

8.3.1 Economic impacts

The availability of better information on the adoption dynamics and of the role of SAI technologies in improving maize and legume productivity is expected enhance the promotion of these practices in agricultural policy, research and extension. The project results have highlighted the superiority of maize-legume innovations. If the agricultural ministries and development agencies heed this message and use it in their policies and programs, smallholder farmers will also benefit from better nutrition, higher labour productivity, improved land quality, and better water management practices that reduce vulnerability and enhance sustainability. Improved agricultural production should lead to better opportunities for agribusinesses that will benefit from increased trade volumes and better economies of scale in maize and legume trade. In the end, if the messages from this project are applied in policies and programs, greater aggregate production will improve national food security, reduce import needs, and foster the evolution of the agribusiness sector, which will be in support of economic growth and poverty alleviation.

The results of this project, when applied consistently on a large scale, can help in imparting resilience to smallholder farmers. This is because increased agricultural productivity using conserving practices will lead to reductions in downside production risks for farm households in target countries who mainly depend on agriculture to earn their livelihoods. The project results, in and of themselves, do not produce direct economic benefits. It is the application of the results to influence and change the decision outcomes of these targeted first users (decision makers), which in turn will influence the technology adoption decisions by farmers (end users) and generate economic, social and environmental impacts. By the reasoning above the results from this project will bring benefits in the medium to long-term and will include: new data and knowledge from key farming systems on the underlying forces of adoption; identification of drivers of change - accelerators and impediments for technology change; tools and methods for analysis of household and local (village) economy-wide impact of new technologies.

By linking the information generated in this project to SIMLESA and related projects, these other projects will be able to increase both the intensity and spread of their target farmers. For example, we estimated that this project would supplement the SIMLESA project to reach an additional 71,000 farmers in SIMLESA sites and an additional 60,000 farmers outside the SIMLESA target areas in 5 countries by year 10 after the inception of the SIMLESA project. It is estimated that a total of about 130,000 households (or 0.7 million people) are likely to benefit directly and through spillovers from this project that will increase crop productivity and household food security. Other indirect economic benefits may come through local multipliers and spillover effects that will benefit poor producers and consumers through lower prices of purchased food staples (maize and legumes). These indirect effects are likely to be mediated through better adoption of SAI practices as results of higher yields of up to 20-30 percent as a result of SAI technology adoption. This will lead to more marketed surplus and income for adopting smallholder farmers. Since maize yield in eastern and southern Africa region has remained low at about 2MT/ha for the last 10 years (FAOSTAT, 2012), a 30 percent yield increase will translate into a yield of over 2.5MT/ha. Similarly, the study predicts reduced vulnerability to drought from income diversification and increased uptake of locally adapted varieties along with risk-reducing soil, water and crop management practices.

8.3.2 Social impacts

Worth re-emphasizing is the fact that these impacts will come about as results of good technology targeting, evidence-based decision making, better access to extension, credit and output markets and increased adoption of new technologies including fertilizers. This should lead to healthier farms and agricultural sectors that, in the medium to long term, will lead to increased household food security and lower the poverty rate thereby improving health and educational outcomes among the target communities. Improved farm income and job creation in associated rural activities is expected to reduce unemployment, increase economic participation and slow the departure of youth from the rural areas. In addition, better understanding of gender technology gaps and key constraints to farmers' technology choices will facilitate women's empowerment and enable gender-inclusive and more accessible improved technologies/services that will open new opportunities in buffering shocks and escaping poverty.

8.3.3 Environmental impacts

The environmental impacts of the work of Adoption Pathways project, like the social and economic impacts, will hinge on the results of this project finding their way into policy and program formulation. In particular, if the message on conservation tillage, crop diversifications in space and time and biomass recycling are promoted in the extension space and if these are supported input support systems, then positive environmental impacts will be possible because the farming communities will move towards a sustainable agricultural intensification path. Alternatively if the messages from this project are not taken into account in extension program and in agricultural research, farmers will inevitably engage in unsustainable intensification, leading to the search for more scarce land and the expansion of the agricultural frontier into fragile environments. Thus, as part of the first pathway, the adoption of improved SAI technologies that increases agricultural productivity is hypothesized to slow down the expansion of farming into marginal and fragile ecosystems like semi-arid and arid land and forests, thus generating environmental impacts in the form of land saving. A second way that this project has the potential to impact positively is when there is widespread adoption of conservation agricultural practices in the maize systems, which will have the effect of increasing the quality of natural resources (e.g., land, soil) in these production systems. Adoption of conservation agricultural practices will enable, in the aggregate, many farmers to better adapt to climate variability and change. The results outlined earlier confirm that these practices can improve the production system in ways that reduce climate induced yield risk.

9 Communication and dissemination activities

Project Meetings and Media: To communicate the results of this project, each year the annual meeting was organized around one science session (where results of the most recent research since the previous meetings were discussed) and a policy day in which the senior management and researchers from the Universities had the chance to comment on and interrogate the results in terms of their relevance to policy. There were also engagements that were made with new media and the project was featured on SciDev and on African Woman and Child Feature Service. (Appendix 1 for Project Synthesis).

Webpages on CIMMYT website: The project leader is discussing with CIMMYT communications personnel around putting the synthesis report on CIMMYT website. This is now scheduled by the Communications team, with the aim to feature the results from the Adoption Pathways project as prominently as possible.

***Proposed upscaling in the short term*:** The project leader will work with CIMMYT and ACIAR management to propose future high-level policy forums for the dissemination of these results. To encourage scaling up of SIPs, stakeholders need access to information about successes in SIPs that can inspire them to act. We believe that the impacts of this project will only be realized if sustained efforts are made to make the work already done available to many people. This is what informs our decision to put the information already synthesized onto the CIMMYT website and to try to convene future policy forums in partnership with sustainable intensification projects (e.g. SIMLESA and AfricaRising) and in concert with regional agricultural research (ReNAPRI, ASARECA) and other regional economic organizations. These upscaling proposals need to happen in the very short term.

10 Conclusions and recommendations

In this section we provide a brief conclusion of the achievements and results of the Adoption Pathways project and thereafter offer some recommendation that, when implemented, we feel will enable the project to achieve lasting impact.

10.1.1 Conclusions

The Adoption Pathways project was conceived to contribute to answering several questions relating to sustainable agricultural intensification in Eastern and Southern Africa. To deal with the existing food security and resource scarcity challenges, the farming systems of Africa need to be rooted in a strong knowledgebase concerning the economic, social, and environmental necessities for sustainable growth of these farming systems. The Adoption Pathways project was part of a portfolio of projects that has contributed to the broader theme of sustainable intensification research led by CIMMYT and made possible by the contribution of several teams from national and international research groups brought together by funding from the Australian Centre for International Agricultural Research (ACIAR). The project was undertaken in the five Eastern and Southern African countries of Ethiopia, Kenya, Malawi, Mozambique and Tanzania.

10.1.2 Recommendations

We consider what has been achieved in the Adoption Pathways project as important milestones on the road towards impact. For the project to have impacts on the livelihood of rural African in East and Southern Africa and beyond, several subsequent actions need to be undertaken. We summarize these key actions in this section. At a basic level, there is work to be done for the project to meet its aim of “generating knowledge on constraints to, and incentives for, faster technology adoption”. The research ideas summarized in this brief are based on lessons learned from the four years of the project. To make these results achieve impact, the following aspects will need to be sustained in the coming years.

Upscaling: Despite comprehensive data and reasonable research results having been generated, efforts need to be made to take these research products to policymakers, farmers, researchers, input suppliers, development partners and so on. Forging partnerships are essential for scaling up research results and undertaking policy dialogue to achieve lasting and meaningful changes at scale. In this regard, practical capacity building and engaging other national and regional policy and research think tanks is an important strategy as these can act as knowledge and information brokers. The recommendation here is to work closely with the suggested institutions to undertake policy dialogue and national policy consultations to overcome these problems. In order to do this, we will try to find funding and allocate budget for media engagement, information dissemination, and facilitate trainings in science communication and involve national and regional think tanks and policy research institutes. We have identified the following organizations as possible collaborators in these efforts:

- Partnership for Economic Policy (PEP) [https://www.pep-net.org] - PEP is an “…international organization that links researchers globally to enhance capacity for development policy analysis in developing countries. PEP research contributes to informing national and international debates…” related to economic policy, poverty, gender and sustainable development.
- Tegemeo Institute at Egerton University in Kenya - This is a policy think tank of the Egerton University in Kenya that focuses on panel data collection and using these to undertake agricultural policy analysis and to engage Kenyan agricultural policy community.

- ReNAPRI (Regional Network of Agricultural Policy Research Institutes based in Mozambique) - This is a consortium of different policy research institutes located in East and South Africa). ReNAPRI is a regionally-coordinated group of national agricultural policy research institutes duly established and operating in the Eastern and Southern Africa (ESA) region member states. Currently, it has membership from DR Congo, Kenya, Tanzania, Malawi, Mozambique, South Africa and Zambia.
- Ethiopian Development of Research Organization (EDRI), hosted in the Prime Minister office.
- African Union (AU)
- COMESA
- ASARECA

Capacity Building: The project experience has been that existing partners' technical skills and time to advance high quality research and to undertake policy outreach is limited. This has implications on sustainability and continuity of the project and policy relevant research flow. During the third annual meeting of the project one of the key issues raised and discussed was capacity development of partners. One of the MTR team member said, "Retooling is needed even for university partners as they are not familiar with new methods".

This (weak capacity) has implications for the visibility of the project results or the *continuity* of the kinds of analyses done in this project, hence the sustainability and continuity of the project and policy relevant research. The key guiding principle of the Adoption Pathways project has been **ensuring sustainability of Adoption Pathways'** work beyond the project time frame – most important will be the need to build on capacity for continuous panel data collection, curation and dissemination of information. We believe that capacity building should be the gold standard for all R4D projects. Obviously the scope and nature of the capacity building will differ by project.

So as the Adoption Pathways team, we propose that future capacity building should focus on.

- Retooling existing and long-serving staff on extant and new methodologies
- Support training of young scientists as Adoption Pathways' contribution to the need for a planned staff succession among the scientific corps in NARs and universities
- Promote and increase the utilization of Adoption Pathways data by graduate students, scientists, policy makers
- Practical write shop to increase research productivity among national partners

The capacity component will also include other stakeholders (policy makers, development actors, farmers) by providing them new knowledge on adoption and empirical evidence on performances of SIPs that can enable them to make informed decision-making process and development.

Long term panel data generation for policy research: The farming systems and socio-economic conditions of farmers are dynamic and change overtime in response to a number of factors such as climate change and variability, rapid population growth, urbanization, change in the economies of countries which can result in change in institutions, markets and policies. Monitoring and tracking of these changes (e.g. rates of adoption of technologies/practices, changes in poverty) and understanding the impacts of these changes (e.g., programs, policies, institutions, markets) on farmers' wellbeing require collecting data over time.

An important activity for ensuring the sustainability of Adoption Pathways work will be the development of long-term panel data sets. We propose that efforts be put in place to develop a regional collaborative effort in panel data construction that will be led by national (universities, think tanks) in the region in collaboration with and international research organizations (e.g. CIMMYT) and supported by regional counterparts such as ReNAPRI, Tegemeo or ASARECA. A formalized framework for collecting, curating and disseminating these data is one of the things we recommend should be continued.

***Empowering women in agriculture – intrahousehold analysis on input use and output sharing*.** Recently, there is greater emphasis on the role of women in technology adoption, agricultural productivity and food security. However, the literature is limited on how, why and where the role of gender within multi-adult households matter for food security, technology adoption and agricultural productivity. The Adoption Pathways project is in a better position to answer these questions as it has developed unique gender disaggregated data sets. We recommend that further research on women's empowerment should focus on understanding how female farmers in the male-headed households contribute to technology adoption, agricultural productivity and food and nutrition security. In the very near future we propose the following questions to be tackled in this area:

- What are the pathways through which empowering women within a household can lead to accelerated technology adoption?
- Which pathway would lead to better outcomes? Improving women's access to technologies on plots and crops managed by women? Or should women be involved in joint management in traditionally male managed crops and plots?
- Is household technology adoption and productivity best served through improvements in access to resources and technologies targeted at "women's crops" e.g. vegetables and plots?
- Is household technology adoption and productivity best served through greater involvement of women in traditionally "men's crops" e.g. cash crops?
- Does joint management of "women" and "men's" plots and crops lead to better technology adoption and productivity outcomes?
- Are women empowered when resources are jointly or individually owned?

Finally we sense a need to disentangle the various components of WEIA (which have been constructed using Adoption Pathways data) in order to understand the relative importance of specific elements (e.g. control versus access, credit access, social capital, access to extension, participation in public affairs etc.) for technology adoption, agricultural productivity and food security

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12 List of publications produced by project

The results presented in this brochure are a summary of a series of publications that have variously been produced by researchers working within the Adoption Pathways Project and in collaborating projects. These are listed below to provide the interested reader with a more complete reading of these results and some of these publications are available at http://aciar.gov.au/aifsc/projects/adoption-pathways, publisher/journal websites and project partner websites.

Journal Articles

1. Beyene, A.D. and Kassie, M. 2015. Speed of adoption of improved maize varieties in Tanzania-an application of duration analysis. Accepted for publication in Technological Forecast and Social Change , 96:298-307.
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3. Holden, S. T. and Lunduka, R. (2013). Who benefit from Malawi's input subsidy program? Forum For Development Studies 40(1), 1-25
4. Holden, S. T. and Lunduka, R. (2013). Input subsidies, cash constraints and timing of input supply. American Journal of Agricultural Economics. 96(3):290-307.
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6. Kassie, M., Teklewold, H., Marenya, P., Jaleta, M. and Erenstein, O. 2015. Production risk and food security under alternative technology choices in Malawi. Application of a multinomial endogenous switching regression. Journal of Agricultural Economics. doi: 66(3): 640-659.
7. Kassie, M., Teklewold, M., Jaleta, M., Marenya, P., and Erenstein, O. (2015). Understanding the adoption of a portfolio of sustainable intensification practices in eastern and southern Africa. Land use Policy, 42: 400-411.

1. Kassie, M, Simon, W., and Jesper, S. (2014). What determines gender inequality in household food security in Kenya? Application of exogenous switching regression. World Development, 56: 153-171.
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3. Marenya, P., Kassie, M. and Tostao, E. (2015). Fertilizer use on individually and jointly managed crop plots in Mozambique. Journal of Gender, Agriculture and Food Security, 1(2), pp 62-83.
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5. Tessema, Y., J. Asafu-Adjaye, D. Rodriguez, T. Mallawaarachchi and B. Shiferaw (2015) 'A Bio-economic Analysis of the Benefits of Conservation Agriculture: The Case of Smallholder Farmers in Adami Tulu District, Ethiopia', forthcoming, Ecological Economics.

6. Wagura, S.; Kassie, M. and Shiferaw, B. (2014). Are there systematic gender differences in the adoption of sustainable agricultural intensification practices? Evidence from Kenya. Food Policy, 49:117-127

Discussion papers

1. Asafu-Adjaye, J, Mallawaarachchi, T. and Yirga, C. (2014). Understanding farmers' ex-ante risk management and ex-post risk coping strategies for climate risk: A case study of smallholder farmers in North West Ethiopia. Adoption Pathways Project Working Paper No. 4/2015.
2. Hitomi, K. (2014). Women's empowerment in agriculture in Tanzania using Adoption Pathways Survey. Adoption Pathways Project Working Paper No. 6/2015.
3. Holden, S. T. (2013). Input subsidies and demand for improved maize: Relative prices and household heterogeneity matter! CLTS Working Paper No. 6/2013. Centre for Land Tenure Studies, Norwegian University of Life Sciences, Ås, Norway.
4. Holden S.T. (2013). High discount rates: - An artifact caused by poorly framed experiments or a result of people being poor and vulnerable? CLTS Working Paper No. 8/2013. Centre for Land Tenure Studies, Norwegian University of Life Sciences, Ås, Norway.
5. Holden S.T. (2014). Agricultural Household Models for Malawi: Household heterogeneity, market characteristics, agricultural productivity, input subsidies, and price shocks. A Baseline Report. CLTS Working Paper No. 5/2014. Centre for Land Tenure Studies, Norwegian University of Life Sciences, Ås, Norway.
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7. Holden, T.S., and Fisher M. (2014). Can adoption of improved maize varieties help smallholder farmers adapt to drought? Evidence from Malawi. CLTS Working Paper No 1/15.
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11. Kankwamba, H., Mangisoni, J.(2015) Are sustainable agricultural practices improving output and incomes of smallholder farmers in Malawi? https://www.conftool.com/icae2015/ index.php?page= browseSessions&presentations=show&search=henry
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15. Kassie M., Marenya, P., Teklewold, H., Erenstein, O. and Qaim, M. (2016). Does adoption of cropping system diversifications and modern seeds affect nutrition security in Ethiopia? Evidence from Panel data analysis. Under review in World Development.
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17. Kassie, M., Teklewold, H., Alene, A., and Dil, R. (2014). Adoption and economics of multiple sustainable Intensification Practices in Ethiopia: Evidence from Panel data analysis. Adoption Pathways Project Working Paper No. 2/2015.
18. Kassie, M., Teklewold, M., Jaleta, M., Marenya, P., Olaf, E., Mekuria, M. (2014). Technology diversification: Assessing impacts on crop income and agrochemical uses in Malawi. Adoption Pathways Project Working Paper No. 5/2015.
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20. Marenya, P.P., Kassie, M., Jaleta, M. (2015) Adoption of conservation agriculture under alternative agricultural policy and market access indicators: Evidence from Eastern and Southern Africa. https://www.conftool.com/icae2015/index.php?page=browseSessions&form_session=79
21. Marenya, P., Kassie, M., Jaleta, M., and Rahut, D. (2014). Does gender of the household head explain smallholder farmers' maize market positions? Evidence from Ethiopia and Kenya. Adoption Pathways Project Working Paper No. 8/2015.
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1. Food security as a gender issue: Why are female-headed households worse off compared to similar male-headed counterparts? Socioeconomics program Policy brief No 1.
2. Give and Take: Tackling trade-offs in crop residue use for conservation agriculture in Kenya. Socioeconomics program Policy brief No 2.
3. Input subsidies and improved maize varieties in Malawi: What can we learn from the impacts in a drought year?
4. Improved maize varieties and household food security: Achieving impact in Tanzania. Socioeconomics program Policy brief No 6.
5. Love, A., Magnan, N., and Colson, G.J (2015). Mens' and women's risk preferences: Evidence from the adoption of maize technology in Kenya. Adoption Pathways Policy brief No. 1
6. Low risk, high returns: How adoption of crop diversification and minimum tillage is a win-win for smallholder farmers in Malawi. Socioeconomics program Policy brief No 5.
7. Sustainable agricultural intensification in Ethiopia: Achieving maximum impact through adoption of suites of technologies. Socioeconomics program Policy brief No 3.
8. Sustainable agricultural intensification through multi-technology adoption: A regional overview from East and Southern Africa. Socioeconomics program Policy brief No 4.

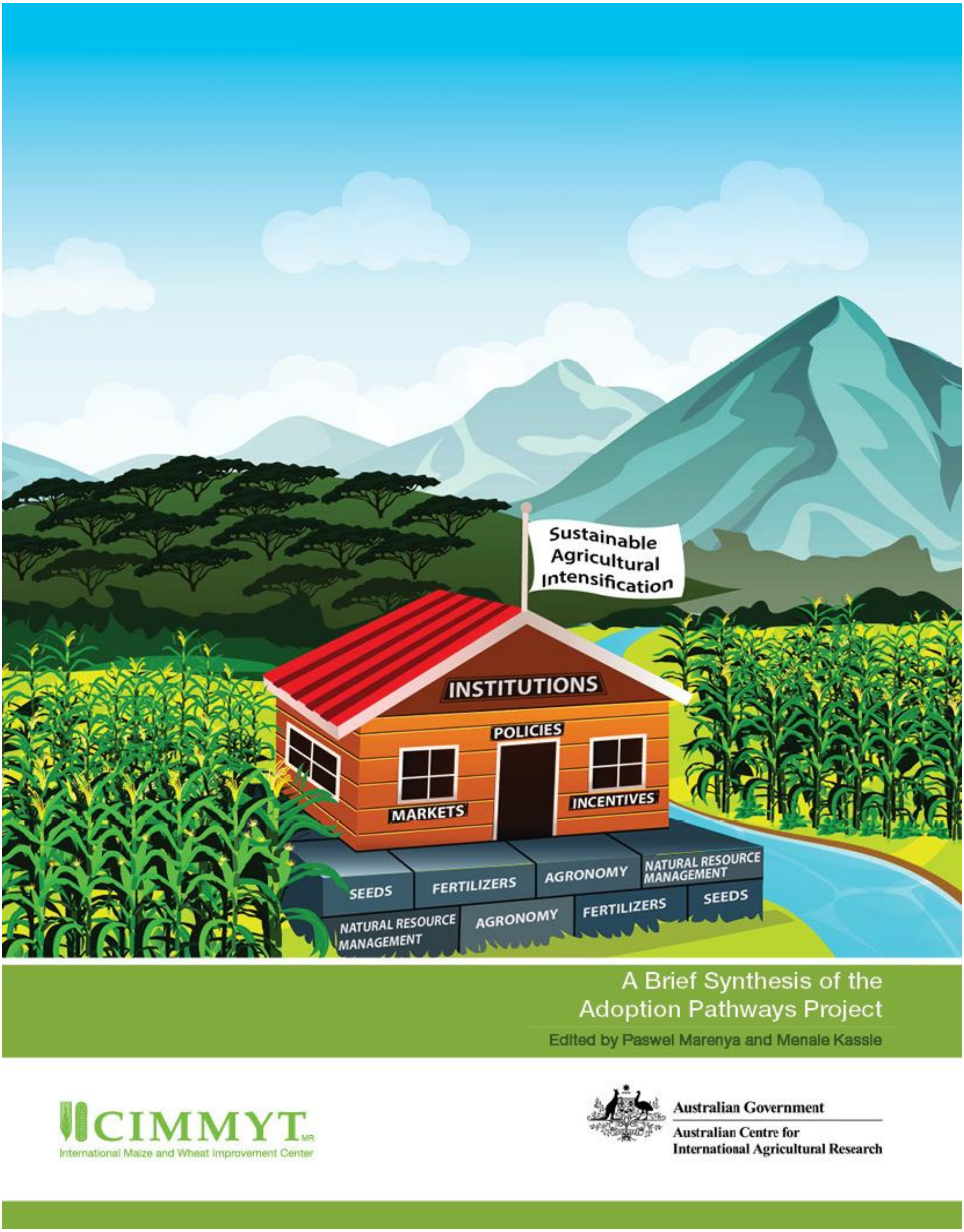
Media Stories

1. Female-headed households 'prone to food insecurity', Available athttp://www.scidev.net/sub-saharan-africa/food-security/news/ female-households-food-insecurity.html.

Female headed households require more than farm input to boost food production, Available at http://awcfs.org/kw/article/female-headed-households-require-farm-input-boost-food-production/

13 Appendices

13.1 Project Synthesis Report



Pathways to sustainable intensification in Eastern and Southern Africa

Looking Forward, Achieving Impact

Nearly a decade and a half into the 21st century, hunger and malnutrition are still harsh realities for more than one billion people around the world. In addition to this, the challenge of feeding a growing world population, which is projected to reach 9 billion by 2050, has to be met despite a declining resource base and dwindling supplies of water and land. Achieving this challenge while protecting the natural ecosystem that supports agriculture and other human needs will involve finding smarter ways to produce more with less Accomplishing this in ways that create opportunities for smallholder farmers, earning only a meager income, is no easy task.

Why this Adoption Pathways Project?

It is clear that knowledge gaps about how eco-systems interact with managed agriculture have led to farming becoming unsustainable across the world. To avoid that happening in the emerging farming systems of Africa, we need to improve our knowledge base on the economic, social, and environmental necessities for the sustainable growth of our farming systems. This involves a two-part effort:

- First, a strong pillar of research in agricultural sciences (involving many disciplines) to support an intense effort to produce critical knowledge.
- Second, sharing knowledge that helps understand the puzzles of farming with farmers and trailing new solutions on their fields to learn what works better, and why.

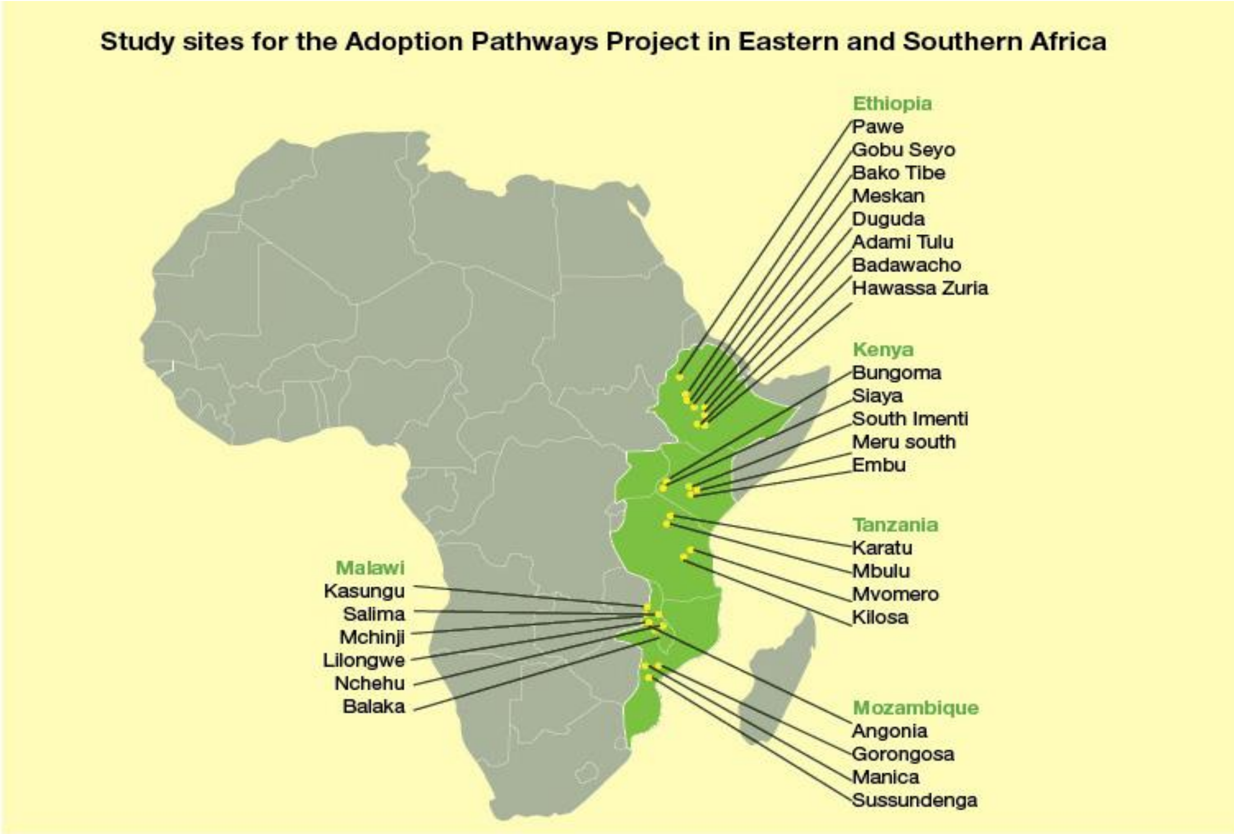
The pathways to sustainable agricultural intensification (SAI) may involve two segments. The first pathway will lead farmers to adopt new knowledge and tools to help them cope better with what they do now and help them find what they could do better later. This would only be an intermediate outcome.

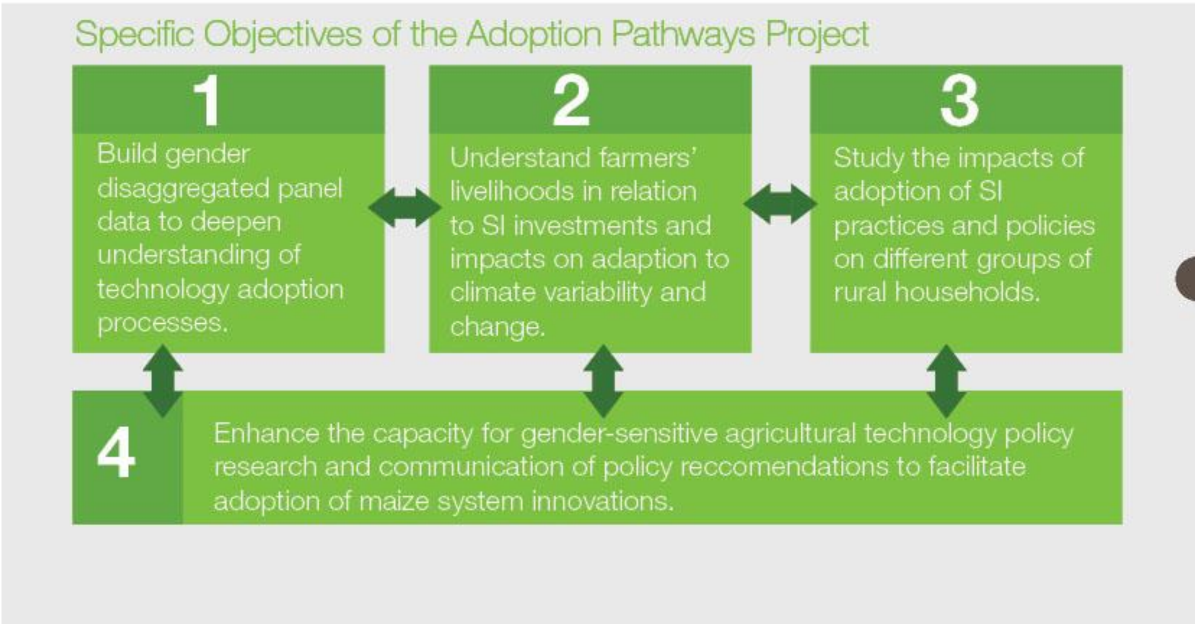
The second, lasting adoption-to-impact pathways would lead farmers to long-term adoption/adaptation; paving ways to increased production, profitability and improved livelihoods.

This second segment involves identifying and understanding important drivers or critical enablers of technology adoption: ways to reduce risks and improve profits from farming. Addressing issues of knowledge transfer through better extension, improving credit markets, and identifying infrastructure needs and/or policy directions to make those support services possible would take time and resources. It would also involve asking pertinent questions, including:

- What are the drivers/impediments of adoption of multiple sustainable agricultural intensification (SAI) practices under different social, institutional, agro-ecology and market conditions?
- Does adoption of SAI practices, including new varieties, lead to positive impact for productivity, incomes, food security and nutrition
- Does adoption of SAI practices serve as coping strategies to climate-induced production risks?
- Can SAI, including new varieties and production methods, help men and women farmers equally?
- Do existing agricultural policies (e.g. subsidies) trigger adoption of SAI practices and improve household welfare?
- What would be better ways to package the evidence and provide support services?
- And, how would this new knowledge help develop new policy directions?

The Adoption Pathways Project was conceived to contribute to the answers to the above questions. It is part of a portfolio of projects that contribute to the broader theme of sustainable intensification research led by the International Maize and Wheat Improvement Center (CIMMYT) and made possible by the contribution of a dedicated team from national and international research groups brought together by the Australian Centre for International Agricultural Research (ACIAR). The project is undertaken in the five ESA countries of Ethiopia, Kenya, Malawi, Mozambique and Tanzania

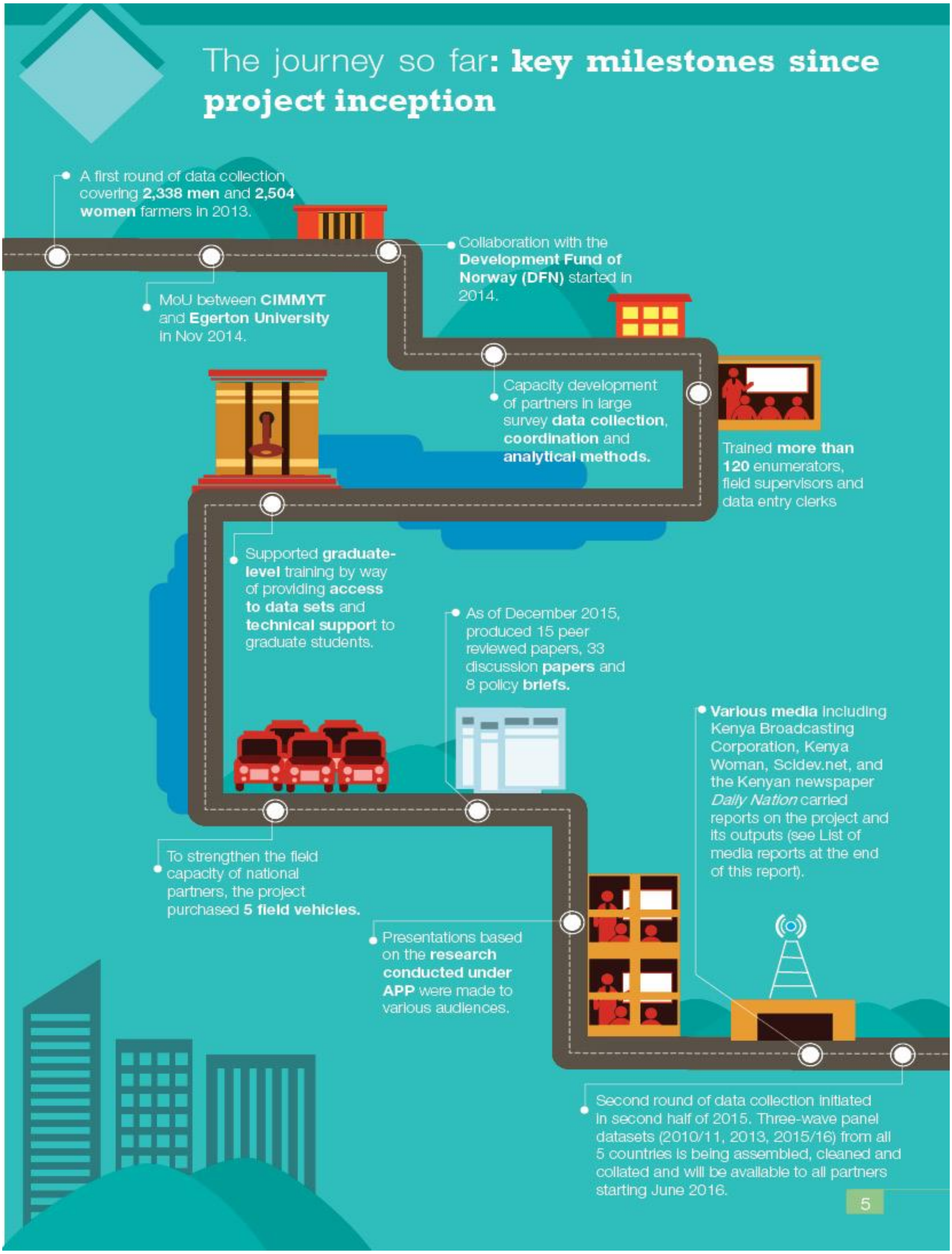




The journey so far: key milestones since project inception

- A first round of data collection covering **2,338 men** and **2,504 women** farmers in 2013.
- MoU between **CIMMYT** and **Egerton University** in Nov 2014.
- Collaboration with the **Development Fund of Norway (DFN)** started in 2014.
- Capacity development of partners in large survey **data collection**, **coordination** and **analytical methods.**
- Trained **more than 120** enumerators, field supervisors and data entry clerks

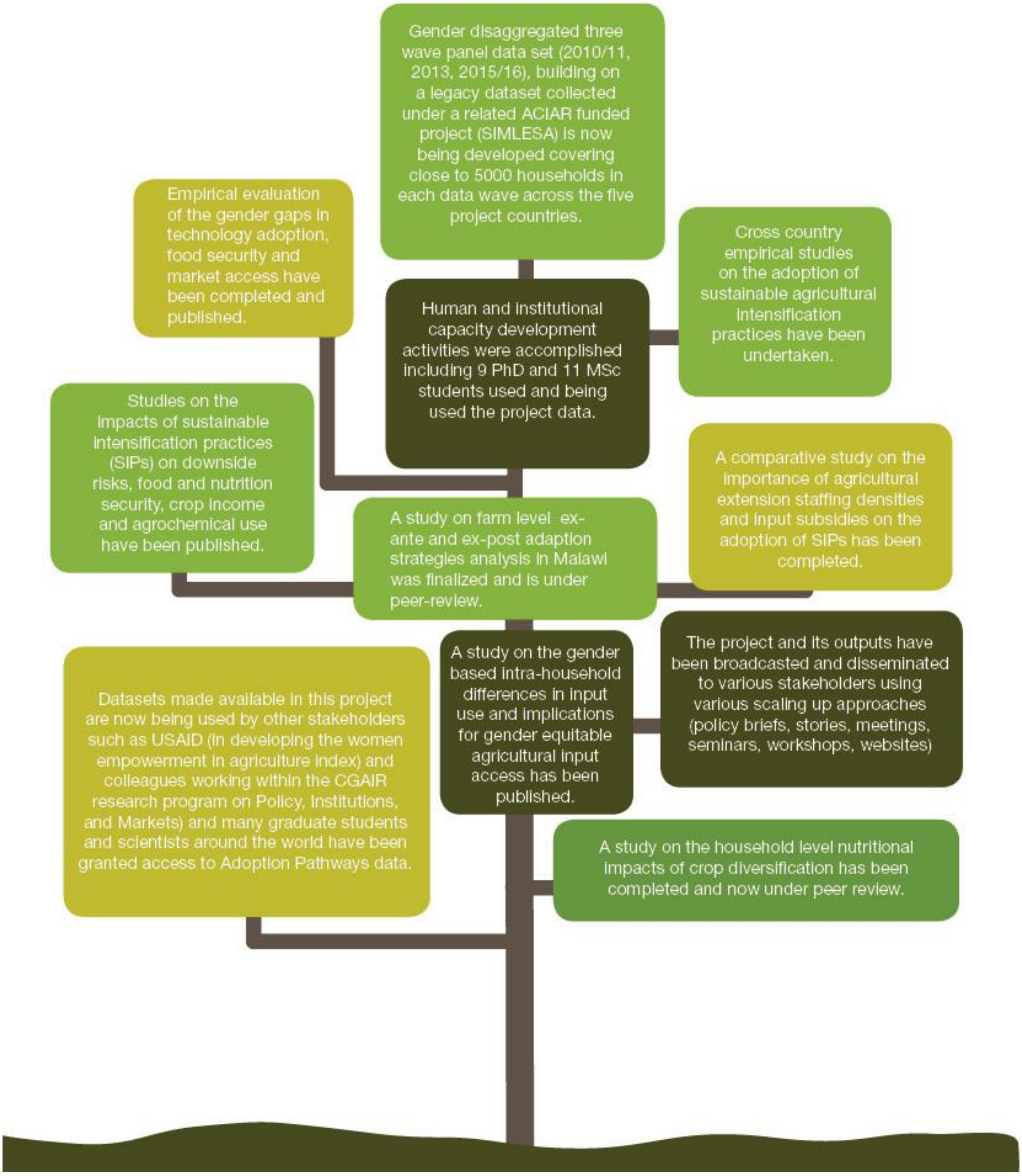
- Supported **graduate-level** training by way of providing **access to data sets** and **technical suppor**t to graduate students.
- To strengthen the field capacity of national partners, the project purchased **5 field vehicles.**
- As of December 2015, produced 15 peer-reviewed papers, 33 discussion **papers** and 8 policy **briefs.**
- Presentations based on the **research conducted under APP** were made to various audiences.
- **Various media** including Kenya Broadcasting Corporation, Kenya Woman, Scidev.net, and the Kenyan newspaper Daily Nation carried reports on the project and its outputs (see List of media reports at the end of this report).
- Second round of data collection initiated in second half of 2015. Three-wave panel datasets (2010/11, 2013, 2015/16) from all 5 countries is being assembled, cleaned and collated and will be available to all partners starting June 2016.



What did the project do to deliver on the objectives? A summary.

The Adoption Pathways project has ,since its inception generated, substantial outputs that can enrich existing agricultural information and change old agricultural information/data, build new knowledge and enable policy makers, donors and programs to enact research-based decisions that facilitate technology adoption and improve livelihoods of smallholder farmers, including women. A summary of these outputs include:

1. Gender disaggregated three wave panel data set (2010/11, 2013, 2015/16), building on a legacy dataset collected under a related ACIAR funded project (SIMLESA) is now being developed covering close to 5000 households in each data wave across the five project countries.
2. Empirical evaluation of the gender gaps in technology adoption, food security and market access have been completed and published.
3. Human and institutional capacity development activities were accomplished, including 9 PhD and 11 MSc students that used or are currently using the project data.
4. Cross country empirical studies on the adoption of sustainable agricultural intensification practices have been undertaken.
5. Studies on the impacts of sustainable intensification practices (SIPs) on downside risks, food and nutrition security, crop income and agrochemical use have been published.
6. A study on farm level ex-ante and ex-post adaption strategies analysis in Malawi was finalized and is under peer-review.
7. A comparative study on the importance of agricultural extension staffing densities and input subsidies on the adoption of SIPs has been completed.
8. Datasets made available in this project are now being used by other stakeholders such as USAID (in developing the women empowerment in agriculture index) and colleagues working within the CGAIR research program on Policy, Institutions, and Markets) and many graduate students and scientists around the world have been granted access to Adoption Pathways data.
9. A study on the gender based intra-household differences in input use and implications for gender equitable agricultural input access has been published.
10. The project and its outputs have been broadcasted and disseminated to various stakeholders using various scaling up approaches (policy briefs, stories, meetings, seminars, workshops, websites)
11. A study on the household level nutritional impacts of crop diversification has been completed and now under peer review.



How can findings from Adoption Pathways research inform policies?

The lessons emerging from the completed research activities can be summarized as follows:

LESSON 1: **Win-win outcomes are possible with adoption of sustainable agricultural practices (SIPs).**

The project research outputs, based on cross-sectional data, provide evidence of win-win outcomes (in terms of crop income, food and nutrition security, environment and risk) if implemented as composites of practices. However, for farmers to successfully progress towards a more complete adoption of multiple combinations of practices a number of information and resource constraints have to be overcome. Our research shows a large role for information, extension and adaptive research to improve farm management and produce evidence on where and when such benefits would occur. This is because the adoption of multiple practices, combined in specific patterns and in a judicious manner, is necessarily a knowledge intensive process.

LESSON 2: **With limited market access and few opportunities for specialization, food security and nutrition depends on autonomous production and crop diversification at the household level.**

The empirical studies associating food security with intensity of adoption (acreage) of improved varieties suggests that own farm production offers one of the most important opportunities among other alternative routes to food security in rural areas. A recently completed paper shows significant effect of adoption of maize-legume diversification and modern seeds on child stunting, per capita consumption of calorie, protein, and iron and diet diversity, These effects were especially manifest when modern seeds and maize-legume diversification occurred simultaneously. These results confirm the need to strengthen smallholder diversification in the face of limited access to diverse diets through local food markets.

LESSON 3: **The role of social capital is important for the adoption of SIPs.**

A variety of social capital indicators were found to be important for the adoption of SIPs. These included factors such as membership to various economic interest and social groups, availability of friends or relatives who could provide support in times of need, and acquaintances in positions of importance, power or influence. The message from this is that opportunities to build the social capital of farming communities, and formalizing and supporting farmers' groups, are important to create networks of information exchange, market access and resource mobilization.

LESSON 4: **Investments in public goods needed for sustainable intensification.**

The influence of public goods on adoption was found in the strong positive association between extension contacts and farmers' perceptions of these services and the probability of adoption of various SIPs. Where farmers had favorable views of extension workers, there was also a greater chance that these farmers would adopt various improved practices. Moreover, the extension staff to farmer ratio was also a strong predictor of adoption of SIPs. Strengthening agricultural extension services and expanding the space of agricultural advisory services to include multiple players should be a policy priority.

LESSON 5: **Strengthening and protecting the assets of the poor should be central to successful adoption of SIPs.**

Private asset endowments (such as land, equipment, livestock) were consistently associated with higher probability of adoption of SIPs. Thus suggesting that those without these assets are less able to access liquidity (or credit markets) to finance adoption of SIPs while those with these assets are probably able to liquidate some of it to generate the finances for input purchases and other farm investments. Moreover ownership of farm equipment enables for timely operations and circumvents labor bottlenecks thereby making it possible for farmers to implement improved production practices more effectively. The policy messages here are that building up systems for financial inclusion is important, and that strengthening and protecting the assets of the poor should be central to agricultural development policies.

LESSON 6: **Gender equity in technology adoption and outcomes is still elusive. This is manifest both between households and between individuals within households.**

Gender gaps that disadvantage women in technology adoption, food security and market access were observed both between and within households. The need to devise positive interventions to facilitate equal access to resources and rectify social impediments to gender equality was confirmed. The Adoption Pathways project analyses household decision-making while cognizant that a household is an institution composed of unique individuals with complex social and economic interrelationships.

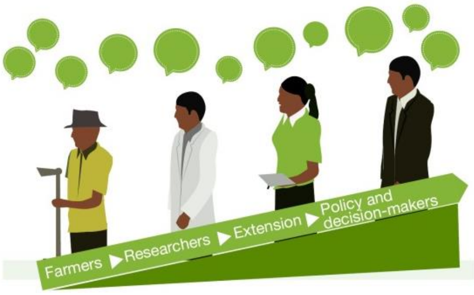
How will Adoption Pathways project achieve impacts and leave a legacy?

The achievements in the Adoption Pathways project are but milestones in the long journey towards impact. Much remains to be done for the project to meet its aim “generating knowledge on constraints to, and incentives for, faster technology adoption” and for the project to have impacts on the livelihood of rural African in East and Southern Africa and beyond. The research ideas summarized in this brief are based on lessons learned from the four-year project. To make these results achieve impact, the following aspects will need to be sustained in the coming years:

Sustaining long-term panel data generation and analysis.

An important activity for ensuring the sustainability of the Adoption Pathways project and to fill outstanding knowledge gaps on adoption and impact pathways analysis will require the development of long-term panel data sets. A collaborative effort in panel data construction to supplement and sustain what has been achieved in this project is proposed. These collaborations are likely to involve universities, think tanks and international institutions (both CGIAR and non-CIGAR) supported by regional counterparts such as Regional Networks of Agricultural Policy Research Institutes (ReNAPRI), Centre for Coordination of Agricultural Research and Development for Southern Africa (CARDESSA) and Association for Strengthening Agricultural Research in East and Central Africa (ASARECA) among others. A formalized framework for collecting, curating and disseminating these data will help achieve long-term impacts from the Adoption Pathways project.

Scaling up project research outputs and policy dialogue.



To encourage scaling up of the promising suites of SIPs identified in this project, stakeholders need access to information about successes in adoption of SIPs that can inspire them to act. Despite comprehensive data and reasonable research results having been generated so far in this project, much work remains to be done to take research products (including new data to replace outdated data) to policy makers, farmers, researchers, input suppliers, development partners, and others along the R4D continuum. In the project countries, there are significant gaps in the technical skills and staff time to advance high quality research and to undertake policy outreach. This has implications on the sustainability of the results of a project like Adoption Pathways. New partnerships are essential for scaling up research results and undertaking policy dialogue to achieve lasting and meaningful changes at scale. To sustain the work of adoption pathways project, close collaboration between various institutions such national and regional think-tanks policy and research institutes is crucial to undertake policy dialogue and national policy consultations.

Seeking answers to outstanding questions on the dynamics of technology adoption and impact analysis.

The micro-econometric adoption and impact analysis of SIPs carried out so far in the project relied on cross-sectional data. With cross-sectional data, important policy and dynamics questions such as household adoption and welfare mobility patterns overtime cannot be answered. Analyses using longitudinal data will help in answering the questions as to who is persistently adopting and disadoption, who is getting ahead, who is falling behind and who is staying where they and so forth. Future research of Adoption Pathways should concentrate on understanding dynamics of adoption and uptake pathways and welfare dynamics, including exploring the economies of scope and risk management benefits of dynamics adoption of SIPs. The study of the dynamics of adoption and the resulting impacts requires several waves of data collected at reasonable time intervals to get more variation on the myriad biophysical and socio-economic variables underpinning adoption and impacts of SIPs.

Prioritizing women empowerment as a critical pillar in sustainable agricultural intensification.

In recent decades there has been an encouraging emphasis on the role of women in technology adoption, agricultural productivity and food security. However, the literature is limited on how, why and where the role of gender within a household (male headed households) matter for food security, technology adoption and agricultural productivity. The Adoption Pathways project is in a good position to answer these questions because it has developed unique gender disaggregated data sets. Nevertheless, questions remain on how women in multi-adult households can contribute to technology adoption, agricultural productivity and food and nutrition security. Some of these questions are about intra-household dynamics and how these affect women's participation in agriculture. For example:

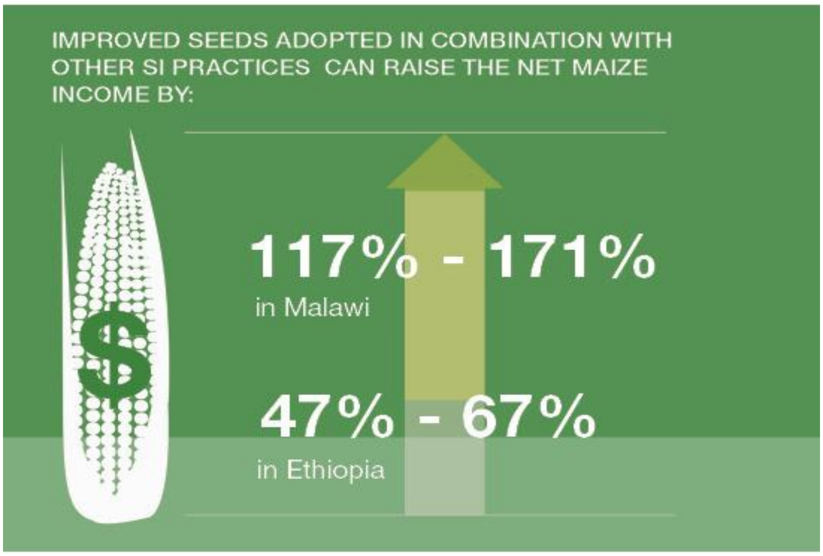
- What are the pathways through which empowering women within a household can participate in accelerated technology adoption? Is it through improving women's access to technologies on plots and crops that they already manage?
- Should women be involved in joint management in traditionally male managed crops and plots? Is household technology adoption and productivity best served through greater involvement of women in traditionally "men's crops" e.g. cash crops?
- Is household technology adoption and productivity best served through improvements in access to resources and technologies targeted at "women's crops" e.g. vegetables and small livestock?
- Does joint management of "women's and men's" plots and crops lead to better technology adoption and productivity outcomes?
- Are women empowered when resources are jointly or individually owned and/or managed?

Capacity development.

During the third annual meeting of the project one of the key issues raised and discussed was capacity development of partners. The first phase of the project witnessed that partners, particularly national partners, have limited technical capacity and staff to advance high quality research using the state of the art methods. The key guiding principle of capacity building beyond the Adoption Pathways project will be primarily that of ensuring sustainability of the work already achieved and started. Most important will be the need to build on capacity for continuous panel data collection, curation and dissemination. These efforts should focus on:

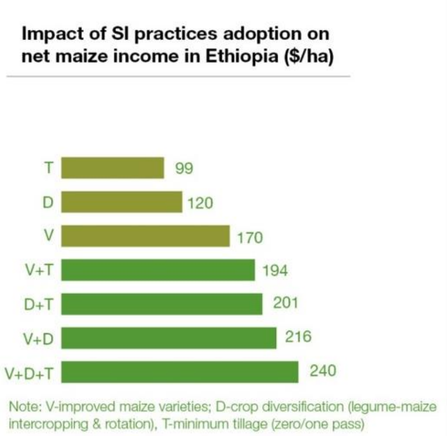
- Retooling existing and long-serving staff on extant and new methodologies .
- Support training of young scientists as part of preparing young scientists for future leadership in NARs and universities in their countries.
- Promote and increase the utilization of the Adoption Pathways data by graduate students, scientists, policy makers.

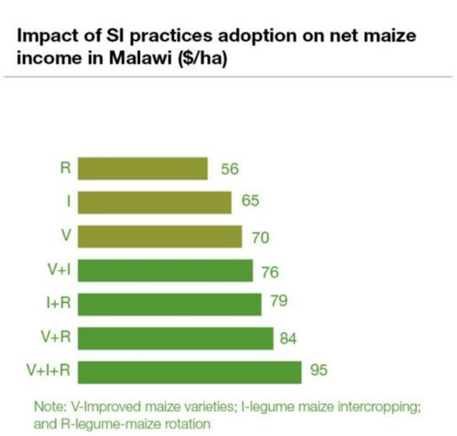
Portfolio selection: technology combinations lead to highest economic and environmental impacts



To achieve sustained high productivity food systems, improved and resilient varieties, application of adequate amounts of fertilizer and high standards of agronomic practices are required. A research paper based on data from Ethiopia and Malawi showed that adopting a suite of SIPs (minimum tillage, legume intercropping and rotations), together with complementary inputs such as improved seeds, can raise the net maize income in Ethiopia by 47 to 67 percent and 117 to 171 percent in Malawi and reduce (or at least not increase) fertilizer and chemical pesticides application without necessarily reducing farmers' net crop income.

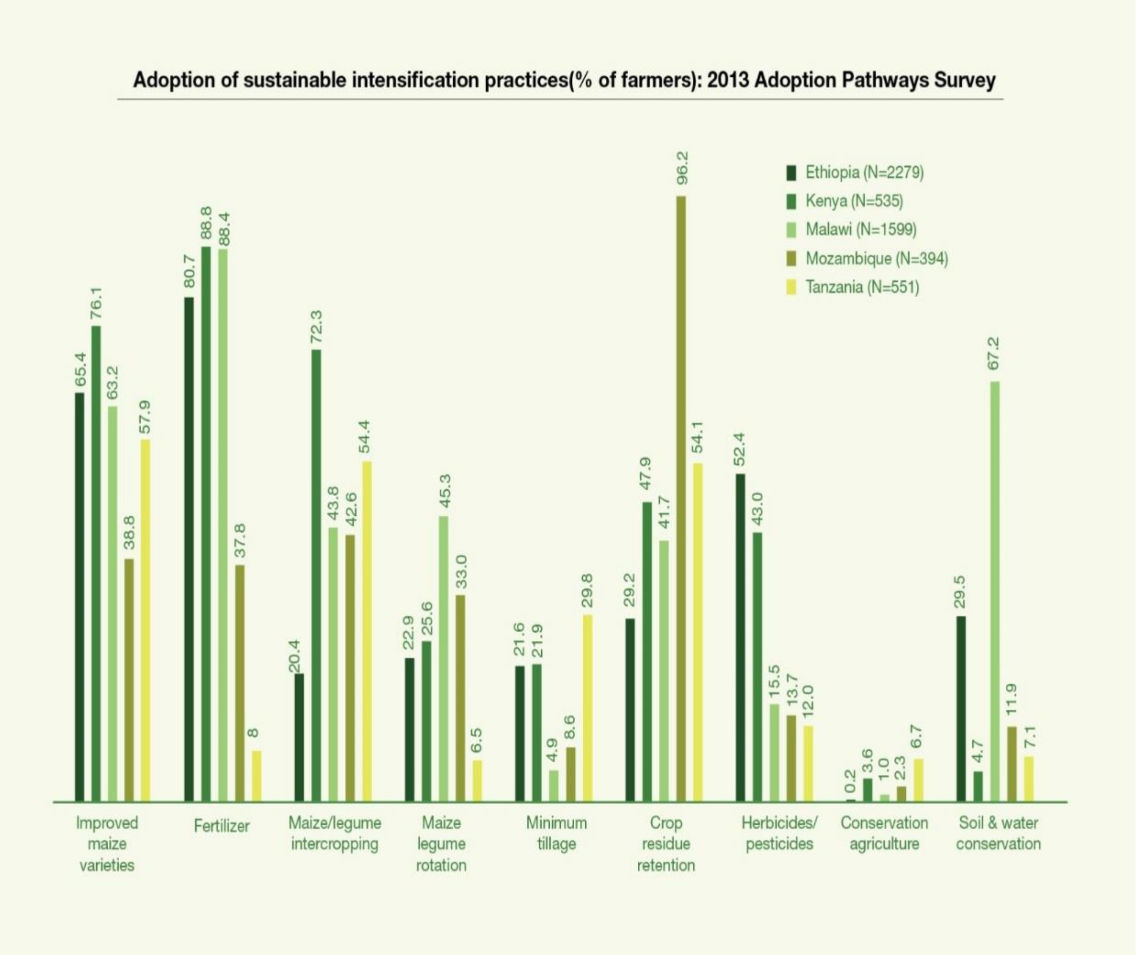
For more information contact: Menale Kassie at mkassie@icipe.org.

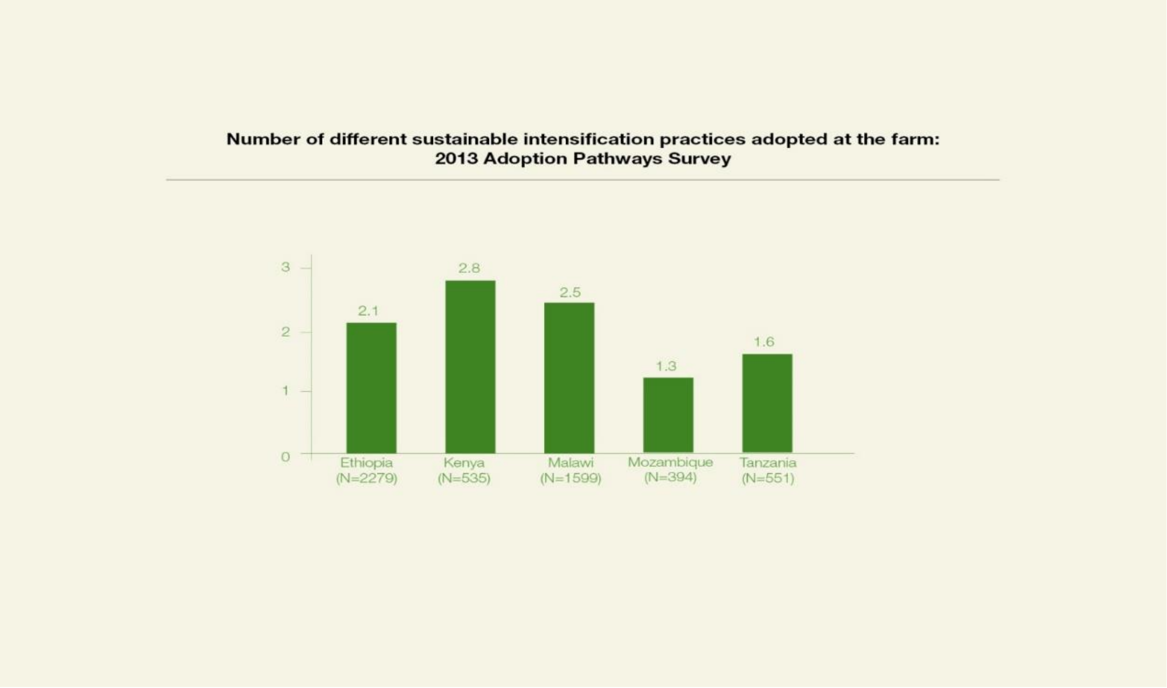




Boosting nutrition through adoption of SI practices

Malnutrition and food insecurity are key development challenges in sub-Saharan Africa (SSA), causing widespread diseases, poor health and even death. Promoting diversification of agricultural food production to enhance nutrition and alleviate





micronutrient deficiency, while improving and/or maintaining the natural resource base, is essential – particularly where farmers have limited opportunities for specialization and constrained access to diversified diets through local food markets. Using panel data in Ethiopia, the impacts of adoption of combination of SI practices (cropping systems diversification - (legume inter-cropping and rotation and improved maize seeds) on household nutrition was carried out. Results showed that 27 percent, 29 percent, 50 percent and 7 percent increase in Kcal, protein, iron and diet diversity, respectively, when crop diversification was adopted jointly with improved maize varieties.

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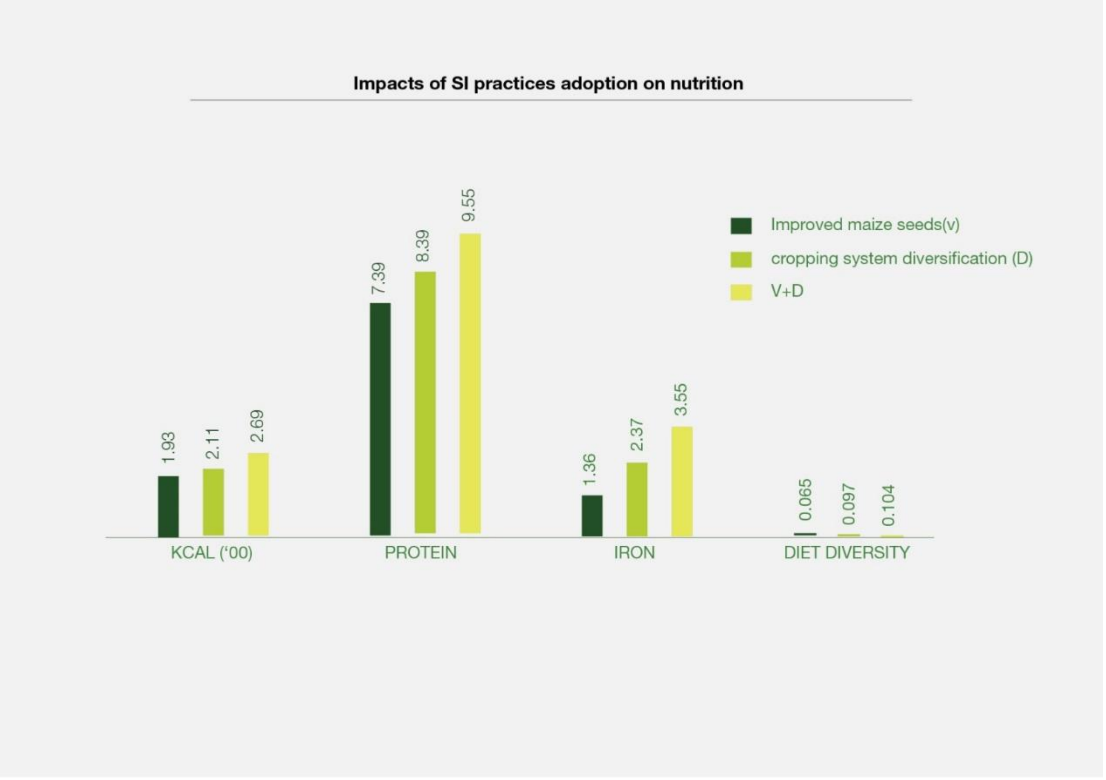


Input subsidies or extension: which policy should take precedence when supporting farmers?

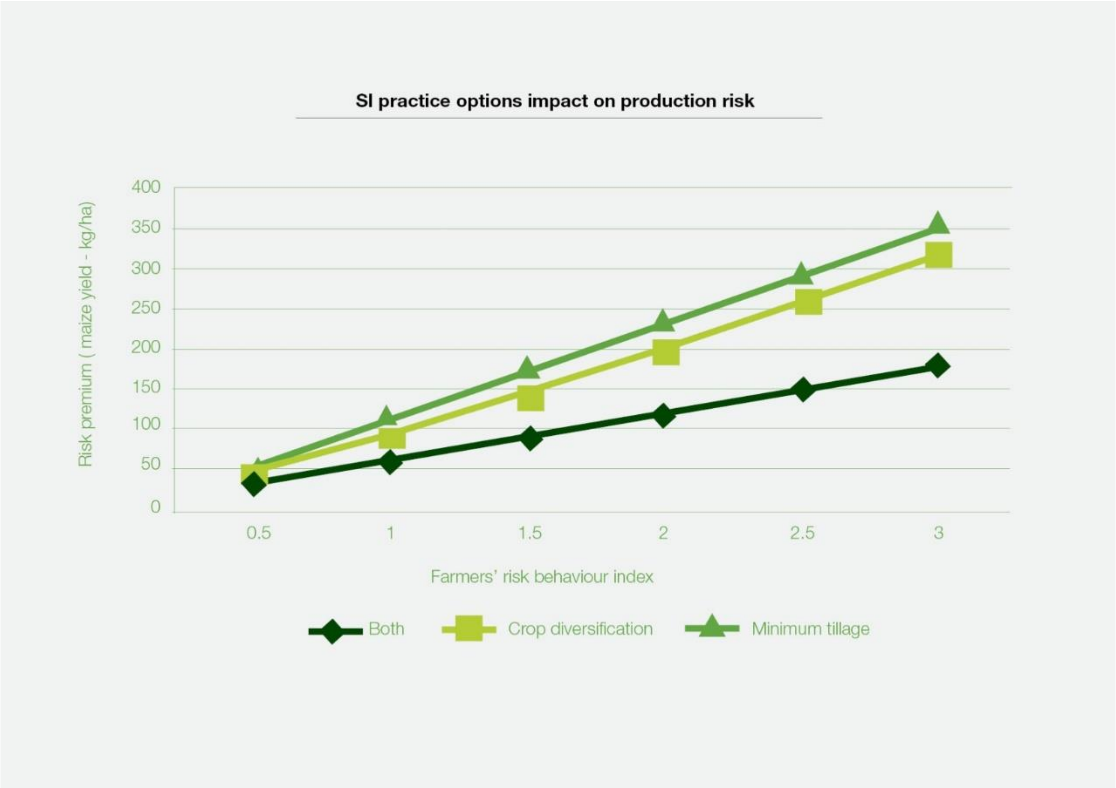
In a policy simulation study, the role of alternative policies such as input subsidy policies, investments in agricultural extension and access to markets in predicting the adoption of minimum tillage and mulching as components of SIPs was analyzed. Using data from 2,700 households in Ethiopia, Kenya, Malawi and Tanzania, and controlling for household and farm level factors, the simulated probabilities of adoption of minimum tillage and mulching were carried out based on varying levels of extension-to-farmer ratio, credit availability and government expenditures on input subsidies. The results indicate that the impact of input subsidies in predicting the adoption of the SIPs studied implies that lowering costs of complementary inputs (fertilizers, seeds, herbicides, and equipment) is central in encouraging adoption of SIPs. Considering that subsidies are essentially ways to reduce prices of inputs, diverse options for structurally lowering input-output price ratios should be of much policy interest. Investing in agricultural extension systems and increasing the number of extension personnel (increasing the extension personnel to farmer ratio for example) and expanding the reach of publicly funded extension systems among other complimentary providers is a crucial element in the success of adoption of SIPs was confirmed by the significant predictive power of high density of extension staff per farmer on probability of SIPs adoption in the policy simulations.

For more information contact: Paswel Marenya at P.Marenya@cgiar.org

Technology adoption and managing the risky business of smallholder farming

Smallholder agricultural production in Africa is done under various abiotic and biotic stressors. It is a truism that risks are an unavoidable part of many economic and social undertakings. In smallholder agriculture, managing these risks is an important aspect of protecting livelihoods and opening up opportunities for investment and income growth. A higher crop yield and a reduction in the chance of crop failure were achieved when farmers jointly adopted crop diversification (legume intercropping and rotations) and minimum tillage. The adoption of these two SIPs was found to be associated with changing the distribution of maize yields above the mean suggesting reduced probability of crop failure. When analysing how to achieve productivity and resilience, these and other SIPs can be seen as important risk mitigation strategies.

For more information contact: Menale Kassie at mkassie@icipe.org



No shortcuts: Food security is tied to adoption of hybrids and other improved varieties

Even when research and extension systems have evidence that improved varieties are superior in terms of yield, their impact on household welfare cannot be taken for granted. Research that evaluated the impact of improved maize varieties on food security and other welfare indicators found strong empirical connections between the area planted under improved varieties. The empirical association of better varieties and food security outcomes suggests that few shortcuts exist for rural households to secure food security absent adequate or income and market mediated food access.

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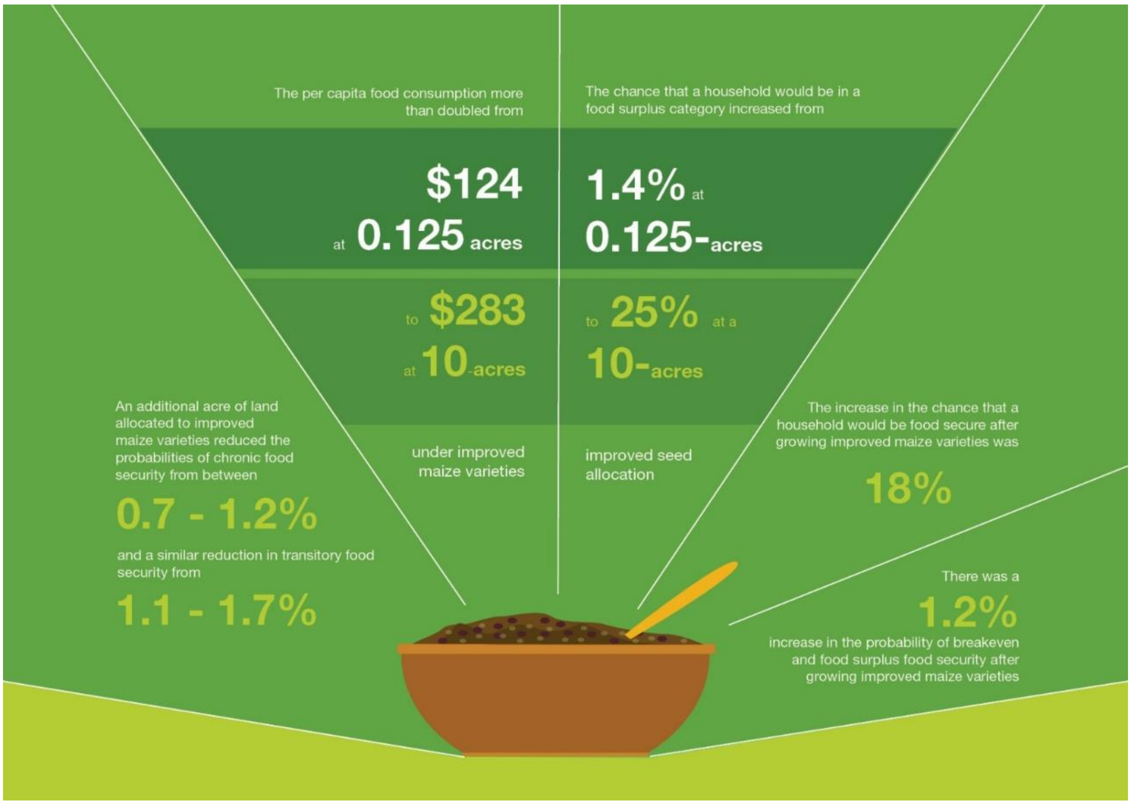

How to achieve inclusive policy support for rural households: results from an agricultural household model

Malawi has one of the highest population densities in East and Southern Africa. In the absence of alternative economic opportunities, many households can remain stuck in an endless poverty trap of low agricultural productivity and low incomes. The government of Malawi has in recent years implemented large-scale fertilizer and seed subsides in an effort to boost maize production and avoid food crises.

A major feature of the subsidy program is to target households with reasonable amounts of land at the risk of ignoring the equity issues arising from the fact that near-landless or landless households may be by passed by the subsidy program. To rectify this situation one suggestion, based on the notion that fertilizer is a land augmenting technology, is that the subsidy need not ignore those with limited land. If this kind of inclusion is not possible, then safety net employment programs should be put in place to reach those with little or no land who may not benefit from input subsidy program. Otherwise a large portion of poor rural households may miss out on these public programs.

For more information contact: Stein Holden at stein.holden@nmbu.no

Balancing risk and resource allocation: learning from farmers

The UQ research team, in close collaboration with the CIMMYT and national partners in Ethiopia, developed a new tool – a farm household decision analysis model – that captures the reality of decision-making by poor farm households. The model incorporates farmers' well-known tendencies for risk aversion and the safety-first approach to ensuring family food security in determining options to improve their livelihood attainments while working within tight resource constraints and limited opportunities for trade-linked exchange. Initial results from the Central Rift Valley region of Ziway, Ethiopia, indicate that farmers have limited ex post risk management measures, and hence they tend to discount potential gains more heavily and prefer farming systems that are more like the status quo. While those with access to irrigation and markets can improve income significantly through diversified farming systems involving multiple cropping, staggered planting and the use of improved varieties and practices, maize-legume farming systems appear to be the solution for more risk averse farmers who have limited abilities for risk mitigation. It is unlikely that the majority of farmers who own less than 0.9 ha of land will find full self-sufficiency of family food requirements from a family farm, unless intensive multi-crop farming systems can be supported with irrigation, making the farm less sensitive to variation in climate.

For more information contact: Thilak Mallawaarachchi at t.mallawaarachchi@uq.edu.au

Identifying and **Rectifying Gender Gaps:** results on technology adoption, food security and market access

Looks can be deceiving: why do households headed by men have better food security than otherwise similar households headed by women?

The notion of gender equality is central to the very concept of social development. The research results summarized here explained why given equivalent opportunities in terms of resources and demographic profiles to those of male-headed households (MHHs), female-headed households (FHHs) still tended to perform worse than their MHH counterparts in terms of food security, technology adoption and market access. The results from this research suggested that the food security status of households headed by women would be enhanced by improving the resource levels and the quality of those resources available to households headed by women.

This implies that appropriate policy responses aimed at closing gender gaps in agriculture should concern themselves with closing observed resource gaps but also deal with subtler issues behind those gaps. These latter issues include the quality of those resources, their differential returns compared to resources held by men and other hard-to-observe social norms and biases that sustain gender gaps in agriculture.

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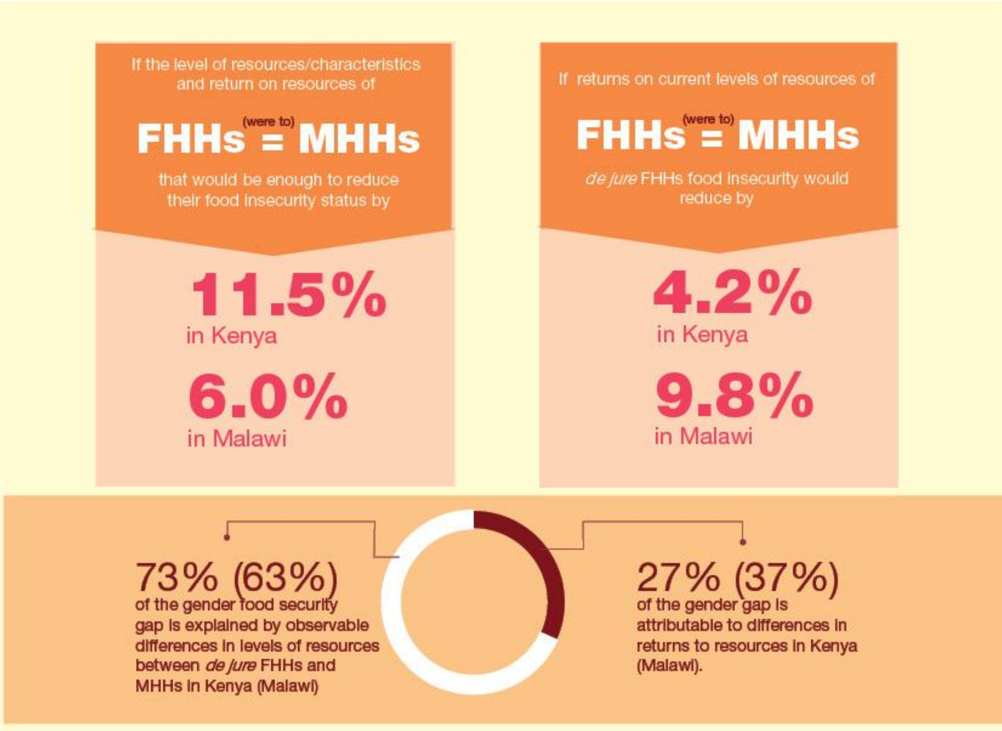

Gender differences in market access: can female-headed households be better off?

Gender-based differences are major determinants of successful participation in agricultural markets among rural households in sub-Saharan Africa. Critical knowledge gaps remain on how to improve women's participation in markets so that opportunities for agricultural development are inclusive, equitable and broad based. Gender differences in agricultural productivity have received more empirical attention than aspects of market participation. Using data from Ethiopia, the study summarized here analyzed the factors that may underlie differences in maize market participation based on the gender of the household head. This research examined the implications of the gender of the household head on market participation among 2,800 smallholder maize farmers in Ethiopia and Kenya.

Generally, male-headed households (MHHs) were found to be more likely to be net sellers of maize and female-headed households were more likely to be net buyers of the commodity. An empirical decomposition of these gaps showed that factors related to returns to (rather than the observed levels of) assets such as farm size, human capital or social networks accounted for 74 percent of the gender gap in favor of MHHs in terms of ability to enter markets as net maize sellers. In terms of being net maize buyer, 65 percent of the gap was explained by these returns effects.

Somewhat differently, endowment effects largely explained the gap between FHH and MHHs regarding quantities of maize sold. This is consistent with the notion that the ability to generate sellable surpluses is in fact driven largely by differences in input use levels, land size and other resources necessary to generate sellable quantities of maize. This agrees with the frequent finding in the literature that women are likely to be as productive as men once resource endowments are equalized. However, market access and participation appear to be mediated by overwhelming structural issues related to transactions costs, information and returns to assets that enable market access.

For more information contact: Paswel Marenya at P.Marenya@cgiar.org

Examining intra-household input use: how to enable women access to more agricultural inputs

Using plot level data, the study summarized in this section examined the differential fertilizer application rates on plots managed individually by men, women, or jointly in dual adult households in three districts in south-central Mozambique. The results suggest that – controlling for the demographics of the manager and plot characteristics – joint management of agricultural plots was associated with higher fertilizer application rates on maize plots but with lower fertilizer application on non-food cash plots. The results seem to suggest that because jointly managed plots are not straightforward or assured received more inputs, if equitable sharing of proceeds from jointly managed plots, then efforts to increase access to inputs by women may need to be targeted at plots already managed by women themselves. In land-scarce environments where women are less likely to have parcels to cultivate autonomously, these results suggest that improving women's bargaining power regarding the destiny of crops produced and financial proceeds from jointly managed plots can be a critical factor in facilitating gender equality in input use and benefit accrual.

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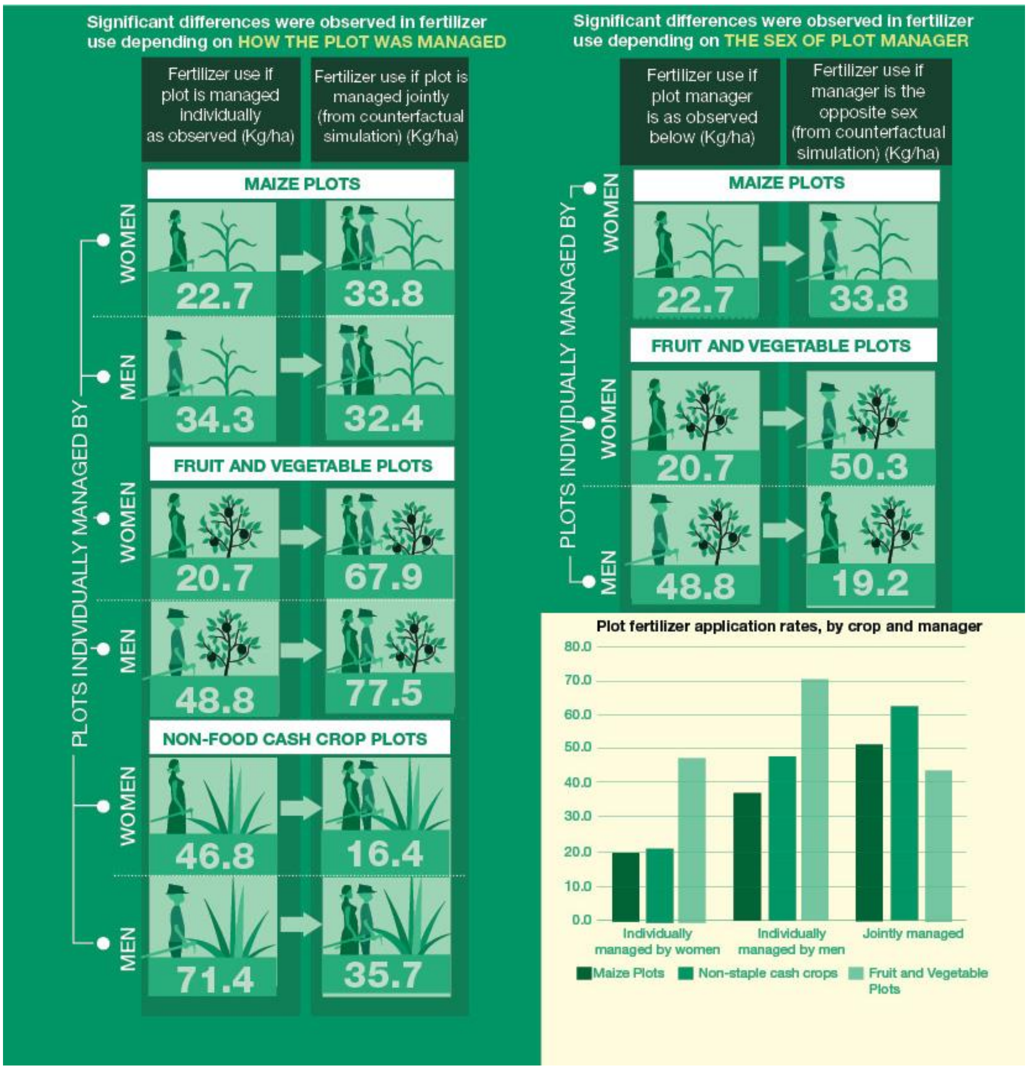


Developing the Women Empowerment in Agriculture Index (WEIA).

In order to achieve equity, both men and women have to be empowered to make informed decisions and participate meaningfully in agricultural production. Greater understanding of how the rural development context affects men and women in their participation in development activities is critical for the effectiveness of development of interventions. In relation to this, the APP data from Tanzania and Ethiopia were used to compute the Women Empowerment in Agricultural Index (WEAI). The data captured four domains of empowerment (4DE)[3] instead of the 5DE proposed by USAID. Findings from the two countries are discussed below.

Findings from Tanzania

While a full-scale women's empowerment index was not computed, the disempowerment measure suggests women may be more empowered in terms of social capital (as defined by group membership), compared to men. Access to credit, participation in speaking in public, and control of assets and income are areas of disempowerment to be dealt with. Women's relative autonomy in production should be matched by the ability to make production decisions, control resultant incomes and participate in community governance.

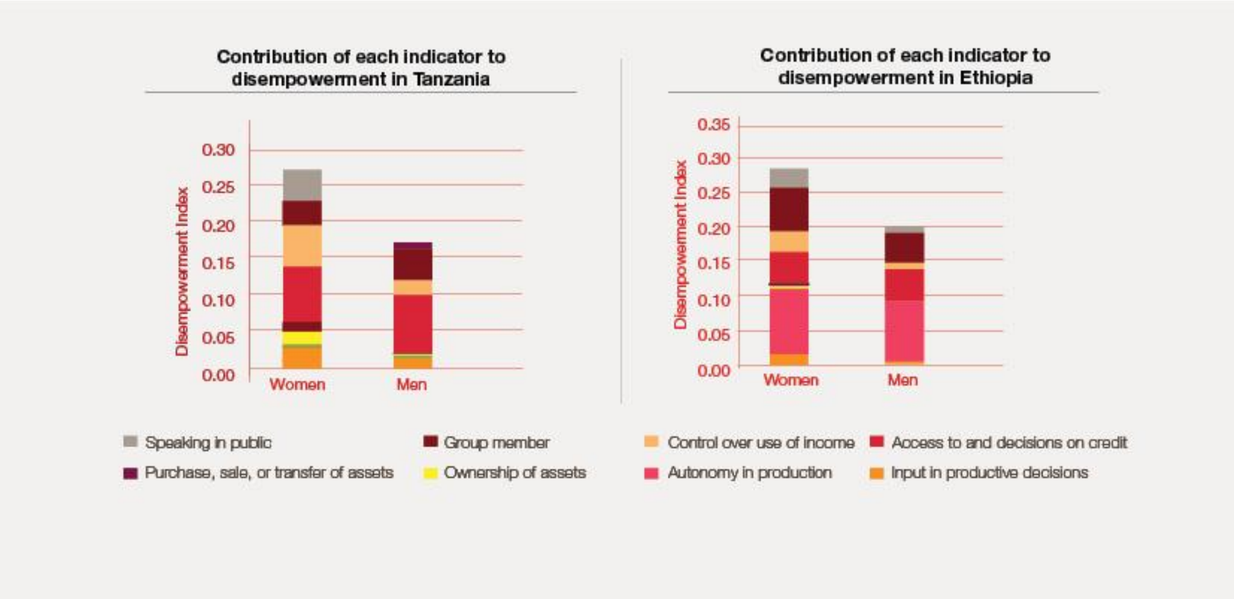
Findings from Ethiopia

A similar story emerged in Ethiopia where women tended to be more disempowered compared to their male counterparts. The indicators that contributed the most to women's disempowerment in Ethiopia were input in productive decisions; ability to speak in public, ownership and control over resource use and control over use of income. Over half of the women were found to not belong to any group compared to only 35 percent of men. On the other hand, almost half of the observed disempowerment among men is attributed to autonomy in production indicators and access to and use of credit.

In summary, the comparisons of the national level analysis from the two countries bring out important differences that require focused attention when dealing with disempowerment in different contexts. Lack of autonomy in production is an area that makes a significant contribution to disempowerment in Ethiopia while in Tanzania access to and decision on use of credit is a major source of disempowerment. Access to and use of credit seemed to be a common constraint in both countries, but its level of importance was different being more significant in Tanzania.

For more information contact: Ruth Meinzen-Dick at r.meinzen-dick@cgiar.org

[3] These domains include production, resources, income and leadership. The fifth domain was time used in productivity, domestic tasks and leisure. Each domain except income has more than one indicator. The input in productive decisions and autonomy in production and group membership and speaking in public indicators represent production and leadership domains respectively. Ownership of assets, purchase, sale or transfer and access to and decision about credit fall under resource domain.



Further readings:

The results presented in this brochure are a summary of a series of publications that have variously been produced by researchers working within the Adoption Pathways Project and in collaborating projects. These are listed below to provide the interested reader with a more complete reading of these results and some of these publications are available at http://aciar.gov.au/aifsc/projects/adoption-pathways, publisher/journal websites and project partner websites.

Journal Articles

1. Beyene, A.D. and Kassie, M. 2015. Speed of adoption of improved maize varieties in Tanzania-an application of duration analysis. Accepted for publication in Technological Forecast and Social Change , 96:298-307.

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6. Kassie, M., Teklewold, H., Marenya, P., Jaleta, M. and Erenstein, O. 2015. Production risk and food security under alternative technology choices in Malawi. Application of a multinomial endogenous switching regression. Journal of Agricultural Economics. doi: 66(3): 640-659.
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7. Kassie, M, Simon, W., and Jesper, S. (2014). What determines gender inequality in household food security in Kenya? Application of exogenous switching regression. World Development, 56: 153-171.
8. Kassie, M., Stage, J., Teklewold, H.; and Erenstein, O. (2015). Gendered food security in rural Malawi: Why is women's food security status lower? Food Security, 7:1299-1320.
9. Marenya, P., Kassie, M. and Tostao, E. (2015). Fertilizer use on individually and jointly managed crop plots in Mozambique. Journal of Gender, Agriculture and Food Security, 1(2), pp 62-83.
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11. Tessema, Y., J. Asafu-Adjaye, D. Rodriguez, T. Mallawaarachchi and B. Shiferaw (2015) 'A Bio-economic Analysis of the Benefits of Conservation Agriculture: The Case of Smallholder Farmers in Adami Tulu District, Ethiopia', forthcoming, Ecological Economics.
12. Wagura, S.; Kassie, M. and Shiferaw, B. (2014). Are there systematic gender differences in the adoption of sustainable agricultural intensification practices? Evidence from Kenya. Food Policy, 49:117-127

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1. Asafu-Adjaye, J, Mallawaarachchi, T. and Yirga, C. (2014). Understanding farmers' ex-ante risk management and ex-post risk coping strategies for climate risk: A case study of smallholder farmers in North West Ethiopia. Adoption Pathways Project Working Paper No. 4/2015.
2. Hitomi, K. (2014). Women's empowerment in agriculture in Tanzania using Adoption Pathways Survey. Adoption Pathways Project Working Paper No. 6/2015.
3. Holden, S. T. (2013). Input subsidies and demand for improved maize: Relative prices and household heterogeneity matter! CLTS Working Paper No. 6/2013. Centre for Land Tenure Studies, Norwegian University of Life Sciences, Ås, Norway.

4. Holden S.T. (2013). High discount rates: - An artifact caused by poorly framed experiments or a result of people being poor and vulnerable? CLTS Workingw Paper No. 8/2013. Centre for Land Tenure Studies, Norwegian University of Life Sciences, Ås, Norway.
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25. Mulwa, C. Marenya, P., Rahut, D. and Kassie, M. (2015) Response to Climate Risks among Smallholder Farmers in Malawi: A Multivariate Probit Assessment of the Role of Information, Household Demographics and Farm Characteristics.https://www.conftool.com/icae2015/index.php?page=browseSessions&form_date=2015-08-14&presentations=show
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28. yaa, M. (2015). Adoption of sustainable agricultural intensification technology under small-scale maize-legumes production in Mvomero and Kilosa districts. Msc thesis.
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Policy Briefs

1. Food security as a gender issue: Why are female-headed households worse off compared to similar male-headed counterparts? Socioeconomics program Policy brief No 1.

2. Give and Take: Tackling trade-offs in crop residue use for conservation agriculture in Kenya. Socioeconomics program Policy brief No 2.

3. Input subsidies and improved maize varieties in Malawi: What can we learn from the impacts in a drought year?

4. Improved maize varieties and household food security: Achieving impact in Tanzania. Socioeconomics program Policy brief No 6.

5. Love, A., Magnan, N., and Colson, G.J (2015). Mens' and women's risk preferences: Evidence from the adoption of maize technology in Kenya. Adoption Pathways Policy brief No. 1

6. Low risk, high returns: How adoption of crop diversification and minimum tillage is a win-win for smallholder farmers in Malawi. Socioeconomics program Policy brief No 5.

7. Sustainable agricultural intensification in Ethiopia: Achieving maximum impact through adoption of suites of technologies. Socioeconomics program Policy brief No 3.

8. Sustainable agricultural intensification through multi-technology adoption: A regional overview from East and Southern Africa. Socioeconomics program Policy brief No 4.

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