Strides in Sustainable Agricultural Intensification: Contributions of the Africa RISING Program

(2011–2023)

Edited by Jonathan Odhong and Guy Manners

AN END-OF-PROGRAM REPORT

The Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) program comprised three regional research-in-development projects supported by the United States Agency for International Development as part of the US Government's Feed the Future initiative. Inaugurated in late 2011 and implemented in two phases (to 2023), the purpose of Africa RISING was to provide pathways out of hunger and poverty for smallholder farm families through sustainably intensified farming systems that sufficiently improve food, nutrition, and income security, particularly for women and children, and conserve or enhance the natural resource base.

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Foreword

Over a decade ago, USAID had a nearly impossible request. How can we conduct cutting-edge and prioritized research while broadening the complexity of this research to ensure agriculture simultaneously delivers greater productivity, profitability, environmental sustainability, and social and human outcomes. At the time of this request, food production was increasing in our Feed the Future focal countries but there was still rapid expansion of agricultural lands and the very farmers that were producing this food were facing increasing rates of poverty, hunger, and malnutrition. Food production alone was not leading to our developmental goals. The research agenda had to shift from a focus on food production alone, to food productivity for impact on livelihoods. Africa RISING took on this challenge and has delivered – both with impacts during the program and in establishing a foundation for the future of farming systems research for development.

Africa RISING simultaneously pioneered the methodologies for conducting systems research and used these new methods to identify keystone technologies and approaches that drove broader systems progress. These keystone innovations included agronomy, soil health, crop genetics, livestock management, mechanization, food storage and safety, and bundles of these practices that were assessed and adapted to maximize system outcomes. Advancements moved beyond the development of the technologies alone, to assessing the systems trade-offs and synergies across both biophysical and socio-economic indicators that then guided the bundled innovations to optimize system outcomes. This proved to be fundamental to ensuring agricultural gains led to livelihood gains.

Essential to this success was Africa RISING's process for bringing transdisciplinary teams together, leveraging the strengths of multiple CGIAR institutions, and ensuring local institutions and farmers were co-leads throughout. This process both guided the co-creation of the research agenda and facilitated the bidirectional transfer of innovations and learning into demand-driven pathways to scale. In addition to the research to develop and improve new innovations, Africa RISING made research advancements on the approaches for accelerating and sustaining technology transfer and scaling. This included conducting participatory action research, developing multi-stakeholder innovation platforms, and developing technology park and lead farmer scaling pathways.

Perhaps equally as important to the research agenda was Africa RISING's partnerships and the processes for disseminating research outputs. From day one, Africa RISING ensured technology development was demand-driven, co-designed, and locally owned. National scientists co-led the research activities and local institutions owned the outputs. This proved to be a multiplier, supporting the flow of research outputs reaching millions of beneficiaries over the life of the program and sustaining delivery into the future.

USAID extends its deepest appreciation and congratulations to the Africa RISING team for charting a new path to ensure agriculture-led growth lifts millions out of hunger, poverty, and malnutrition.

Jerry Glover and Zach Stewart

Bureau for Resilience, Environment, and Food Security
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Preface

Sustainable agricultural intensification (SAI) remains a key focus topic in Africa. The continent's need to double food production and feed the growing human population without compromising its natural resource base continues to make SAI an imperative. The Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) program was born out of this need in 2011 when the USAID Agricultural Research Division solicited proposals to address this challenge. USAID's concern at the time was about the limited information on specific practices with the most significant potential to contribute to sustainable intensification and thus food security for smallholder farmers in sub-Saharan Africa.

The mission of Africa RISING was thus set: to integrate action research and development partnerships to create opportunities for smallholder farm households to move out of hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, particularly for women and children, and conserve or enhance the natural resource base. Over 12 years, through two phases of implementation, the Program focused on this mission and, in the process, made several strides in providing farmers with viable options for sustainable intensification.

These strides have been made in terms of practical crop–livestock sustainable intensification (SI) innovations for farmers and how to integrate them successfully in the context of the farming systems in which they were validated. Through Africa RISING, the Sustainable Intensification Assessment Framework (SIAF) was piloted and fine-tuned by scientists, providing a criterion for evaluating the inherent trade-offs that were hitherto overlooked in assessing innovations – yet another stride highlighted in Chapter 3 of this report.

Implementing a program successfully and integrating the rich contributions of a transdisciplinary team of scientists and development practitioners, as Africa RISING has done over the years, presents an excellent learning opportunity shared in Chapter 4 of this report. These lessons cover governance and management, experiences in implementing farming systems research by integrating biophysical and socio-economic sciences in collaborative innovation research and deployment, gender integration into the selection and promotion of technologies, approaches for optimum technology transfer, capacity building, and more.

It is important to recognize that Africa RISING did not begin with a well-defined proposal and program design, rather through co-creation by the core team and partners it evolved over time and offered an opportunity to integrate lessons learned through the years. However, a firm commitment to intervention communities was one of the most exciting and relevant characteristics of Africa RISING. Long-term research-in-development in the same communities endows Africa RISING with an institutional memory that is valuable and needed for sustainable intensification. Therefore, we hope this report helps share the nuggets of wisdom from our institutional memory gained from this one-of-a-kind 12-year program.

We trust that the lessons learned from the Africa RISING Program and the innovations validated through the Program

will be advanced further by the newer CGIAR Initiatives and others involved in farming systems research and sustainable intensification work. As highlighted in Chapter 5 of this report, aptly titled 'Passing the Baton', some of that experience-sharing has actively started with the One CGIAR Initiative on Sustainable Intensification of Mixed Farming Systems. We hope this can continue, and this report will be a facilitative document for that process.

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Acknowledgements

Various individuals have aided in putting together this End-of-Program Report for the Africa RISING Program from conceptualization to a published open-access resource. It provides rich reading, highlighting the successes and valuable lessons learned after over a decade of program implementation by various partners in six countries. We thank the United States Agency for International Development (USAID) for not only funding this publication but also the entire research and development work of the Africa RISING Program that positively impacted the lives of millions of smallholder farmers through agricultural innovations developed and promoted with the objective of sustainable intensification. This vital support was given through the US Government's Feed the Future Initiative. The editors of this report also greatly appreciate the time and effort put in by various contributors who drafted some sections of this report and offered to review drafts at different stages. This interdisciplinary team of contributors was the bedrock of the Program's achievements! In equal measure, we thank the farmers and partners in all Africa RISING Program countries – Ethiopia, Ghana, Malawi, Mali, Tanzania, and Zambia. Further thanks go to: Robert Bertram, Jerry Glover, Zachary Stewart, Betty Maeda, and Harry Ngoma of USAID, for their immense and constant support to the Africa RISING Program. Finally, we appreciate the support of the editors and designers at Green Ink, who have been instrumental in putting this document together into a quality product.

Abbreviations

CIMMYT	International Maize and Wheat Improvement Center
COVID-19	coronavirus disease 2019
EPA	Extension Planning Area
ESA	East and Southern Africa
FtF	Feed the Future
GAPs	good agricultural practices
GIZ	German Agency for International Cooperation
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
iREACH	Innovation, Research, Extension, and Advisory Coordination Hub
M&E	monitoring and evaluation
NARS	national agricultural research system
NGO	non-governmental organization
PVS	participatory varietal selection
SAIRLA	Sustainable Intensification of Agricultural Research and Learning in Africa
SIAF	Sustainable Intensification Assessment Framework
SIMLEZA	Sustainable Intensification of Maize–Legume Systems in Eastern Province of Zambia
SMS	short message service
USAID	United States Agency for International Development
WECARD	West and Central African Council for Agricultural Research and Development (French acronym is CORAF)

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Happy livestock farmers at Duko village in northern Ghana after harvesting forage. Photo credit: Wilhelmina Ofori Duah/IITA.

Chapter 1

Introduction

The Africa RISING continuum[1]

The genesis of the Africa RISING program stemmed from initial discussions between scientists from the International Institute of Tropical Agriculture (IITA), the International Livestock Research Institute (ILRI), and the United States Agency for International Development (USAID) in the late 2000s. This took place against the backdrop of the 2008 global food crisis, which spurred interest in boosting agricultural productivity in Africa. At that time, the emphasis in agricultural research was on increasing food production to meet growing population needs.

USAID was keen to fund an integrated research program to holistically address the multiple challenges faced by smallholder farmers, in contrast to the more narrowly focused crop or livestock projects typical at that time. With USAID support through the United States Government Feed the Future initiative, three regional Africa RISING projects were conceived to fill this niche: East and Southern Africa Project (implemented in Malawi, Tanzania, and latterly Zambia); Ethiopian Highlands Project; and West Africa Project (implemented in Ghana and Mali). Today, the groundwork laid by the Africa RISING Program (a collective of the three regional projects) has advanced the focus of agricultural research toward sustainable food systems perspectives and climate change adaptation.

The aim was to sustainably intensify agricultural production systems while considering trade-offs and consequences across components (an integrated systems approach spanning soils, water, livestock, crops, socio-economic, and other factors), rather than compartmentalized ('siloed') interventions. This integrated perspective was novel compared with previous projects tackling issues in isolation.

A major contributory factor to the success and longevity of Africa RISING was the donor's – USAID's – flexibility. Their desire was to help smallholder farmers improve their lives in the long term, rather than aiming for short-term results and to approve how every dollar of public funds should be spent. This gave the program an immense degree of flexibility that is extremely rare in donor-funded projects, and meant that the implementing teams within the respective projects could be 'agile' in the face of changing circumstances on the ground.

Phase 1 of Africa RISING (2011–2016) concentrated on problem diagnosis, technology testing, and validation through participatory research with farmers across three regions in sub-Saharan Africa. After compiling an initial list of potential key partners for such an integrated multidisciplinary research program, competitive grants were awarded for short-term 'quick win' projects, with the aim of producing small deliverables within 6–8 months to showcase early outputs in the first year (a donor requirement). Concurrently, the process of developing the overarching research framework was unfolding through an organic process involving articulating core hypotheses and research questions toward the goal of sustainable intensification; this built on the program's theory of change (Fig. 1). A major undertaking was formulating the Sustainable Intensification Assessment Framework (SIAF) to measure and analyze sustainability indicators related to productivity, economic, environmental, human, and social dimensions. Multidisciplinary country and project teams were formed across the regions, planning meetings held, and physical project offices established in strategic locations in Ethiopia, Ghana, Malawi, Mali,

1 Based on an interview with Irmgard Hoeschle-Zeledon and Peter Thorne.

Africa RISING partners discuss phase II research agenda during a planning and review meeting in November 29–30, 2016. Photo credit: Apollo Habtamu/ILRI.

and Tanzania. The International Food Policy Research Institute (IFPRI) led an extensive process of identifying suitable sites for research across diverse agro-ecosystems and farming systems.

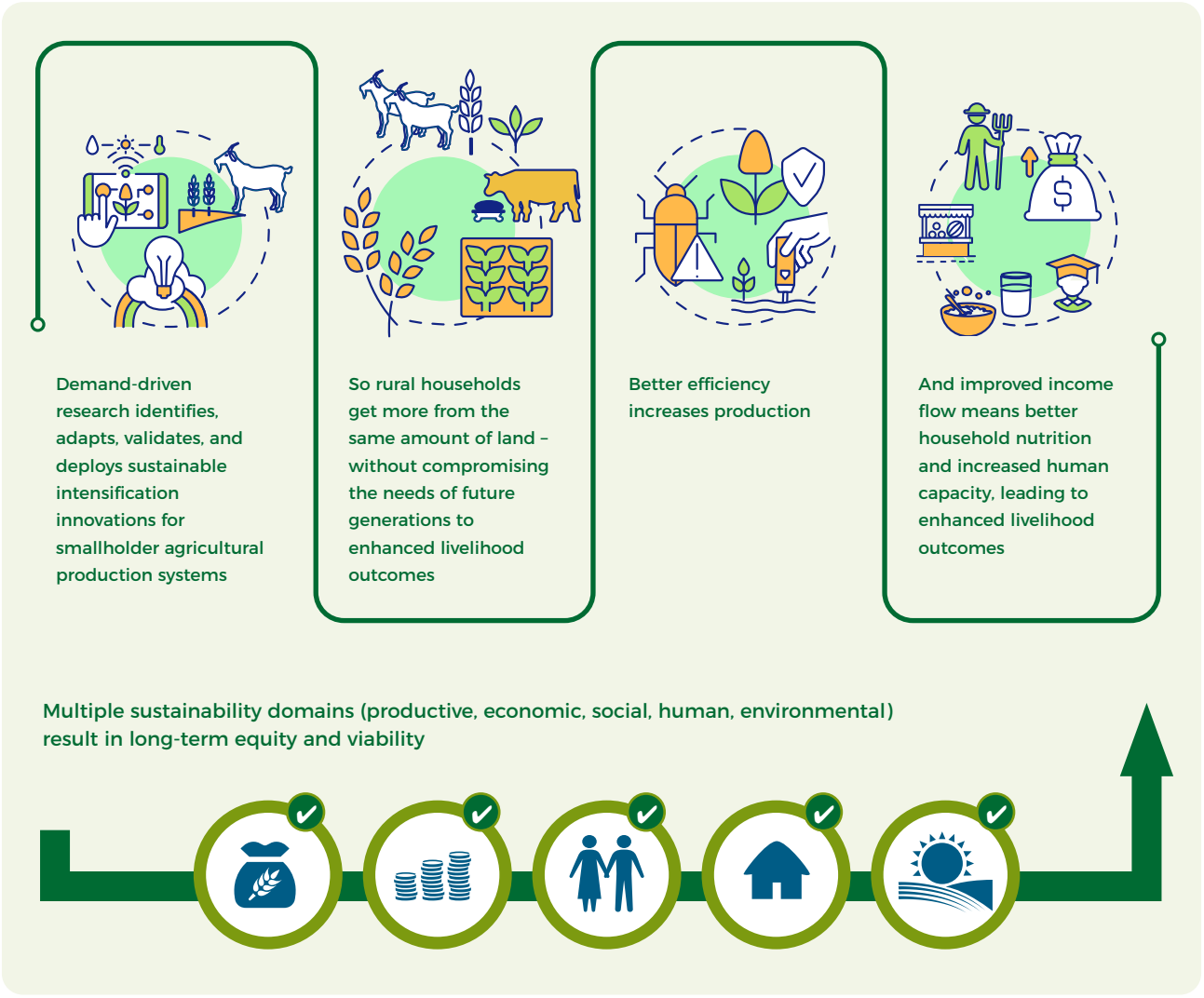
Key outcomes included honing effective coordination across the three lead CGIAR centers (IITA, ILRI, IFPRI) and over 130 partner organizations, plus extensive capacity building of national researchers and institutions through graduate training programs and short-term training. In 2013, the project was expanded by USAID to incorporate certain activities from SIMLEZA, a concluding project in Zambia. The following year, SIMLEZA–Africa RISING extended at least six sustainable intensification technologies to 807 farmers in Eastern Province, Zambia, through mother–baby trials.

The transition to Phase 2 was smooth, helped by retention of core staff and continuity of activities, as well as a natural evolution of the program's theory of change. Phase 2 (2017–2023) prioritized scaling of proven technologies through development partners, while continuing context-specific adaptive research – for example, Phase 2 was expected to benefit 1.1 million farmers (directly and indirectly), while during Phase 1 the program had worked directly only with thousands. A hallmark of Phase 2 was flexibility to pivot in response to emerging issues, without the strict logframes and timelines typical of more rigid projects. When potential program termination arose due to funding uncertainty in mid-2017, efforts rapidly shifted toward wind-down activities such as synthesizing findings, analyzing already collected data, and producing extension materials to share results. When normal funding flows resumed in 2018, the research and scaling work was quickly put back on track.

The main highlight of Africa RISING was research translated into action and benefits – a balance between research and ground-level action resulting in direct benefits for farmers. However, the well-attended program-wide annual meetings – 'learning events' – that built camaraderie across countries, projects, and the diversity of partners involved was a highlight for project staff and partners alike. Exchange visits enabling staff from one regional project to spend time with another were also impactful for sharing knowledge, learning from each other, and fostering connections across the program.

Major successes involved mainstreaming innovative project practices into government programs and partner non-governmental organization (NGO) initiatives, for example fertilizer recommendations developed

Figure 1. The Africa RISING theory of change.



Source: Redrawn from Africa RISING. 2018. *Footprints of Africa RISING. Phase I: 2011–2016.* International Institute of Tropical Agriculture, Ibadan and International Livestock Research Institute, Addis Ababa. (https://hdl.handle.net/10568/92816). (© CC BY 4.0)

in Ethiopia (see box in section 3.4) and doubled-up legume systems in Malawi (section 3.2, p. 27). The USAID Missions in Malawi, Tanzania, and Zambia also directly funded complementary projects implemented through Africa RISING platforms in those countries. And **more than 244 peer-reviewed academic publications** advanced global scientific knowledge related to sustainable intensification (see Appendix).

Significant legacies include the research and leadership capacity developed among hundreds of students trained through their involvement in the projects; establishing effective coordination approaches across diverse CGIAR centers and partners; and providing an influential model for integrated systems research. The latter has guided the design of subsequent initiatives such as the One CGIAR Initiative on Sustainable Intensification of Mixed Farming Systems incepted in 2022. Africa RISING's longevity of about 12 years was itself a major achievement, catalyzed by a flexible donor and responsive program leadership.

Africa RISING program partners group photo during a learning event held in Addis Ababa, Ethiopia on 24-26 September 2013. Photo credit: Apollo Habtamu/ILRI.

Chapter 2

Highlights of Africa RISING Achievements

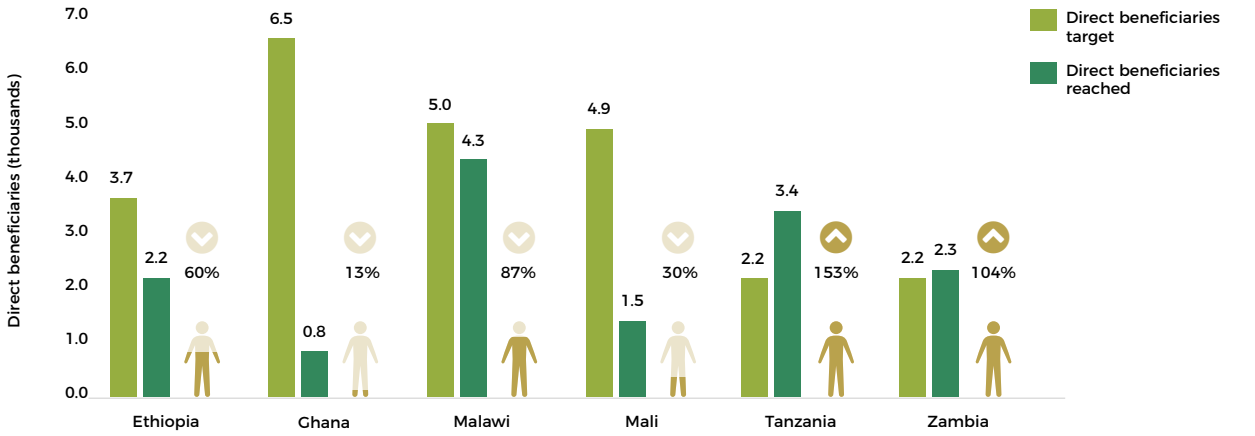
This chapter presents some highlights of the Africa RISING program's achievements, with a focus on overall program reach (Men numbers of beneficiaries) and impacts in relation to the SIAF indicators. Other achievements and lessons are included the subsequent chapters of this report.

Program reach[2]

Direct program beneficiaries

Direct beneficiaries (Fig. 2) are those involved in participatory testing, validation, and application of Africa RISING sustainable intensification innovations (e.g., in mother–baby trials).[3]

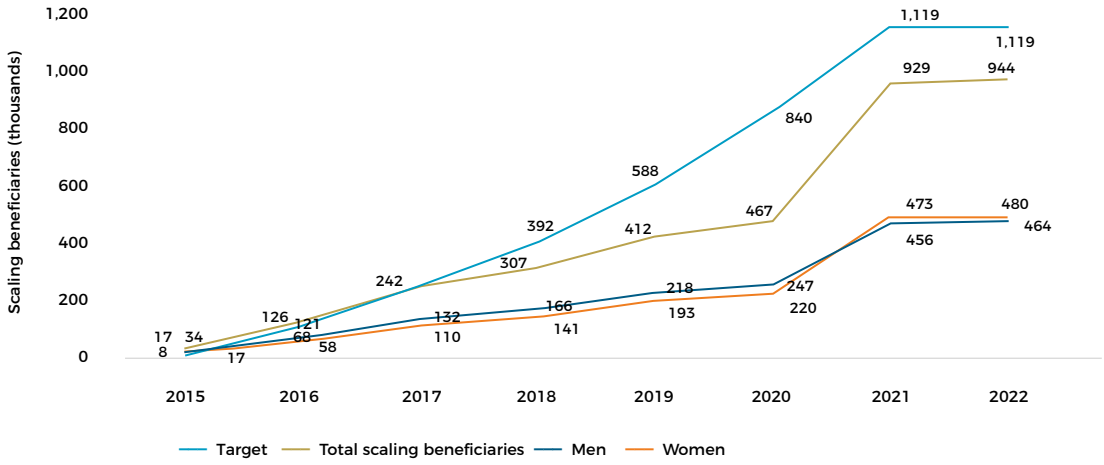
Figure 2. Number of direct beneficiaries targeted and reached, Africa RISING, 2012–2022



Scaling beneficiaries

Scaling beneficiaries (Figs 3 and 4) are those reached primarily by scaling partners, which for Africa RISING were local development agencies, institutions, and NGOs; these beneficiaries were not directly involved in the research (including research-in-development) activities.

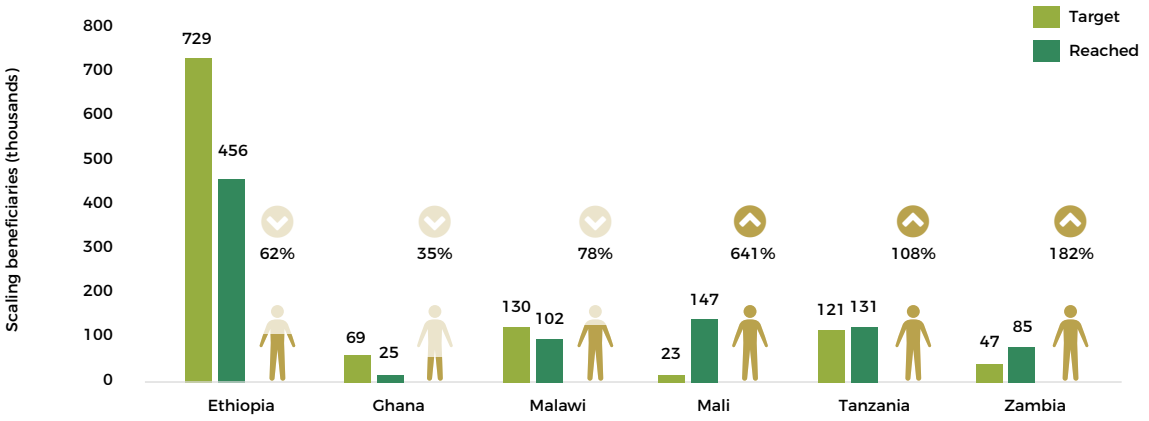
Figure 3. Cumulative numbers of scaling beneficiaries targeted and reached by sex, Africa RISING, 2015–2022



2 Data from: Mgalla, D., Boyubie, B.E. and Abdulkadir, B. 2023. Monitoring, evaluation, and data management. Presentation at Africa RISING Close-out Event, Accra, Ghana, 7–9 February 2023.

3 Azzarri, C. and Haile, B. 2017. *Monitoring and evaluation data requirement guide*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/89965).

Figure 4. Total numbers of scaling beneficiaries targeted and reached, Africa RISING, 2015–2022



Impact achievements within the SIAF domains

Our impact estimates covered all program countries, except Zambia, and are based on two rounds of household panel survey data, except for Ethiopia for which program effect is estimated using one round of survey data. Impact is estimated using statistical, non-experimental methods: Propensity Score Matching (PSM) and difference-in-differences (DiD)[4] for countries with panel data or, for Ethiopia, based on simple comparison of outcomes between program beneficiaries and non-beneficiaries.

The principal guide to the impact estimate of Africa RISING–promoted sustainable agricultural intensification technologies was the Sustainable Intensification Assessment Framework (SIAF) (Musumba et al. 2017),[5] particularly in Phase 2 of the program. Thus, the end-of-program impact assessment focuses on indicators chosen within the SIAF domains.[6]

In the following subsections, all monetary values are expressed in US dollar purchasing power parity (PPP) figures. PPP conversion rates equalize the local price of a common basket of goods and services expressed in each country's currency in relation to the US dollar.[7]

4 DiD refers to the average difference in the outcomes of interest between Africa RISING beneficiaries and non-beneficiaries before and after receiving interventions. More formally, in our case, DiD = $(\bar{Y}_1^B - \bar{Y}_0^B) - (\bar{Y}_1^C - \bar{Y}_0^C)$, where B and C represent the beneficiary and control group, respectively; 1 and 0 represent post- and pre-treatment periods, respectively; and $\bar{Y}$ represents sample average. For ease of interpretation, we express the impa.t as percentage change in Y. The RDiD is used to deal with bias in DiD estimates due to systematic time-varying confounding factors, such as the Normalized Difference Vegetation Index, to control for their time-varying effects on Y through regression adjustment.

5 Musumba, M., Grabowski, P., Palm, C. and Snapp, S. 2017. *Guide for the Sustainable Intensification Assessment Framework*. Washington, DC: Feed The Future, United States Agency for International Development. (https://cgspace.cgiar.org/server/api/core/bitstreams/4b74b077-064c-4b3e-8344-ae3b761985ea/content).

6 Africa RISING. 2024. *Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) impact assessment report*. Washington, DC: IFPRI (forthcoming).

7 The PPP relies on construction of an adjusted exchange rate for each country that equalizes the nominal exchan.e rate in terms of the local cost of a common basket of goods and services. In this report, monetary values in all countries in different years have been converted to international dollar at the 2011 PPP conversion rate.

Ethiopia[8] Indicators

8 Data source: Haile, B., Azzarri, C., Tzintzun, I., Boukaka, S.A. and Vitellozzi, S. 2024. *Impacts of Africa RISING in Ethiopia.* Washington, DC; Nairobi, Kenya; Ibadan, Nigeria: IFPRI, ILRI and IITA (forthcoming).

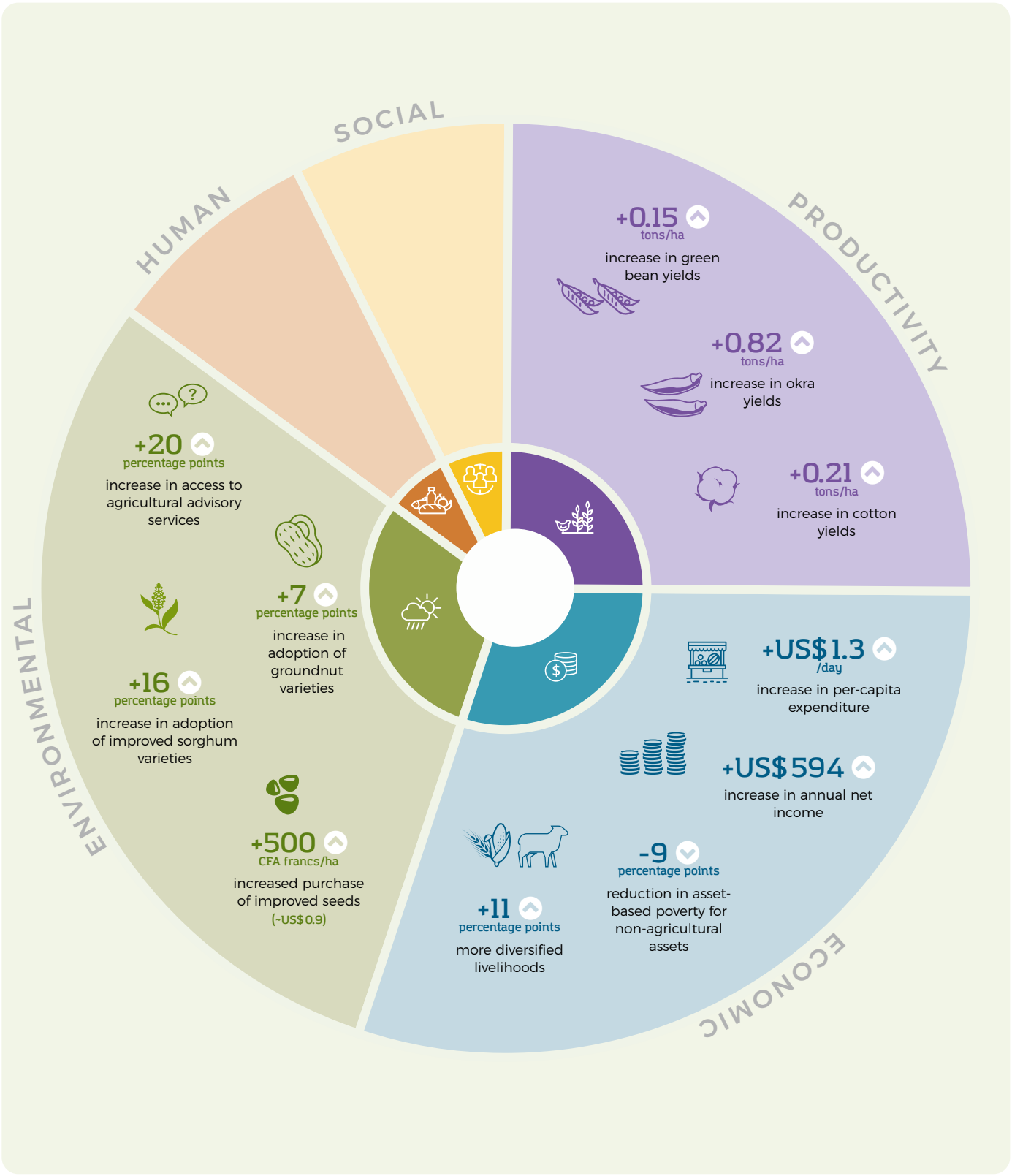
Ghana[9] Indicators

9 Data source: Beliyou, H., Azzarri, C., Castaing, P., Glover, J., Kizito, F., Vitellozzi, S. and Boukaka, S.A. 2024. *Impacts of Africa RISING in Ghana*. Washington, DC; Nairobi, Kenya; Ibadan, Nigeria: IFPRI, ILRI and IITA (forthcoming).

Malawi[10] Indicators

10 Data source: Haile, B., Azzarri, C., Boukaka, S.A., Vitellozzi, S. and Chikowo,R. 2023. *Impacts of Africa RISING in Malawi.* Washington, DC; Nairobi, Kenya; Ibadan, Nigeria: IFPRI, ILRI and IITA. https://doi.org/10.2499/p15738coll2.137004

Mali[11] Indicators



11 Data source: Haile, B., Azzarri, C., Tzintzun, I., Boukaka, S.A. and Vitellozzi, S. 2023. *Impacts of Africa RISING in Mali.* Washington, DC; Nairobi, Kenya; Ibadan, Nigeria: IFPRI, ILRI and IITA. https://doi.org/10.2499/p15738coll2.137003

Tanzania[12] Indicators

12 Data source: Haile, B., Azzarri, C., Tzintzun, I., Boukaka, S.A. and Vitellozzi, S. 2024. *Impacts of Africa RISING in Tanzania.* Washington, DC; Nairobi, Kenya; Ibadan, Nigeria: IFPRI, ILRI and IITA (forthcoming).

13 Tractors, sprayers, sickles, plows, yokes, harrows, yokes, shovels, etc.

Bekelech Belachew harvests ripe avocados on her farm in Lemo District, Ethiopia. Africa RISING worked with farmers in Ethiopia to validate and promote high-value fruit trees as one of the options for sustainably intensifying the farms. Photo credit: Apollo Habtamu/ILRI.

Africa RISING field staff holding up freshly harvested groundnut pods from a doubled-up legume intercropping arrangement plot. Photo credit: Jim Richards.

A group of farmers take part in a practical demonstration of the motorized maize shelling machine in Seloto village, Babati District, Tanzania. Photo Credit: Gloriana Ndibalema/IITA.

Chapter 3

Technology Case Studies

Africa RISING researchers and development partners collaborated with smallholder farmers in six countries to enhance agroecosystems sustainability. The goal was to introduce innovations that increase food production on existing land, ensure present-day well-being, and fortify ecosystem services for enduring agricultural productivity. This chapter focuses on selected innovations aligned with the sustainable intensification pillars of genetic, ecological, and socio-economic intensification, as outlined in the Montpellier Panel Report on Sustainable Intensification in Africa (2013).[14] Genetic intensification is defined as using modern plant and livestock breeding to achieve higher yields, improved nutrition, resilience to pests and diseases, and resilience to climate change, thereby creating sustainable livelihoods. Ecological intensification refers to the application of agricultural ecological processes, including intercropping, integrated pest management, conservation farming, organic farming, and socio-economic intensification entails providing an enabling environment to support technology adoption and develop markets for the products of sustainable intensification. This chapter is organized by type of intensification following these definitions.

To evaluate the innovations highlighted in this chapter, Africa RISING pioneered use of the Sustainable Intensification Assessment Framework (SIAF)[15] indicators to assess their sustainable intensification merits and risks across productivity, economic, environmental, human, and social domains. To achieve sustainable intensification, interventions need to positively impact multiple domains, ideally all five, necessitating mitigation for any negative effects in specific areas.

The final section of this chapter looks at one of the overarching themes of Africa RISING – farming systems research and development, highlighting the importance of innovation bundling and the overall dynamics of adopting this approach.

14 Agriculture for Impact. 2013. *Sustainable intensification: A new paradigm for African agriculture.* A 2013 Montpellier Panel report. London: Agriculture for Impact. (https://www.mamopanel.org/media/uploads/files/SUSTAINABLE_INTENSIFICATION-_A_NEW_PARADIGM_FOR_AFRICAN_AGRICULTURE_2013.pdf)

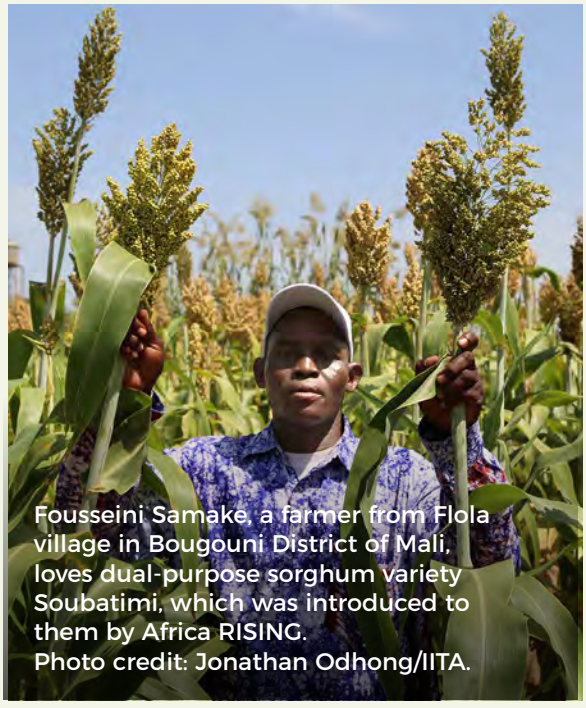
15 https://sitoolkit.com

3.1 Genetic intensification

Dual-purpose sorghum in southern Mali[16]

In the dry Sahelian and Sudan savannahs, rural people typically rely on both crops and livestock for food and livelihoods. However, since the devastating droughts of the 1970s and 1980s and subsequent changes in the climate, natural pasture has become increasingly scarce. Dual-purpose cereals (primarily millet and sorghum) are therefore a lifeline, providing grains for farming families and edible stems (stover) for their livestock, especially during the dry season.

Through Africa RISING, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) validated and promoted three dual-purpose high-yielding sorghum varieties with improved stover palatability for livestock (Peke, Soubatimi, and Tiandougou-coura), in the technology parks of Koutiala (semi-arid with around 600–800 mm annual rainfall) and Bougouni (sub-humid, 900–1,100 mm) in southern Mali. The same trials were implemented by 27 farmers in their own fields (later scaled to 5,844 farmers through demonstration plots).



Fousseini Samake, a farmer from Flola village in Bougouni District of Mali, loves dual-purpose sorghum variety Soubatimi, which was introduced to them by Africa RISING.
Photo credit: Jonathan Odhong/IITA.

The new sorghum varieties produced over 40% more grain and edible stems than the local varieties, and even more when either mineral or organic fertilizers were applied. They retain green stems and leaves through to grain maturity and harvest, and so are less woody than those of the local varieties. Combined, these attributes make the stover more palatable to livestock and increase its digestibility.

The improved dual-purpose sorghum varieties provide benefits across the spectrum of sustainability domains, from increasing crop and livestock productivity, to contributing to improved economic status through either reduced reliance on purchasing staple food and livestock feed or providing surplus grain and livestock feed for sale, and the potential for native pasture to regrow because of the reduced pressure from livestock grazing. The stover used to feed livestock thus contributes to increased availability of milk and meat, which improves population nutrition status and income.

However, while farmers in Bougouni overwhelmingly preferred the new varieties – Peke (89%), Tiandougoucoura (80%), and Soubatimi (76%) – those in Koutiala preferred the local variety (80%) for its grain quality despite its low stover quality. Thus, in introducing improved dual-purpose sorghum to new areas, it is important to allow farmers to make their own decisions through processes such as participatory varietal selection.

16 With input from Baloua Nebie.

4.4 t/ha
grain yield (Soubatimi)

Increased profit from grain sales
US$ 308–410/ha
in Bougouni and
US$ 125–160/ha
in Koutiala

43%
average grain yield advantage
(three varieties)
over local variety

56–70% rating
by women farmers (across sites),
cf. **45%** for local variety and
61% for variety Fadda
Women typically keep small ruminants

53–67% rating
by men farmers (across sites),
cf. **49%** for local variety and
65% for variety Fadda
Men typically keep large ruminants

The grains of Soubatimi are bigger than [those of] the local varieties and the cattle seem to enjoy the stover much more than [that of] the local variety. It also gives me a better than the local variety. For example, I am guaranteed to harvest eight bags of 100 kg weight if I cultivate a quarter hectare of Soubatimi compared to only five bags if I grow the local variety over the same area.

Fousseini Samake, farmer, Flola village, Bougouni District

Farmer Fousseini Samake said that he preferred 'tô' (thick porridge) made from variety Soubatimi because it looked 'cleaner' than that made from the local varieties. He also suggested that women would also likely select Soubatimi over the local varieties because of the quality of the tô and other local dishes.

Upon visiting the technology park in Koutiala in October 2017, Country Director of the Mali Agricultural Market Development Trust (MALIMARK) Aminata Tangara was attracted to the thick green stems and grain yield of Soubatimi. She selected the variety to be included among the crops to be produced by MALIMARK outgrower farmers. "I was already collaborating [with one of the Africa RISING projects], so through this partnership I acquired 300 kg of Soubatimi foundation seed and distributed 5 kg each to 60 of our outgrower farmers. They will cultivate it and produce certified seed, which we will buy back from them, package, and sell, because this is a very promising variety," she said. By the closure of the program, dual-purpose sorghum and millets had been scaled to 5,844 farmers in Mali through Africa RISING demonstration plots.

Increasing sorghum productivity has been a major policy goal of the Government of Mali since the 1970s. Africa RISING has made a significant contribution to that with its improved dual-purpose varieties, which are also available for testing and adoption in other sorghum-growing regions that also rely heavily on livestock.

New groundnut varieties in central Tanzania[17]

Groundnut is an important crop in central Tanzania, providing income, improving food and nutrition security, enhancing soil fertility, promoting climate resilience, and earning foreign exchange through exports. The leaves and stems are used as livestock feed, as is 'groundnut meal', the by-product of oil extraction. 'Dual-purpose' varieties are grown specifically to produce both food (human) and feed (livestock).

Kongwa 650 is a short-duration, dual-purpose variety that is tolerant to drought. Kongwa 724 is a big-seeded, medium-duration variety that is resistant to groundnut rosette disease. Both yield more than the commonest local variety and landraces, and are suitable for climate-smart farming.

These two groundnut varieties were promoted by Africa RISING after being evaluated and validated in nine villages across four districts in central and southern Tanzania. They proved particularly well adapted to low-altitude agro-ecosystems with 400–800 mm of rain a year, such as in central Tanzania. Kongwa 650 performs consistently across central Tanzania, including in areas unsuitable for other crops. With participatory research, the variety was delivered to and quickly adopted by farmers, with consequent improvement in their food and nutrition security status. Over 1,000 farmers (50% women) across central Tanzania were involved in the participatory evaluation, and received training and quality seed of these new varieties.

In terms of sustainability factors, the new varieties deliver on the productivity, economic, environmental, and (nutrition) fronts.

Kongwa 650

PRODUCTIVITY

High yield of **Biomass** >700 kg/ha

2.4 t/ha **grain yield**

YIELD ADVANTAGE

>37% over **Mnanje** (released check) & >64% over the **landrace**

NUTRITION

Nutrient rich: 32% Protein; 2.1mg Iron/100g; 42% Oil

INCOME

>Tsh 2,500,000/ha Net benefits (>US$ 1,386)

SOCIAL

Most preferred by farmers for its

Drought tolerance; Earliness; High grain yield

Kongwa 724

PRODUCTIVITY

High yield of **Biomass** >710 kg/ha

YIELD ADVANTAGE

>60% over **Mnanje** (released check) & >73% over the **landrace**

NUTRITION

Nutrient rich: 32% Protein; 2.1mg Iron/100g; 48% Oil

INCOME

>Tsh 3,230,000/ha Net benefits (>US$ 1,073)

SOCIAL

Most preferred by farmers for its

High yield; Large seeds; Resistance to Groundnut rosette virus

17 With input from James Mwololo and Patrick Okori.

High-yielding drought-tolerant common bean[18]

NUA45 is a drought-tolerant, short-season variety of common bean adapted to slightly acidic soil (pH 5.0–6.0) in low-, mid-, and high-altitude areas. It can be grown as an intercrop or in rotation with maize, pearl millet, or sorghum.

Maize is the predominant staple grown on up to 80% of the agricultural land of southern Africa, and it dominates people's diets. This has the drawback of not supplying essential protein and micronutrients. Iron and zinc deficiencies are of particular concern since they lead to anemia and stunting in children.

NUA45 is rich in both iron and zinc, containing 22 mg more iron and 6 mg more zinc than local varieties per kg of beans.

The variety was selected in participatory varietal selection (PVS) by 45 farmers (32 women) at Bembeke Extension Planning Area (EPA), Malawi, and seed distributed to 500 farmers (186 women) for testing on a large scale in Linthipe area of Dedza district. It was again selected in PVS in Linthipe and Kandeu EPAs (99 farmers, 47 of them women). It has subsequently been released as 'Chitedze 09' by the Government of Malawi.

NUA45 makes for highly productive farming; it not only produces doub×e the yield of local varieties, but it can also be intercropped with maize. It also increases household income via food-purchase substitution or direct sale of beans. It does, however, incur costs in the form of mineral fertilizers, which may be out of the reach of some farmers.

In terms of the environment, NUA45 should ultimately reduce the need for mineral fertilizer through biological nitrogen fixation and incorporation of crop residues. It is also grown either alongside or in rotation with the cereal, thus not requiring extra land to be brought into production. For people, it is a highly nutritious foodstuff, contributing protein, fiber, iron, and zinc to the diet and being adaptable in terms of preparation (various dishes may be prepared from the beans). In terms of social impact, the variety was preferred as much by women farmers as by men.

FOOD SECURITY

Yields up to
2,000 kg per hectare

2X
the yield of local varieties

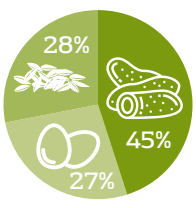
HEALTHY SOILS

Fixes approx.
25–30 kg

Nitrogen per hectare, sufficient for its own growth

NUTRITION

Comprises
45% carbohydrate,
27% protein,
28% fiber,
80 mg/kg iron, and
32 mg/kg zinc



SOURCE OF INCOME

Yields up to
400 kg
from **0.2 hectares,**

providing a net income of **US$ 210** when sold

18 With input from Chifuniro Mankwala.

A researcher examines 'magic' bean (NUA45) plants at a farmer's field in central Malawi. Photo credit: Neil Palmer/CIAT.

My household has earned more from selling NUA45 beans than we did planting local varieties. I planted NUA45 in 2019/20. I sold part of the harvest and kept some for household use. I have used the proceeds to buy a calf that will diversify my income source to include milk sales.

Cosmas Ganizani, farmer, Linthipe EPA

I planted on a small area of 0.1 hectares. Rain was not consistent in 2020/21 season but I harvested 300 kg, which I sold at 1,700 kwacha per kilogram. I have used the proceeds to buy iron sheets for my house.

Charles Kuyenda, farmer

Growing vegetables in Tanzania[19]

Most vegetables produced in Tanzania come from the smallholder sector, which is characterized by low levels of mechanization, poor infrastructure, limited access to credit, limited technical expertise, and poor access to improved seeds, and is strongly affected by unpredictable weather changes.

Through Africa RISING, the World Vegetable Center introduced improved varieties of six vegetable crops along with good agricultural practices (GAPs) to Babati and Karatu districts of northern-central Tanzania. The crops are African eggplant (1 variety), African nightshade (1), amaranth (2), Ethiopian mustard (1), sweet pepper (1), and tomato (3).

GAPs include good-quality seed, seed and seedling health, field and nursery management, use of manure and mineral fertilizers, plant spacing, integrated pest management, weeding, and post-harvest management. GAPs in vegetables increased farmers' yields by an average of 12.8%, increased their gross margin by 13%, and enabled a 75% reduction in pesticide use.

About 2,500 smallholder farmers (c.1,000 women) have been reached with improved crop management technologies, GAPs, and nutrition messages. Fifteen government extension staff (9 women) were trained on various aspects of crop management and nutrition. And a total of 1,178 farmers (560 women) were trained as farmer trainers to train other farmers. For scaling of vegetables with GAPs, WorldVeg worked with Iles de Paix, a not-for-profit non-governmental organization, and trained 7 trainers (2 women) for this work. Iles de Paix is collaborating with Mtandao wa Vikundi vya Wakulima Tanzania and other research community and organizational development associates.

Traditional vegetable recipes introduced to communities resulted in a 119% increase in per-capita vegetable consumption and a 60% increase in types of vegetables consumed, including greater increases in vegetable consumption among households that previously ate few or no vegetables prior to the project.

A group of women farmers carry tomatoes to the market after harvest. Africa RISING introduced farmers in Tanzania to high-performing and farmer-preferred vegetable varieties as a pathway for improved nutrition and income for families. Photo credit: Jonathan Odhong/IITA.

19 With input from Inviolate Dominick.

Valuable lessons learned

- Farmers responded better to a business service approach than to methods focused on production; many showed interest in producing vegetable seeds for market.
- Women farmers benefited from the use of improved technologies: some are getting better yields than before and have access to their income from vegetable sales.
- Community members are keen to take up technologies that safeguard their health. Thus, when promoting any technology, it is good to help communities understand the benefits of the technology and the implications of not taking it up.
- Additional side benefits of the technology in the farm system contribute to its uptake, such as utilizing "vegetable waste" as feed for chickens; chicken droppings in turn were used as manure in the gardens.
- Growing vegetables in rotation or intercropping with other crops benefits from a large, diverse population of soil organisms, producing good yields and improving livelihoods, particularly for women farmers who are a major part of the labor force in crop production.
- Working with research and development partners increases knowledge and skills within the team and greatly enhances smallholder farmers' access to improved and relevant sustainable agricultural technologies. Such access is necessary to increase productivity, ensure food security, and reduce poverty.
- Dissemination of technologies to non-group members has been successful as a result of the active participation of lead farmers and quarterly monitoring of dissemination activities.
- Community sensitization and mobilization to own the development process, coupled with the well-selected, adaptive basket of options, helped the farmers achieve results.
- Implementation of the program in step-wise phases was instrumental in achieving focused results, which would have been unlikely had the work started in all regions at the same time.
- Training the farmer community in vegetable production for improved nutrition through good agricultural practices, and in vegetable use (including recipe preparation) contributed to balanced diets with much-needed micronutrients, and generated income along the vegetable value chain in both urban and rural communities.

I opted to come back home and farm because I learned first-hand from my mother how much income one could generate from agriculture, with the right technologies, know-how, and efforts.

The introduction of improved vegetable production technologies by Africa RISING has greatly helped us. We have learned lots of modern ways of boosting our vegetable production: improved agronomic practices such as fertilizer and manure application rates and plant spacing. And can now see the benefits. So I decided to cultivate eggplant using the same technology.

Agriculture pays – particularly if you put in the effort, and when you follow all the advice by researchers, then you are bound to succeed.

Olais Lukumay, accounting graduate (diploma) and farmer, Bermi village, Manyara Region, who had previously been looking for formal employment in Dar es Salaam

Adoption of new varieties and good agricultural practices:

INCREASED YIELDS

5-fold

increase in fruit yield over the national average with tomato Tengeru 2010

Healthy seedlings increased yield by

28%

alone, and by

128%

in combination with other good agricultural practices

INCREASED FOOD AND NUTRITION SECURITY

79%

of **households food secure** in 2021
cf. 35% in 2019

Dietary diversity
up from

4 groups (2019)
to 6 groups (2021)

INCREASED REVENUES

57%
from **tomatoes**

39%
from **African nightshade**

40%
from **Ethiopian mustard**

DECREASED MINERAL FERTILIZER AND PESTICIDE USE

Pesticide use **down** from

76% (2019) to
11% (2021)

of households

We used to consume insufficient vegetables because we did not know how important they were and the nutritional benefits of a balanced diet. We also lacked good-quality seeds of traditional vegetables. Thanks to the project, we were trained on the nutritional benefits of vegetables and how to cultivate and consume varieties of vegetables.

Pelagia Gaudence, farmer and farmer-trainer, Kambi ya Simba village, Kilimanjaro Region

3.2 Ecological intensification

Cowpea living mulch in Ghana[20]

A living mulch is a plant grown specifically to cover the soil surface, add nutrients, increase soil moisture, and reduce weeds. When intercropped with maize, cowpea acts as a living mulch and provides a protein-rich food for farming families and high-quality feed for their livestock. It also has valuable dietary micronutrients such as iron and folic acid, which are particularly important for the health of pregnant women.

A spreading cowpea variety (rather than a climbing one) is used both to prevent choking of and overzealous competition with the maize plants, and to provide soil cover. Planting cowpea one to two weeks after maize gives the maize a head start in accessing water, light, and nutrients. The cowpea can then be harvested before the maize, providing valuable food during a time when food is traditionally scarce.

Scaling of the technology was tested in 2017–2019 in six districts and 12 communities across three regions of northern Ghana, covering 188 farmers' fields. Total attendance at organized community field days in 2018 and 2019 was 2,133.

By increasing maize grain yield and providing an additional food source in the cowpea grain, this technology increases the food available to the household. Cowpea grains offer a valuable source of protein and micronutrients for dietary diversity. The technology thus improves field-level productivity, household nutrition, and economic status. It also decreases environmental impacts compared with monocropped maize, as the cowpea adds nitrogen and other elements to the soil via biological fixation and residue incorporation, and minimizes soil erosion.

There are some challenges associated with using cowpea living mulch, however. For example, it works best when farmers have access to improved seeds, fertilizers, and even pesticides via agro-input dealers. Additionally, maize and cowpea market prices are subject to fluctuation, depending on the prevailing socio-economic conditions, so farmers need access to markets and market information for cowpea grains and livestock fodder to maximize their incomes from cowpea sales.

Compared with a sole maize crop, cowpea living mulch requires more labor for planting (65%), harvesting (221%),

Cowpea living mulch demonstration plot at a technology park in northern Ghana. Photo credit: Jonathan Odhong/IITA.

20 With input from Nurudeen Abdul Rahman.

and processing – and these activities are performed mostly by women and children. And, while weeding is reduced from twice to once, early weeding requires a third more labor time since it is necessary to weed around the cowpea seedlings carefully. Harvesting the intercropped cowpea is also more complicated than that of a monocrop because of the need to avoid damaging the maize plants.

All maize-growing households can implement this technology, regardless of their level of resource endowment. By reducing weeding time, cowpea living mulch can free farmers to perform other activities during a period of peak demand. Cowpea fodder is particularly useful as livestock feed during the dry season. While farmers need extra labor for harvesting and transporting the fodder to the livestock compound or area, there are benefits to feeding livestock in a confined space (see the case study 'Feed and health package for small ruminant production'). For example, the manure can be collected more efficiently and used to improve soil fertility for subsequent crops. However, women require access to land resources to benefit fully from these practices.

Other grain legumes, such as groundnut or soybean, could be grown instead of cowpea in areas where the agro-ecosystem favors these crops, or where farmers prefer them for dietary or market reasons. Similarly, cowpea living mulch can be used in sorghum and millet production, where these cereals are more suited to the agro-ecosystem (because of climate, or for dietary or market reasons).

According to a focus group discussion with farmers in 2019: "The technology increases yield (harvest from two crops), improves soil fertility and moisture retention, smothers weeds, and … complements what we consume mostly at home to help improve a balanced diet". However, the group also observed that there is no doubt that the living mulch had increased the labor of the women at harvest since they harvested more than once on the same field.

Intercropping cowpea with maize results in:

+34%

increased maize grain yield when intercropped with cowpea

Cowpea–maize intercrop produced

75%

more protein than a sole crop of maize

Soil moisture increased by

80%

and **soil nitrogen** by

17%

in a maize–cowpea intercrop

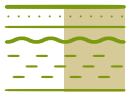
only

1

weeding session is needed per growing season when cowpea is intercropped with maize

50%

improvement in **soil quality** index



Contour bunding in southern Mali[21]

The semi-arid region of southern Mali has a long history of implementing soil and water conservation (SWC) practices, such as erosion control and soil fertility measures, with the aim of increasing water availability, reducing farm water run-off and gully formation, and improving soil nutrient content to enhance crop yield. Despite the widespread adoption of SWC practices since the 1980s, the landscape of southern Mali continues to suffer from high levels of run-off and soil erosion, leading to low crop yields in farmers' fields.

The Kani watershed landscape has changed a lot since 1986. Expansion of cotton, maize, and sorghum cultivation was driven by population growth and low crop yields. Clearing natural vegetation for farming quickly led to soil erosion and nutrient loss, which resulted in poor crop performance. This situation is likely to be happening throughout the region.

To overcome this, contour bunding was introduced. It is a relatively simple and inexpensive way of reducing soil erosion and water run-off, and thereby improving agricultural production. The technique involves building ridges (bunds) along the contour of the field to catch or slow rainfall run-off as it flows down the slope. For stability and longevity, perennial grasses or trees are planted on the bunds, preventing them from being destroyed by heavy rainfall, run-off, or strong winds.

Despite being one of the commonly known SWC practices in watersheds across the drier savannah areas of central and southern Mali, and many other parts of West Africa, the proper use of contour bunds was limited by farmers' limited awareness on the proper construction techniques and the bunds' long-term usefulness.

With promotion by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) under Africa RISING, contour bunding has been adopted by more than 2,500 farmers in nine villages across Bougouni and Koutiala districts, and a further 250 in Kani, Kolokani district. Initiatives spearheaded by CARE International and the United Kingdom Foreign, Commonwealth and Development Office (formerly the Department for International Development) took the technology to a further 3,700 farmers. Expansion has been aided by the Malian NGO Association Malienne d'Éveil au Développement Durable (AMEDD) offering to demarcate contour lines in farmers' fields for just US$ 10 per hectare, while still making a profit.

> I have been contacted by other farmers now, who also wish to have this in their fields. An NGO, AMEDD, put this together for us at a cost of US$ 10 per hectare of land. I am more than willing to pay this cost since we have seen the benefit.
>
> **Sekou Berthe, farmer, Kani village, Kolokani district, Mali**

21 With input from Birhanu Zemadim.

CASE STUDIES

12–13 tons
of **soil** lost by erosion from each hectare of non-bunded fields

73%
reduction in run-off with contour bunds

42%
reduction in soil loss with contour ridges

162 mm
rain water saved with contour bunding

14.5% and 11%
increase in soil moisture at 40 cm and 60 cm depth

Improved crop maturation during terminal drought thanks to retained soil moisture

5.13
marginal rate of return with sorghum on bunded fields. And **20%** net benefit over unbunded fields

78%
of farmers perceived **increased income** from growing crops on bunded fields

Africa RISING scientists look at a contour bunding efficacy monitoring station at the Africa RISING M'pessoba technology park in southern Mali. Photo credit: Jonathan Odhong/IITA.

Doubled-up legumes[22]

The 'doubled-up' legumes system is based on intercropping two grain legumes, as opposed to conventional intercropping systems that often have a cereal crop and a legume crop. The most successful doubled-up legumes system is pigeon pea with groundnut, with both crops planted at their normal monocrop densities (additive) or pigeon pea planted at a lower density (partial substitutive), depending on the level of water stress on the site. The system's success is based on exploiting the complementary growth habits and plant architectures of the two legumes. Groundnut and pigeon pea are planted at the same time. Pigeon pea grows very slowly for the first three months, only starting rapid growth as the groundnut approaches maturity. After the groundnut is harvested, the pigeon pea grows as a sole crop.

Groundnut is often considered as the main crop within the intercrop, and so is planted at its normal 'sole cropping' density. Pigeon pea is then planted at 50–100% of its sole cropping density. In marginal areas, reduced plant density minimizes competition for nutrients and water between the two crops.

The system diversifies and intensifies cropping on smallholder farms. Crop diversification on small farms is strongly constrained by limited land, as farmers allocate a large proportion of the farmland to the staple crop, which is usually a cereal. Doubling up legumes fulfills multiple objectives, including: (i) integrating more grain legumes when land is limiting; (ii) rehabilitating fields with poor soil fertility; and (iii) extending ground cover in cropped lands as pigeon pea can be in the field for six to eight months, depending on the variety used.

A farmer's field with doubled-up legume intercrop. Photo credit: Christian Thierfelder/CIMMYT.

22 With input from Regis Chikowo.

CASE STUDIES

This legume–legume intercrop 'doubles' farmers' grain yields, with up to

40%

more grain per unit area

A farmer growing **0.3 ha doubled-up system** will produce **180 kg pigeon pea,** which is equivalent to about

30%

of the protein requirement of a family of six

The doubled-up legumes intercrop was officially 'released' by the Government of Malawi because of documented benefits in **soil fertility** improvement and improved **human nutrition** outcomes

Over 9,000 farmers have had the opportunity to trial doubled-up legumes through a seed multiplication scheme that generated 90 tons of 'quality declared' seed of an improved and well-adapted groundnut variety over three years in central Malawi (Dedza and Ntcheu districts). This was combined with a well-adapted local pigeon pea variety (landrace), leading to an increase in cereal–legume rotations and scaling up of the technology. Doubled-up legumes was officially 'released' by the Government of Malawi in 2017 as an innovation to improve soil fertility and human nutrition across the whole country.

In terms of sustainability, compared with a 'standard' groundnut–maize rotation, doubled-up legumes increases nitrogen cycling by 50%, reducing the need for mineral fertilizer application to the subsequent maize crop by half. It produces 30% more legume grain and increases the grain yield of maize grown in rotation by 20%. The combined legume crop produces 45% more protein than sole-cropped groundnut. The system also increases land and labor productivity, and diversifies income sources for farmers. Doubled-up legumes also enhances women's empowerment as women can meaningfully participate in marketing of diverse legume crops.

Drawbacks include the need to herd livestock (mostly goats) for an extra two to four months after groundnut harvest to protect the pigeon pea crop; the susceptibility of modern pigeon pea varieties to arthropod pests, which may need to be chemically controlled (two to three applications of, e.g., dimethoate); and pigeon pea's requirement for phosphorus. However, the latter can often be met by residual phosphorus if fertilizer containing it is applied to the preceding maize crop. Price fluctuations may be a concern if a farmer plans to sell the pigeon pea.

This technology is so important for us women, as it gives us more room to grow more legume crops on the farms that are now tiny.

Common testimony of women farmers who implemented doubled-up legumes on farms of less than 0.5 hectares.

Mbili-mbili[23]

Mbili-mbili (Swahili for 'two by two') is an intercrop of two rows of maize with two species of legume. It has its origin in a combination of two other successful intercropping schemes: 'MBILI' innovation from Kenya and doubled-up legumes from Malawi.

Originally devised using maize, pigeon pea, and common bean, other crops may be used as long as the growth patterns for the crops are complementary. Much of the success of Mbili-mbili derives from this combination of the fast-growing bush bean, intermediate growth rate of maize, and slow-growing, intermediate-stature pigeon pea. The three crops are grown at precise spacings (Fig. 5) to maximize synergies in the use of growth resources (light, water, and nutrients). The four lowest maize leaves are removed at silking stage ('stripping'), and the top portion of the maize plant is cut 10 cm above the ear leaf at dough stage ('topping') to improve light penetration to the growing pigeon pea. Moreover, the cut leaves are used as livestock fodder.

The technology was validated under research-managed trials run for four years on six farmers' fields in Babati district, Tanzania. Concurrently, a participatory test was conducted by 225 farmers on plots of at least 0.1 hectares for one to three seasons in the same district. Of these, 56% modified the crop mix, including cassava, cowpea, groundnut, lablab, pumpkins, or sunflower; and 84 increased their Mbili-mbili area to over 0.2 hectares (seven of these expanded their areas to >0.8 hectares).

Mbili-mbili was preferred by more women than men farmers. One of the reasons for this preference is because it provides room for cultivation of more 'vegetable' crops such as cowpea, which is not commonly planted as an intercrop in cereal systems (legumes are locally referred to as 'vegetables').

Figure 5. Mbili-mbili crop arrangement and spacing of rows

Source: Redrawn from Kihara, J., Kinyua, M., Massam, J., Pallagjo, R., Songoyani, I. and Kyekaka, J. 2022. *Compendium of success stories in integrated soil fertility management. Farmer's voices from Babati District in Tanzania*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/121876).

23 With input from Michael Kinyua and Job Kihara.

CASE STUDIES

Mbili-mbili technology ensures **food security for farmers** through its staggered harvests over a **10-month growing season,** beginning with

BEANS
(0.3 t/ha),
then **MAIZE**, and later
PIGEON PEA
(0.6 t/ha)

Farmers implementing **Mbili-mbili technology** harvested
4 t/ha
more in maize yield compared with conventional systems

Applying **Mbili-mbili** technology reduces the **weeding effort** for the farmers by half, freeing them for other chores and concerns

US$ 115
more net profit per growing season than other improved maize–legume systems

Less risk compared with other systems; Mbili-mbili is **climate-resilient**

0.7 tons
of maize leaf biomass per hectare (from stripping) for livestock feed

11%
pigeon pea yield increase from maize stripping

US$ 370 to 470
US$ 630
Increased gross income compared with common cereal–legume intercropping with one legume

Up to 37%
less capital investment cf. conventional intercropping systems (a result of the reduction in weeding)

A farmer's field with Mbili-mbili intercrop arrangement. Photo credit: Jonathan Odhong/IITA.

With Mbili-mbili, I can get enough food for my children, contribute a portion of maize and beans to a school feeding program for my son, and sell the excess to boost my fishmongering business. I am going to abandon the traditional farming method and adopt Mbili-mbili in future.

Prisca Peter, farmer, Riroda village, Babati District, Tanzania

Integrated soil fertility management in Babati, Tanzania[24]

In 2012, farmers in Babati District, Tanzania typically applied animal manure on their fields, but few (3%) applied fertilizers. Many were surprised to learn (through Africa RISING capacity building and field demonstrations) that there is a lot more to increasing soil fertility – and consequently yields – than the simple question of whether they (can afford to) apply fertilizers to their crops. Soil fertility is affected by everything from land preparation and crop variety choice to what is done with plant residues after harvest.

Africa RISING experimented with and promoted integrated soil fertility management among farmers in Babati for over a decade. The 'package' was composed of manure, fertilizers, and other good agricultural practices that improve farmers' yields, food and nutrition security status, incomes, and general well-being, enabling farmers to get the best from their farms, crops, livestock, and soils.

Land preparation needs to be timely and not so late that it delays planting. Any tillage should be done when the soil is dry to avoid compaction and hardpan formation, and any tillage on a slope should follow the contours of the land to reduce run-off and erosion. Manure can be applied and incorporated in the soil during plowing to avoid nutrient loss.

Improved crop varieties that have high productive potential are key for maximizing resource use. These typically yield more than local commercial varieties and landraces. (See case study examples under 'Genetic intensification'.)

Seed quality is also important. For maize, certified seed is far superior to recycled seed from one's own or a neighbor's crop. It has a better germination rate, is more nutrient-use efficient, is more tolerant of or resistant to pests and diseases, and has higher yield potential. When buying certified seed, it is important to select varieties adapted to the area where they are to be grown. Factors that affect choice include duration of growing season (long or short) and the prevailing climate conditions. For legumes and other non-staple crops, Africa RISING facilitated access to 'quality declared seed' where certified seed was not accessible.

Plant spacing is a vital ingredient for crop production. Before the Africa RISING Program started, Babati farmers typically broadcast seeds behind animal or tractor plows, resulting in poor spacing, exposing soil to erosion, and reducing yield. With the Africa RISING Program, farmers learned how to plant in rows. In general, achieving correct plant spacing is easier with a planter.

When it comes to **planting**, it is not only spacing that is important, but also depth (formerly, farmers planted seed so deep it reduced germination), timing, considering the contours of the slope, the (predicted) weather, and crop diversification.

Manure should be well composted (for which the project provided advice), and applied at regular frequency at a rate of 1.4 tons per acre (3.5 tons per hectare) in two years out of five.

Crop residue retention provides soil cover after crop harvest and contributes to recycling nutrients in agricultural systems. However, Babati farmers typically removed all crop residues from fields distant from their homes to feed livestock kept near their house, but without returning livestock manure to the fields that provided the feed. Africa RISING recommends removal of as little of the crop residues from distant fields as is necessary to feed the livestock, and returning some of the manure to those fields wherever possible.

Soil erosion (primarily of valuable topsoil) is a major problem, especially on sloping fields. Such fields require consideration of

24 With input from Michael Kinyua and Job Kihara.

>200%
maize yield increase from adoption of integrated soil fertility management (adding fertilizers and good agricultural practices to basic manure) from 8 bags to 27 bags per acre

33%
maize yield increase from choosing the best seed variety alone

100 kg/acre
maize yield loss and risk of **maize lethal necrosis disease** from late planting

up to 4 tons
more maize per hectare from adopting **Mbili-mbili**

60%
maize yield increase from using **manure**

the right application of fertilizers, manure, and soil conservation structures put in place to prevent transfer of applied nutrients to fields located in bottom lands.

Soil conservation measures such as contour bunds and tied ridges need to be put in place to reduce run-off and erosion down slopes. Farmers should also not allow livestock into fields to directly graze on crop residues (which should rather be collected and fed to the livestock where they are kept), as they may compact the soil with their feet or expose it to erosion by feeding on residues on the soil surface. In dry areas, water-harvesting in the field – using structures such as terraces, retention ditches, tied ridges, and cultivation pits – is recommended to improve soil moisture content for growing crops.

Crop choice also influences soil fertility. Legumes directly benefit the soil and any accompanying crop or crops planted in the subsequent season as they fix atmospheric nitrogen into a plant-usable form. Companion crops may be intercropped, relay cropped (the second crop planted some weeks after the first crop), or grown in rotation. If no other option is seemingly available, a fallow crop will help restore soil fertility between main crop seasons.

Fertilizer (mineral) is a valuable contributor to soil fertility, but it needs to be accessed from the right source and applied at the right time, in the right amount, and in the right way. Babati field crops benefit from both basal phosphorus and top-dressed (or sprayed) nitrogen fertilizers.

Weed, pest, and disease management contribute to proper use of nutrients, and to increased soil moisture and crop yields.

Crop arrangements can have a big impact on soil fertility, especially growing multiple legumes such as in doubled-up legumes (section 3.2, p. 27) and Mbili-mbili (section 3.2, p. 29).

Stripping and topping of maize enable better light penetration to a companion crop (e.g., pigeon pea in Mbili-mbili), which is then able to fix more nitrogen and give a greater yield.

Thus, 14 good agricultural practices were selected by farmers who worked with Africa RISING in Babati. The more of these they adopted in combination, the better their yields were.

I used to harvest between 6 and 8 bags of maize which after the training increased to between 15 and 19 bags.

Albert Edward Shayo, farmer, Gallapo village, Babati District, Tanzania (adopted fertilizer, proper spacing, pest and disease management, and new maize varieties)

Conservation agriculture and related technologies for low-input agriculture in Malawi and Zambia[25]

Conservation agriculture is a cropping management system and represents a movement toward greater sustainability of farming by changing unsustainable practices of traditional agriculture. In particular, conservation agriculture reduces soil tillage and increases the duration of soil coverage to reduce erosion, nutrient loss, and run-off, and to increase soil moisture and nutrient retention. Planting into surface mulch is usually done with a pointed stick, a shallow hoe, or in rip-lines, employing the latter if animal traction is available.

The International Maize and Wheat Improvement Center (CIMMYT) has been experimenting with and promoting conservation agriculture in eastern Zambia for over a decade, initially under the Sustainable Intensification of Maize–Legume Systems in Eastern Province of Zambia (SIMLEZA) project and, since 2013, under Africa RISING, expanding to central and southern Malawi in 2018/19.

The CIMMYT conservation agriculture work fostered crop diversification in predominantly maize-based systems by including grain legumes and green manure cover crops; it also promoted farm and dietary diversity by introducing intercropping and crop rotation, including the Africa RISING doubled-up legume technology.

Under SIMLEZA, conservation agriculture reached 50,000 direct and indirect beneficiaries, and Africa RISING saw 6,000 people practicing conservation agriculture on almost 2,000 hectares. Subsequently, partnerships with the ministries of agriculture, Total LandCare, and others reached more than 200,000 (indirect) beneficiaries, with a significant rise in the number of farmers practicing conservation agriculture across the region.

Data from a recent impact assessment in Malawi, in an area of longer-term conservation agriculture promotion in the Extension Planning Areas (EPAs) of Mwansambo and Zidyana, showed that 57% of the rural farmers in the community had adopted full conservation agriculture systems on parts of their farmland, and that about 90% of farmers had adopted at least one conservation agriculture component. In a non-project EPA, only 7% of farmers adopted a full conservation agriculture system.

Conservation agriculture entails no tillage, crop residue retention as mulch, and crop rotations. Photo credit: Christian Thierfelder/CIMMYT.

25 With input from Christian Thierfelder.

CASE STUDIES

INCREASED PRODUCTIVITY

Up to
99%
yield increase in manual systems (and 140% in drought seasons)

35%
average yield increase in systems using **animal traction** (and 60% in drought seasons)

20–50%
increase in water productivity

25–35
labor days saved in land preparation and weeding per hectare

INCREASED INCOME

US$ 17.8
return on each dollar invested in maize–soybean conservation agriculture systems

ENVIRONMENTAL BENEFITS INCLUDE

64%
reduction in soil erosion

NUTRITIONAL BENEFITS FROM MAIZE-LEGUME INTERCROPPING CF. SOLE MAIZE CROPPING

18.9%
more energy (calories)

59.7%
more protein

I started conservation agriculture with the help of SIMLEZA in 2011. I was travelling with CIMMYT to Monze in Southern Province of Zambia where we met farmers who had practiced conservation agriculture for more than seven years. They showed me how to plant crops without tillage using an animal traction ripper. When I tried this on my own farm, I soon realized that there is less labor involved in preparing the land. Through the project we were also exposed to new crops such as soybean and cowpea, which we planted in rotation with our maize. Today, I have converted my whole farm to conservation agriculture. All crops are seeded in rip-lines and I rotate maize with different types of legumes but mostly soybeans, which give me a lot of cash. I can send all my children to school and can buy some of my agricultural inputs (seed and fertilizer) every year.

Getrude Banda, Chifulo, Sinda District, Eastern Province, Zambia

Optimal groundnut plant spacing[26]

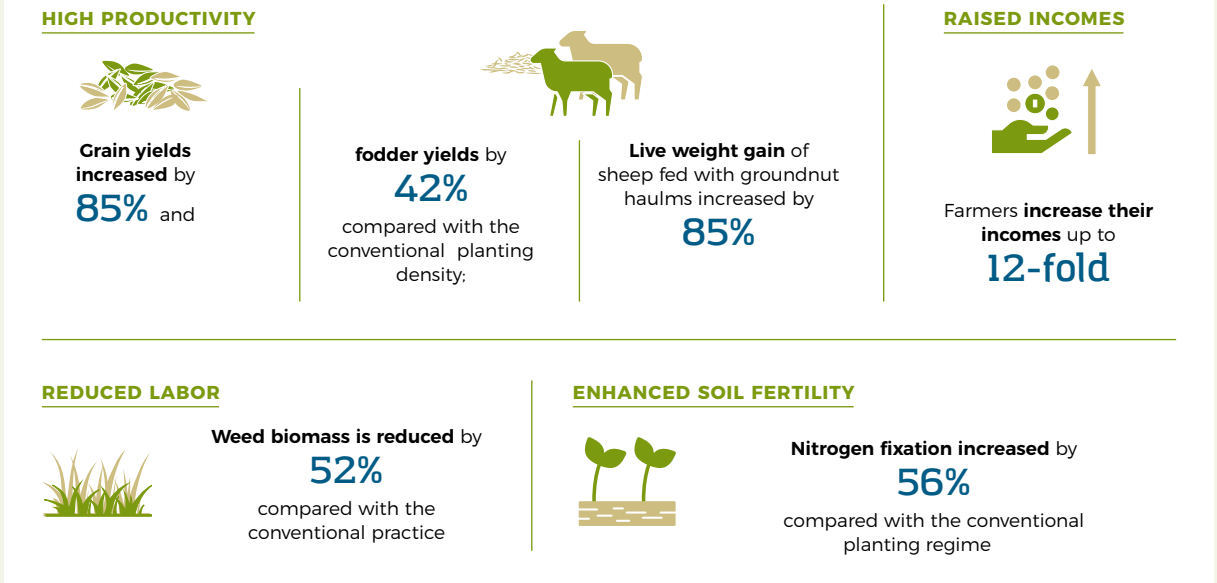
While farmers in northern Ghana traditionally plant groundnut at 9 plants per square meter, research conducted by IITA through Africa RISING demonstrated multiple benefits when increasing plant density to 22 plants per square meter. The desirable plant density is achieved with plants 15 cm apart in rows and 30 cm between rows. This plant spacing works with all groundnut plant types (erect, semi-erect, and spreading growth types). However, movement within fields with this plant spacing is challenging when conducting field activities (good agronomic management practices such as weeding and fertilizer application). However, the same 22 plants per square meter density can be achieved by planting at 10 cm apart in rows and 45 cm between rows, which makes movement along the rows easier and can allow for innovation such as small-scale mechanized weeding.

The 'technology' is particularly attractive to farmers who have both crops and livestock.

The increased density can also be adopted for groundnut–cereal (maize, millets, and sorghum) intercrops or crop rotations.

The advice is applicable in areas with similar conditions to those of northern Ghana: deep, well-drained, fertile, sandy soil that is slightly acidic (pH 5–7); rainfall of at least 700 mm during the growing season; and a temperature range of 25–35°C.

To maximize the benefit of the increased plant density, it should be combined with good agricultural practices, including: (i) appropriate choice of variety, for example, Yenyawoso for short seasons (90 days) or Mani-pinta for long seasons (120 days); (ii) weeding once between 20 and 50 days after planting; (iii) inoculation of seed with rhizobia in areas where the native soil rhizobia are ineffective with groundnut; (iv) applying phosphorus fertilizer prior to planting and starter nitrogen fertilizer at planting if the soil has very low nitrogen content; and (v) application of Aflasafe biocontrol product to protect against aflatoxin infection.



26 With input from Nurudeen Abdul Rahman.

Profit maximization requires access to agro-inputs (seed and fertilizer) via dealers and to agricultural markets to sell groundnuts and livestock fodder.

The technology was tested and validated on-farm in 12 communities across 6 districts in Northern, Upper East, and Upper West regions of northern Ghana. The trials were conducted in researcher-managed fields of 580 square meters in each of the 12 communities and 51 farmer-managed fields of 4,000 square meters each across the 12 communities. Some 1,002 farmers were reached with the technology through field days in the 12 communities.

Closer plant spacing leads to faster closing of the crop canopy over the bare soil, which helps reduce soil erosion and improve water infiltration (aided by reduced evaporation), as well as suppressing weeds (once the canopy is closed).

Conversely, more labor is required for planting, harvesting, and processing, and these tasks are generally undertaken by women and children. Maximum benefit can only be obtained if the farmer has access to improved seeds or fertilizers. Extra care must be taken (compared with traditional handling of groundnut) to ensure that an aflatoxin-free crop remains aflatoxin free during harvesting, storage, and processing (Aflasafe biocontrol product reduces aflatoxin levels by 96–100% from harvest to table – see 'Aflasafe biocontrol of aflatoxin in Ghana', section 3.3, p. 48).

The technology increases grain yield, improves soil fertility, and reduces weed growth. However, weeding between the crops is quite challenging due inadequate space for movement.

Focus group discussion, 2018

Groundnuts and maize. Photo credit: Kathy Lopez/IITA.

Compost from cotton plant stems[27]

Declining soil fertility is a major problem for farmers in southern Mali. Cotton and sorghum farmers typically apply fertilizers to their crop fields, but many have moved away from retaining crop residues in the field after harvest. While sorghum and maize crop residues are collected mainly for livestock feed (for farmers' own animals or for sale), cotton stems are simply burned as they are considered too difficult to manage.

Crops usually grow better when organic fertilizer (manure or compost) is included in the mix of nutrient-adding products. Experiments with farmers from three villages near Koutiala city in the Sikasso Region of southern Mali determined that micro-dosing of composted cotton stems at a rate of 2.5 tons per hectare was effective in improving sorghum yield, as was broadcasting the same compost at 5 tons per hectare.

Fifteen volunteer farmers from each of the three villages were trained how to compost cotton stems at M'pessoba technology park prior to conducting the experiments.

Ultimately, 30 farmers conducted the experiments (12 of them women). An additional 400 farmers attended two-day training sessions on heap-composting of cotton stems in three villages.

Before, we were unaware of the advantages of the composting technique. In 2019, the Africa RISING team first trained us on how to make good compost to better fertilize our soils while spending less. From three villages in the region of Koutiala, 30 farmers produced the compost and ran the experimentation in our fields in 2019 and 2020. I can confirm that my sorghum production has significantly improved with compost application by micro-dose and I was able to cover more land compared to the spreading method. We really thank the Africa RISING project for all the achievements in favor of rural development in Mali.

N'fah Coulibaly, farmer, Koutiala, Sikasso

Micro-dosing cotton-stem compost when planting sorghum results in:

10–22%
faster daily growth rate

16%
taller plants

78%
grain yield increase

24%
increased biomass yield

120%
greater nitrogen use efficiency

80%
gross margin cf. 40% without the compost

27 With input from Bouba Traore.

3.3 Socio-economic intensification

Maize shellers in northern Ghana[28]

Smallholder farmers in northern Ghana lose a significant portion of their staple crops after harvest, with up to one-fifth of the crop being lost during processing.

While mechanization can help reduce losses and labor requirements, most farmers cannot afford to buy machines, and mechanics are usually located in towns and cities far from rural farms, making maintenance difficult.

Consequently, through Africa RISING, IITA validated and is promoting group ownership of a diesel-powered maize sheller that is managed and maintained locally. The approach involves farmer groups, the maize sheller, and local technicians who maintain the machines.

Farmers are encouraged to form groups of 18–20 members to jointly own, manage, and maintain a sheller. Group members contribute at least a quarter of the sheller's cost and develop a constitution to guide group and sheller management.

The diesel-powered sheller reduces both the labor and cost of shelling compared with manual shelling, a burden that falls primarily on women in farming households. The sheller has a 4-horsepower engine and can process 1.5 tons per hour. Some farmers have been trained as 'para-technicians' to maintain the machines across the region; they are supported by a series of 35 'how-to' videos on all aspects of sheller operation and maintenance in five major local dialects of northern Ghana (Dagare, Daghani, Gruni, Kasim, and Wale). These videos are available on the web[29] and can also be distributed via apps such as WhatsApp.

Some 270 farmers participated in testing the sheller (cost–benefit analysis) in nine communities in Northern, Upper East, and Upper West regions of Ghana. Subsequently, about 1,100 farmers were introduced to the technology via demonstrations across 18 communities. Twenty-one farmer groups (comprising men and women) were trained to manage the shellers, and 18 business groups formed to develop and implement collective agreements for group sharing of their shellers. Three farmers were trained as para-technicians for the 18 groups of farmers across the three regions.

28 With input from Bekele Kotu.

29 See Africa RISING Communications. 2021. No technician? No problem: Africa RISING releases 35 vernacular DIY videos on maintenance of maize shelling machines for use by farmers in Ghana. Africa RISING blog, 4 October. (https://africa-rising.net/no-technician-no-problem-africa-rising-releases-35-vernacular-diy-videos-on-maintenance-of-maize-shelling-machines-for-use-by-farmers-in-ghana/). And YouTube playlist at: https://www.youtube.com/playlist?list=PL48GL1y1VagVFM-4ZVBZEg3ZOylXYoPFu

Farmers at a training event organized by Africa RISING in Upper West Region, Ghana on proper maintenance of diesel-powered maize shelling machines. Photo credit: Wilhelmina Ofori Duah/IITA.

The training was quite good. I learned lots of new things about the proper servicing and operation of the diesel-operated maize sheller. For example, I only knew how to fuel the sheller, but now I know how to fix a loose drum in a faulty machine. I used to think any minor problem with the machine was a fault in the engine! I don't need to call on commercial technicians for every little thing, and I think my skills will help our farmer group earn more from the machine because it will reduce time wasted waiting to fix minor problems.

Benjamin Ambana, trainee, Upper West Region, Ghana
(photo credit: Wilhelmina Ofori Duah/IITA)

High-value fruit trees in the Ethiopian Highlands[30]

Agriculture in the Ethiopian Highlands is dominated by smallholder mixed crop–livestock systems, with farm sizes mostly in the range of 0.5 to 5 hectares. Despite the wide variety of crops grown (large- and small-grain cereals, legumes, vegetables, potatoes, and fruits) and livestock raised (cattle, sheep, goats, horses, donkeys, and chickens), dietary diversity at the farm level is low, and most farming is for subsistence. While tree fruits are popular, local varieties are slow to mature and low yielding.

Through Africa RISING Phase 1, the World Agroforestry Centre introduced six high-yielding varieties of avocado and two of apple, along with improved tree management practices. The best of the avocado varieties (Ettinger, Fuerte, Hass, Nabal, and Reed) had good survival rates (to maturity) and produced high yields; however, there was much variation across sites, varieties, management intensities, and gender-sensitive management options.

The Government of Ethiopia wants to scale up avocado production widely to serve potential export markets in China and France. Government extension agencies therefore committed to disseminating 36,027 apple and avocado seedlings in the Amhara Region and 5,733 in the Southern Nations, Nationalities, and Peoples' Region. Initial distribution comprised 41,760 grafted trees to 2,657 farmers (295 women) for an area of 23.6 hectares, and farmers were trained by government extension agents in early tree management practices for the first 2.5 years after planting.

At least another 300 farmers have been trained in avocado management through Africa RISING. Some 125 farmers

Mr Aberra, one of the beneficiary farmers from the Africa RISING intensification through high-value fruit trees intervention in the Ethiopian Highlands, now harvests avocados for home consumption and market sales. Photo credit: Apollo Habtamu/ILRI.

30 With input from Endalkachew Woldemeskel and Kindu Mekonnen.

Improved avocado and apple tree varieties

90–100%
tree survival to maturity for **avocado** and
75–96%
for **apple**

98.7
tons per hectare of highest-yielding avocado variety Nabal, from 547 fruits per tree, at an average weight of 330 g

High market demand leading to **increased income** particularly for women

Increased dietary diversity and better household nutrition

20%
of **avocado produced sold** on average

(35 women) in Endamehoni and Lemo woredas participated in apple and avocado household surveys and yield data collection. Local stakeholders were trained in propagation, management, marketing, and value chain development. An extension learning manual is in preparation on avocado tree production.

The Fruit Tree Multiplication and Training Center of Butajira was set up to propagate and disseminate trees, and provide practical training to farmers; it was the source of grafted avocado varieties for the project, and worked closely with the project on farmer training and at field days and other field visits. A multipurpose nursery was established at Sinana, Oromia Region, and jointly managed by the Sinana Office of Agriculture and Africa RISING for some time. It had a capacity of 50,000–100,000 seedlings, enough to supply 50,000 households each year. Africa RISING supported the agriculture office to graft avocado seedlings and distribute them to the farmers via a cost-sharing arrangement. The office also raised millions of multipurpose tree seedlings and distributed them to farmers. Further outscaling is envisioned in collaboration with national partners and international development agencies.

Bekelech, a woman farmer in southern Ethiopia, received training from Africa RISING on avocado farming. She also took part in experience-sharing visits to other farms. She says that support from Africa RISING has been key to her success:

> **Before I gained these skills, I struggled in my farming activities. But the experience-sharing visits and training programs made me see that I could do more in agribusiness. My eyes were opened to see new opportunities in my neighborhood, not just on my farm.**
>
> **Bekelech, farmer, southern Ethiopia**

Feed and health package for small ruminant production[31]

Small ruminants (sheep and goats) are an essential component of livelihood strategies in resource-poor rural areas of West Africa. The animals fulfill various roles in household food security, providing meat and milk, and a source of income to meet food and cash needs. They also serve as food security insurance for most smallholder families in the event of crop failures. Rural women and youth are particularly involved in rearing small ruminants, so they provide an important source of employment and empowerment.

The feed and health package has three components. First, a supplemental feed composed of cotton seed cake, maize and wheat bran, and cotton and soybean seed. The ingredients are mixed in prescribed ratios and the supplement addresses common nutrient deficiencies; it is given at the rate of 200–300 g per animal per day.

The second component is improved veterinary care. Africa RISING trained several community animal health workers to complement mainstream veterinarians. The animal health workers live within their communities and provide a limited range of services (primary veterinary health care) to other livestock farmers. Their activities are regulated by the Veterinary Council of Ghana. The improved veterinary care includes regular vaccination against ovine rinderpest (*peste des petits ruminants*, given annually) and pasteurellosis (given once or twice per year), with antibiotic treatment on a needs basis, multivitamin injections every quarter, and deworming twice a year. On average, the overall medication cost per animal is about US$ 0.60 per year.

The third component comprises building improved feed troughs made from locally available materials (wood and grass for thatching) to improve feeding efficiency and reduce feed waste.

At the start of Africa RISING Phase 2 in 2016, stakeholder workshops were held in both Ghana and Mali, each involving 24 participants from among the local research and development partners.

Feeding trough demonstration site at Tibali Community in northern Ghana. Photo credit: Wilhelmina Ofori Duah/IITA.

31 With input from Sadat Salifu.

In 2016/17, some 90 farmers' flocks were being monitored for daily weight gain in light of health and feed, health only, and control treatments. At least 904 small ruminants benefited from the feed and health package and at least 645 from the health package alone. Vaccination campaigns were conducted in seven communities in Ghana and Mali, involving 494 households and 6,908 small ruminants.

Initially introduced to Ghana and Mali (after prior successful validation in the Ethiopian Highlands) as part of a feed and health package from 2016, the feed trough was validated, modified, and promoted as a 'stand-alone' technology from 2018. Thirty troughs were demonstrated in two regions of northern Ghana and 45 disseminated in Koutiala district, southern Mali, followed by training in trough use for 75 farmers (20 women) and 29 youths (10 young women) from a Tamale-based NGO. Fifteen troughs made from local materials were constructed initially in Ghana. At the same time, two farmers in Duko (Ghana) constructed troughs with their own resources, and an extra one was set up as a demonstration in Duko technology park. To aid out-scaling, youth entrepreneurs, livestock development officers in Northern and Upper East regions of Ghana, and personnel from Heifer International in Tamale received training in trough construction and use. To aid promotion of the improved feed trough, 18 have been installed across 9 technology parks in northern Ghana, where they are accessible to visiting farmers. The improved trough technology benefited from the flexibility of the project in allowing the farmers to make modifications to suit their own particular circumstances. For example, one farmer included a feed storage space above the trough. Furthermore, the local artisan engaged to construct the improved troughs in northern Ghana was able to turn this into an income-generating activity since interested farmers have been directed to his services.

Previously, a one-year-old sheep or goat looked and weighed like a four-month-old animal. With the improved feed and health package for small ruminants, our animals now fetch us premium prices at the market. I am also selling more animals because my flock has expanded due to the feed and health package.

Abukari Abdul-Rahman, farmer, Tibali community, Northern Region, Ghana

Technologies to reduce post-harvest losses in Tanzania[32]

Post-harvest losses can rob Tanzanian maize farmers of up to 40% of their crop yields. Poor harvesting and post-harvest processes can add a further economic burden, as damaged or diseased grains attract lower prices on the market. Moreover, the handling and storage of grain can lead to chemical changes that impact the household's nutritional status (the quality of their diet).

Through Africa RISING, IITA has been promoting improved post-harvest practices for a number of years. These include mechanized shelling, using clean surfaces for drying (tarpaulin or collapsible drier case), cleaning prior to storage, and storage in hermetic (airtight) bags or metal silos.

The sheller saves labor time. The clean drying surface reduces contamination with soil and other debris during drying. Cleaning enables the farmer to remove damaged, diseased, and insect-infested grains, thus reducing cross-contamination of healthy grains going into storage. And storage in hermetic containers helps prevent intrusion of moisture, disease pathogens, and insect pests in storage.

Other aspects of the post-harvest work include communal storage to improve market bargaining power, empowerment of youth as mechanics, micronutrient fortification of maize, and business acumen.

The initial proof of concept for these post-harvest technologies was conducted during Africa RISING Phase 1. Subsequently, the

Sifrosa Forna, a farmer from Khanam Rotia village, uses the improved storage bags to store her maize grains. According to her, the quality of her maize grains are "super" when she stores them in PICs bags. Photo credit: Eveline Massam/IITA.

32 With input from Christopher Mutungi.

work directly benefited 2,292 stakeholders across 34 villages in 7 districts, with a further 27,200 sensitized on the technologies via interactions with project farmers or attendance at trade fairs.

Scaling partners included the Tanzania Agricultural Research Institute at Hombolo, ICRISAT, Iles de Paix, and Sokoine University of Agriculture.

Africa RISING set up experiments at my homestead. They demonstrated how to use a diesel-powered maize sheller, collapsible drier case, and hermetic bags. For me the hermetic bags were the most interesting. The new bags performed very well and they stopped [grain] damage by insects. I have been using the same set of bags for the last four years. Last year, I stored maize in 13 of these bags and in 34 ordinary bags which I [had to treat] with insecticide. The technology is good!

Abel Michael, farmer-cum-entrepreneur, Seloto village, Babati district, Tanzania

18–27%
more food available when using **tarpaulin drying** and **hermetic storage**

24–26%
greater food accessibility when using tarpaulin drying and hermetic storage

Increase in **household income**
111–155%
when using **tarpaulin drying** and **hermetic storage**
68%
when using **mechanical shelling**

Reduced household expenditure on food by
11%
when using **mechanical shelling**
42%
when **drying on tarpaulin**
51%
when using **hermetic storage**

Nutritional value added to maize by post-harvest technologies
5–40%
more **calories**
14–34%
more **protein**
10–40%
more **minerals**

Nutritional value added to common bean by post-harvest technologies
1–9%
more calories
1–7%
more **protein**
14–27%
more **minerals**

My living standards have really improved. Because of the income I make in a day, I can now provide more for my family than I could do before. I am also happy that I have employed other young men to work with me and they can support their families through this work.

Kassim Lebora, farmer-cum-small business owner (maize sheller), Dahinda village, Mvomero district, Tanzania

Improving household nutrition[33]

The nutritional status of resource-poor and subsistence households – particularly those with children under 5 years of age – is a major concern in development because of the huge health and economic impacts of malnutrition. For example, it is estimated that 34% of under-fives in Malawi and 26% in Tanzania are stunted, and that undernutrition costs Malawians 10% of the country's gross domestic product. This is a price that individual families and countries can ill afford.

Africa RISING has been promoting hands-on education on relevant topics, with follow-up monitoring to tackle this issue across its three regional projects.

The 'technology' is primarily intensive learning-by-doing (typically for 21 days) on the topics of breastfeeding, personal hygiene, food safety, nutrition and the different food groups, and nutrition-sensitive food handling, storage, and preparation.

Breastfeeding is well-known as the best form of nourishment for babies as the sole food source for the first six months of life, but this is a message that does not seem to reach all sectors of society. Personal hygiene includes hand-washing after going to the toilet, before preparing food, and before eating. Food safety includes selection of food matter by looking at its physical quality (e.g., the best grains of cereals and legumes for use in infant supplemental feeds). Nutrition includes the different values (in the diet) of the seven groups of foodstuffs and their complementarity.

Sensitivity to the nutritional values of food has direct implications for the way foodstuffs are handled, stored, and prepared. Food preparation includes hygiene and nutrition, and the preparation of nutritious meals, including infant supplemental food (porridge) made from locally available food (e.g., cereals, pulses/legumes, and vegetables).

Abiy Traore standing by her sack vegetable garden in Sirakele village, Koutiala District, southern Mali. She is among 100 farmers who worked with Africa RISING to demonstrate sack vegetable gardening. Photo credit: Jonathan Odhong/IITA.

33 With input from Yasinta Muzanila.

Various experimental and validation trials involved about 800 family households (some represented by mother–infant couplets) and 29 food producers in Malawi and Tanzania. Results and recipes have been published, including in the Africa RISING handbook on sustainable agricultural intensification (Bekunda et al., 2022).

Several participants have indicated that they wish to turn what they have learned in the Africa RISING nutrition training into a business, both passing on the information and manufacturing complementary foods developed with local ingredients.

My child used to get sick often. I was in and out of the hospital ... I learned that my child's health will change if I followed the food diversity I learned at the training. Now I have observed that my child is not ill as she used to be and her health has improved from before.

Mrs Idesi Chimkonde, Mali village, Kongwa District, Tanzania, talking about the hygiene training

Impacts of intense learning-by-doing on nutrition for infants under two years

Reduced numbers underweight (weight-for-age measure for acute and chronic malnutrition)

Reduced wasting (weight-for-height measure for acute malnutrition)

Reduced **diarrheal** infection

Reduced **aflatoxin** exposure

Improved **dietary diversity** at no extra cost

Processed milk products for under-fives

Increased number of **children receiving adequate diet** (minerals and vitamins)

VEGETABLE FORMULATIONS

119%
increased **vegetable consumption**

Increase from
3 to 5
different **vegetables consumed**

WHERE WOMEN CONTROL INCOME

Increased number of households with minimum **dietary diversity** (i.e., at least four of the seven food groups)

Increased **meal frequency**

Increase in **age-defined acceptable diets**

AFLATOXIN-FREE FOOD 'SCIENCE' AND HYGIENE

64%
reduction in **aflatoxin load** (in urine)

Slightly reduced **stunting** (height for age measure for chronic malnutrition)

Aflasafe biocontrol of aflatoxin in Ghana[34]

Aflatoxin is a harmful toxin produced by several strains of the fungi *Aspergillus flavus* and *A. parasiticus*. It is a particular problem in maize and groundnut cultivated across sub-Saharan Africa. In Ghana, studies have shown that over 15% of maize and 11% of groundnut samples at harvest have aflatoxin levels above Ghana Standards Authority thresholds. Those percentages may increase if suboptimal storage occurs. Of course, variability is expected from year to year, and within and among regions due to diverse biotic and abiotic factors. Exposure to aflatoxin through consumption of contaminated crops can lead to stunting in children, and immune system suppression, liver cancer, and liver cirrhosis (among others) in adults. In some cases, unfortunately, high exposure results in loss of life. Data on the prevalence of aflatoxin-related disease are scarce, but aflatoxin exposure is believed to be responsible for 25% of all child stunting cases in sub-Saharan Africa, that is over 10% of all children on the continent. Aflatoxin thus has negative impacts on both farming families' health and their income (as crops contaminated above threshold levels cannot be sold locally or exported to aflatoxin-conscious markets). Dealing with aflatoxin is, therefore, critical as maize and groundnut are both vital staple foods and valuable livestock feedstuffs.

Aflasafe GH01 and Aflasafe GH02 are aflatoxin biocontrol products, each containing as active ingredients four genetically diverse *A. flavus* fungi strains that do not produce aflatoxin. The products are broadcast in the field at a rate of 10 kg per hectare at two to three weeks before crop flowering. The field is then left undisturbed for 7 to 10 days. The atoxigenic strains of *A. flavus* in Aflasafe out-compete the native toxigenic strains in the soil by a process known as 'competitive exclusion': the atoxigenic strains become associated with the treated crop, but do not contaminate it. The two products have been registered for use on groundnut, maize, and sorghum in Ghana.

A farmer applies the aflatoxin biocontrol to her maize farm. Photo credit: Gloriana Ndibalema/IITA.

34 With input from Alejandro Ortega-Beltran and Daniel Agbatiameh.

Large-scale efficacy trials in six districts of Ghana covered over 800 maize and groundnut fields. The careful selection of superior, highly competitive strains resulted in highly effective production, leading to 98–100% less aflatoxin in treated compared with untreated crops. Three national partners were involved in awareness-creation, cross-border movement of Aflasafe, and facilitating registration. These efforts combined reached over 1,000 maize and groundnut farmers. The Market Development program in northern Ghana, and projects of the German Agency for International Cooperation (GIZ) and United States Agency for International Development (USAID)–funded Feed the Future Ghana Agricultural Development and Value Chain Enhancement Project have demonstrated the technology across 65 (15 groundnut, 35 maize, and 15 sorghum) sites in Northern, Upper East, and Upper West regions. Further outreach included briefing of 50 farmers by previously trained staff of Adakant Enterprise, and a newspaper article on the dangers of aflatoxin, Aflasafe, and aflatoxin management.

Outputs from Africa RISING resulted in the technology (after registration) being transferred for commercialization across Ghana by Callighana Company Limited, a subsidiary of the global group UPL (formerly United Phosphorus Limited), as the exclusive distributor of the two aflatoxin biocontrol products. IITA continues to backstop UPL-Callighana for farmer training, advocacy, and advice for scaling up integrated mycotoxin management centered on the use of biocontrol.

When you apply it [Aflasafe], you will get quality produce. The food is good for family consumption and you will get good market price for your produce. You can even sell your produce to pay your children's school fees. So to me the Aflasafe is very useful to every farmer. It will be very helpful if we have a regular supply of Aflasafe so that we will have less farming problems.

Adawina Lydia, farmer, Bui Kodima, Upper East Region, Ghana

Use of Aflasafe results in:

80–100%
less **aflatoxin contamination** in the field and throughout storage

Increased **trade opportunities** as less produce fails to meet stringent standards for premium markets

Increased **income** when farmers participating in **value chain approach** access premium markets

Healthier farming families, because a portion of the production is kept for their consumption

Increased **poultry productivity** and **profitability** when birds receive feed prepared with aflatoxin-reduced crops

3.4 Mixed farming systems require bundling of technologies for impact[35]

As highlighted in the case studies presented in section 3.3 of this report, the Africa RISING program implemented a pioneering farming systems science approach to develop integrated innovations tailored to the complex realities of smallholder farming across Africa. As successor projects such as the One CGIAR Research Initiative on Sustainable Intensification of Mixed Farming Systems carry this work forward, key lessons learned from Africa RISING may be useful to inform future research and development efforts with a systems perspective.

The rationale for incorporating systems science within Africa RISING stemmed from the multidisciplinary nature of the program, which brought together diverse institutions, disciplines, and countries to holistically address interconnected farming challenges. Smallholder farmers simultaneously contend with challenges pertaining to crops, livestock, and natural resources management, coupled with nutritional demands and market constraints (among others). Tackling these effectively required transcending institutional and disciplinary silos to promote synergies, minimize trade-offs, and deliver integrated innovations fitting the whole farming system context rather than isolated components. For research to match the complex decision making farmers face, systems approaches (evaluated through the SIAF domains) were essential.

At the start of Africa RISING, the levels of expertise in and awareness of how to implement systems science among agricultural researchers in general were low. Thus, implementing the ambitious vision required extensive capacity building and forging partnerships across institutions, disciplines, and countries. However, achieving true collaboration and functional diverse teams took time and continuous effort to bridge different terminologies, methods, and ways of working. Collaborating in planning field activities helped immensely. But ultimately, researchers' change in mindset and identifying them as true partners in 'Africa RISING' rather than as representatives of their individual disciplines or institutions proved critical in this process. Farming systems science requires data exchange among the researchers of the various disciplines and this was a challenge for Africa RISING as researchers bought gradually into the modalities for data sharing, ownership, credit, merit, and publications (among other things).

Tools – particularly the Sustainable Intensification Assessment Framework (SIAF) – assisted in aligning diverse partners in a shared vision around program objectives and monitoring progress. Given the dynamic farming challenges associated with smallholder farming systems, such tools required continuous adaptation rather than being fixed blueprints. Building robust evidence to demonstrate the benefits of systems approaches using such tools necessitated drawing insights from different sources – quantitative, qualitative, modeling, participatory – and triangulating these to develop a comprehensive understanding.

Africa RISING projects developed integrated innovations fitting localized contexts. In West Africa, integrated farming activities were promoted to enhance nutrition, incomes, and women's access to land through farming enterprises such as home gardens that are linked crop–livestock farming systems. The home gardens receive kitchen residues and livestock manure, promoting intensification with increased productivity over small land areas. Africa RISING Ethiopia focused on livestock technologies and multi-purpose crops such as apple[36] and avocado[37] to

35 Based on an interview with Mateete Bekunda, Fred Kizito, and Kindu Mekonnen.
36 Apple trees provide food and feed in their fruits, and are also ideal for agro-forestry, with other food, feed, or green-manure crops grown between the trees.
37 Avocado trees produce nutritious fruits that can be eaten raw or prepared, foliage suitable for feeding to livestock, and their productivity means that with just a few trees farmers can have surplus fruits for sale.

jointly address food security, nutrition, and sustainability. In East Africa, innovative partnerships were brokered with the private sector development partners who provided improved seeds, fertilizers, and small-scale farming implements (forage choppers) to promote productivity and reduce farming drudgery. Cross-regional exchanges and annual learning events went a long way to enable transfer of ideas between countries – for example, the feed troughs innovation being transferred successfully from the Ethiopian Highlands smallholder farming context to the northern Ghana and southern Mali contexts (see 'Feed and health package for small ruminant production', section 3.3, p. 42). Assessing technologies at the whole farming system level provided critical insights, such as Ethiopian farmers weeding their faba bean plots very late, and using the weeds for animal fodder; this revealed the need for faba bean–forage crop intercropping suited to local realities.

While integrated farm redesign has potential for future farming systems, barriers to adopting wholescale integrated innovations meant that only some components were implemented initially, allowing a step-wise approach toward implementing full integration. Hence, participatory research was vital to understand constraints, priorities, and desired outcomes from farmers' perspectives. This in turn enabled the agricultural development to be demand driven, and guide farmers appropriately. Technologies that demonstrably address these needs and concerns and are championed by fellow farmers are far more likely to be widely adopted. Continuous adaptation is required rather than seeking fixed end solutions, because no one solution and no single pathway fits every system.

Given the complexity of farming systems and consequent complicatedness of promoting multi-component innovations, researchers promoting Africa RISING component innovations took opportunities to combine or 'bundle' other innovations to enhance the value of the innovations they were focusing on. Examples from the preceding case studies are: improving poultry farming with waste from new vegetable crops, and returning the chicken manure to the vegetable plots as fertilizer (see 'Growing vegetables in Tanzania', section 3.1, p. 20); including doubled-up legumes or Mbili-mbili in integrated soil fertility management packages (see 'Integrated soil fertility management in Babati, Tanzania', section 3.2, p. 31); bundling the 'hard' technology of the maize sheller with the 'soft' technology of organizational management (see 'Maize shellers in northern Ghana', section 3.3, p. 38)'; improving household nutrition through the introduction of improved recipes being predicated on the introduction of improved crop varieties onto the farm (see 'Improving household nutrition', section 3.3, p. 46); combining Aflasafe with optimizing groundnut spacing for improved and safer crop production (see 'Optimal groundnut plant spacing', section 3.2, p. 35). This bundling may be considered a first step in integrated systems development.[38]

A poignant example of work on the minutiae of farming systems complexity (in this case, focused on soil physical and chemical variations), while also demonstrating the value of partnership with government and government agencies, is shown in the work in Ethiopia to overcome the poor adoption of fertilizer recommendations for wheat farming in the highly heterogeneous Ethiopian Highlands (see box). In a way, this is the 'other' side of farming systems science – focusing on the heterogeneity of one component across farming systems rather than looking at the components of a single system. Overall, advances in technology bundling and farming systems science were

38 See Barrett, C.B., Benton, T.G., Cooper, K.A., Fanzo, J., Gandhi, R., et al. 2020. Bundling innovations to transform agri-food systems. *Nature Sustainability* 3: 974–976. (https://doi.org/10.1038/s41893-020-00661-8).

a major achievement of Africa RISING, pushing boundaries.

Significant challenges remain in convincing development partners to invest in scaling up more complex, multi-component innovations emerging from systems science. Future efforts will require targeted co-creation of promising bundled solutions for emerging challenges with development partners to allow for demand-driven research. With diligence and patience, systems approaches hold immense potential for sustainably improving smallholder livelihoods across Africa and elsewhere. This requires focusing collaborative, participatory projects on priority farming challenges, and nurturing enabling environments where transdisciplinary systems work can thrive.

Fertilizer recommendations in the Ethiopian Highlands

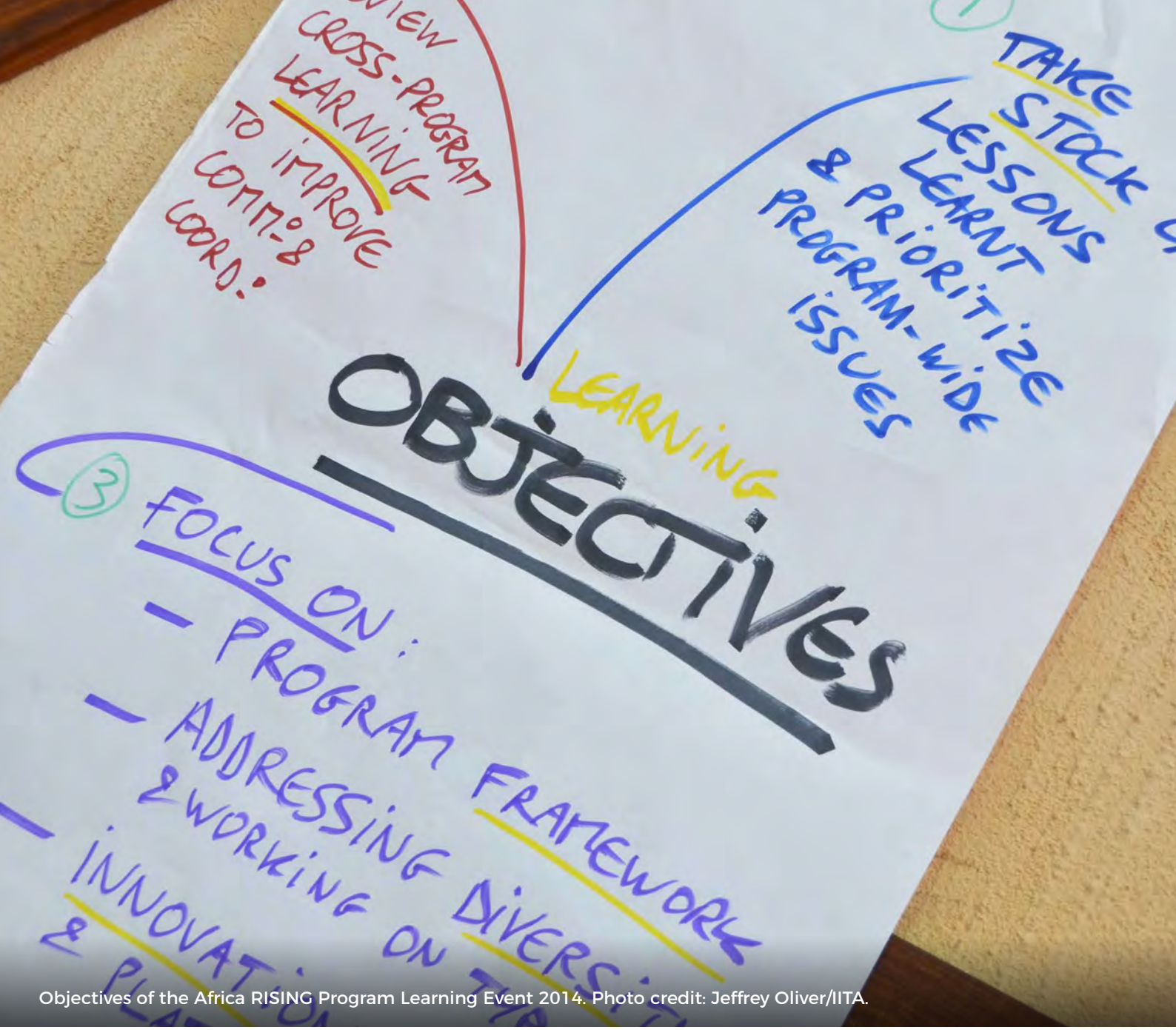
Ethiopian farming has experienced decades if not centuries of soil nutrient mining. The country's soils are severely eroded and degraded, producing just 40% of global average crop yields. In the early 2010s, the Ethiopian government invested huge sums in imported fertilizers and local fertilizer blending plants, developed detailed soil maps, and issued district-level fertilizer recommendations. The maps clearly demonstrate nitrogen, phosphorus, potassium, sulfur, and organic matter deficiencies across most of the country. However, fertilizer adoption levels were low. Moreover, national agricultural research system– (NARS-) run national fertility trials found few relationships between soil maps and crop responses to recommended fertilization levels. District-level recommendations took no account of farming system, landscape/topography, or cropping system, all of which are highly diverse in Ethiopia.

In response to the need for fine-tuning, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) – through Africa RISING and the GIZ Integrated Soil Fertility Management project – embarked on widescale fertilizer trials with wheat. This work, conducted during Africa RISING Phase 1, led to the identification of three slope-related nutrient zones, with very different responses to fertilizer inputs and very different yield levels. Crop response to fertilizer is dependent on many more biophysical characteristics of farmers' fields than just native soil fertility. Under the direction of the Ethiopian NARS, ICRISAT organized a national workshop in December 2015 at which the results and draft extension guide (decision-support tool) were presented and discussed. A national task force including the Ministry of Agriculture, NARS, local universities, Africa RISING, and others, was established to take the work forward.

After the workshop, work soon began on a new soil strategy for Ethiopia. The decision-support tool has been tested on other cereals (maize, sorghum, and teff) with some success. Subsequently, the Nutrient Expert app was developed for wheat-based systems by the International Maize and Wheat Improvement Center (CIMMYT) in collaboration with ICRISAT and Africa RISING.

Without the government and NARS groundwork on fertilizers and soil mapping, and the NARS subsequent finding of poor crop response, ICRISAT may not have become involved in this work. Without government buy-in on ICRISAT and Africa RISING research findings, Ethiopian farmers could still be facing 'blanket' fertilizer recommendations that do not appear to work in their fields, and the government's investment could have gone to waste.

See: ICRISAT. 2018. *Feeding degraded soils in Ethiopia to feed the people and the environment*. Patancheru, India: International Crops Research Institute for the Semi-Arid Tropics. (https://hdl.handle.net/10568/91676).



Objectives of the Africa RISING Program Learning Event 2014. Photo credit: Jeffrey Oliver/IITA.

Chapter 4

Lessons learned from the Africa RISING program

4.1 Monitoring and evaluation, and data management[39]

Context

The Africa RISING program involved diverse activities conducted by various partners in multiple countries to test and promote innovations across domains such as crop production, livestock, nutrition, gender, and capacity building. With so many partners and components, a monitoring and evaluation (M&E) system was needed to systematically gather data, monitor program activities, manage data collected, and facilitate data sharing among partners. The M&E and impact assessment system and strategy was intended to serve the purpose of aggregating and synthesizing evidence on outcomes relevant to program objectives on agricultural sustainability and livelihood improvements.

Monitoring

IFPRI led and coordinated M&E activities across the three regional projects. In Phase 2, monitoring responsibilities were devolved to regional teams through local M&E specialists, while IFPRI continued with centralized evaluation. The M&E team collected the following data.

1. **Direct beneficiaries and technologies.** These were individuals directly participating in testing Africa RISING innovations as part of the research activities.
2. **Indirect beneficiaries and technologies.** These were individuals who were exposed to Africa RISING technologies through field days, training activities, and other outreach activities. Researchers provided these farmers with a variety of services, including assistance with on-farm technology implementation, finance for agro-inputs, enhanced water provision for vegetable cultivation, and capacity building.
3. **Beneficiaries of scaling.** These were individuals who adopted/participated in the scaling of validated Africa RISING technologies as part of Africa RISING development partners' scaling activities, including through mass media, private sector–to-farmer scaling, and spillover scaling.
4. **Feed the Future (FtF) indicators.** These are a set of five performance management indicators established by the US Government's FtF initiative, guided by the Global Food Security Strategy, designed to measure progress against results in the FtF results framework.
5. **Agronomic/socio-economic data.** These are field-based data from agricultural trials on various technologies and innovations. For these types of data, technical backstopping was mainly provided by the M&E team on tools development, survey coordination, and data management.

To align M&E methods across the regional projects, IFPRI ensured regular interaction and coordination among regional specialists. Monitoring was mostly conducted through the following activities.

1. **Field visits.** The aim of the field monitoring visits was to meet project implementing partners and/or beneficiaries in the field, assess project progress, validate reports from activity leads, and document challenges and lessons learned. During field days, visits were conducted to collect data on beneficiaries exposed to technologies.
2. **Interaction with researchers.** Personal interaction with the researchers was key to enabling the M&E team to keep track of project status. This strategy was adopted for training on FtF indicators

39 With input from Carlo Azzarri, Beliyou Haile, Benedict Boyubie, and Daniel Mgalla.

and data collection. It was also used in the verification and validation of project beneficiary details and statistics.

3. **Interaction with scaling partners.** Development partners were key in the diffusion of validated technologies outside the operational areas of Africa RISING. Data on individuals reached through this approach was critical. For scaling partners, data were sourced from partners' reports and publications. Also, data collection tools were co-developed to report directly to the M&E team at regular intervals (quarterly, semi-annually, or annually).

The project adopted a multifaceted approach to scale out various technologies developed and/or validated (see section 4.4 Approaches to technology transfer). In light of these approaches, various methods of data collection were used as highlighted in Table 1.

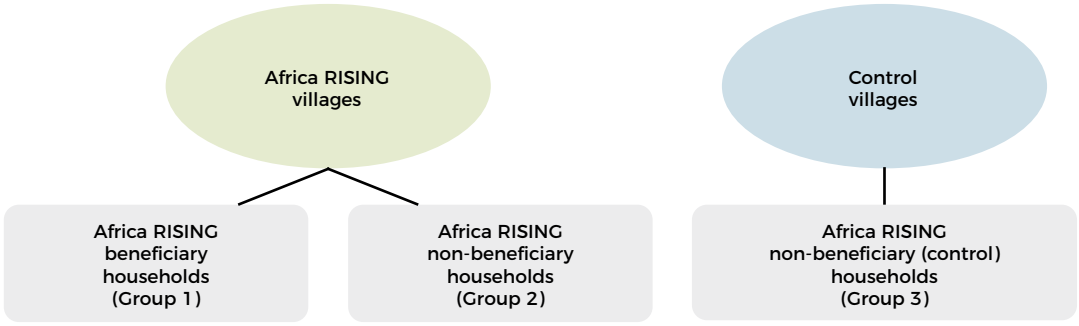
Evaluation

As the program was winding down its operations, it became important to evaluate its impact in various countries. A quasi-experimental design and two rounds of panel survey data are used to estimate the impact of Africa RISING interventions in Ghana, Malawi, Mali, and Tanzania (Fig. 6). Before conducting the baseline survey, a random sample of households was selected from a list of beneficiaries provided by program implementers (group 1). In addition, samples of non-beneficiary households from program villages (group 2) and non-program (control) villages (group 3) were selected.

Table 1. Data collection by Africa RISING: methods and timings

Data type	Tool	Timing of data collection
Feed the Future indicators	Project Mapping and Monitoring Tool	Once a year
Direct beneficiaries and technologies	Beneficiary and Technology Tracking Tool	After each growing season
Indirect beneficiaries and technologies	Exposure	After every exposure event
Beneficiaries of scaling up/out	Scaling	Annually
Agronomic/socio-economic data	Various	Per Sustainable Intensification Assessment Framework (SIAF); uploaded on Dataverse

Figure 6. Africa RISING impact assessment design



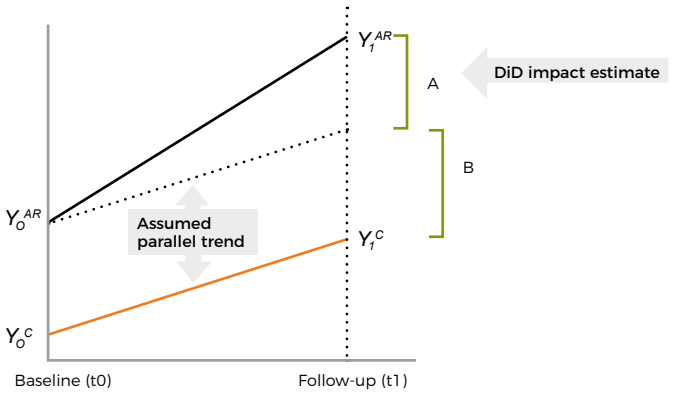
The Difference-in-differences (DiD) method was used for impact estimation by taking the difference in outcomes of groups 1 and 2 between baseline and follow-up (shown by 'A' in Fig. 7). DiD overcomes biases due to potential differences at baseline between treated and control groups (shown by 'B' in Fig. 7). Under the assumption that the outcomes of the two groups would have evolved similarly in the absence of the Africa RISING interventions, DiD produces unbiased estimates even in case of differences at baseline between the groups, assuming that other factors affect the outcomes of the groups the same way over time.

The study design also allowed the measurement of potential spillovers (e.g., due to information exchange across households within program villages), controlling for variables that have varied over time across villages by taking the difference in outcomes of groups 2 and 3 between baseline and follow-up (placebo comparison). Some of the impact results are reported in Chapter 2 Highlights of Africa RISING achievements.

Data management

In Phase 1, Africa RISING data were managed through the Comprehensive Knowledge Archive Network (CKAN) platform operated by ILRI. In Phase 2, to comply with donor requirements for data security and open access, data storage and sharing was made mandatory for all partners implementing Africa RISING

Figure 7. Impact estimate using Difference-in-Differences (DiD) approach



activities and the chosen repository was Harvard University's Dataverse. All data were anonymized by removal of personal identifying information prior to uploading to Dataverse. Data access was embargoed for 12 months (i.e., 12 months after uploading for single-year datasets and till after completion of agricultural trials for multi-year datasets), but all data then became open access. Per CGIAR policy, "Open Access means the immediate, irrevocable, unrestricted and free online access by any user worldwide to information products, and unrestricted re-use of content (which could be restricted to non-commercial use and/or granted subject to appropriate licenses in line with the CGIAR [Information Assurance] Principles), subject to proper attribution." Dataverse also provides backup supported by US federal funding, as it is a certified repository according to the USAID Open Access Policy.

The M&E team developed a Data Management Plan that outlined Africa RISING data management guidelines (IITA et al., 2019). The document sought to provide guidelines on data management practices, including uploading, sharing, and access of data on Dataverse. The data management plan was discussed, agreed upon, and approved by the three lead CGIAR centers (IITA, ILRI, and IFPRI) in consultation with the donor (USAID), and thus all Africa RISING staff and collaborators needed to comply with its provisions and rules.

The number of datasets submitted to the Dataverse repository and the number of downloads by country as of April 2022 are reported in Fig. 8. Table 2 shows the number of downloads of Africa RISING datasets (again up to April 2022) for datasets with at least 1,000 downloads. Both of these achievements demonstrate the enormous interest in data collected by Africa RISING researchers.

Figure 8. Datasets submitted to the Dataverse repository up to April 2022

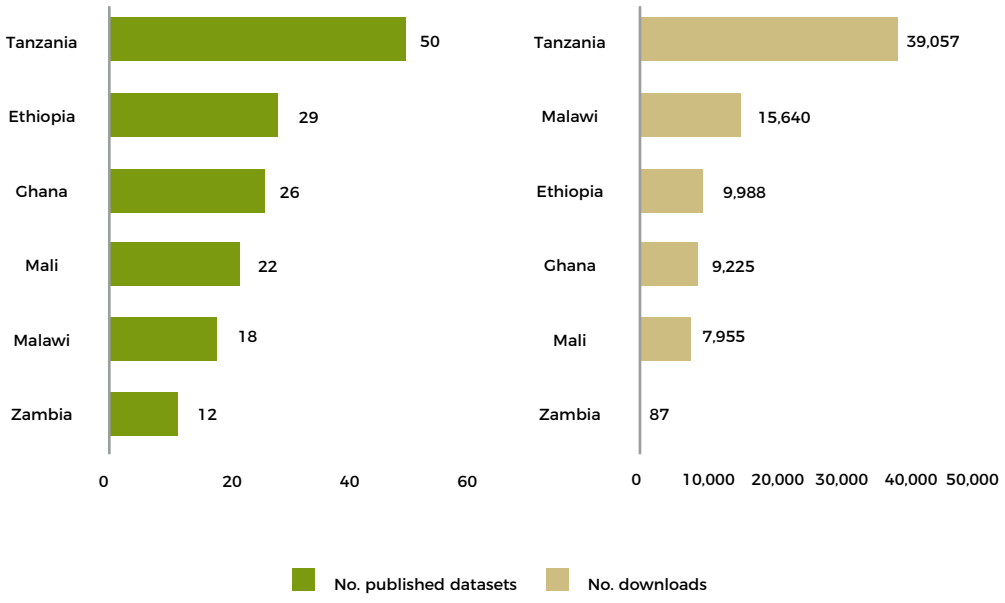


Table 2. Africa RISING datasets with more than 1,000 downloads up to April 2022

Dataset	2015	2016	2017	2018	2019	2020	2021	2022	Total
Rapid characterization of farming systems in Africa RISING-Tanzania	0	0	0	2,429	12,373	3,610	1,134	0	19,546
Tanzania Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) baseline evaluation survey (ARBES)	1	869	1,758	8,505	7,573	246	118	0	19,070
Malawi ARBES	231	1,002	390	1,805	6,096	264	57	0	9,845
Ethiopia ARBES	0	950	877	2,219	5,609	117	0	0	9,772
Ghana ARBES	0	1,094	457	2,225	3,815	222	175	1	7,989
Mali ARBES	0	495	107	1,355	5,570	39	2	4	7,572
Rapid characterization of farming systems in Africa RISING-Malawi	0	0	1	1,522	3,037	899	270	0	5,729

Milestones achieved

- Valuable data collection tools and systems were developed, including: the Beneficiary and Technology Tracking Tool to track direct beneficiary participation; the exposure assessment tool to estimate numbers of indirect beneficiaries; and the online Project Mapping and Monitoring Tool to report on FtF and other indicators, and map project sites and contextual data.
- In Phase 2, M&E activities were integrated into researcher work plans, improving data gathering and enabling rigorous evaluation of technologies and approaches.
- A monitoring system tracked diffusion of promoted technologies, approaches, and beneficiaries; This was pivotal for adoption and impact assessment.
- Baseline and endline surveys were conducted as planned in five countries, providing foundation data for impact evaluation. The data were widely shared within and outside Africa RISING (Table 2), reflecting a commitment to openness.
- Capacity building was delivered through regional workshops to enhance partner skills in areas such as use of data collection tools and data analysis.
- Open access data repositories and management systems were established to promote transparency and wide data sharing among project stakeholders and among the overall international research and practitioner communities.
- Great interest and outreach was achieved by the data management and sharing platform, demonstrating the value of the data collected, managed, and shared by Africa RISING.

Conclusions and key recommendations for future projects

- Establish the M&E framework, indicators, impact evaluation strategy, and data management plan early in consultation with implementing teams.
- Hire in-country/regional M&E staff from the outset to liaise between field and coordination teams.
- Foster close M&E team–researcher collaboration starting at project inception through joint planning and capacity building.
- Directly manage data systems (rather than relying on third party repositories) to minimize communication lags.
- Enforce contractual data-sharing requirements with partners upfront.
- Develop a data access policy early on with all stakeholders, including donors.
- Set realistic targets aligned with resources and capacity.
- Align communication channels and incentives between researchers and M&E to ensure collaboration and reporting.
- Simplify data collection tools whenever possible to avoid excessive time burdens on researchers.

4.2 Governance and management of a collaborative program: the Africa RISING experience[40]

Context

Africa RISING was structured as a program comprising three distinct regional projects led by CGIAR centers chosen for their expertise in those regions. While working toward common goals, this structure aimed to balance investments and leverage CGIAR strengths across diverse contexts. The regional projects had flexibility to tailor activities to local needs, unified under a shared research framework developed early on that provided a 'backbone' for inter-project collaboration. In fact, the genesis of Africa RISING was the creation of an umbrella program to maximize synergies across three pre-existing projects that already had the same ethos, rationale, and theory of change.

Key lessons

The lean management structure worked well by relying on existing infrastructure to save resources. However, it required dedicated, accessible leaders willing to take on extra responsibilities. The two project managers (one for the Ethiopian Highlands project and one for the projects in East and Southern Africa and West Africa) in particular needed to be multi-functional, including managing administration, finance, and human resources, because the projects did not recruit specialists for these roles. They also needed to be flexible and reachable for spontaneous interactions with project partners and the donor across different time zones. Regular, candid communication with the donor, even about

A Farmers' Field Day event in Maichew, Tigray, Ethiopia, October 2020. Photo credit: Apollo Habtamu/ILRI.

40 Based on an interview with Irmgard Hoeschle-Zeledon and Peter Thorne.

challenges such as problematic partner relationships, elicited advice and support. Informally checking in with donor staff regularly and inviting them to participate in key meetings and field trips kept the funder abreast of on-the-ground realities.

Africa RISING developed and empowered an apex decision making organ (which included the donor), the Program Coordination Team, which provided critical 'glue' to hold the collaboration together and maintain coherence despite contextual differences across regions. It brought project leaders together to discuss cross-cutting issues.

Annual funding cycles posed planning challenges but were managed through careful budgeting and coordination. Holding a reasonable buffer in each year's budget helped bridge delays between funding installments. This contingency buffer also helped overcome shortfalls when they occurred. This mechanism proved invaluable during an unforeseen major budget disruption.

Hiring specialized expertise (gender, economics, communications) addressed emerging needs identified over the first two years, balanced against costs. Additional skills could have added even more value, but hiring was constrained by budgets and availability of qualified experts.

Each project benefited from a chief scientist who strengthened project technologies through expert review and constructive feedback on partner proposals and technologies. Combined with review by the project managers, this provided quality control of partner proposals and reports, forced clearer explanations of complex topics, and ensured judicious funding for suggested partner activities based on scope.

Proportional cost-sharing among the projects enabled joint activities such as meetings and conferences without disputes over fairness.

Transparency with partners about funding availability and activity costs enabled collective planning of annual work plans matched to budget realities.

Project managers provided backstopping support to partners when needed, helping manage relationships and resources.

Strong involvement of local partners and authorities in research activities proved very helpful in technology dissemination and was key during the coronavirus disease 2019 (COVID-19) pandemic, when national and international travel was banned, to keep up the field activities.

Membership of high-level oversight groups – in the case of Africa RISING, these were the Science Advisory Group and Project Steering Committees – needs careful consideration; the invited individuals and representatives of organizations who make up these groups need the appropriate skills and experience to make a valuable contribution, especially in relation to the integrated systems approach. The same applies to review teams, whether commissioned internally or externally.

Donor commissioned and internally commissioned external project and program reviews provided critical and constructive feedback and guidance for future adaptation on all project and program related aspects (management, science, staffing, fund allocation, etc.), primarily from those review team members with the technical and scientific capabilities to understand the integrated systems science approach and the complexity of the program.

Annual partner agreements, necessitated by the donor's annual funding cycles, added a time-consuming bureaucratic burden compared with typical multi-year research contracts, requiring renegotiation with every partner each year; however, they also allowed for timely corrections in research directions and partner composition.

In summary, the flexible, collaborative program model enabled sharing of CGIAR expertise across diverse regional contexts through strong relationships and a unifying research vision. But it required dedicated leaders and engaged partners to navigate complexities. The lean management approach conserved resources for research while meeting evolving needs. The Africa RISING experience provides insights that are useful for designing future complex research collaborations.

When the world stood still: the COVID-19 pandemic

When the COVID-19 pandemic struck in early 2020, it significantly disrupted planned field research, capacity building, physical interactions with research implementers and beneficiaries, and technology dissemination efforts.

To adapt, the program increased its use of digital tools to allow remote work and coordination; field staff leaned more on local partners to continue critical activities; and researchers pivoted to focus on analyzing existing data and writing publications for different audiences. The program also found creative ways to continue serving farmers, such as adapting a pre-lockdown field visit to train lead farmers so they could then train others.

The vital partnerships already established with local communities became key to operating safely and distributing inputs for the planting season; for example, purchasing (by phone and email) and distributing over 20 tons of crop and forage seeds to over 5,000 farmers in Ethiopia.

The pandemic brought immense challenges, but Africa RISING remained determined to pursue its mission through adaptation. This experience built resilience that strengthened the program for the last two years of its activities.

4.3 Gender integration into the selection and promotion of technologies[41]

Context

Africa RISING's mandate was to generate research outcomes that improve the livelihoods of smallholder farmers, specifically those of women and young people (including children). As a result, gender and equity issues constituted key areas of work. Gender teams were set up in 2015 for activities in all three regional projects. They comprised senior and junior social scientists from IITA, ILRI, other CGIAR centers, and other partners (e.g., Lilongwe University of Agriculture and Natural Resources, Malawi; University of Dodoma, Tanzania; University of Development Studies, Ghana; Association Malienne d'Éveil au Développement Durable, Mali; and GIZ, Germany).

Smallholder farming in sub-Saharan Africa is considered highly gendered, and various organizations and projects over the past 40 years or so have sought to redress historical bias in development that primarily targeted men.

An important initial step was to learn from ongoing and completed project activities and to better tailor gender activities toward needs in target communities. Consequently, Africa RISING commissioned gender evaluations of its work in Ghana, Malawi, and the Ethiopian Highlands on livestock management and women farmers' participation in the agricultural research process. The Ghana evaluation recommended more research on maize (a staple that women are culturally permitted to plant and sell) and small ruminants (Ghanaian women farmers said that rearing small ruminants would help them generate their own incomes). The Malawi research emphasized the importance of taking a household approach, in which several household members are trained jointly in agricultural innovations and equitable production relations. The evaluation team in Malawi determined that gender capacity building for all types of Africa RISING stakeholders would be required to make gender integration sustainable.

Abeid Chonya and his wife Sumaiya collaborated with the Africa RISING-NAFAKA project in bean seed multiplication in Mkungugu village, Iringa District of Tanzania.
Photo credit: Jonathan Odhong/IITA.

41 With input from Gundula Fischer and Annet Abenakyo Mulema.

The recommendations arising from this early research fed into the gender teams' workplans, with activities grouped under two core tasks: (i) integration of gender and intersectional analysis into the projects' interdisciplinary research for development; and (ii) gender capacity development for a diverse range of stakeholders involved in the projects and beyond.

Integration of gender and intersectional analysis in interdisciplinary research

Historically, technology transfer has failed when the research and out-scaling have omitted the social science element.

Weaving gender and intersectional analysis into experimentation with agricultural technologies matters for several reasons. One is that a better fit can be achieved between technologies' requirements and outputs and the needs of different user groups (based on age, gender, resource endowment, etc.). Another reason is that women's voice in household decision making on technology adoption remains low. This is not only due to unequal household power relations but also to the fact that extension activities often do not consciously reach out to women. These and other aspects were turned into key research questions for evaluations of Africa RISING technologies.

Africa RISING conducted gender assessments of mechanization, maize, soil and water conservation, irrigation technologies, and vegetable varieties. The program also recognized the need to assess the correspondence of technologies with gendered user needs in the context of the value chains to which they contribute. Thus, gendered value chain analyses were carried out on small ruminants and maize in Ghana, and traditional vegetables in Tanzania. The Africa RISING Sustainable Intensification of Agricultural Research and Learning in Africa (SAIRLA) sub-project paid specific attention to how young people can be included in sustainable intensification initiatives.

During Phase 2, two main approaches characterized the Africa RISING gender research. First, the Sustainable Intensification Assessment Framework (SIAF), which was introduced as a mandatory framework for Africa RISING technology validations in 2018. SIAF supports interdisciplinary exchange and cooperation, including a stronger gender and intersectional perspective. Equity issues were limited initially to SIAF's social domain, but were later mainstreamed across all domains of the framework to help identify where technologies or their contexts would need to be adapted or transformed to improve the livelihoods of women and men farmers. In addition to assessing technology impact, SIAF can also be used as a gendered research planning tool, an aspect highlighted by Feed the Future in a case study on gender integration in USAID agricultural research investments in 2019.

The second approach was linked to the fact that gender relations in agriculture must not only be understood and considered, but also transformed to achieve equity in the long term. Africa RISING gender-transformative research included a study on sustainable intensification initiatives in the context of gender-biased land tenure systems in Ghana and Malawi, and a small ruminant value chain analysis in Ghana that explored how gender norms shape men's and women's participation in the value chain and the resulting gains.

Gender capacity building

Gender capacity and training needs assessments (conducted in all three projects) and the work on integrating gender and intersectional analysis into research clearly identified the skills needed to conduct gendered or gender-responsive research and development. Consequently, the gender teams provided capacity development in these skills to diverse

stakeholders both within and beyond the projects.

In Ethiopia, a gender capacity development workshop was conducted by ILRI, the International Water Management Institute (IWMI), and the University of Florida. The workshop used materials from the USAID-funded Modernizing Extension and Advisory Services program that had previously been tested in various countries in Africa, Asia, and Latin America to strengthen the gender capacity development of partners in analyzing agricultural value chains with a gender and intersectional lens, and applying appropriate strategies when interacting with men and women, young men, and young women. This contributed to the design and implementation of interventions and technologies that responded directly to the needs of men and women. Overall, the workshop highlighted the value of gender training, but also the need for additional ongoing support in this area.

The gender capacity and training needs assessment conducted in 2015 prompted the East and Southern Africa and West Africa teams to draft a training manual for gender analysis in agriculture. This manual was then put to the test through four two-day training workshops conducted in Ghana, Malawi, Mali, and Tanzania in 2017. Feedback from the 60 participants (14 women, 46 men; mainly researchers) fed into revision of the draft manual, which was then peer-reviewed by three gender experts. The final manual was published in 2019 as *Gender analysis in farming systems and action research: a training manual* (Fischer et al., 2019). It has 15 modules grouped under 4 'learning units'.

Meanwhile, the Africa RISING Ethiopia project team published guidance for researchers on integrating gender into project proposals: *Integrating a gender perspective to help scale Africa RISING technologies and practices: requirements for proposal development and implementation* (Mulema, 2017).

It is not only practitioners but also policymakers who need to understand gender issues in agricultural research and development to aid appropriate decision making. In response to policymakers' and practitioners' self-identified needs, the Africa RISING-SAIRLA team developed tools that were then tested and refined through several national workshops in Ghana and Malawi, with the same participants involved throughout the process. The final output was *A decision makers' guide to equitable sustainable agricultural intensification* (Grabowski et al., 2022).

Meanwhile, in Malawi and Tanzania, the gender team combined training on agricultural technologies with gender-transformative exercises from the Gender Action Learning System (GALS). Two members from each selected household (usually husband and wife) participated in the (training) workshop, which enabled peer-to-peer learning about the technology, in which farmers familiar with a particular technology shared their experiences with farmers who were unfamiliar with it. The GALS tools enabled participants to reflect on household (and community) gender imbalances. According to participants, the presence of husbands and wives together in the training strengthened their participation in joint decision making on technology adoption. They also learned together about achieving balanced gender relations. Several households subsequently moved toward greater equity, as noted in gender team follow-up visits. A manual was developed to guide practitioners and farmers elsewhere to follow this process: *Gender-transformative decision-making on agricultural technologies: participatory tools* (Farnworth et al., 2022), which provides six tools for use by extension and development workers, policymakers, and research-for-development projects. The tools are specifically designed for use with non-literate people.

Throughout its second phase, Africa RISING provided and refined gender capacity development training for all levels of stakeholders, from decision makers, through

A farmer and his family in northern Ghana. Photo credit: Michael Dakwa.

government ministries, researchers, extension and development workers (including NGOs), and local government, to farmers.

Conclusions and recommendations

In the latter stages of the program, extremely valuable insights were gained into the benefits of conducting gender analysis prior to scaling out of technologies.

In particular, the studies of social dynamics in the context of sustainable intensification in all three project countries concluded that conducting gender analyses prior to promotion of technologies is essential to mitigate trade-offs, such as significant labor increases among women or men. Using participatory community engagement approaches to develop complementary technology packages can redress trade-offs associated with new technologies and labor requirements – for example, water pumps to meet increased watering requirements of new varieties.

Gender-responsive approaches should be used to promote technologies that women choose, prefer, and manage – to improve productivity and, hence, income and nutrition benefits – for example, livestock feed and fodder technologies that increase milk production. Socially inclusive scaling approaches that engage women and men will ensure that gendered preferences are embedded in the selection and promotion of technologies that meet both women's and men's needs, and improve sustainable intensification in diverse households and communities.

Application of an inter- and trans-disciplinary framework gives gender a fixed place in interdisciplinary cooperation. In the case of Africa RISING, this was the SIAF, which brought together natural sciences, economics, social sciences, and technology assessment, establishing Africa RISING as a pacesetter in this field.

The abilities of scaling partners to integrate gender in technology validation and out-scaling cannot be assumed. They must first be assessed and, if found inadequate, training must be provided. Africa RISING's training materials and guides for various types of stakeholders and partners are freely available for use by anyone.

4.4 Approaches to technology transfer[42]

Overview

This chapter presents highlights from lessons learned through the technology-scaling approaches applied by the three projects of the Africa RISING program in relation to the research-in-development continuum. It also identifies potential constraints to wide-scale adoption of technologies validated in the Africa RISING project areas and beyond.

Partnerships are key

It will come as no surprise to most technology transfer practitioners that the key to successful technology transfer – or, rather, development in general – is successful partnerships at every level. If there is no rapport with the target audience, development simply will not happen. If there is no engagement and rapport with scaling partners, the dissemination of technologies will likely result in slow and limited uptake.

Much of what has been 'learned' about scaling during the implementation of Africa RISING is more confirmation of what has worked in many previous projects and programs, but herein effectively refined into a set of best practices that are grounded by evidence-based research-in-development.

In that light, we look at various groups of partners in turn. For Africa RISING, the partnership combinations for technology transfer consisted of various and context-specific collaborations between CGIAR centers, international research entities, national agricultural research centers, NGOs (both local and international), other public and private research projects and development entities operating at various levels.

Nuggets for a successful scaling/technology transfer partnership from the Africa RISING experience include the following.

- **Partner identification.** A useful preliminary step to engagement was mapping of potential partners, and consulting with identified potential partners on a shared ethos and approach, and on the modalities of the proposed partnership. These steps help avoid partnering with entities that do not share the project ethos and may later prove a barrier to effective work should they come on board. Complementarity of expertise, connections, and strengths is valuable in any partnership.
- **Champions for regular interactions.** Where a scaling partner is a vast organization, reaching all its extension agents directly may be an impossibility for the researchers. It is therefore invaluable to identify, cultivate, and engage 'champions' or focal persons to form a bridge by interacting regularly with the researchers and then championing the technologies among their colleagues. This was the case with the government extension service in Ethiopia, where two champions were identified for each district. These champions received a small allowance from the project to maintain their motivation.
- **Joint planning.** This was a major success factor identified in partnerships with NGOs, but is equally valid in all partnerships. Where multiple partners are involved, it is probably best to do joint planning with all partners at one time rather than trying to plan with each partner individually. This helps provide transparency in the process and can avoid duplication of effort and resolve any 'turf wars' at one time. Particularly in the context of planning with NGOs, involvement of local government planning staff in multi-stakeholder platforms was deemed

42 Based on an interview with Fred Kizito, Mateete Bekunda, and Kindu Mekonnen.

a success criterion. Especially when funding is limited, strict prioritization of activities through joint planning will avoid spreading (financial) resources too thin.

- **Full engagement.** Except where a specific partner has a very specific role within a multi-partner initiative, all scaling partners should be closely involved in the whole process from problem diagnosis, through action-research, to scaling, where they are co-creators of the research agenda, co-implementers of field research and scaling activities, and co-evaluators of achievements. This is especially true for the numerically or resource dominant partner.
- **Partner expectations.** There is a need to manage partner expectations from the beginning to ensure that one is not committing to more than what can be realistically offered in the partnership. This is especially important in the context of agricultural research where other exogenous drivers – for example, a massive health care crisis such as COVID-19 – could swing the pendulum for donor priorities to another urgent demand, which may invariably affect the funding of a given development. In such cases, legal clauses built into the partnership agreement will allow both parties to anticipate unforeseen circumstances and allow the partnership to adapt accordingly.
- **Open and regular communication.** It is valuable for partners to communicate and engage through a diversity of methods. All partners need to be aware of the available technologies being considered, develop an interest in them, and seek support in their own activities. Engagement modes differ according to partner type, but may include one-to-one (organization-wise), especially in early stages when the lead organization is trying to bring partners on board; multi-stakeholder platforms (involving, e.g., farmers, processors, agro-input dealers, mechanics, other service providers, research, extension, development specialists, NGOs, private sector, finance institutes); field days; exchange visits; capacity building; and use of published online or offline materials.
- **Stepwise engagement.** The research side needs to engage with scaling partners in a series of incremental steps. First, providing them with the needed research evidence of technology performance, via a demonstration trial, for example. Then introducing them to the pilot participant farmers and other partners, perhaps through a multi-stakeholder platform. And finally, helping them integrate the scaling work in annual planning that targets many farmers.
- **Cost-sharing.** Equitable cost-sharing at some level or another not only promotes joint ownership, but also prevents engaging those who might only be 'in it for the money'. It is important to explore the various modalities where 'cost-sharing' benefits could come into play. Sometimes, partnerships are built on non-monetary in-kind support or contributions. For example, activities that invite a partner to a regional field day or disseminate their technology through a digital platform promote the visibility of that development partner and offer greater dividends and market opportunities with a much wider reach than they would have achieved without the partnership.
- **Unified messaging.** Clear messaging on the trade-offs of technologies will communicate a united front to the ultimate beneficiaries and enhance informed decision making for adoption.
- **Market-based identification of entrepreneurs.** Creating a cadre of entrepreneurs is a major component of many agricultural development projects. It is important to always bear in mind that these people are being trained to become part of the private sector, so market considerations are essential.

Dodoma Regional Commissioner, Rosemary Senyamule officially launching the Sustainable Agricultural Intensification Handbook on 26 August 2022 in Dodoma, Tanzania. Photo credit: Jonathan Odhong/IITA.

Involve stakeholders early on

Farmers' or stakeholders' involvement in technology transfer should start as early as problem diagnosis and action-research. Successful technologies – that is, those that are adopted by farmers (or other stakeholders) and have the desired impact – are generally those that have been developed in partnership with the ground-level actors, be they farmers or other value chain actors. If the farmer does not recognize the problem that the technology is designed to overcome as something they face on a regular basis, they will not be interested in it. It is equally important for farmers to be involved in the action research that takes tried-and-tested technologies from the shelf and validates them in the context of their fields.

Lead farmers and farmer groups help with scaling

In the action-research stage – typically technology testing, adaptation, and validation – principal project participants-cum-beneficiaries are often lead farmers. These typically receive almost everything that makes up the technology, from the researchers working with them, to seed and agro-inputs, and full details of how to get the best from the technology, along with training and technical support. They also often receive training in skills for making the most of their increased production, such as leadership, business acumen, marketing, and communication. This applies equally to farmers engaged in on-farm experimentation and those who host technology demonstrations.

A second layer of beneficiaries includes those who see the technology in action research or demonstration and decide to try it for themselves. While they are sufficiently motivated to invest in the technology, they will typically receive the training and essential inputs such as seed of new crop varieties.

A third layer of beneficiaries also see the technology in action research or demonstration and decide to try it for themselves. Typically, this group may not get formal training, but rather learn from seeing their peers and are sufficiently motivated to invest in the technology by purchasing the essential inputs such as improved seed varieties or fertilizers. This group, which does not get handouts, is likely to continue with the technology and scale it further beyond the lifecycle of the donor-funded project. Especially in the context of scaling, it is common (and productive) for

development projects to work with groups of stakeholders, be that farmer groups, processor groups, or other kinds of groups. This has the advantage of engaging multiple beneficiaries simultaneously and enabling them to share their own experiences with each other.

A key and ongoing constraint to the autonomy of farmer groups is financing. Except for large-scale commercial farms, agriculture is typically excluded from formal financing arrangements established by banks. It is therefore invaluable to the ongoing work of farmer groups if a project can encourage financial institutions to develop financing instruments and products that the farmers can tap into, whether individually or collectively.

Innovative, accessible, and inclusive farmer learning approaches help with scaling

Technology parks

In West Africa (Ghana and Mali), Africa RISING adopted the technology park approach, using a plot of 0.5–1 hectare within the community as a learning center for hosting agronomic trials and demonstrations. Farmers from the community received a full explanation of the background and objectives of the trials and hands-on training through being involved in all activities, from field establishment to final technology evaluation. The same farmers received support from the research staff to implement the technology in their own fields, which included agro-inputs on credit, improved water provision, and capacity building. Africa RISING set up a total of 16 technology parks in Ghana and Mali, which enabled many farmers to access improved technologies.

There were several keys to the success of the technology parks. First, partner engagement from government extension services and NGOs in project implementation, which strengthened the partnerships to sustain project activities. Second, empowerment of women farmers by giving them (improved) access to capacity building, and enabling them to provide nutritious food for their families. Third, the parks provided an opportunity for engagement with non-conventional partners, such as Peace Corps Volunteers, who in turn shared their own ideas and extended technology reach beyond the project communities. Fourth,

A farmer standing in a technology park in Cheyohi No. 2 Community in Northern Region, Ghana. Photo credit: Jonathan Odhong/IITA.

the parks fostered enthusiastic technology champions who took the technologies to an even wider audience.

The future of the technology parks is being assured through discussions about handing over their managerial oversight to the West and Central African Council for Agricultural Research and Development (WECARD; French acronym CORAF) through the Innovation, Research, Extension, and Advisory Coordination Hub (iREACH) initiative that is funded by the USAID Bureau for Resilience and Food Security. It is important that the future of technology parks and similar endeavors is planned before the winding down of a project, so that they leave a legacy and the land is not simply reverted to 'regular' farmland or allowed to lie fallow.

'Mother and baby' approach

Applied by Africa RISING in East and Southern Africa, 'mother trials' on volunteers' farms offered whole farming communities an opportunity to participate in implementing new technologies in familiar and accessible settings. The hosts managed the trials and demonstrations under research and development partner guidance, provided security for the plots, and allowed access to other farmers for joint evaluations and field days. Other farmers from the community then adapted and adopted those components (technologies) that interested them as 'baby trials' on their own farms, with support and some inputs from the project research team. The approach also triggered new research ideas from participants' observations and challenges.

Multi-stakeholder innovation platforms

The traditional technology transfer model follows an approximately linear approach from research to scaling partner to farmers and other stakeholders. Where this is the case, the lead research and development partner has a role in training up the 'dominant' scaling actors (public, NGO, or private sector) for them to take the technologies to farmers. A more 'modern' approach is for all partners to be involved in, for example, a multi-stakeholder innovation platform, where they can all work together or specific partners can form smaller groups for specific activities.

Multi-stakeholder forums have a valuable role to play in identifying and filling gaps, especially in value chains. Value chain development is essential if critical gaps are found. For example, for the case of the Ethiopian Highlands, once it became evident that there were no faba bean seed suppliers, the issue of seed production and dissemination was addressed.

Reach more sustainably by collaborating with the public sector (including NGOs)

For Africa RISING, the 'public sector' comprised NARS, universities, government extension services, NGOs, USAID mission–supported projects, and other government services. Despite being technically in the private sector, NGOs have much in common with public sector partners in terms of their structure and ethos.

In countries where the public (government agencies) sector is strong (such as Ethiopia), this sector will most likely be the biggest and strongest partner for any agricultural development project reaching for scale.

When technologies align with government development goals and objectives, public sector partners will be enthusiastic, as was the case in Ethiopia where an estimated 25% of the 34,000 beneficiaries of capacity development (i.e., 8,500 people) were trained via the government extension system.

Meanwhile, in Ghana, nutrition-related interventions that were co-developed with target smallholders were delivered by 15 staff of the Ghana Health Service and community radio stations trained by the project, reaching an estimated 40,000 farmers beyond the Africa RISING target zones.

Several important lessons about partner engagement in general and engagement with a powerful public sector in particular were learned (especially in the Ethiopian Highlands context, but also elsewhere). Some of these are included among the common elements for successful partnership (above), while the public sector–specific ones follow.

- The research side needs to be aware of the many support connections that local extension is tapping into (e.g., local research systems, academia, input suppliers, formal farmer organizations), which are essential to extension efficiency. The researchers also need to connect with these players, either directly or through multi-actor structures.
- The project operational calendar should be aligned with that of the extension service as much as possible to maximize the investment in scaling.
- Africa RISING was able to tap into federal and regional expertise and technology providers to the benefit of local extension.
- .On occasion, local extension was constrained by decisions made at higher levels, be that other government ministries or higher up in the extension service or ministry of agriculture itself. In some of these cases, Africa RISING was able to use its influence at those higher levels to achieve the desired progress. Projects (or project partners) with enough clout may have opportunities to engage national government at higher levels, especially when national policy works against project and sustainable development aims. For example, ad hoc export bans of (certain) agricultural products can be a major disincentive to farmers for increasing production.
- Where the government extension system receives funding from diverse sources, there are opportunities to align funding proposals with scaling goals.
- Africa RISING was able to access resources that were otherwise effectively out of reach of the extension services (because of lack of human resources or inability to access); for example, using geographic information systems (GIS) in Tanzania to generate recommendation domains (i.e., maps of where specific technologies would be applicable).
- Get academia involved! If a research and development partnership can be developed with a local university, a project can tap into student resources, or rather, students as resources. The project can benefit from the synergistic effects of students gaining valuable hands-on experience while also gaining extra research capacity. For example, in Ghana, Africa RISING collaborated with the student-led Youth Mappers Association from the geography department at the University of Cape Coast in mapping out boundaries and extent of farmer-led initiatives in intervention communities. In return, the project's GIS lead helped build the youth mappers' capacity in the context of extrapolation domain analysis. These kinds of collaborations ensure that students gain practical skills and training, in addition to learning about available technologies, both of which are valuable additions to their subsequent careers.

Ally with the private sector

Private sector actors can be valuable allies in development; indeed, there are few development initiatives that will become self-sustaining if the private sector is not involved in one way or another. It is essential to remember, however, that private sector actors are unavoidably enmeshed in the commercial world: they are not philanthropists; they need to make a living. Consequently, the private sector is typically involved in development through the provision of goods or services. Where an intervention calls for seed of improved varieties and agro-inputs, the private sector can often be relied upon to multiply and sell seeds and to trade in agro-inputs. It may

even extend to farmers the option to pay in-kind or to give out inputs on credit with a view to being paid in full once the final crop is sold. The institutional arrangements around these need agreements that are simple, clear, and transparent from the beginning to avoid potential conflicts between producers and the private sector.

One incentive for engaging the private sector is the inconsistency in availability and affordability of critical inputs, such as quality seeds, fertilizers, and pesticides, which leads to farmers (and projects) trying different alternatives each season. In most cases, these inconsistencies are outside the sphere of control of researchers. Initially, researchers need to be better prepared with alternative options for farmers. One option is engaging value chain systems to include alternative input production and distribution systems, such as was the case with Mount Meru Millers Limited and MERU-AGRO in Tanzania; and alternative organic and biological nutrient inputs may be introduced in place of industrial fertilizers. While this approach presents a basket of multiple choices, it does introduce complications in consistent messaging.

Staff of companies are perhaps best trained in the skills needed for a particular technology 'on the job', for example by actively participating in research-led trials and demonstrations, and playing an active role in farmer training and farmer field days.

It is of immense value if agro-dealers know how to use the inputs they supply – for example, pesticides, fertilizers, and tools – so they should be trained in proper use and associated good agricultural practices. It is also worth training seed dealers in variety identification. In this way, agro-dealers become para-extension agents and can sell a package comprising the input plus appropriate training in its use.

In addition to input suppliers and marketing intermediaries, the private sector includes outgrower schemes, in which a farming company supplies seed, agro-inputs, and agronomic advice so that their farmers all grow the same variety of a crop to the same quality, which the company itself is contracted to buy. The inputs supplied by the company are usually given on credit against the final value of the crop supplied at the end of the season.

In an effort to address the dual scenarios of a burgeoning youth population and rural–urban migration, many development projects across the continent are targeting youth with agriculture-related training. Africa RISING was also engaged in this approach. In addition to encouraging many young people to take up farming as a livelihood, many others have taken the path of entrepreneurship, in particular agricultural service provision. These young people require training, not only in the technologies they will provide, but also in business acumen, including accounting. This training of farmers and prospective (often youth) agricultural entrepreneurs by projects and development organizations is in and of itself a means of building the future private sector.

Development project investment in supplying technologies, training, advice, and blueprints to the private sector is a vital step in making development self-perpetuating beyond project life.

Lean on the power of the mass media channels that are available and preferred by the communities

When the target audience for scaling is widely scattered or living in areas far from the original target communities, it is necessary to use different mechanisms to reach them. Two of the most successful are radio and text messages or short message service (SMS).

Production of radio programs involves close partnership between development project staff with knowledge of the technology and radio station staff who know how to make a radio program. Training works both ways. The output is often a series of agricultural programs that lead the farmers through

various activities in the season. In southern Mali, before developing and airing radio programs about the production of dual-purpose sorghum varieties, Africa RISING and Farm Radio International conducted pre-broadcast surveys to establish audience preferences, such as the best time to air the programs for the majority of the audience. Publicity posters were then sent out to the target communities and on-air announcements made to help ensure that the audience knew the day and time of broadcast. It is valuable to have peer discussion groups in the target communities to discuss the program and the implementation (and possibly adaptation) of the advice given. These groups can also provide feedback through the program, potentially in the form of a panel discussion. Another popular route for listener–practitioner engagement is listener phone-ins. These typically take an additional slot after the airing of the program, are hosted and facilitated by a radio presenter, and possibly include an expert from the project in the studio to answer questions.

Radio also proved particularly useful for Africa RISING during the COVID-19 lockdowns when visits to communities were forbidden by blanket bans on all but essential travel.

Text messaging is an alternative means of broadcasting information to a wider audience. Ultimately, it is probably much cheaper than radio program production. However, an SMS campaign still requires careful planning; it also requires recipients to sign up. SMS campaigns may be semi-automated through an information and communications technology system. Again, communities of recipients may be encouraged to meet (in consultation with the agricultural extension agent responsible for the target area) to discuss what they are learning and implementing, and to feed back. SMS is particularly useful for disseminating weather forecasts, 'what needs to be done now' messages, and market intelligence (e.g., prices). SMS was particularly useful for delivering a full training course for fall armyworm control when this moth-caterpillar pest of maize arrived in East Africa.

With the boom in smartphone use, simple text messaging may be expanded into multimedia. Via the Mwanga platform in Tanzania, for example, the Africa RISING project was able to make a series of 'how-to' (step-by-step educational) videos available for streaming or downloading to use offline. While these can be viewed by individual farmers on their smartphones, extension agents promoted community engagement by placing a tablet in each community to be loaned out to small groups to watch the videos together.

While not considered by Africa RISING, television is another mass media channel that could provide a route into farmers' homes.

Keeping track of 'spillover' effects

There comes a point – ideally before the end of the project – when scaling goes beyond the reach of the original research partner. This may be the first steps outside the target communities through farmer-to-farmer interaction or via open events such as farmer field days. It may be someone casually picking up project material in a 'random' place, being convinced by what they read, and deciding to try it out. Or it may be existing or new scaling partners taking the technology to new areas. Whichever way it happens, it is usually at this point in scaling that the technology becomes impossible to track completely (it may be possible to find many adopters outside the original project scope, but not all of them). If this 'spillover' occurs on a large or wide scale, the technology and the project may well be considered a success.

Other considerations and constraints

Awareness raising. Lack of awareness of available technologies and their benefits continues to be a primary concern, and is a major reason why awareness-raising is such a critical part of scaling projects. The more

means that can be found for such activities, the faster technologies will spread, and the more people will benefit.

Projects need to remember the business case for technology adoption, which is otherwise too easily clouded by the handouts provided for project participants.

Language must not be a barrier. For example, the Africa RISING-NAFAKA sub-project on staple value chains in Tanzania trained non-English-speaking lead farmers as village-based advisers, especially in remote communities. They were given a motorbike and linked with the local (nearest) ago-dealer (as a source of supplies for farmers).

Be gender conscious. While the western model of society may look toward equal opportunity regardless of gender, that is very much not the case in some of the rural communities where the program implemented activities. It has long been known that men, women, young men, and young women all play different roles in African farming communities. The past four or more decades have seen an emphasis on these differences in research and development, especially in developing technologies for women. This must continue. Africa RISING promoted gender-transformative approaches. One pertinent example is the intensification of market gardening with technologies requiring little space and minimal water compared with traditional market gardening. This has opened a major economic opportunity for women farmers, especially those in male-headed households. See section 4.2 for more information on Africa RISING's gender work and recommendations.

Dedicated research, accurate on-farm data, and extensive documentation. Researchers not affiliated with the project may question or discount the viability and suitability of certain technologies even after the project has validated them. However, dedicated research, accurate on-farm data, and extensive documentation encouraged continued interest by funders. In addition, a common vision between researchers and the development partners to scale certain sustainable intensification practices (e.g., conservation agriculture) led to the needed continuity in effort and funding.

There may be competition for partners' resources. Some development partners were scaling many technologies at the same time, some of them originating from actors not affiliated with Africa RISING. This seemed to weaken the quality of engagement in supporting the Africa RISING technologies. The apparent level of engagement of the development partner with the technology may have a direct impact on adoption within the scaling target audience. Multi-stakeholder engagement proved one of the best mechanisms for tackling this issue.

Success

Africa RISING formed a range of successful formal and institutionalized partnerships (20 in East and Southern Africa, 45 in West Africa, and at least 41 in Ethiopia) with both public and private sector entities. Over its 12 years and with continued support by funders, this joint venture reached well over a million beneficiaries through various methods and approaches across the scaling and delivery continuum within and beyond target sites. Numerous other informal partnerships were forged and undocumented indirect beneficiaries benefited from Africa RISING via various actors along the scaling route. The lessons learned from the Africa RISING experience related above provide a guide to scaling efforts for funders, researchers, and policymakers.

4.5 Use of geospatial tools for sustainable intensification[43]

Overview

Farming occupies vast swathes of land on the African continent, much of it inaccessible in practical terms, especially for carefully monitored projects. Geospatial tools offer the possibility of identifying agro-ecosystems, tracking weather patterns and climate change, and monitoring land degradation, all on a continental scale. Africa RISING made use of these powerful tools to determine where the technologies it was promoting might feasibly be applied (domain extrapolation) and what their impacts might be under a changing climate.

The value added to the program's work may best be illustrated by two examples: monitoring rainfall trends in East and Southern Africa, and mapping land degradation.

Monitoring rainfall trends in East and Southern Africa

Agricultural advisory services in Africa are hampered by limited availability of weather station data. However, due to advancement of technology, high-resolution and longer time-series rainfall data are currently available from remote-sensing platforms and models. Africa RISING used the available gauge station data to validate satellite rainfall products from the Climate Hazards Infrared Precipitation with Stations (CHIRPS-v2), Climatologies at high resolution for the earth's land surface areas (CHELSA), and TerraClimate databases. These satellite gridded rainfall products showed high potential to complement the scarce rainfall data. Satellite data obtained from CHIRPS-v2 was used to map the long-term spatial–temporal trends and variability of rainfall in seven countries within the East and Southern Africa (ESA) region for 37 years (1981 to 2017). Trend analyses identified zones experiencing significant increasing or decreasing rainfall trends over the region. Zones in southwest Zambia and the northern Lake Victoria Basin transboundary region between western Kenya and eastern Uganda are subject to increasing annual rainfall of 3–15 mm per year. Meanwhile, central-south Kenya, western Rwanda, southwest Tanzania, and central Uganda are experiencing decreasing annual rainfall of 4–10 mm per year. The most dramatic decrease in annual rainfall was observed for Mount Kilimanjaro in Tanzania at 20 mm per year.

This information can help quantify the risks posed by climate change and climate variability, and so guide prioritization of scarce development resources to the most vulnerable zones. Maps generated from the study are expected to improve agro-advisories and spatial targeting of climate-smart agricultural technologies.

Traditionally, climatic trends have been deciphered from stationary weather stations, which are at low density with significant data gaps in ESA. The pixel-level analysis of rainfall trends complements or compensates for sparse rain gauges to improve agro-advisory services. Moreover, the approach undertaken to analyze rainfall trends and variability in a transboundary ecosystem is expected to promote harmonization of climate change adaptation and resilience policies across the region. The information provides spatial evidence to enable agronomic and crop breeding programs to target cultivar development and management practices that are locally relevant to the prevailing climatic trends in characterized zones.

Mapping land degradation

Land degradation is a critical issue for agriculture worldwide and is included as a key indicator in Sustainable Development Goal 15, the "proportion of land that is

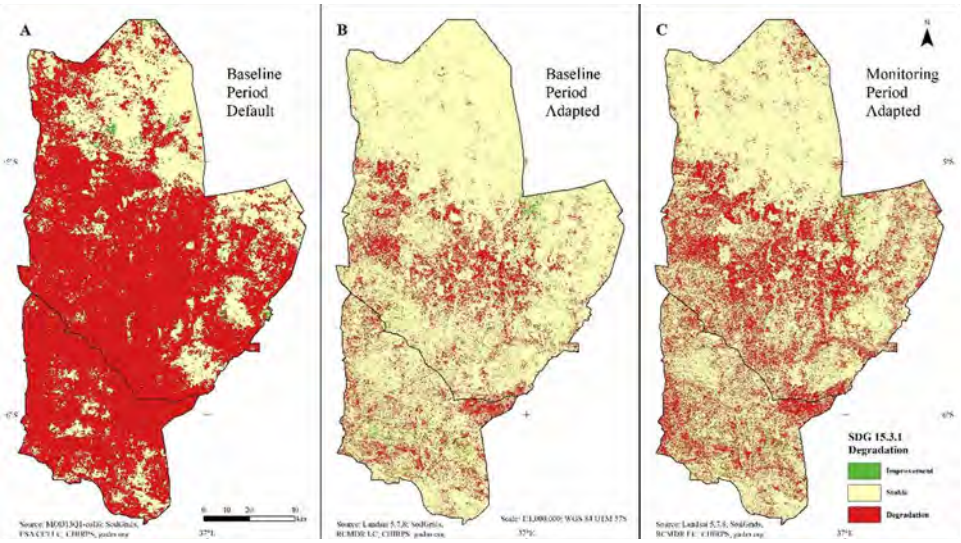
43 With input from Francis Muthoni.

degraded over a total land area" (indicator 15.3.1). Data available for Africa are typically 'grainy', derived from medium-resolution data and a methodology suggested by the United Nations Convention to Combat Desertification at a resolution that generalizes the land status over much broader areas than is ideal when targeting interventions for small-scale farmers to reverse degradation.

Africa RISING used higher spatial resolution (30 m) satellite data to measure land degradation at a local scale in the semi-arid districts of Kiteto and Kongwa in Tanzania from 2000 to 2019. Trends in land productivity, land cover, and soil organic carbon were mapped. The higher resolution earth observation data enabled identification of subtle changes in land degradation in an area dominated by small-scale farms. The method identified 27% of the land as degraded over the period, while the medium-resolution method suggested 70% (Fig. 9). Thus, the hotspots for land degradation were precisely identified to guide spatial targeting of sustainable land management practices to avoid, reduce, and rehabilitate degraded land. The developed methodology is generic – including Landsat time-series and customized land cover datasets, open-source software, and cloud-computing – and therefore widely applicable to other geographies.

The validation of available datasets and the development of new methodologies based on available tools have proven their value in enabling targeting of technologies to those most likely (to become) in need of them and those most likely to benefit from them. These and other geospatial methods adopted, adapted, or developed by Africa RISING will be valuable in extending the reach of technologies to promote sustainable agricultural intensification across greater areas of the African farming landscape.

Figure 9. Land degradation maps of Kiteto and Kongwa districts, central Tanzania, derived from medium-resolution (left) and high-resolution (right) remotely sensed data



Source: Reith, J., Ghazaryan, G., Muthoni, F.K. and Dubovyk, O. 2021. Assessment of land degradation in semiarid Tanzania—Using multiscale remote sensing datasets to support Sustainable Development Goal 15.3. *Remote Sensing* 13(9): art. 1754. (https://doi.org/10.3390/rs13091754). © authors CC BY 4.0.

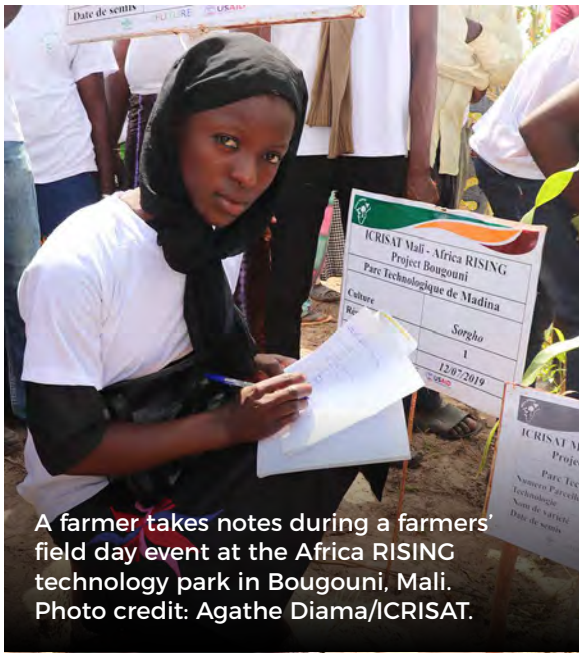
4.6 Capacity building in Africa RISING[44]

Context

Capacity building was core to the impact and sustainability goals of the Africa RISING program. Efforts focused on building capacity in the human, institutional, and technical areas. The aim was to strengthen capacities in the countries where work was being implemented, so that achievements could be sustained after the program ended.

Multiple levels of capacity development

Through what Africa RISING called long-term professional training, graduate students received opportunities to conduct research at Africa RISING sites, often via 'sandwich' study programs with partner universities, all with the aim of creating a cadre of young scientists at MSc and PhD levels specializing in integrated agricultural research. While some students were recruited and funded directly by the program, some were encouraged to engage in Africa RISING research from other funding channels. Africa RISING proved a rewarding experience for students – for example, a PhD student supported by the program was named IITA's youngest, best researcher. On graduation, some of them were even promoted to higher levels of research and management responsibilities (e.g., head of soil science department at Sokoine University of Agriculture and head of Tanzania Livestock Research Institute). Table 3 shows the number of postgraduate students trained during Phases 1and 2.



A farmer takes notes during a farmers' field day event at the Africa RISING technology park in Bougouni, Mali. Photo credit: Agathe Diama/ICRISAT.

Table 3. Number of postgraduate students trained via Africa RISING in Phases 1 and 2

Country	Masters	Doctorate
Ethiopia	36	23
Ghana	9	6
Mali	15	8
Malawi	18	4
Tanzania	19	4
Zambia	11	0

44 Based on an interview with Fred Kizito, Mateete Bekunda, and Kindu Mekonnen.

In addition to the long-term graduate training, Africa RISING scientists also occasionally hosted undergraduate intern students for practical learning during specific periods.

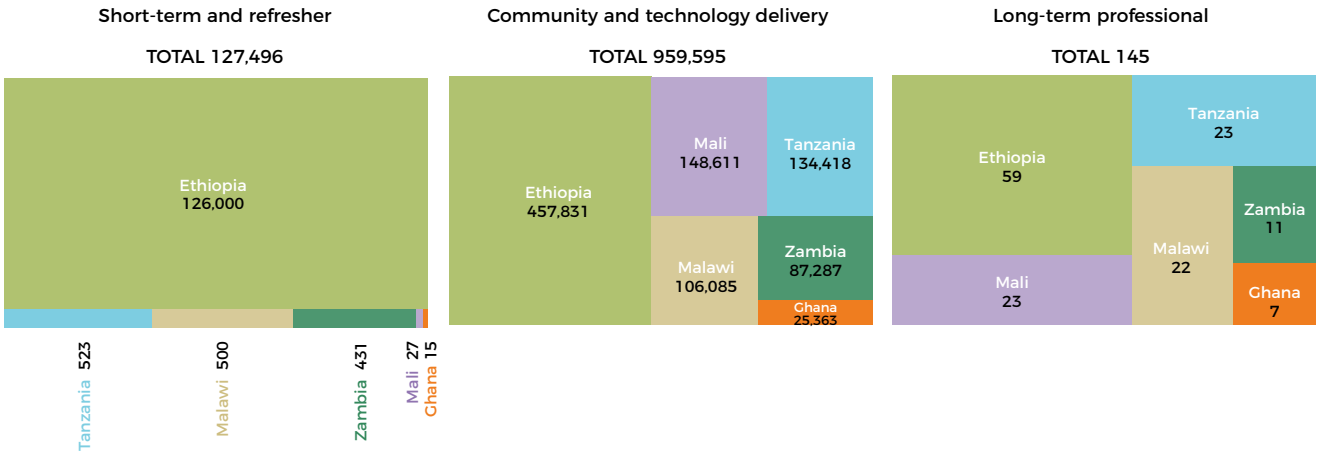
From government and development partners, extension agents were trained on technologies promoted by the program, so they could support their dissemination and scaling. The project teams provided ongoing mentoring and backstopping. For instance, 'training of trainers' programs were held, and brochures were translated into local languages with key lessons to share with farmers.

Lead farmers received more thorough training than their peers, especially as they hosted research trials and technology demonstrations, so they could train other farmers. There was better trust and communication when messages came from peer farmers rather than from outside experts. Throughout the first and second phases of the Africa RISING program, a total of 127,496 people benefited from this form of short-term capacity building across the six project countries (see Fig. 10).

Farmers gained knowledge hands-on through ongoing collaboration in field activities such as planting, weeding, harvesting, and data collection. Across the two program phases, over a million farmers benefited from such training focused on technology delivery at community level. This helped farming communities improve their decision making in farming, health, and selection of the sustainable intensification technologies.

Partner organizations at the local level (farmer organizations, NARS, private sector, universities, extension services, government agencies) got hands-on experience with technologies and approaches so they could sustain implementation after the project ended. For example, as a member of a group of 53 village chiefs, Karitié Coulibaly of M'Pessoba village, southern Mali, was determined to keep the village technology park functional. Management and use of the two Africa RISING technology parks in Mali was transferred to the Agricultural Learning Center of M'Pessoba (a center hosting 300 students), under the leadership of its Director General Hassane Tolo. Through iREACH, funded by USAID through the

Figure 10.Africa RISING capacity building achievements overview



Sustainable Intensification Innovation Lab, WECARD/CORAF adopted the technology park method of innovation and information flow to farming communities in Burkina Faso, Ghana, Mali, Niger, and Senegal.

In Ethiopia, the Africa RISING team has published six extension learning modules on livestock feed and forage innovations, improved crop varieties, and natural resources management. The learning modules are acting as guides and reference resources for extension workers.

Policymakers and officials were engaged so they understood and enabled project activities. The project teams made visits to government bodies to strengthen these relationships, but also hosted them at farmer field days. In East and Southern Africa, details of technologies that were developed iteratively and validated by the ESA project with smallholders were published in the ESA handbook (Bekunda et al., 2022). This now provides 'off the shelf' technologies ready for use by extension workers, practitioners, development partners, and policymakers. At the handbook's official launch, Dodoma Regional Commissioner Rosemary Senyamule lauded the publication, which showed commitment to continue the benefit of Africa RISING technologies to Tanzanian farmers. She also offered to explore how her office could further support promotion of the technologies.

Specific capacity building approaches

- Farmer field days and demonstrations for practical learning. These were ongoing, rather than one-off events.
- Exchange visits so stakeholders could see technologies in action elsewhere. For example, researchers and farmers visiting sites in other countries and regions.
- Translating materials such as manuals into local languages, such as soil and water brochures in Swahili.
- Farmer research groups enabled peer learning among farmers using similar innovations. Farmers adopting the same technology worked together.

Banner at the entrance of a demonstration plot at Ilu-Sanbitu Kebele in Ethiopia. Photo credit: Apollo Habtamu/ILRI.

Clear as day and night! Drs Regis Chikowo (Michigan State University) and Christian Thierfelder (CIMMYT) compare maize treatments for maize–legume rotation with reduced fertilizer vs control (no maize–legume rotation, no fertilizer). Photo credit: Eveline Massam/IITA.

- Regular stakeholder platform meetings to discuss challenges, results, and next steps. Partners met regularly throughout the duration of the program.
- One-on-one mentorship of extension agents by scientists, such as demonstrating techniques.
- Radio, phone/SMS outreach. An estimated 32,000 listeners heard a program about sorghum technology in Mali, thanks to collaboration with Farm Radio International and local agro-input dealers; up to 160,000 farmers were reached by a series of one-hour programs broadcast by nine community radio stations in Tanzania during the COVID-19 lockdown; and nearly 20,000 farmers were reached via SMS through the Mwanga Platform between 2015 and 2019. In Ethiopia, the Africa RISING project in 2022 and early 2023 used local radio programs and mobile audio messages to reach over 47,000 farmers and extension agents and share information on improved feed and forage innovations and post-harvest utilization practices.
- Handbooks and publications that are still widely used after the end of the program. For example, the ESA handbook is the most downloaded book from the CAB International website, with over 6,000 downloads from the CABI digital library to date.
- Technology parks managed by lead farmers and NGOs after project closure.
- 'Mother and baby' model where a lead farmer trains others. Advanced farmers trained less experienced ones.
- Conventional classroom and practical skills training.
- Videos and posters in farmers' local dialects covering various topics ranging from agronomic practices to maintenance of maize shelling machines. (See https://cgspace.cgiar.org/handle/10568/16926 for example videos.)

- Intra-team mentorship of less experienced scientists by senior researchers.

Key lessons learned

- Lead farmers are effective change agents for capacity building as farmers listen to their peers.
- Practical learning is key – farmers want to see technologies in action.
- Build partner capacity – critical for sustainability after a project ends.
- Collect more evidence on numbers trained, knowledge gains, etc., to improve monitoring of capacity building impacts.
- Translate materials into local languages to increase access.
- Identify and leverage innovative local partners as models.
- Training must be ongoing with backstopping, not just one-off events.
- Intra-team mentorship among project scientists is important but often overlooked.
- Ensure women and youth can access information and training, as they often have less access to resources such as mobile phones.

4.7 Communications and knowledge management at the heart of project and program operations[45]

Context

From the initial Africa RISING Phase 1 design meetings held in late 2011 and early 2012, communication and knowledge management were acknowledged as vital enablers for achieving program and project goals. Both functions were therefore deeply embedded in critical operations at all levels and complemented by a team of specialists at IITA and ILRI to oversee this function. Operating through consistent program-wide approaches with decentralized implementation at project and country levels, the communication and knowledge management work within Africa RISING focused on six core areas.

1. External communication: informing and engaging project stakeholders.
2. Research for impact: knowledge translation and getting research into use by stakeholders.
3. Knowledge sharing and learning: enriching project learning, interaction, and exchange.
4. Publishing: capturing, organizing, and disseminating research products and outputs – print and electronic.
5. Internal communication: linking the project teams to facilitate effective implementation of activities.
6. Cross-project exchange and learning.

Valuable lessons were learned over the course of Africa RISING projects and program implementation. This section lists some of the key lessons.

Context determines action

Africa RISING communication and knowledge management was implemented through well-thought-out annual workplans informed by program and project

Documenting farmer voices and feedback about the sustainable intensification innovations through video documentaries. Photo credit: Olaoluwa Olumide Olabode/IITA.

45 With input from Jonathan Odhong, Peter Ballantyne, Ewen Le Borgne, Haimanot Seifu, and Gloriana Ndibalema.

research and development priorities set by project partners at the various country sites. Recognizing the heterogeneity of the different project countries and sites, all communications and knowledge management activities had to be tailored to the context in which they would be applied. For example, although the feed trough technology for small ruminants was validated with smallholder farmer communities in both the Ethiopian Highlands and northern Ghana, communication materials were prepared for the communities in local dialects and languages, and in formats accessible to and preferred by the respective communities. Similarly, face-to-face policy engagement activities were heavily supported by synthesis materials, and dissemination to scientists was built around traditional articles, books, and chapters.

Cross-project exchange visits offer real learning and cohesion-building opportunities

Developing a learning culture and cohesive implementation of activities for a large program bringing together over 100 partners implementing activities in six countries – as was the case with Africa RISING – is imperative for success. Africa RISING also aimed (as much as possible) to use common research approaches and tools including the Sustainable Intensification Assessment Framework (SIAF), Dataverse (for storing data), CGSpace (for organizing and disseminating research outputs and publications), and farming systems approaches. Scheduling regular exchange visits at various project and program implementation levels ensured that Africa RISING partners had an opportunity to develop a common understanding on the key elements of the program and could begin to build good camaraderie as a foundation for cohesive project implementation, while also learning from the activities and work being implemented by their peers.

Communication approaches are valuable for catalyzing and reinforcing scaling

For its second phase, the Africa RISING program set itself an ambitious scaling target of reaching 1.1 million households in the six implementation countries with sustainable intensification technologies. To reach this target, the project aimed to establish development partnerships that would enable it to bridge the numbers gap as it only directly worked with 24,500 farmers. Different communication approaches were used to support and catalyze the achievement of Africa RISING scaling ambitions. For example, in southern Mali, a series of tailor-made radio programs in the local Bambara dialect were aired on Radio KAFO KAN in 2017 at various points during the farming season to give farmers valuable information on dual-purpose sorghum varieties validated through Africa RISING. Video tutorials on how to repair and maintain maize-shelling machines introduced by Africa RISING to farmer communities in northern Ghana were also developed and shared with the farmers.

Other conventional approaches such as the publication of brochures and farmer training materials were also deployed to great effect. Africa RISING produced a series of radio programs in local languages that were aired on national and community radio stations. In Ethiopia, radio programs such as 'ገበታ' ('serving plate' or 'dish' in Amharic) aired on Debre Birhan Fana FM 94.0 featuring interviews with farmers, scientists, and other experts, who discussed the benefits of sustainable intensification practices.

Facilitate science through communication and knowledge management

Every year, the Africa RISING regional projects held their own review and planning meetings, and there was a program-wide annual learning event that brought together all partners from the regional

projects. These marquee events, which were organized and facilitated by the communications team, were critical for ensuring that project implementation was discussed in a well-facilitated and conducive atmosphere, allowing for brainstorming and planning. In designing these meetings, the communications team always aimed to encourage full participation, build mutual understanding as a prerequisite for collaboration, and ensure that discussions ended with inclusive solutions and workplans. As well as giving attention to process, the communications team made sure that key interactions were well documented and shared.

Pay attention to the policymaker behind your donor

Although Africa RISING was exclusively implemented in sub-Saharan Africa, the importance of its outcomes and achievements needed to be communicated to the policymakers (including US Congress) behind the donor at USAID. This meant that the project team had to refine its messaging for the benefit of this group, one that could easily have been overlooked. Developing materials and packaging them in ways that resonate with policymakers therefore became critical to Africa RISING communications. It is also valuable (in addition to regular project channels) to engage in the preferred platforms and media of this group. For example, although Africa RISING had its official repository on CGSpace, the program also archived some information about its technologies on the Agrilinks and Global Innovation Exchange websites, which were primary reference sources for USAID and its key stakeholders.

Document as you implement

Documentation was an important aspect of Africa RISING operation over its 12-year life span. Along with the impact on the livelihoods of smallholder farmers, documentation is a significant legacy of the program. Use was made of intricate, interlinked, cost-effective, and high-reach web-based tools, such as the Africa RISING website (with a total of 563 posts and 83 pages to date), the Africa RISING wiki (capturing proceedings of 498 meetings and events held by the projects, plus innumerable draft outputs produced by the project partners), CGSpace (housing 1,571 final publications by the program), SlideShare (with 621 PowerPoint presentations to date), and Flickr (with 2,555 photographs of project activities to date). These platforms ensured that key experiences and lessons from the program were captured for reference and learning. Stakeholders in the agricultural research and development space still therefore find useful resources on these platforms because Africa RISING has made arrangements to guarantee that they stay live until at least August 2025, which is two years beyond the project life span.

Proactively include, engage, and work with local partners

One of the key lessons learned by Africa RISING is the importance of working with local partners to ensure that communication materials are relevant and appropriate for the target audiences, and that their insights and experiences are fully taken into account in the program's research. This is especially important in countries with many different languages and cultures. By working with local partners, Africa RISING was able to ensure that the communication materials were tailored to the specific needs and interests of farmers. For example, in Ethiopia, Africa RISING worked with local agricultural extension experts to translate the communication materials into three local languages and to distribute them to farmers.

Utilize agile and user-friendly platforms to instill a learning and sharing culture

Africa RISING set up a number of platforms and processes to ensure efficient internal communication, and knowledge sharing and management. The communications

team set up and trained all project partners on Microsoft Yammer (now Viva Engage), a professional social networking platform to promote spontaneous, but well-documented learning and knowledge sharing. The use of Yammer was supported and enhanced through its interlinkage with other program platforms such as the website, wiki, Slideshare, Flickr, and the organizational email systems. Research-based thematic communities of practice were another avenue through which knowledge sharing was facilitated by the program. The use of these platforms was voluntary and helped establish and emphasize the importance of 'working out loud' and sharing insights, questions, and ideas quickly rather than waiting for established, formal moments.

Successful communications and knowledge management needs deliberate support

A critical reason for the successful communication and knowledge management function within Africa RISING was the vocal and financial backing it received at all levels. The program's donor (USAID Bureau for Resilience and Food Security plus USAID Missions in Mali, Tanzania, and Zambia) set the tone by dedicating funds to support this function within the program, which resulted in its recognition by all the important program and project decision making organs, such as the program coordination team, the project steering committees, and the managers of each regional project.

Africa RISING Communication and Knowledge Sharing Specialist, Jonathan Odhong (center) shows drone video footage to farmers at Cheyohi No. 2 Community in Northern Region, Ghana. Photo credit: Olaoluwa Olumide Bode/IITA.

Former Africa RISING project managers Irmgard Hoeschle-Zeledon (left) and Peter Thorne (center) engage in a discussion with the Lead of the One CGIAR Initiative on Sustainable Intensification of Mixed Farming Systems, Fred Kizito. Photo credit: Olaoluwa Olumide Olabode/IITA.

Chapter 5

Passing the baton: Africa RISING and CGIAR Mixed Farming Systems Initiative leaders discuss lessons and future prospects for sustainable intensification and farming systems science

The panel reflected extensively on lessons learned from Africa RISING's decade-long experience in applying systems approaches to sustainable agricultural intensification across farming contexts in Africa. Their perspectives illuminated achievements, challenges, and priorities going forward.

Stakeholders (researchers, donors, and development partners) gathered in Accra, Ghana as the curtain came down on the Africa RISING program during a close-out event held on 7–9 February 2023. After a dozen years of implementation (2011–2023), important lessons had been learned through Africa RISING about sustainable agricultural intensification and farming systems science program implementation. The close-out event therefore provided a great opportunity and platform for stakeholders to engage in a discussion about the future of this important work. Panel members representing Africa RISING scientific leadership and management (Irmgard Hoeschle-Zeledon and Peter Thorne) and the scientific leadership for the new One CGIAR Initiative on Sustainable Intensification of Mixed Farming Systems (Fred Kizito and Santiago Lopez Ridaura) led the discourse. From the CGIAR's new portfolio of 32 research initiatives, the Mixed Farming Systems Initiative is one of the main ones designated to carry forward sustainable intensification work and farming systems science.

The term 'farming system' has been defined in various ways. While a common denominator of the definitions has been the agricultural system of a population of farmers in the landscape, the plot or individual farm could also be looked at through a 'farming system' lens, especially in the context of research. However, when exploring phenomena such as land and water management, the lens view is naturally zoomed out to the landscape level.

A key point of discussion was the juxtaposition of component technology research and integrated systems perspectives. The panelists were keen to point out that it is not a matter of 'either/or' but of 'both/and': that is, systems science is perhaps more of a broad research paradigm. Systems science provides crucial context about the larger farming system setting for evaluating and adapting new component innovations such as improved crop varieties and livestock breeds. For example, a sole focus on increasing faba bean yields by Africa RISING in Ethiopia at the start overlooked existing practices of late weeding of the crop to provide weed biomass for livestock fodder. Once this was understood, the researchers started to look at intercropping beans with forage crops to provide vital livestock fodder and thereby overcame a major barrier to adoption of high-yielding faba bean varieties and improved agronomic practices. Other situations in which systems science was able to provide valuable context were the work in Ghana on living mulch, improved maize and cowpea, row planting and intercropping, introduction of the feed trough, and use of veterinary care (see case studies in sections 3.2 and 3.3).

Farming system modeling is a powerful tool facilitating ex-ante impact assessment for proposed new technologies or practices, enabling the identification of synergies and trade-offs between multiple objectives such as productivity, natural resource sustainability, climate resilience, and livelihoods. However, models need input data from the farming system as well as from the proposed technological changes, so it is vital to understand the existing system prior to modeling redesign. Even so, fully redesigning complex diversified farming systems is extremely difficult and risky. Scaling systems science is not about wholesale adoption of an entirely redesigned model system. Rather it is some theoretical bases of systems science that allow such approaches to be used in diverse settings. The systems researchers highlighted the need for realistic expectations, noting that farmers are more likely to adopt suitable components from a basket of options offering a redesigned system, rather than the whole package. Providing farmers with multiple redesign options is a form of 'discussion support'

rather than the more traditionally understood 'decision support' to encourage a farmer to adopt a particular technology.

Panelists unanimously agreed on the importance of strengthening capacities for systems science through formal training programs and institutional change. Agricultural research leadership must achieve equivalent recognition and resourcing for systems science approaches alongside more established disciplines such as plant breeding, agronomy, and animal science within research department teams, institutes, and national agencies. Profiling successful experiences of adding value through systems science, such as providing essential context for targeting and adapting new technologies to enhance adoption, can help demystify systems perspectives for stakeholders. Africa RISING was probably the first opportunity many of its researchers had to work in interdisciplinary teams, and it takes time to build integrated systems science teams with individuals working well together. With so few agricultural researchers familiar with systems thinking, it is important that systems science is built into formal training programs, such as agricultural degree courses.

Social science insights are vital for understanding the dynamics of diverse, complex farm household systems, which strongly influence technology adoption decisions and resulting livelihood impacts. Therefore, mixed systems science initiatives should foster and prioritize social science research components from the outset, rather than incorporating socio-cultural factors as an afterthought to make new technical innovations more adoptable. Robust mixed-methods evidence combining qualitative and quantitative data are required to build a persuasive evidence base demonstrating the benefits of integrated approaches such as sustainable intensification. Rather than relying on single sources of data, multicriteria participatory M&E should measure and incorporate diverse perspectives on priorities and indicators of success such as environmental sustainability, gender equity, and social empowerment. Panelists emphasized that effectively communicating synthesized evidence from systems approaches in clear, compelling ways will be essential to convince donors and policymakers of their value.

Going forward, partnerships to advance systems science should engage diverse stakeholders, including farmers, development partners, and researchers, at all levels when jointly designing the research agenda and approach. While acknowledging that truly participatory priority setting is challenging, panelists argued that the investment required is well worth it to appropriately delineate system boundaries and focus on key leverage points from different stakeholder perspectives. With the benefit of hindsight, they noted that Africa RISING lacked a clear strategy and protocols for consistent data collection across disciplines from its inception phase. Learning and adaptation are integral to the dynamic long-term process of transforming farming systems toward sustainable intensification, rather than reaching a defined end state. Retrospective analysis of past system trajectories combined with exploratory ex-ante scenario modeling can help guide strategic focus and priority setting while navigating trade-offs.

Panelists unanimously concurred that integrated systems science approaches are essential precisely because most smallholder farms across Africa operate as diversified, integrated mixed systems. Therefore, despite the inherent complexities involved, they contended that continued long-term investment in mixed-methods systems science offers immense potential to accelerate progress toward improving smallholder livelihoods and sustainability in Africa's predominant farming system context. While recognizing that donors need to understand that typical project timeframes will not yield results from systems science, they concluded that funders and researchers must jointly persist in developing and improving systems science approaches, capacities, and communications to optimally serve the needs of highly diversified smallholder farm households in the future.

Appendix

Africa RISING publications by year

The list includes peer-reviewed journal articles, book chapters, training manuals, and student theses.

Year 2023

1. Adimassu, Z., Tamene, L., Tibebe, D., Abera, W., Mekonnen, K., Gebreyes, M. and Zerfu, E. 2023. *Extension manual on creating multifunctional climate smart landscapes for district experts and extension agents.* Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/130360).
2. Agegnehu, G., Abera, D., Desta, G., Van Rooyen, A., Mekonnen, K., Gebreyes, M. and Zerfu, E. 2023. *Current innovations in making site specific nutrient management.* Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/130359).
3. Akinseye, F.M., Birhanu, Z.B., Ajeigbe, H., Diancoumba, M., Sanogo, K. and Tabo, R. 2023. Impacts of fertilization management strategies on improved sorghums varieties in smallholder farming systems in Mali: Productivity and profitability differences. *Heliyon* 9(2003): art. e14497. (https://doi.org/10.1016/j.heliyon.2023.e14497).
4. Bezabih, M., Adie, A., Mekonnen, K. and Gebreyes, M. 2023. *Livestock feed and forage innovations for improved productivity in the highlands of Ethiopia.* Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/130358).
5. Birhanu, Z.B, Sanogo, K., Traore, S.S., Minh, T. and Kizito, F. 2023. Solar-based irrigation systems as a game changer to improve agricultural practices in Sub-Sahara Africa: a case study from Mali. *Frontiers in Sustainable Food Systems* 7: art. 1085335. (Available from https://www.frontiersin.org/articles/10.3389/fsufs.2023.1085335/pdf).
6. Bishaw, Z., Ahmed, S., Aynewe, Y., Mekonnen, K., Gebreyes, M., Asfaw, A., Alene, T., Ebrahim, M., Dubale, W., Tadesse, N., Seifu, H. and Thorne, P. 2023. *Approaches on validating and scaling of food crops innovations in Ethiopia.* Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/130327).
7. Dissa, A. 2023. *Expanding the adaptive capacity of cotton-producing smallholders to cope with (un)expected climate and market variability in southern Mali* [PhD thesis, Wageningen University & Research]. Wageningen, The Netherlands. (https://doi.org/10.18174/582566).
8. Getachew Agegnehu, Tilahun Amede, Gizaw Desta, Teklu Erkossa, Gizachew Legesse, et al. 2023. Improving fertilizer response of crop yield through liming and targeting to landscape positions in tropical agricultural soils. *Heliyon* 9: art. e17421. (https://doi.org/10.1016/j.heliyon.2023.e17421).
9. Hammond, J., Pagella, T., Caulfield, M.E., Fraval, S., Teufel, N., Wichern, J., Kihoro, E., Herrero, M., Rosenstock, T.S. and Wijk, M.T. van. 2023. Poverty dynamics and the determining factors among East African smallholder farmers. *Agricultural Systems* 206: art. 103611. (https://doi.org/10.1016/j.agsy.2023.103611).
10. Hermans, T.D.G., Smith, H.E., Whitfield, S., Sallu, S.M., Recha, J., Dougill, A.J., Thierfelder, C., Gama, M., Bunderson, W.T., Museka, R., Doggart, N. and Meshack, C. 2023. Role of the interaction space in shaping innovation for sustainable agriculture: Empirical insights from African case studies. *Journal of Rural Studies* 100: art. 103012. (https://doi.org/10.1016/j.jrurstud.2023.103012).
11. Kifle Woldearegay, Berhane Grum, Hessel, R., van Steenbergen, F., Fleskens, L., et al. 2023. Watershed management, groundwater recharge and drought resilience: An integrated approach to adapt to rainfall variability in northern Ethiopia. *International Soil and Water Conservation Research.* (https://doi.org/10.1016/j.iswcr.2023.08.009).
12. Kotu, H.B., Manda, J., Mutungi, C., Fischer, G. and Gaspar, A. 2023. Farmers' willingness to invest in mechanized maize shelling and potential financial benefits: Evidence from Tanzania. *Agribusiness.* (https://hdl.handle.net/10568/128801).
13. Mekonnen, K., Thorne, P., Gebreyes, M., Hammond, J., Bezabih, M., et al. 2023. Research for development approaches in the mixed crop-livestock systems of the Ethiopian Highlands. *Frontiers in Sustainable Food Systems* 7: art. 1080725. (https://www.frontiersin.org/articles/10.3389/fsufs.2023.1080725/full).
14. Muthoni, F.K., Delore, J.M., Lukumay, P.J. and Ochieng, J. 2023. Extrapolation suitability index for sustainable vegetable cultivation in Babati district, Tanzania. *Frontiers in Sustainable Food Systems* 7. (https://doi.org/10.3389/fsufs.2023.1047505).
15. Nigir, B., Gebrehawaryat, Y., Tilahun, M., Fadda, C., Mekonnen, K., Gebreyes, M. and Zerfu, E. 2023. *Extension module: Crowdsourcing seed-based innovations to improve diversity, nutrition and crop productivity.* Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/130355).
16. Odame, P.K. and Boateng, E.N.K. 2023. Leveraging spatial technology for agricultural intensification to address hunger in Ghana. In: Solís, P. and Zeballos, M. (eds), *Open mapping towards Sustainable Development Goals.* Sustainable Development Goals Series. Cham, Switzerland: Springer: 29–45. (https://doi.org/10.1007/978-3-031-05182-1_3).
17. Sanogo, K., Zemadim, B., Sanogo, S. and Ba, A. 2023. Landscape pattern analysis using GIS and remote sensing to diagnose soil erosion and nutrient availability in two agroecological zones of southern Mali. *Agriculture and Food Security* 12: art. 4. (https://doi.org/10.1186/s40066-023-00408-6).

Year 2022

1. Abdul Rahman, N., Larbi, A., Addah, W., Sulleyman, K.W., Adda, J.K., Kizito, F. and Hoeschle-Zeledon, I. 2022. Optimizing food and feed in maize-livestock systems in northern Ghana: The effect of maize leaf stripping on grain yield and leaf fodder quality. *Agriculture* 12: art. 275. (https://doi.org/10.3390/agriculture12020275).
2. Abdul Rahman, N., Larbi, A., Berdjour, A., Kizito, F. and Hoeschle-Zeledon, I. 2022. Cowpea living mulch effect on soil quality and grain yield in smallholder maize-based cropping systems of northern Ghana. *Journal of Soil Science and Plant Nutrition* 22: 3925–3940. (https://doi.org/10.1007/s42729-022-00942-5).
3. Akrong, R. and Kotu, H.B. 2022. Economic analysis of youth participation in agripreneurship in Benin. *Heliyon* 8: art. e08738. (https://doi.org/10.1016/j.heliyon.2022.e08738).
4. Badolo, F., Kotu, B., Oyinbo, O., Sanogo, K. and Birhanu, B. 2022. Farmers' preferences for sustainable intensification attributes in sorghum-based cropping systems: Evidence from Mali. *Renewable Agriculture and Food Systems.* (http://dx.doi.org/10.1017/S1742170522000345).
5. Bekunda, M., Hoeschle-Zeledon, I. and Odhong, J. 2022. *Sustainable agricultural intensification: A handbook for practitioners in East and Southern Africa*. Wallingford, UK: CAB International. (https://doi.org/10.1079/9781800621602.0000).
6. Bitew, B., Fininsa, C. and Terefe, H. 2022. Estimating yield loss of faba bean (*Vicia faba* L.) caused by gall disease in north Shoa, Ethiopia. *Crop Protection*, 155 (2022): art. 105930. (https://doi.org/10.1016/j.cropro.2022.105930).
7. Burke, W.J., Snapp, S.S., Peter, B. and Jayne, T.S. 2022. Sustainable intensification in jeopardy: Transdisciplinary evidence from Malawi. *Science of the Total*. (https://doi.org/10.1016/j.scitotenv.2022.155758).
8. Burke, W.J., Jayne, T.S. and Snapp, S.S. 2022. Nitrogen efficiency by soil quality and management regimes on Malawi farms: Can fertilizer use remain profitable? *World Development* 152: art. 105792. (https://doi.org/10.1016/j.worlddev.2021.105792).
9. Dembele, C.O., Traore, K., Karembe, M., Zemadim, B., Traore, B., Cisse. F. and Samake, O. 2022. Intercropping sorghum and soybean efficiency using contour ridges technology in southern Mali. *Journal of Agricultural Science* 14(4): 126–135. (https://doi.org/10.5539/jas.v14n4p126).
10. Desta, G., Amede, T., Gashaw, T., Legesse, G., Agegnehu, G., Mekonnen, K. and Whitbread, A. 2022. Sorghum yield response to NPKS and NPZn nutrients along sorghum-growing landscapes. *Experimental Agriculture* 58: art. e10. (https://doi.org/10.1017/S0014479722000072).
11. Desta, G., Amede, T., Gashaw, T., Legesse, G., Agegnehu, G., Mekonnen, K. and Whitbread, A. 2022. Corrigendum: Sorghum yield response to NPKS and NPZn nutrients along sorghum-growing landscapes. *Experimental Agriculture* 58: art. E52. (https://doi.org/10.1017/S0014479722000473).
12. Farnworth, C.R., Fischer, G., Chinyophiro, A., Swai, E., Said, Z., Rugalabam J., Mshana, E., Athumani, Z., Nnko, J., Chikowo, R., Namagowa, R., Mkwapatira, A., Kapenda, T., Namakhoma, A. and Livuza, H. 2022. *Gender-transformative decision-making on agricultural technologies: Participatory tools.* Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/127692).
13. Getaneh, Y., Abera, W., Abegaz, A. and Tamene. L. 2022. A systematic review of studies on freshwater lakes of Ethiopia. *Journal of Hydrology: Regional Studies* 44: art. 101250. (https://doi.org/10.1016/j.ejrh.2022.101250).
14. Govoeyi, B., Tignégré, J.-B.D.L.S., Badolo, F., Zaato, P.A., Sanogo, K. and Birhanu, B.Z. 2022. Perceptions on sack gardening in rural areas: The case of vegetable stakeholders in Koutiala and Bougouni, Mali. *Sustainability* 14(22): art. 14896. (https://doi.org/10.3390/su142214896).
15. Grabowski, P., Fischer, G., Djenontin, I.N.S., Zulu, L., Kamoto, J., Kampanje-Phiri, J., Egyir, I. and Darkwah, A. 2022. *A decision makers' guide to equitable sustainable agricultural intensification*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/121982).
16. Guindo, M., Traoré, B., Birhanu, B.Z., Coulibaly, A. and Tabo, R. 2022. Microdosing of compost for sustainable production of improved sorghum in southern Mali. *Agronomy* 12: art. 1480. (https://doi.org/10.3390/agronomy12061480).
17. Huet, E.K., Adam, M., Traore, B., Giller, K.E. and Descheemaeker, K. 2022. Coping with cereal production risks due to the vagaries of weather, labour shortages and input markets through management in southern Mali. *European Journal of Agronomy* 140: art. 126587. (https://doi.org/10.1016/j.eja.2022.126587).
18. Johnson, R. 2022. *Bias correction of daily CHIRPS-v2 rainfall estimates in Ghana*. [MSc thesis in Meteorology and Climate Science. Kwame Nkrumah University of Science and Technology-Kumasi]. Ghana.
19. Kihara, J., Manda, J., Kimaro, A.A., Swai, E., Mutungi, C., Kinyua, M., Okori, P., Fischer, G., Kizito, F. and Bekunda, M. 2022. Contributions of integrated soil fertility management (ISFM) to various sustainable intensification impact domains in Tanzania. *Agricultural Systems* 203: art. 103496. (https://hdl.handle.net/10568/125653).
20. Kihara, J., Gurmessa, B., Tamene, L., Amede, T. and Sommer, R. 2022. Understanding factors influencing wheat productivity in Ethiopian Highlands. *Experimental Agriculture* 58: art. e6. (https://doi.org/10.1017/S0014479721000296).
21. Kinyua, M., Kihara, J., Bolo, P., Mairura, F., Fischer, G. and Mucheru-Muna, M. 2022. Agronomic and economic performance of legume-legume and cereal-legume intercropping systems in northern Tanzania. SSRN. (https://doi.org/10.2139/ssrn.4226643).
22. Kotu, B.H., Oyinbo, O., Hoeschle-Zeledon, I., Nurudeen, A.R., Kizito, F. and Boyubie, B. 2022. Smallholder farmers' preferences for sustainable intensification attributes in maize production: Evidence from Ghana. *World Development* 152: art. 105789. (https://doi.org/10.1016/j.worlddev.2021.105789).
23. Kotu, B.H., Nurudeen, A.R., Muthoni, F., Hoeschle-Zeledon, I. and Kizito, F. 2022. Potential impact of groundnut production technology on welfare of smallholder farmers in Ghana. *PLoS ONE* 17(1): art. e0260877. (https://doi.org/10.1371/journal.pone.0260877).
24. Mbaga, D.A. 2022. *Soil erosion and sediment yield analysis in semi-arid Tanzania. Case study of Kongwa district.* [BSc thesis in Geoinformatics. Ardhi University]. Dar es Salaam, Tanzania. (https://hdl.handle.net/10568/120476).
25. Mellon S.B. 2022. *Disseminating sustainable intensification practices: Empirical evidence from Ghana*. [PhD Dissertation. University of Bonn]. Germany. (https://hdl.handle.net/20.500.11811/9841).

26. Mhlanga, B., Pellegrino, E., Thierfelder, C. and Ercoli, L. 2022. Conservation agriculture practices drive maize yield by regulating soil nutrient availability, arbuscular mycorrhizas, and plant nutrient uptake. *Field Crops Research* 277: art. 108403. (https://doi.org/10.1016/j.fcr.2021.108403).

27. Mokria, M., Gebrekirstos, A., Said, H., Hadgu, K., Hagazi, N., Dubale, W. and Bräuning, A. 2022. Fruit weight and yield estimation models for five avocado cultivars in Ethiopia. *Environmental Research Communications* 4: art. 075013. (https://doi.org/10.1088/2515-7620/ac81a4).

28. Mokria, M., Gebrekirstos, A., Said, H., Hadgu, K., Hagazi, N., Dubale, W. and Brauning, A. 2022. Volume estimation models for avocado fruit. *PLoS ONE* 17(2): art. E0263564. (https://doi.org/10.1371/journal.pone.0263564).

29. Mponela, P., Manda, J., Kinyua, M. and Kihara, J. 2022. Participatory action research, social networks and gender influence soil fertility management in Tanzania. *Systemic Practice and Action Research* 36: 141–163. (https://doi.org/10.1007/s11213-022-09601-3).

30. Mupangwa, W., Yahaya, R., Tadesse, E., Ncube, B., Mutenje, M., Chipindu, L., Mhlanga, B. and Kassa, A. 2022. Crop productivity, nutritional and economic benefits of no-till systems in smallholder farms of Ethiopia. *Agronomy* 13(1): art. 115. (https://doi.org/10.3390/agronomy13010115).

31. Mutungi, C., Tungu, J., Amri, J., Gaspar, A. and Abass, A. 2022. Nutritional benefits of improved post-harvest handling practices for maize and common beans in northern Tanzania: A quantitative farm-level assessment. *Journal of Stored Products Research* 95: art. 101918. (https://doi.org/10.1016/j.jspr.2021.101918).

32. Odame, P.K. and Boateng, E.N.K. 2022. Leveraging spatial technology for agricultural intensification to address hunger in Ghana. In: Solís, P. and Zeballos, M. (eds.), *Open mapping towards Sustainable Development Goals* (Sustainable Development Goals Series). Cham: Springer: 29–45. (https://doi.org/10.1007/978-3-031-05182-1_3).

33. Saaka, M., Awini, S. and Nang, E. 2022. Prevalence and predictors of appropriate complementary feeding practice among mothers with children 6–23 months in northern Ghana. *World Nutrition* 13(2): 14–23. (https://doi.org/10.26596/wn.202213214-23).

34. Saaka, M., Awini, S., Kizito, F. and Hoeschle-Zeledon, I. 2022. Fathers' level of involvement in childcare activities and its association with the diet quality of children in northern Ghana. *Public Health Nutrition* 26(4): 1–8. (https://doi.org/10.1017/S1368980022002142).

35. Swamila, M., Philip, D., Akyoo, M., Manda, J., Mwinuka, L., Smethurst, P., Sieber, S. and Kimaro, A. 2022. Profitability of gliricidia-maize system in selected dryland areas of Dodoma region, Tanzania. *Sustainability* 14: art. 53. (https://doi.org/10.3390/su14010053).

36. Tamene, L., Abera, W., Demissie, B., Desta, G., Woldearegay, K. and Mekonnen, K. 2022. Soil erosion assessment in Ethiopia: A review. *Journal of Soil and Water Conservation* 77(2): 144–157. (https://doi.org/10.2489/jswc.2022.00002).

37. Tamene, L., Abera, W., Bendito, E., Erkossa, T., Tariku, M., Sewnet, H., Tibebe, D., Sied, J., Feyisa, G., Wondie, M. and Tesfaye, K. 2022. Data-driven similar response units for agricultural technology targeting: An example from Ethiopia. *Experimental Agriculture* 58: art. e27. (https://doi.org/10.1017/S0014479722000126).

38. Thierfelder, C. and Mhlanga, B. 2022. Short-term yield gains or long-term sustainability? – A synthesis of conservation agriculture long-term experiments in Southern Africa. *Agriculture, Ecosystems & Environment* 326: art. 107812. (https://doi.org/10.1016/j.agee.2021.107812).

39. Tignegre, J.B.D.L.S., Traore, A.S., Konate, M., Zaato, P.A., Diarra, B.G., Hanson, P., Kizito, F., Birhanu, B.Z. and Afari-Sefa, V. 2022. Bulb yield stability study of onion lines over locations and seasons in Ghana and Mali. *Agronomy* 12(12): art. 3037. (https://doi.org/10.3390/agronomy12123037).

40. Toure, O. 2022. *Influence de la technologie de l'aménagement en courbe de niveau sur des ligneux fourragers et l'association des cultures (sorgho, soja) dans la zone soudanienne du Mali (Kani et Noumpinesso).* Présenté et soutenu par Ousmane TOURE pour l'obtention du Diplôme de Master de l'Institut Polytechnique Rural de Formation et de Recherche Appliquée (IPR/IFRA) de Katibougou. Spécialité : Agroforesterie.

41. Yahaya, R., Mekonnen, K. and Gebreyes, M. 2022. *Training manual for two-wheel tractor and ancillary equipment for operators, service providers, extension experts and workshop owners.* Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/130372).

42. Zulu, L.C., Djenontin, I.N.S., Kamoto, J.F., Kampanje-Phiri, M.J. and Fischer, G. 2022. Do youth conceptualizations influence the inclusion of young people in sustainable agriculture intensification? Insights from Ghana and Malawi. *Environment, Development and Sustainability* 25: 13909–13935. (https://doi.org/10.1007/s10668-022-02632-9).

Year 2021

1. Abdul Rahman, N., Larbi, A., Kotu, B., Asante, M.O., Akakpo, D.B., Mellon-Bedi, S. and Hoeschle-Zeledon, I. 2021. Maize–legume strip cropping effect on productivity, income, and income risk of farmers in northern Ghana. *Agronomy Journal* 113: 1574–1585. (https://doi.org/10.1002/agj2.20536).

2. Abera, W., Tamene, L., Abegaz, A., Hailu, H., Piikki, K., Söderström, M., Girvetz, E. and Sommer, R. 2021. Estimating spatially distributed SOC sequestration potentials of sustainable land management practices in Ethiopia. *Journal of Environmental Management* 286: art. 112191. (https://doi.org/10.1016/j.jenvman.2021.112191).

3. Adams, A., Jumpah, E.T. and Caesar, L.D. 2021. The nexuses between technology adoption and socioeconomic changes among farmers in Ghana. *Technological Forecasting and Social Change* 173: art. 121133. (https://doi.org/10.1016/j.techfore.2021.121133).

4. Amede, T., Legesse, G., Agegnehu, G., Gashaw, T., Degefu, T., Desta, G., Mekonnen, K., Schulz, S. and Thorne, P. 2021. Short term fallow and partitioning effects of green manures on wheat systems in East African highlands. *Field Crops Research* 269: art. 108175. (https://doi.org/10.1016/j.fcr.2021.108175).

5. Ansah, T., Sahoo, A., Abdul Rahman, N., Kumawat, P.K. and Bhatt, R.S. 2021. In vitro digestibility and methane gas production of fodder from improved cowpea (*Vigna unguiculata L.*) and groundnut (*Arachis hypogaea L.*) varieties. *Scientific African* 13: art. e00897. (https://doi.org/10.1016/j.sciaf.2021.e00897).

6. Atiah, W.A., Muthoni, F.K., Kotu, B., Kizito, F. and Amekudzi, L.K. 2021. Trends of rainfall onset, cessation and length of growing season in northern Ghana: Comparing the rain gauge, satellite and farmers' perceptions. *Atmosphere* 12: art. 1674. (https://doi.org/10.3390/atmos12121674).

7. Ayantunde, A.A., Salifu, S., Konlan, S.P. and Shaibu, M.T. 2021. Assessing the effect of improved feed trough on feed utilization by small ruminants in northern Ghana. *Tropical Animal Health and Production* 53: art. 440. (https://doi.org/10.1007/s11250-021-02847-4).

8. Bedaso, N.H., Bezabih, M., Zewdu Kelkay, T., Adie, A., Khan, N.A., Jones, C.S., Mekonnen, K. and Wolde-meskel, E. 2021. Effect of fertilizer inputs on productivity and herbage quality of native pasture in degraded tropical grasslands. *Agronomy Journal* 114(1): 216–227. (https://doi.org/10.1002/agj2.20862).

9. Bedi, S.M., Azzarri, C., Kotu, B.H., Kornher, L. and von Braun, J. 2021. Scaling-up agricultural technologies: Who should be targeted? *European Review of Agricultural Economics* 49(4). (https://doi.org/10.1093/erae/jbab054).

10. Bezabih, M., Adie, A. and Mekonnen, K. 2021. *Africa RISING Ethiopian Highlands feed and forage development training manual*. Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/113387).

11. Bezabih, M., Mekonnen, K., Adie, A., Tadesse, T., Nurfeta, A., Dubale, W., Habiso, T., Kelkay, T.Z., Getnet, M., Ergano, K., Duncan, A.J. and Thorne P. 2021. Redesigning traditional weed management practices in faba bean fields to optimize food-feed production in the smallholder system. *Agronomy Journal* 114(1): 248–258. (https://doi.org/10.1002/agj2.20779).

12. Bitew, B., Fininsa, C., Terefe, H., Barbetti, M. and Ahmed, S. 2021. Spatial and temporal distribution of faba bean gall (*Physoderma*) disease and its association with biophysical factors in Ethiopia. *International Journal of Pest Management*. (https://doi.org/10.1080/09670874.2021.1998724).

13. Burke, J.W. and Jayne, T.S. 2021. Disparate access to quality land and fertilizers explain Malawi's gender yield gap. *Food Policy* 100: art. 102002. (https://doi.org/10.1016/j.foodpol.2020.102002).

14. Chande, M., Muhimbula, H., Mremi, R., Muzanila, Y., Kumwenda, N., Msuya, J. and Gichohi-Wainaina, W.N. 2021. Drivers of millet consumption among school aged children in central Tanzania. *Frontiers in Sustainable Food Systems* 5: art. 694160. (https://doi.org/10.3389/fsufs.2021.694160).

15. Chikowo, R., Olwande, J., Wanzala, M., Lubungu, M., Ngoma, H. and Sanchez, P. 2021. Opportunities for building resilience of African farming systems. In: AGRA. 2021. *Africa agriculture status report 2021: A decade of action: Building sustainable and resilient food systems in Africa.* Nairobi, Kenya: Alliance for a Green Revolution in Africa. (https://hdl.handle.net/10568/119621).

16. Dembele, C.O., Traore, K., Karembe, M., Zemadin, B., Fotigui, C. and Samake, O. 2021. Contour ridge tillage for improved crops and fodder trees production in the villages of Kani and Noumpinesso, southern Mali. *Journal of Agricultural Studies* 9(2): 550–572. (https://doi.org/10.5296/jas.v9i2.18513).

17. Desta, G., Abera, W., Tamene, L. and Amede, T. 2021. A meta-analysis of the effects of land management practices and land uses on soil loss in Ethiopia. *Agriculture, Ecosystems and Environment* 322: art. 107635. (https://doi.org/10.1016/j.agee.2021.107635).

18. Dissa, A., Bijman, J., Slingerland, M., Sanogo, O.M., Giller, K.E. and Descheemaeker, K. 2021. Growing cotton to produce food: Unravelling interactions between value chains in southern Mali. *Development Policy Review* 40(5). (https://doi.org/10.1111/dpr.12605).

19. Fischer, G., Kotu, B. and Mutungi, C. 2021. Sustainable and equitable agricultural mechanization? A gendered perspective on maize shelling. *Renewable Agriculture and Food Systems* 36(4): 396–404. (https://doi.org/10.1017/S1742170521000016).

20. Fischer, G., Darkwah, A., Kamoto, J., Kampanje-Phiri, J., Grabowski, P. and Djenontin, I. 2021. Sustainable agricultural intensification and gender-biased land tenure systems: An exploration and conceptualization of interactions. *International Journal of Agricultural Sustainability* 19(5–6): 403–422. (https://doi.org/10.1080/14735903.2020.1791425).

21. Gebreyes, M., Mekonnen, K., Thorne, P., Bezabih, M., Adie, A., Mulema, A., Ahmed, S., Tamene, L., Amede, T., Haileslassie, A., Gebrekirstos, A., Mupangwa, W.T., Ebrahim, M., Alene, T., Asfaw, A., Dubale, W. and Yasabu, S. 2021. Overcoming constraints of scaling: Critical and empirical perspectives on agricultural innovation scaling. *PLoS ONE* 16(5): art. e0251958. (https://doi.org/10.1371/journal.pone.0251958).

22. Gwenambira-Mwika, C.P., Snapp, S. and Chikowo, R. 2021. Broadening farmer options through legume rotational and intercrop diversity in maize-based cropping systems of central Malawi. *Field Crops Research* 270: art. 108225. (https://doi.org/10.1016/j.fcr.2021.108225).

23. Habermann, B., Vogl, R.C., Mekonnen, K., Bekele, K. and Felt, U. 2021. Farmers and scientists in AR4D: Looking at a watershed management project through an STS lens. *NJAS: Impact in Agricultural and Life Sciences* 93(1): 126–151. (https://doi.org/10.1080/27685241.2021.1993095).

24. Habiyaremye, N., Ochieng, J. and Heckelei, T. 2021. Economic analysis of integrated vegetable–poultry production systems in the Babati district of Tanzania. *Agriculture & Food Security* 10: art. 1. (https://doi.org/10.1186/s40066-020-00272-8).

25. Hafner, J.M., Steinke, J., Uckert, G., Sieber, S. and Kimaro, A.A. 2021. Allometric equations for estimating on-farm fuel production of *Gliricidia sepium* (Gliricidia) shrubs and *Cajanus cajan* (pigeon pea) plants in semi-arid Tanzania. *Energy, Sustainability and Society* 11: art. 43. (https://doi.org/10.1186/s13705-021-00310-8).

26. Hammond, J., van Wijk, M., Teufel, N., Mekonnen, K. and Thorne, P. 2021. Assessing smallholder sustainable intensification in the Ethiopian Highlands. *Agricultural Systems* 194: art. 103266. (https://doi.org/10.1016/j.agsy.2021.103266).

27. Hermans, T.D.G., Dougill, A.J., Whitfield, S., Peacock, C.L., Eze, S. and Thierfelder, C. 2021. Combining local knowledge and soil science for integrated soil health assessments in conservation agriculture systems. *Journal of Environmental Management* 286: art. 112192. (https://doi.org/10.1016/j.jenvman.2021.112192).

28. John, I., Snapp, S., Nord, A., Chimonyo, V., Gwenambira, C. and Chikowo, R. 2021. Marginal more than mesic sites benefit from groundnut diversification of maize: Increased yield, protein, stability, and profits. *Agriculture, Ecosystems & Environment* 320: art. 107585. (https://doi.org/10.1016/j.agee.2021.107585).

29. Lamboll, R., Nelson, V., Gebreyes, M., Kambewa, D., Chinsinga, B., Karbo, N., Rukonge, A., Sekeleti, M., Wakun'uma, W., Gutema, T., Henjewele, M., Phiri, J., Hlanguyo, P., Quaye, W., Duah, S., Kivuyo, M., Nyanga, P., Essilfie, M., Yamoah, A., Clottey, V. and Martin, A. 2021. Strengthening decision-making on sustainable agricultural intensification through multi-stakeholder social learning in Sub-Saharan Africa. *International Journal of Agricultural Sustainability* 19(5–6): 609–635. (https://doi.org/10.1080/14735903.2021.1913898).

30. Lema, Z., de Bruyn, L.A.L., Marshall, G.R., Roschinsky, R. and Duncan, A.J. 2021. Multilevel innovation platforms for development of smallholder livestock systems: How effective are they? *Agricultural Systems* 189: art. 103047. (https://doi.org/10.1016/j.agsy.2020.103047).

31. Kalumba, P.J. 2021. *Effect of seed generation, rhizobia inoculation and plant density on productivity and seed quality of soybean [Glycine max (L.) Merril] and groundnut [Arachis hypogea (L.)] in Dedza and Machinga districts of Malawi.* [MSc thesis in Agronomy. Lilongwe University of Agriculture and Natural Resources]. Lilongwe, Malawi.

32. Kenjewala, V.G. 2021. *Comparative analysis of groundnuts and maize seed value chains in semi-arid agro-ecologies of central Tanzania.* [MSc thesis. Sokoine University of Agriculture], Morogoro, Tanzania..

33. Komarek, M.A., Thierfelder, C. and Steward, R.P. 2021. Conservation agriculture improves adaptive capacity of cropping systems to climate stress in Malawi. *Agricultural Systems* 190: art. 103117. (https://doi.org/10.1016/j.agsy.2021.103117).

34. Komarek, A.M., Abdul Rahman, N., Bandyopadhyay, A., Kizito, F., Koo, J. and Addah, W. 2021. Trade-offs and synergies associated with maize leaf stripping within crop-livestock systems in northern Ghana. *Agricultural Systems* 193: art. 103206. (https://doi.org/10.1016/j.agsy.2021.103206).

35. Liguluwe, R. 2021. *The effect of integrating nutrition education, food budgeting and food processing and preparation on household dietary diversity: A case of Ntcheu and Dedza districts in Malawi.* [MSc thesis in Human Nutrition. Lilongwe University of Agriculture and Natural Resources]. Lilongwe, Malawi.

36. Manda, J., Azzarri, C., Feleke, S., Kotu, B., Claessens, L. and Bekunda, M. 2021. Welfare impacts of smallholder farmers' participation in multiple output markets: Empirical evidence from Tanzania. *PloS ONE* 16(5): art. e0250848. (https://doi.org/10.1371/journal.pone.0250848).

37. Massop, E. 2021. *Farm performance evaluation: Holistic impact assessment of project promoted sustainable intensification innovations at farm-level in Tanzania.* [MSc thesis in Farming Systems Ecology. Wageningen University and Research Centre]. Wageningen, The Netherlands.

38. Maselema, D., Chigwa, F. and Chingala, G. 2021. Effect of pumpkin (*Cucurbita maxima*) seed meal as a supplementing diet to free-ranging goats on growth performance and semen quality. *Livestock Research for Rural Development* 33(1): art. 2. (https://hdl.handle.net/10568/115897).

39. Mathews, M. 2021. Healthy soils, healthy plants, healthy humans: A holistic exploration of sustainable intensification effects on farming systems in Malawi. [MSc thesis in Earth Sciences. University of Amsterdam]. Amsterdam, The Netherlands.

40. Maviko, I. 2021. *Impact of sustainable intensification practices adoption on farm income of smallholder farmers: Empirical evidence from Africa RISING project in Malawi.* [MSc thesis in Agricultural and Applied Economics. Lilongwe University of Agriculture and Natural Resources]. Lilongwe, Malawi.

41. Mekonnen, K., Bezabih, M., Thorne, P., Gebreyes, M.G., Hammond, J. and Adie, A. 2021. Feed and forage development in mixed crop–livestock systems of the Ethiopian Highlands: Africa RISING project research experience. *Agronomy Journal* 114(1): 46–62. (https://doi.org/10.1002/agj2.20853).

42. Mekonnen, K., Gebreyes, M., Abdulkadir, B., Seifu, H. and Thorne, P. 2021. *Training module on livestock feed and forage innovations.* Wageningen, The Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security. (https://hdl.handle.net/10568/117289).

43. Mengistu, S., Nurfeta, A., Tolera, A., Adie, A., Mekonnen, K., Wolde-meskel, E., Khan, A., Jones, C. and Bezabih, M. 2021. Forage yield and replacing concentrate supplements with oat and vetch mixed forage on the performance of sheep fed Desho grass (*Pennisetum pedicellatum*) based diets. *Ethiopian Journal of Science and Technology* 12(1): 10–17. (https://hdl.handle.net/10568/114291).

44. Mhlanga, B. and Thierfelder, C. 2021. Long-term conservation agriculture improves water properties and crop productivity in a Lixisol. *Geoderma* 398: art. 115107. (https://doi.org/10.1016/j.geoderma.2021.115107).

45. Mhlanga, B., Mwila, M. and Thierfelder, C. 2021. Improved nutrition and resilience will make conservation agriculture more attractive for Zambian smallholder farmers. *Renewable Agriculture and Food Systems* 36(5): 443–456. (https://doi.org/10.1017/S1742170521000028).

46. Mulokozi, G. 2021. *Power relation dynamics among actors in the groundnuts seed value chain: A case of Kongwa and Kiteto districts, Tanzania.* [MSc thesis, Sokoine University of Agriculture]. Morogoro, Tanzania.

47. Mulugeta, B., Tesfaye, K., Keneni, G. and Ahmed, S. 2021. Genetic diversity in spring faba bean (*Vicia faba L.*) genotypes as revealed by high-throughput KASP SNP markers. *Genetic Resources and Crop Evolution (*https://doi.org/10.1007/s10722-021-01110-x).

48. Mwila, M., Mhlanga, B. and Thierfelder, C. 2021. Intensifying cropping systems through doubled-up legumes in eastern Zambia. *Scientific Reports* 11: art. 8101. (https://doi.org/10.1038/s41598-021-87594-0).

49. Nkhata, W., Shimelis, H. and Chirwa, R. 2021. Productivity of newly released common bean (*Phaseolus vulgaris* L.) varieties under sole cropping and intercropping with maize (*Zea mays* L.). *Frontiers in Sustainable Food Systems* 5: art. 741177. (https://doi.org/10.3389/fsufs.2021.741177).

50. Nziguheba, G., Adewopo, J., Masso, C., Nabahungu, N.L., Six, J., Sseguya, H., Taulya, G. and Vanlauwe, B. 2021. Assessment of sustainable land use: Linking land management practices to sustainable land use indicators. *International Journal of Agricultural Sustainability* 20(3): 265–288. (https://doi.org/10.1080/14735903.2021.1926150).

51. Ochieng, J., Afari-Sefa, V., Muthoni, F., Kansiime, M., Hoeschle-Zeledon, I., Bekunda, M. and Thomas, D. 2021. Adoption of sustainable agricultural technologies for vegetable production in rural Tanzania: Trade-offs, complementarities, and diffusion. *International Journal of Agricultural Sustainability* 20(4): 478–496. (https://doi.org/10.1080/14735903.2021.1943235).

52. Peter, B.G., Messina, J.P., Carroll, J.W. and Chikowo, R. 2021. A case for green-based vegetation indices: Plot-scale sUAS imagery related to crop chlorophyll content on smallholder maize farms in Malawi. *Remote Sensing Letters* 12(8): 778–787. (https://doi.org/10.1080/2150704X.2021.1938733).

53. Reith, J., Ghazaryan, G., Muthoni, F.K. and Dubovyk, O. 2021. Assessment of land degradation in semiarid Tanzania – Using multiscale remote sensing datasets to support Sustainable Development Goal 15.3. *Remote Sensing* 13(9): art. 1754. (https://doi.org/10.3390/rs13091754).

54. Richardson, R.B., Olabisi, L.S., Waldman, K.B., Sakana, N. and Brugnone, N.G. 2021. Modeling interventions to reduce deforestation in Zambia. *Agricultural Systems* 194: art. 103263. (https://doi.org/10.1016/j.agsy.2021.103263).

55. Saaka M., Kizito F. and Hoeschle-Zeledon, I. 2021. Effect of nutrition education on nutrition-related knowledge, attitudes, and consumption of diversified diets among families owning a home garden in northern Ghana. *World Nutrition* 12(4): 15–31. (https://doi.org/10.26596/wn.202112415-31).

56. Saaka, M., Wemah, K., Kizito, F. and Hoeschle-Zeledon, I. 2021. Effect of nutrition behaviour change communication delivered through radio on mothers' nutritional knowledge, child feeding practices and growth. *Journal of Nutritional Science* 10: art. E44. (https://doi.org/10.1017/jns.2021.35).

57. Sanogo, K., Zemadim, B., Sanogo, S., Aishetu, A. and Ba, A. 2021. Spatiotemporal response of vegetation to rainfall and air temperature fluctuations in the Sahel: Case study in the forest reserve of Fina, Mali. *Sustainability* 13(11): art. 6250. (https://doi.org/10.3390/su13116250).

58. Sseguya, H., Robinson, D.S., Mwango, H.R., Flock, J.A., Manda, J., Abed, R. and Mruma, S.O. 2021. The impact of demonstration plots on improved agricultural input purchase in Tanzania: Implications for policy and practice. *PLoS ONE* 16(1): art. E0243896. (https://doi.org/10.1371/journal.pone.0243896)

59. Tadesse, M., Simane, B., Abera, W., Tamene, L., Ambaw, G., Recha, J.W., Mekonnen, K., Demeke, G., Nigussie, A. and Solomon, D. 2021. The effect of climate-smart agriculture on soil fertility, crop yield, and soil carbon in southern Ethiopia. *Sustainability* 13(8): art. 4515. (https://doi.org/10.3390/su13084515).

60. Tenakwa, E.A., Imoro, A.Z., Ansah, T. and Kizito, F. 2021. Pigeon pea (*Cajanus cajan*) fodder cutting management in the Guinea Savanna Agro-Ecological Zone of Ghana. *Agroforestry Systems* 96: 1–10. (https://doi.org/10.1007/s10457-021-00679-7).

61. Thierfelder, C., Paterson, E., Mwafulirwa, L., Daniell, T., Cairns, J., Mhlanga, B. and Baggs, E. 2021. Toward greater sustainability: How investing in soil health may enhance maize productivity in Southern Africa. *Renewable Agriculture and Food Systems* 37(2). (https://doi.org/10.1017/S1742170521000442).

62. Wabwire, S. 2021. *Performance of elite cereal and legume genotypes in varying potential agro-ecologies in central Tanzania*. [MSc thesis, Sokoine University of Agriculture]. (Available at https://www.suaire.sua.ac.tz/handle/123456789/3947).

63. Wachiebene, S.K. 2021. *Assessment of feed resources for ruminant production in Northern Region of Ghana*. [MSc thesis in Animal Science (Animal Nutrition). University of Development Studies]. Tamale, Ghana. (https://hdl.handle.net/10568/115599).

64. Worku, M., Lemma, H., Shawle, K., Adie, A., Duncan, A.J., Jones, C.S., Mekonnen, K., Notenbaert, A. and Bezabih, M. 2021. Potential of *Urochloa* grass hybrids as fodder in the Ethiopian Highlands. *Agronomy Journal* 114(1): 126–137. (https://doi.org/10.1002/agj2.20789).

Year 2020

1. Abdul Rahman, N., Larbi, A., Kotu, B., Kizito, F. and Hoeschle-Zeledon, I. 2020. Evaluating sustainable intensification of groundnut production in northern Ghana using the Sustainable Intensification Assessment Framework approach. *Sustainability* 12: art. 5970. (https://doi.org/10.3390/su12155970).

2. Abed, R., Sseguya, H., Flock, J., Mruma, S. and Mwango, H. 2020. An evolving agricultural extension model for lasting impact: How willing are Tanzanian farmers to pay for extension services? *Sustainability* 12(20): art. 8473. (https://doi.org/10.3390/su12208473).

3. Addah, W., Ayantunde, A. and McAllister, T.A. 2020. Row spacing of annual peanut (*Arachis hypogaea* L.) and the conservation of peanut haulm as hay or silage: Effects on nutritive value and growth performance of sheep. *Ghanaian Journal of Animal Science* 11(1): 149–162. (https://hdl.handle.net/10568/115698).

4. Adams, A., Osei-Amponsah, C. and Jumpah, E.T. 2020. Analysing the determinants, constraints, and opportunities of smallholder farmers' access to input markets: Evidence from northern Ghana. *Journal of Agribusiness and Rural Development* 2(56): 133–143. (https://hdl.handle.net/10568/109100).

5. Adimassu, Z., Balana, B.B., Appoh, R. and Nartey, E. 2020. The use of the wetting front detector as an irrigation-scheduling tool for pepper production in the Upper East Region of Ghana: Evidence from field experiment and farmers' perceptions. *Irrigation and Drainage* 69(4): 696–713. (https://hdl.handle.net/10568/108362).

6. Agbetiameh, D., Ortega-Beltran, A., Awuah, R.T., Atehnkeng, J., Elzein, A., Cotty, P.J. and Bandyopadhyay, R. 2020. Field efficacy of two atoxigenic biocontrol products for mitigation of aflatoxin contamination in maize and groundnut in Ghana. *Biological Control* 150: art. 104351. (https://hdl.handle.net/10568/109102).

7. Amede, T., Gashaw, T., Legesse, G., Tamene, L., Mekonen, K., Thorne, P. and Schultz, S. 2020. Landscape positions dictating crop fertilizer responses in wheat-based farming systems of East African highlands. *Renewable Agriculture and Food Systems* 37(S1): S4–S16. (https://doi.org/10.1017/S1742170519000504).

8. Anders, E.J., Zulu, L.C. and Jambo, E.R. 2020. Limits to grain-legume technology integration by smallholder farmers: The case of time-sensitive labor demands and food security primacy in Malawi. *Agricultural Systems* 184: art. 102879. (https://doi.org/10.1016/j.agsy.2020.102879).

9. Baijukya, F., Sabula L., Mruma S., Mzee, F., Mtoka, E., Masigo, J., Ndunguru, A. and Swai, E. 2020. *Maize production manual for smallholder farmers in Tanzania*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/109806).

10. Bellon, M.R., Kotu, B.H., Azzarri, C. and Caracciolo, F. 2020. To diversify or not to diversify, that is the question: Pursuing agricultural development for smallholder farmers in marginal areas of Ghana. *World Development* 125: art. 104682. (https://doi.org/10.1016/j.worlddev.2019.104682).

11. Berdjour, A., Dugje, I.Y., Dzomeku, I.K. and Abdul Rhaman, N. 2020. Maize–soybean intercropping effect on yield productivity, weed control and diversity in northern Ghana. *Weed Biology and Management* 20(2): 69–81. (https://doi.org/10.1111/wbm.12198).

12. Birhanu, B.Z., Traoré, K., Sanogo, K., Tabo, R., Fischer, G. and Whitbread, A.M. 2020. Contour bunding technology – Evidence and experience in the semiarid region of southern Mali. *Renewable Agriculture and Food Systems* 37(S1): S55–S63. (https://doi.org/10.1017/S1742170519000450).

13. Burke, W.J., Snapp, S.S. and Jayne, T.S. 2020. An in-depth examination of maize yield response to fertilizer in central Malawi reveals low profits and too many weeds. *Agricultural Economics* 51(6): 923–940. (https://doi.org/10.1111/agec.12601).

14. Chilanga, F. 2020. *Growth performance, carcass characteristics, meat quality and profitability of local Malawi goats under pen fattening conditions*. [MSc thesis in Animal Science. Lilongwe University of Agriculture and Natural Resources]. Lilongwe, Malawi. (https://hdl.handle.net/10568/108418).

15. Desta, W.H., Alemu, G.B., Kinati, W., Mulem, A.A., van Eerdewijk, A. and Wieland, B. 2020. Contribution of small ruminants to food security for Ethiopian smallholder farmers. *Small Ruminant Research* 184: art. 106064. (https://repo.mel.cgiar.org/handle/20.500.11766/11858).

16. Fischer, G., Darkwah, A., Kamoto, J., Kampanje-Phiri, J., Grabowski, P. and Djenontin, I.N.S. 2020. Sustainable agricultural intensification and gender-biased land tenure systems: An exploration and conceptualization of interactions. *International Journal of Agricultural Sustainability* 19(5–6): 403–422. (https://doi.org/10.1080/14735903.2020.1791425).

17. Fischer, G., Patt, N., Ochieng, J. and Mvungi, H. 2020. Participation in and gains from traditional vegetable value chains: A gendered analysis of perceptions of labour, income and expenditure in producers' and traders' households. *European Journal of Development Research* 32: 1080–1104. (https://doi.org/10.1057/s41287-020-00257-0).

18. Frake, A.N., Peter, B.G., Walker, E.D. and Messina, J.P. 2020. Leveraging big data for public health: Mapping malaria vector suitability in Malawi with Google Earth Engine. *PloS ONE* 15(8): art. e0235697. (https://doi.org/10.1371/journal.pone.0235697).

19. Hafner, J.M., Uckert, G., Hoffmann, H.K., Rosenstock, T.S., Sieber, S. and Kimaro, A.A. 2020. Efficiency of three-stone fire and improved cooking stoves using on-farm and off-farm fuels in semi-arid Tanzania. *Energy for Sustainable Development* 59: 199–207. (https://doi.org/10.1016/j.esd.2020.10.012).

20. Hermans, T.D.G., Whitfield, S., Dougill, A.J. and Thierfelder, C. 2020. Bridging the disciplinary gap in conservation agriculture research, in Malawi. A review. *Agronomy for Sustainable Development* 40: art. 3. (https://doi.org/10.1007/s13593-020-0608-9).

21. Hermans, T.D.G., Whitfield, S., Dougill, A.J. and Thierfelder, C. 2020. Why we should rethink 'adoption' in agricultural innovation: Empirical insights from Malawi. *Land Degradation and Development* 32(4): 1809–1820. (https://doi.org/10.1002/ldr.3833).

22. Kihara J., Kizito F., Jumbo, M., Kinyua M. and Bekunda, M. 2020. Unlocking maize crop productivity through improved management practices in northern Tanzania. *African Journal of Food, Agriculture, Nutrition & Development* 20(7): 17095–17112. (https://doi.org/10.18697/ajfand.95.17965).

23. Killenga, S.K., Chuwa, C., Mvukiye, N., Zakayo, J., Paul, I. and Kimaro, D. 2020. *Rice production manual*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/109813).

24. Killenga, S.K., Mvukiye, N., Chuwa, C., Kimaro, D., Paul, I. and Zakayo, J. 2020. *Mwongozo wa kufundishia kilimo bora cha Mpunga*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/109805).

25. Lark, R.M., Ligowe, I.S., Thierfelder, C., Magwero, N., Namaona, W., Njira, K., Sandram, I., Chimungu, J.G. and Nalivata, P.C. 2020. Longitudinal analysis of a long-term conservation agriculture experiment in Malawi and lessons for future experimental design. *Experimental Agriculture* 56(4): 506–527. (https://doi.org/10.1017/S0014479720000125).

26. Madembo, C., Mhlanga, B. and Thierfelder, C. 2020. Productivity or stability? Exploring maize-legume intercropping strategies for smallholder conservation agriculture farmers in Zimbabwe. *Agricultural Systems* 185: art. 102921. (https://doi.org/10.1016/j.agsy.2020.102921).

27. Mellon-Bedi, S., Descheemaeker, K., Hundie-Kotu, B., Frimpong, S. and Groot, J.C.J. 2020. Motivational factors influencing farming practices in northern Ghana. *NJAS: Wageningen Journal of Life Sciences* 92: art. 100326. (https://doi.org/10.1016/j.njas.2020.100326).

28. Mekuria, W., Mekonnen, K. and Adugna, M. 2020. Farm diversification in the central highlands of Ethiopia: Patterns determinants and its effect on household income. *Review of Agricultural and Applied Economics* 23(1): 73–82. (https://doi.org/10.15414/raae.2020.23.01.73-82).

29. Mkhutche, C.A. 2020. *On-station and on-farm evaluation of fodder tree resources for local goats' production under extensive management systems in Malawi*. [MSc thesis in Animal Science. Lilongwe University of Agriculture and Natural Resources]. Lilongwe, Malawi.

30. Mkutche, C.D. 2020. *Evaluation of feed resources for local goat production under traditional management systems in Golomoti EPA Dedza and on-station at Bunda Campus, LUANAR, Malawi*. [MSc thesis in Animal Science. Lilongwe University of Agriculture and Natural Resources]. Lilongwe, Malawi. (https://hdl.handle.net/10568/108504).

31. Muthoni, F. 2020. Spatial-temporal trends of rainfall, maximum and minimum temperatures over West Africa. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* 13: 2960–2973. (https://doi.org/10.1109/jstars.2020.2997075).

32. Muthoni, F.K., Bekunda, M., Hoeschle-Zeledon, I., Sseguya, H., Kizito, F., Baijukya, F. and Mruma, S. 2020. *A compendium of maps on biophysical and socioeconomic context, suitability of maize varieties and inorganic fertilizers in Tanzania*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/109958).

33. Mutungi, C., Gaspar, A. and Abass, A. 2020. *Viwango vya Ubora wa Mahindi na Ufafanuzi: Mwongozo wa mwezeshaji wa wakulima wadogo nchini Tanzania*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/109817).

34. Mutungi, C., Gaspar, A. and Abass, A. 2020. *Maize quality standards and specifications: A trainer's manual for smallholder farmers in Tanzania*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/109807).

35. Mutungi, C., Gaspar, A. and Abass, A. 2020. *Postharvest operations and quality specifications for rice: A trainer's manual for smallholder farmers in Tanzania*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/109808).

36. Mutungi, C., Ndunguru, G., Gaspar, A. and Abass, A. 2020. *Improved postharvest practices for reduction of losses and improvement of produce quality: A trainer's manual for smallholder maize farmers in Tanzania*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/109804).

37. Mutungi, C., Ndunguru, G., Gaspar, A. and Abass, A. 2020. *Shughuli zilizoboreshwa kwa ajili ya kupunguza upotevu na kuboresha mazao baada ya kuvuna: Mwongozo wa mkufunzi kwa wakulima wadogo wa mahindi nchini Tanzania*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/109814).

38. Mutungi, C., Chamwilambo, M., Masanja, S., Massam, C., Wayda, P., Tungu, J., Gaspar, A., Bekunda, M. and Abass, A. 2020. Quality and storability of common beans in small-holders farm stores in northern Tanzania: A multivariate analysis of agro-location, variety, and storage method effects. *Journal of Stored Products Research* 89: art. 101723. (https://doi.org/10.1016/j.jspr.2020.101723).

39. Niayale, R., Addah, W. and Ayantunde, A.A. 2020. Effects of ensiling cassava peels on some fermentation characteristics and growth performance of sheep on-farm. *Ghana Journal of Agricultural Science* 55(2): 107–121. (https://doi.org/10.4314/gjas.v55i2.9)

40. Ngonyani, H., Okoruwa, A., Kyungu, L., Gaspar, A., Mutungi, C. and Abass, A. 2020. *Improved complementary feeding: A trainer's manual for rural nutrition and health caregivers*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/109803).

41. Ngonyani, H., Okoruwa, A., Kyungu, L., Gaspar, A., Mutungi, C. and Abass, A. 2020. *Matumizi ya Soya katika kuboresha afya ya kaya Tanzania: Mkusanyiko wa mapishi mbalimbali*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/109809).

42. Ngonyani, H., Okoruwa, A., Kyungu, L., Gaspar, A., Mutungi, C. and Abass, A. 2020. *Soybeans utilization for improved household nutrition in Tanzania: Compendium of popular soybean recipes*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/109815).

43. Ngonyani, H., Okoruwa, A., Kyungu, L., Gaspar, A., Mutungi, C. and Abass, A. 2020. *Utayarishaji bora wa vyakula vya watoto wadogo: Mwongozo kwa watoaji huduma ya lishe*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/109816).

44. O'Dell, D., Eash, N.S., Hicks, B.B., Oetting, J.N., Sauer, T.J., Lambert, D.M., Thierfelder, C., Muoni, T., Logan, J., Zahn, J.A. and Goddard, J.J. 2020. Conservation agriculture as a climate change mitigation strategy in Zimbabwe. *International Journal of Agricultural Sustainability* 18(3): 250–265. (https://doi.org/10.1080/14735903.2020.1750254).

45. Peter, B.G., Messina, J.P., Lin, Z. and Snapp, S.S. 2020. Crop climate suitability mapping on the cloud: A geovisualization application for sustainable agriculture. *Scientific Reports* 10(1): art. 15487. (https://doi.org/10.1038/s41598-020-72384-x).

46. Reith, A.J. 2020. *Assessment of land degradation in semi-arid Tanzania: Using remote sensing to inform the Sustainable Development Goal 15.3*. [MSc thesis in Geography. University of Bonn]. Bonn, Germany. (https://hdl.handle.net/10568/113186).

47. Renwick, L.L.R. 2020. *Drought resistance and resource use efficiency in diversified cropping systems*. [PhD Candidate, Horticulture & Agronomy/MS International Agricultural Development, Department of Plant Sciences, University of California]. Davis, California. (Available from https://www.proquest.com/openview/19001cce9d14275b52ac6e57c2a4c3ba).

48. Renwick, L.L.R., Kimaro, A.A., Hafner, J.M., Rosenstock, T.S. and Gaudin, A.C.M. 2020. Maize-pigeonpea intercropping outperforms monocultures under drought. *Frontiers in Sustainable Food Systems* 4: art. 562663. (https://doi.org/10.3389/fsufs.2020.562663).

49. Scherer, L., Svenning, J.C., Huang, J., Seymour, C.L., Sandel, B., Mueller, N., Kummu, M., Bruelheide, H., Hochman, Z., Siebert, S., Rueda, O.and Van Bodegom, P.M. 2020. Global priorities of environmental issues to combat food insecurity and biodiversity loss. *Science of the Total Environment* 730: art. 139096. (https://doi.org/10.1016/j.scitotenv.2020.139096).

50. Swamila, M., Philip, D., Akyoo, A.M., Sieber, S., Bekunda, M., and Kimaro, A.A. 2020. Gliricidia agroforestry technology adoption potential in selected dryland areas of Dodoma Region, Tanzania. *Agriculture* 10(7): art. 306. (https://doi.org/10.3390/agriculture10070306).

51. Terefe, H., Argaw, M., Tamene, L. and Mekonnen, K. 2020. Sustainable land management interventions lead to carbon sequestration in plant biomass and soil in a mixed crop-livestock system: The case of Geda watershed, central highlands of Ethiopia. *Ecological Processes* 9: art. 34. (https://doi.org/10.1186/s13717-020-00233-w).

52. Wortmann, C., Amede, T., Bekunda, M., Ndung'u-Magiroi, K., Masikati, P., Snapp, S., Stewart, Z.P., Westgate, M., Zida, Z. and Kome, C.E. 2020. Improvement of smallholder farming systems in Africa. *Agronomy Journal* 112(6): 5325–5333. (https://doi.org/10.1002/agj2.20363).

53. Yaekob, T., Tamene, L., Gebrehiwot, S.G., Demissie, S.S., Adimassu, Z., Woldearegay, K., Mekonnen, K., Amede, T., Abera, W., Recha, J.W., Solomon, D. and Thorne, P. 2020. Assessing the impacts of different land uses and soil and water conservation interventions on runoff and sediment yield at different scales in the central highlands of Ethiopia. *Renewable Agriculture and Food Systems* 37(S1): S73–S87. (https://doi.org/10.1017/S1742170520000010).

54. Zeleke, F., Kassie, G., Haji, J. and Legesse, B. 2020. Would market sheds improve market participation and earnings of small ruminant keepers? Evidence from Ethiopia. *Journal of Agricultural Economics* 72(2): 470–485. (https://doi.org/10.1111/1477-9552.12411).

55. Zulu, L.C., Djenontin, I.N.S., Darkwah, A., Kamoto, J., Kampanje-Phiri, J., Fischer, G., Grabowski, P. and Egyir, I. 2020. Realizing inclusive SAI: Contextualizing indicators to better evaluate gender and intergenerational inequity in SAI processes and outcomes – Cases from Southern and Western Africa. *International Journal of Agricultural Sustainability* 19(5–6): 376–402. (https://doi.org/10.1080/14735903.2020.1737356).

Year 2019

1. Belete, S., Bezabih, M., Abdulkadir, B., Tolera, A., Mekonnen, K. and Wolde-meskel, E. 2019. Inoculation and phosphorus fertilizer improve food-feed traits of grain legumes in mixed crop-livestock systems of Ethiopia. *Agriculture, Ecosystems & Environment* 279: 58–64. (https://doi.org/10.1016/j.agee.2019.04.014).

2. Berdjour, A. 2019. *Interseeding timing of cowpea (*Vigna unguiculata *L. Walp) living mulch on weed diversity, physical soil properties and performance of maize (*Zea mays *L.).* [MSc dissertation. University of Development Studies]. Tamale, Ghana. (https://hdl.handle.net/10568/108889).

3. Fischer, G., Wittich, S. and Fründt, S. 2019. *Gender analysis in farming systems and action research: A training manual*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/100149).

4. Habiyaremye, N., Tabe-Ojong, M.P., Ochieng, J. and Chagamoka, T. 2019. New insights on efficiency and productivity analysis: Evidence from vegetable-poultry integration in rural Tanzania. *Scientific African* 6: art. E00190. (https://doi.org/10.1016/j.sciaf.2019.e00190).

5. Harrison, R.D., Thierfelder, C., Baudron, F., Chinwada, P., Midega, C., Schaffner, U. and van den Berg, J. 2019. Agro-ecological options for fall armyworm (*Spodoptera frugiperda* JE Smith) management: Providing low-cost, smallholder friendly solutions to an invasive pest. *Journal of Environmental Management* 243: 318–330. (https://doi.org/10.1016/j.jenvman.2019.05.011).

6. IFPRI, IITA and ILRI. 2019. *Africa RISING program data management plan: 2019–2021*. Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/100536).

7. Jambo, I.J., Groot, J.C.J., Descheemaeker, K., Bekunda, M. and Tittonell, P. 2019. Motivations for the use of sustainable intensification practices among smallholder farmers in Tanzania and Malawi. *NJAS: Wageningen Journal of Life Sciences* 89(1): 1–10. (https://doi.org/10.1016/j.njas.2019.100306).

8. Kasse, H. 2019. *Influence du parcage de nuit des bovins sur la fertilité du sol et la productivité du sorgho à Koutiala en zone Mali-sud*. [Thèse pour l'obtention du diplôme de d'Ingénieur Agronome. Institut Polytechnique Rural de Formation et de Recherche Appliquée]. Bamako, Mali. (https://hdl.handle.net/10568/108797).

9. Kihara, J., Bolo P. and Kinyua, M. 2019. *Soil fertility management in Babati: A practical guide on good agricultural management practices in smallholder farming systems*. Nairobi, Kenya: CIAT. (https://hdl.handle.net/10568/107779).

10. Kimaro, A.A., Sererya, O.G., Matata, P., Uckert, G., Hafner, J., Graef, F., Sieber, S. and Rosenstock, T.S. 2019. Understanding the multidimensionality of climate-smartness: Examples from agroforestry in Tanzania. In: Rosenstock, T., Nowak, A. and Girvetz, E. (eds), *The climate-smart agriculture papers*. Cham, Switzerland: Springer: 153–162. (https://doi.org/10.1007/978-3-319-92798-5_13).

11. Komarek, A.M., Kwon, H., Haile, B., Thierfelder, C., Mutenje, M.J. and Azzarri, C. 2019. From plot to scale: Ex-ante assessment of conservation agriculture in Zambia. *Agricultural Systems* 173: 504–518. (https://hdl.handle.net/10568/101214).

12. Kotu, B.H., Abass, A., Hoeschle-Zeledon, I., Mbwambo, H. and Bekunda, M. 2019. Exploring the profitability of improved storage technologies and their potential impacts on food security and income of smallholder farm households in Tanzania. *Journal of Stored Products Research* 82: 98–109. (https://doi.org/10.1016/j.jspr.2019.04.003).

13. Kusi, F., Nboyine, J.A., Abudulai, M., Seidu, A., Agyare, Y.R., Sugri, I., Zakaria, M., Owusu, R.K., Nutsugah, S.K. and Asamoah, L. 2019. Cultivar and insecticide spraying time effects on cowpea insect pests and grain yield in northern Ghana. *Annals of Agricultural Sciences* 64(1): 121–127. (https://doi.org/10.1016/j.aoas.2019.03.001).

14. Mekonnen, K., Jogo, W., Bezabih, M., Mulema, A. and Thorne, P. 2019. Determinants of survival and growth of tree lucerne (*Chamaecytisus palmensis*) in the crop-livestock farming systems of the Ethiopian Highlands. *Agroforestry Systems* 93(1): 279–293. (https://doi.org/10.1007/s10457-016-0066-1).

15. Michalscheck, M., Groot, J.C.J., Fischer, G. and Tittonell, P. 2019. Land use decisions: By whom and to whose benefit? A serious game to uncover dynamics in farmland allocation at household level in northern Ghana. *Land Use Policy* 91: art. 104325. (https://doi.org/10.1016/j.landusepol.2019.104325).

16. Mulema, A.A., Jogo, W., Damtew, E., Mekonnen, K. and Thorne, P. 2019. Women farmers' participation in the agricultural research process: Implications for agricultural sustainability in Ethiopia. *International Journal of Agricultural Sustainability* 17(2): 127–145. (https://doi.org/10.1080/14735903.2019.1569578).

17. Mulema, A., Jogo, W., Damtew, E., Mekonnen, K. and Thorne, P.J. 2019. Women farmers' participation in the agricultural research process: Implications for agricultural sustainability in Ethiopia. Presented at the Seeds of Change Conference, University of Canberra, Australia, 2–4 April. Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/101232).

18. Muoni, T., Mhlanga, B., Forkman, J., Sitali, M. and Thierfelder, C. 2019. Tillage and crop rotations enhance populations of earthworms, termites, dung beetles and centipedes: Evidence from a long-term trial in Zambia. *Journal of Agricultural Science* 157(6): 504–514. (https://doi.org/10.1017/S002185961900073X).

19. Mupangwa, W., Thierfelder, C., Cheesman, S., Nyagumbo, I., Muoni, T., Mhlanga, B., Mwila, M., Sida, T.S. and Ngwira, A. 2019. Effects of maize residue and mineral nitrogen applications on maize yield in conservation-agriculture-based cropping systems of Southern Africa. *Renewable Agriculture and Food Systems* 35(3): 322–335. (https://doi.org/10.1017/S174217051900005X).

20. Mutenje, M.J., Farnworth, C.R., Stirling, C., Thierfelder, C., Mupangwa, W. and Nyagumbo, I. 2019. A cost-benefit analysis of climate-smart agriculture options in Southern Africa: Balancing gender and technology. *Ecological Economics* 163: 126–137. (https://doi.org/10.1016/j.ecolecon.2019.05.013).

21. Mutungi, C., Muthoni, F., Bekunda, M., Gaspar, A., Kabula, E. and Abass, A. 2019. Physical quality of maize grain harvested and stored by smallholder farmers in the northern highlands of Tanzania: Effects of harvesting and pre-storage handling practices in two marginally contrasting agro-locations. *Journal of Stored Products Research* 84: art. 101517. (https://doi.org/10.1016/j.jspr.2019.101517).

22. Ndibalema, G. 2019. *Effective communication for disseminating soil and water management practices to bring about sustainable smallholder agriculture in Tanzania: Case study of Manyara and Dodoma regions*. [MSc Communication, Health and Life Sciences. Wageningen University and Research Centre]. Wageningen, The Netherlands. (https://hdl.handle.net/10568/101928).

23. Ochieng, J., Afari-Sefa, V., Lukumay, P.J., Dominick, I. and Muthoni, F. 2019. Smallholder farmers' adoption of vegetable production technologies in Babati district, Tanzania. *Acta Horticulturae* 1255: art. 31. (https://doi.org/10.17660/ActaHortic.2019.1255.31).

24. Rahman, N.A., Ansah, T., Sadia Osuman, A., Frimpong, S. and Arnold, A. 2019. Improved *Arachis hypogeae* variety effect on grain yield, fodder quality and livestock growth. *Agriculture and Natural Resources* 53(3): 244–250. (https://biblio1.iita.org/handle/20.500.12478/6523).

25. Rahman, N.A., Larbi, A., Opoku, A., Tetteh, F.M. and Hoeschle-Zeledon, I. 2019. Crop-livestock interaction effect on soil quality and maize yield in northern Ghana. *Agronomy Journal* 111(2): 907–916. (https://doi.org/10.2134/agronj2018.08.0523).

26. Seetha, A., Muzanila, Y., Tsusaka, T.W., Kachulu, L., Kumwenda, N., Musoke, M., Swai, E., Shija, J., Siambi, M., Monyo, E.S., Bekunda, M. and Okori, P. 2019. Reducing child undernutrition through dietary diversification, reduced aflatoxin exposure, and improved hygiene practices: The immediate impacts in central Tanzania. *Ecology of Food and Nutrition* 59(3): 243–262. (https://doi.org/10.1080/03670244.2019.1691000).

27. Shedrack, C., Ansah, T. and Kadyampakeni, D. 2019. Comparative yield performance and fodder quality of Napier grass varieties in the dry savanna region of Ghana. *Ghanaian Journal of Animal Science* 10(1): 172–182. (Available from https://www.researchgate.net/profile/Terry-Ansah/publication/341550090_COMPARATIVE_YIELD_PERFORMANCE_AND_FODDER_QUALITY_OF_NAPIER_GRASS_VARIETIES_IN_THE_DRY_SAVANNA_REGION_OF_GHANA/links/5ec6ad5c458515626cbd1c7f/COMPARATIVE-YIELD-PERFORMANCE-AND-FODDER-QUALITY-OF-NAPIER-GRASS-VARIETIES-IN-THE-DRY-SAVANNA-REGION-OF-GHANA.pdf) (Accessed 20 June 2023).

28. Shitindi, M., Kpomblekou-A, K., McElhenney, W.H., Ankumah, R., Semoka, J., Bekunda, M. and Bonsi, C. 2019. Maize response to leguminous biomass composted with phosphate rocks in the northern zone of Tanzania. *Journal of Experimental Agriculture International* 35(4): 1–15. (https://doi.org/10.9734/jeai/2019/v35i430209).

29. Silberg, T.R., Chimonyo, V.G.P., Richardson, R.B., Snapp, S.S. and Renner, K. 2019. Legume diversification and weed management in African cereal-based systems. *Agricultural Systems* 174: 83–94. (https://doi.org/10.1016/j.agsy.2019.05.004).

30. Snapp, S., Rogé, P., Okori, P., Chikowo, R., Peter, B. and Messina, J., 2019. Perennial grains for Africa: Possibility or pipedream? *Experimental Agriculture* 55(2): 251–272. (https://doi.org/10.1017/S0014479718000066).

31. Snapp, S.S., Cox, C.M. and Peter, B.G. 2019. Multipurpose legumes for smallholders in Sub-Saharan Africa: Identification of promising 'scale out' options. *Global Food Security* 23: 22–32. (https://doi.org/10.1016/j.gfs.2019.03.002).

32. TerAvest, D., Wandschneider, P.R., Thierfelder, C. and Reganold, J.P. 2019. Diversifying conservation agriculture and conventional tillage cropping systems to improve the wellbeing of smallholder farmers in Malawi. *Agricultural Systems* 171: 23–35. (https://doi.org/10.1016/j.agsy.2019.01.004).

33. Togo, A. 2019. *Effets de la fertilisation et de la date de semis sur des variétés de sorgho à double usage*. Thèse pour l'obtention du diplôme d'Ingénieur Agronome. Bamako, Mali: Institut Polytechnique Rural de Formation et de Recherche Appliquée. (https://hdl.handle.net/10568/108798).

34. Traore, K. and Birhanu, B.Z. 2019. Soil erosion control and moisture conservation using contour ridge tillage in Bougouni and Koutiala, southern Mali. *Journal of Environmental Protection* 10(10): 1333–1360. (https://doi.org/10.4236/jep.2019.1010079).

35. Wang, H., Snapp, S.S., Fisher, M. and Viens, F. 2019. A Bayesian analysis of longitudinal farm surveys in central Malawi reveals yield determinants and site-specific management strategies. *PLoS ONE* 14(8): art. e0219296. (https://doi.org/10.1371/journal.pone.0219296).

Year 2018

1. Abass, A.B., Fischler, M., Schneider, K., Daudi, S., Gaspar, A., Rüst, J., Kabula, E., Ndunguru, G., Madulu, D. and Msola, D. 2018. On-farm comparison of different postharvest storage technologies in a maize farming system of Tanzania Central Corridor. *Journal of Stored Products Research* 77: 55–65. (https://doi.org/10.1016/j.jspr.2018.03.002).

2. Adie, A., Bezabih, M., Mekonnen, K. and Thorne, P.J. 2018. *Fodder beet (*Beta vulgaris*) for livestock feed*. Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/91952).

3. Alvarez, S., Timler, C.J., Michalscheck, M., Paas, W., Descheemaeker, K., Tittonell, P., Andersson, J.A. and Groot, J.C.J. 2018. Capturing farm diversity with hypothesis-based typologies: An innovative methodological framework for farming system typology development. *PloS ONE* 13(5): art. e0194757. (https://doi.org/10.1371/journal.pone.0194757).

4. Ayizanga, R.A., Kayang, B.B., Adomako, K. and Asamoah, L. 2018. Rural pig production systems and breeding preferences of pig farmers in northern Ghana. *Ghanaian Journal of Animal Science* 9(1): 49–57. (https://hdl.handle.net/10568/92509).

5. Birhanu, B.Z., Traoré, K., Gumma, M.K., Badolo, F., Tabo, R. and Whitbread, A.M. 2018. A watershed approach to managing rainfed agriculture in the semiarid region of southern Mali: Integrated research on water and land use. *Environment, Development and Sustainability* 21: 2459–2485. (https://doi.org/10.1007/s10668-018-0144-9).

6. Fischer, G., Wittich, S., Malima, G., Sikumba, G., Lukuyu, B., Ngunga, D. and Rugalabam, J. 2018. Gender and mechanization: Exploring the sustainability of mechanized forage chopping in Tanzania. *Journal of Rural Studies* 64: 112–122. (https://doi.org/10.1016/j.jrurstud.2018.09.012).

7. Gramzow, A., Sseguya, H., Afari-Sefa, V., Bekunda, M. and Lukumay, P.J. 2018. Taking agricultural technologies to scale: Experiences from a vegetable technology dissemination initiative in Tanzania. *International Journal of Agricultural Sustainability* 16(3): 297–309. (https://doi.org/10.1080/14735903.2018.1473103).

8. Kinati, W., Mulema, A., Desta, H., Alemu, B. and Wieland, B. 2018. Does participation of household members in small ruminant management activities vary by agro-ecologies and category of respondents? Evidence from rural Ethiopia. *Journal of Gender, Agriculture and Food Security* 3(2): 51–73. (https://hdl.handle.net/10568/99314).

9. Konlan, S.P. 2018. *Availability and utilization of feed resources in small ruminant production among smallholder farmers in northern Ghana.* [PhD thesis in Animal Science (Nutrition Option). University for Development Studies]. Tamale, Ghana. (https://hdl.handle.net/10568/98497).

10. Lukumay, P.J., Afari-Sefa, V., Ochieng, J., Dominick, I., Coyne, D. and Chagomoka, T. 2018. Yield response and economic performance of participatory evaluated elite vegetable cultivars in intensive farming systems in Tanzania. *Acta Horticulturae* 1205: 75–86. (https://doi.org/10.17660/actahortic.2018.1205.9).

11. Lunt, T., Ellis-Jones, J., Mekonnen, K., Schulz, S., Thorne, P., Schulte-Geldermann, E. and Sharma, K. 2018. Participatory community analysis: Identifying and addressing challenges to Ethiopian smallholder livelihoods. *Development in Practice* 28(2): 208–226. (https://doi.org/10.1080/09614524.2018.1417354).

12. Marwa, L.J., Mbaga, S.H., Mutayoba, S.K. and Lukuyu, B. 2018. The productivity and management systems of free-range local chickens in rural areas of Babati district, Tanzania. *Livestock Research for Rural Development* 30(8): art. 134. (https://hdl.handle.net/10568/99490).

13. Mekuria, W. and Mekonnen, K. 2018. Determinants of crop–livestock diversification in the mixed farming systems: Evidence from central highlands of Ethiopia. *Agriculture & Food Security* 7: art. 60. (https://doi.org/10.1186/s40066-018-0212-2).

14. Mekuria, W., Mekonnen, K., Thorne, P., Bezabih, M., Tamene, L. and Abera, W. 2018. Competition for land resources: Driving forces and consequences in crop-livestock production systems of the Ethiopian Highlands. *Ecological Processes* 7: art. 30. (https://doi.org/10.1186/s13717-018-0143-7).

15. Morrone, V. and Livuza, H. 2018. *Action learning: Teaching others to engage with learners*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/93421).

16. Morrone, V., Mzumara, E. and Livuza, H. 2018. *Seed production guide curriculum for Malawi – A farmer field school approach*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/93422).

17. Mhango, K. 2018. *Effect of nutrition education and milk processing on nutritional status of under-five children among dairy farming households in Dedza district of Malawi*. [MSc thesis in Human Nutrition. Lilongwe University of Agriculture and Natural Resources]. Lilongwe, Malawi.

18. Michalscheck, M., Groot, J.C.J., Kotu, B., Hoeschle-Zeledon, I., Kuivanen, K., Descheemaeker, K. and Tittonell, P. 2018. Model results versus farmer realities. Operationalizing diversity within and among smallholder farm systems for a nuanced impact assessment of technology packages. *Agricultural Systems* 162: 164–178. (https://doi.org/10.1016/j.agsy.2018.01.028).

19. Minta, M., Kibret, K., Thorne, P., Nigussie, T. and Nigatu, L. 2018. Land use and land cover dynamics in Dendi-Jeldu hilly-mountainous areas in the central Ethiopian Highlands. *Geoderma* 314: 27–36. (https://doi.org/10.1016/j.geoderma.2017.10.035).

20. Muthoni, F.K., Odongo, V.O., Ochieng, J., Mugalavai, E.M., Mourice, S.K., Hoesche-Zeledon, I., Mwila, M. and Bekunda, M. 2018. Long-term spatial-temporal trends and variability of rainfall over Eastern and Southern Africa. *Theoretical and Applied Climatology* 137: 1869–1882. (https://doi.org/10.1007/s00704-018-2712-1).

21. Mutyasira, V., Hoag, D., Pendell, D.L. and Manning, D.T. 2018. Is sustainable intensification possible? Evidence from Ethiopia. *Sustainability* 10(11): art. 4174. (https://doi.org/10.3390/su10114174).

22. Mutyasira, V., Hoag, D., Pendellc, D., Manning, D.T. and Berhe, M. 2018. Assessing the relative sustainability of smallholder farming systems in Ethiopian Highlands. *Agricultural Systems* 167: 83–91. (https://doi.org/10.1016/j.agsy.2018.08.006).

23. Mwafulirwa, S.P. 2018. *Efficacy of TIPs approach and partial processing on household utilization of legumes: A case study of Ntcheu and Dedza districts*. [MSc thesis in Human Nutrition. Lilongwe University of Agriculture and Natural Resources]. Lilongwe, Malawi.

24. Peter, B.G., Messina, J.P. and Snapp, S.S. 2018. A multiscalar approach to mapping marginal agricultural land: Smallholder agriculture in Malawi. *Annals of the American Association of Geographers* 108(4): 989–1005. (https://doi.org/10.1080/24694452.2017.1403877).

25. Peter, B.G., Messina, J.P., Frake, A.N. and Snapp, S.S. 2018. Scaling agricultural innovations: Pigeonpea in Malawi. *The Professional Geographer* 70(2): 239–250. (https://doi.org/10.1080/00330124.2017.1347798).

26. Pretty, J., Benton, T.G., Bharucha, Z.P., Dicks, L.V., Flora, C.B., Godfray, H.C.J., Goulson, D.G., Hartley, S., Lampkin, N., Morris, C., Pierzynski, G., Prasad, P.V., Reganold, J., Rockström, J., Smith, P., Thorne, P. and Wratten, S. 2018. Global assessment of agricultural system redesign for sustainable intensification. *Nature Sustainability* 1: 441–446. (https://doi.org/10.1038/s41893-018-0114-0).

27. Rahman, A.N., Larbi, A., Kotu, B.H., Tetteh, F.M. and Hoeschle-Zeledon, I. 2018. Does nitrogen matter for legumes? Starter nitrogen effects on biological and economic benefits of cowpea (*Vigna unguiculata* L.) in Guinea and Sudan Savanna of West Africa. *Agronomy* 8(7): art. 120. (https://doi.org/10.3390/agronomy8070120).

28. Sanogo, S. 2018. *Analyse du fonctionnement des exploitations agricoles pour la gestion de la fertilité des sols: Mémoire de Fin de Cycle*. [MSc thèse pour l'obtention du Diplôme d'Ingénieur Agronome. Institut Polytechnique Rural de Formation et de Recherche Appliquée, Mali]. Bamako, Mali. (https://hdl.handle.net/10568/101927).

29. Setimela, P., Gasura, E., Thierfelder, C., Zaman-Allah, M., Cairns, J.E. and Boddupalli, P.M. 2018. When the going gets tough: Performance of stress tolerant maize during the 2015/16 (El Niño) and 2016/17 (La Niña) season in Southern Africa. *Agriculture, Ecosystems & Environment* 268: 79–89. (https://doi.org/10.1016/j.agee.2018.09.006).

30. Snapp, S.S., Grabowski, P., Chikowo, R., Smith, A., Anders, E., Sirrine, D., Chimonyo, V. and Bekunda, M. 2018. Maize yield and profitability tradeoffs with social, human and environmental performance: Is sustainable intensification feasible? *Agricultural Systems* 162: 77–88. (https://doi.org/10.1016/j.agsy.2018.01.012).

31. Sseguya, H., Bekunda, M., Muthoni, F., Flavian, F. and Masigo, J. 2018. Training transfer for sustainable agricultural intensification in Tanzania: Critical considerations for scaling-up. *Journal of Agricultural Science and Technology* 20: 661–671. (https://hdl.handle.net/10568/93380).

32. Thierfelder, C., Baudron, F., Setimela, P., Nyagumbo, I., Mupangwa, W., Mhlanga, B., Lee, N. and Gérard, B. 2018. Complementary practices supporting conservation agriculture in Southern Africa: A review. *Agronomy for Sustainable Development* 38: art. 16. (https://doi.org/10.1007/s13593-018-0492-8).

33. Thornton, P.K., Whitbread, A., Baedeker, T., Cairns, J., Claessens, L., Baethgen, W., Bunn, C., Friedmann, M., Giller, K.E., Herrero, M., Howden, M., Kilcline, K., Nangia, V., Ramirez-Villegas, J., Kumar, S., West, P.C. and Keating, B. 2018. A framework for priority-setting in climate smart agriculture research. *Agricultural Systems* 167: 161–175. (https://doi.org/10.1016/j.agsy.2018.09.009).

34. Woldearegay, K., Tamene, L., Mekonnen, K., Kizito, F. and Bossio, D. 2018. Fostering food security and climate resilience through integrated landscape restoration practices and rainwater harvesting/management in arid and semi-arid areas of Ethiopia. In: Filho, W.L. and de Tricheria Gomez, J. (eds). *Rainwater-smart agriculture in arid and semi-arid areas*. New York, USA: Springer: 37–57. (https://doi.org/10.1007/978-3-319-66239-8_3).

Year 2017

1. Abudulai, M., Kusi, F., Seini, S.S., Seidu, A., Nboyine, J.A. and Larbi, A. 2017. Effects of planting date, cultivar and insecticide spray application for the management of insect pests of cowpea in northern Ghana. *Crop Protection* 100: 168–176. (http://dx.doi.org/10.1016/j.cropro.2017.07.005).
2. Akello, J., Chabi-Olaye, A. and Sikora, R.A. 2017. Insect antagonistic bio-inoculants for natural control of leaf-mining insect pests of French beans. *African Crop Science Journal* 25(2): 237–251. (https://doi.org/10.4314/acsj.v25i2.8).
3. Aku, A.O. 2017. *Influence of farmer organizations as a market information system on market access and income of smallholder vegetable farmers in Babati district, Tanzania*. [MSc thesis in Agricultural Economics. Egerton University]. Nakuru, Kenya. (https://hdl.handle.net/10568/90677).
4. Bezabih, M., Mekonnen, K., Adie, A. and Thorne, P.J. 2017. *A guiding manual for the utilization of cultivated oat-vetch and tree lucerne fodder in the Africa RISING sites of the Ethiopian Highlands*. Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/89800).
5. De Moor, T. 2017. *Why do smallholder farmers in northern-Ghana choose to plough by hoe, with bullocks or with tractors?* [MSc thesis, Farming Systems Ecology Group. Wageningen University and Research Centre]. Wageningen, The Netherlands. (https://hdl.handle.net/10568/89064).
6. Gramzow, A., Laizer, A., Lukumay, P.J., Mndiga, H. and Tilya, M. 2017. *Africa RISING–NAFAKA Project Compendium of vegetable production training protocols*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/91193).
7. International Livestock Research Institute. 2017. Creating climate-smart multifunctional landscapes through integrated soil, land, and water management at different scales. *Africa RISING Factsheet* 1. Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/89127).
8. International Livestock Research Institute. 2017. Feeding trough and storage shed technologies. *Africa RISING Factsheet* 8. Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/89126).
9. International Livestock Research Institute. 2017. Identification of farmer preferences as a tool to intensify cereal and legume production in the Ethiopian Highlands. *Africa RISING Factsheet* 5. Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/89155).
10. International Livestock Research Institute. 2017. Introducing high-value fruit trees to enhance food and nutritional security in the Ethiopian Highlands. *Africa RISING Factsheet* 6. Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/89154).
11. International Livestock Research Institute. 2017. Oat-vetch mixture forage. *Africa RISING Factsheet* 9. Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/89137).
12. International Livestock Research Institute. 2017. Potato plant growth technology. *Africa RISING Factsheet* 3. Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/89156).
13. International Livestock Research Institute. 2017. Scaling out small-scale mechanization in the Ethiopian Highlands. *Africa RISING Factsheet* 2. Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/89153).
14. International Livestock Research Institute. 2017. Scaling up/out of enset research technologies through integrated disease management approaches. *Africa RISING Factsheet* 4. Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/89139).
15. International Livestock Research Institute. 2017. Sweet lupine as a feed and food crop. *Africa RISING Factsheet* 10. Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/89180).
16. International Livestock Research Institute. 2017. Tree lucerne, providing agricultural products and ecosystem services. *Africa RISING Factsheet* 7. Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/89138).
17. Jape, V.W. 2017. *Patterns and determinants of vegetable intake in Babati district, Tanzania*. [MSc thesis in Agricultural Economics. University of Copenhagen]. Copenhagen, Denmark. (https://hdl.handle.net/10568/82977).
18. Jun Xiong, Thenkabail, P.S., Gumma, M.K., Teluguntla, P., Poehnelt, J., Congalton, R.G., Yadav, K. and Thau, D. 2017. Automated cropland mapping of continental Africa using Google Earth Engine cloud computing. *ISPRS Journal of Photogrammetry and Remote Sensing* 126: 225–244. (https://doi.org/10.1016/j.isprsjprs.2017.01.019).
19. Kachapulula, P.W., Akello, J., Bandyopadhyay, R. and Cotty, P.J. 2017. Aflatoxin contamination of groundnut and maize in Zambia: Observed and potential concentrations. *Journal of Applied Microbiology* 122(6): 1471–1482. (https://doi.org/10.1111/jam.13448).
20. Kashenge-Killenga, S., Chuwa, C., Mvukiye, N., Zakayo, J., Paul, I. and Kangile, R. 2017. *Africa RISING–NAFAKA Project Compendium of rice production training protocols*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/91192).
21. Kihara, J., Sileshi, G.W., Nziguheba, G., Kinyua, M., Zingore, S. and Sommer, R. 2017. Application of secondary nutrients and micronutrients increases crop yields in Sub-Saharan Africa. *Agronomy for Sustainable Development* 37: art. 25. (https://doi.org/10.1007/s13593-017-0431-0).
22. Kirimbo, G.E. 2017. *Engaging smallholder-farmers in model-based identification of alternative options, trade-offs, and synergies for sustainable intensification in north-Tanzania*. [MSc thesis. Wageningen University and Research Centre]. Wageningen, The Netherlands. (https://hdl.handle.net/10568/92912).
23. Kotu, H.B., Alene, A., Manyong, V., Hoeschle-Zeledon, I. and Larbi, A. 2017. Adoption and impacts of sustainable intensification practices in Ghana. *International Journal of Agricultural Sustainability* 15(5): 539–554. (https://doi.org/10.1080/14735903.2017.1369619).
24. Lazaro, V., Rajendran, S., Afari-Sefa, V. and Kazuzuru, B. 2017. Analysis of good agricultural practices in an integrated maize-based farming system. *International Journal of Vegetable Science* 23(6): 598–604. (https://doi.org/10.1080/19315260.2017.1341445).
25. Li, G., Messina, J.P., Peter, B.G. and Snapp, S.S. 2017. Mapping land suitability for agriculture in Malawi. *Land Degradation & Development* 28(7): 2001–2016. (https://doi.org/10.1002/ldr.2723).
26. Manda, J., Alene, A.D., Mukuma, C. and Chikoye, D. 2017. Ex-ante welfare impacts of adopting maize-soybean rotation in eastern Zambia. *Agriculture, Ecosystems & Environment* 249: 22–30. (https://doi.org/10.1016/j.agee.2017.07.030).
27. Mariki, A. 2017. *Distribution of maize lethal necrosis disease, its causal viruses and alternative hosts in the north central regions of Tanzania*. [MSc thesis in Crop Science. Makerere University]. Kampala, Uganda. (https://hdl.handle.net/10568/81213).

28. Mengesha, M., Bezabih, M., Mekonnen, K., Adie, A., Duncan, A.J., Thorne, P. and Tolera, A. 2017. Tagasaste (*Chamaecytisus palmensis*) leaf supplementation to enhance nutrient intake and production performance of sheep in the Ethiopian Highlands. *Tropical Animal Health and Production* 49(7): 1415–1422. (https://doi.org/10.1007/s11250-017-1342-4).

29. Mengistu, G., Bezabih, M., Hendriks, W.H. and Pellikaan, W.F. 2017. Preference of goats (*Capra hircus* L.) for tanniniferous browse species available in semi-arid areas in Ethiopia. *Journal of Animal Physiology and Animal Nutrition* 101(6): 1286–1296. (https://doi.org/10.1111/jpn.12648).

30. Messina, J.P., Peter, B.G. and Snapp, S.S. 2017. Re-evaluating the Malawian farm input subsidy programme. *Nature Plants* 3(4): art. 17013. (https://doi.org/10.1038/nplants.2017.13).

31. Mewes, A. 2017. *Risk perception in agriculture depending on community characteristics – A Study of northern Ghanaian communities*. [MSc thesis, University of Passau]. Germany. (Abstract available from https://www.tropentag.de/2017/abstracts/links/Mewes_4vBFi8Tv.pdf) (Accessed 29 February 2024).

32. Mtui, M.A. 2017. *Economic cost evaluation of selected vegetable post-harvest losses in Babati District Tanzania*. [MSc thesis in Agricultural Economics. Egerton University]. Nakuru, Kenya. (https://hdl.handle.net/10568/106354).

33. Mulema, A.A. 2017. *Integrating a gender perspective to help scale Africa RISING technologies and practices: Requirements for proposal development and implementation*. Addis Ababa, Ethiopia: ILRI. (https://hdl.handle.net/10568/80191).

34. Muthoni, F.K., Baijukya, F., Bekunda, M., Sseguya, H., Kimaro, A., Alabi, T., Mruma, S. and Hoeschle-Zeledon, I. 2017. Accounting for correlation among environmental covariates improves delineation of extrapolation suitability index for agronomic technological packages. *Geocarto International* 34(4): 368–390. (https://doi.org/10.1080/10106049.2017.1404144).

35. Muthoni, F., Baijukya, F., Sseguya, H., Mateete, B., Hoeschle-Zeledon, I., Ouko, E. and Mubea, K. 2017. Geospatial approach for delineating extrapolation domains for sustainable agricultural intensification technologies. Presented at the 37 International Symposium on Remote Sensing of Environment, Tshwane, South Africa, 8–12 May 2017. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/88989).

36. Muthoni, F.K., Guo, Z., Bekunda, M., Sseguya, H., Kizito, F., Baijukya, F. and Hoeschle-Zeledon, I. 2017. Sustainable recommendation domains for scaling agricultural technologies in Tanzania. *Land Use Policy* 66: 34–48. (https://doi.org/10.1016/j.landusepol.2017.04.028).

37. Mupangwa, W., Mutenje, M., Thierfelder, C., Mwila, M., Malumo, H., Mujeyi, A. and Setimela, P. 2017. Productivity and profitability of manual and mechanized conservation agriculture (CA) systems in eastern Zambia. *Renewable Agriculture and Food Systems* 34(5): 380–394. (https://doi.org/10.1017/S1742170517000606).

38. Musumba, M., Grabowski, P., Palm, C. and Snapp, S. 2017. *Guide for the sustainable intensification assessment framework*. Manhattan, Kansas, USA: Kansas State University. (https://hdl.handle.net/10568/90523).

39. Musumba, M., Grabowski, P., Palm, C. and Snapp, S. 2017. *Sustainable intensification assessment methods manual (working draft)*. Manhattan, Kansas, USA: Kansas State University. (https://hdl.handle.net/10568/90517).

40. Paas, W. and Groot, J.C.J. 2017. Creating adaptive farm typologies using Naive Bayesian classification. *Information Processing in Agriculture* 4(3): 220–227. (https://doi.org/10.1016/j.inpa.2017.05.005).

41. Patt, N. 2017. *Gender dynamics in smallholder vegetable production: Insights from Tanzania*. [MSc thesis in Geographical Development Studies. Freie Universität Berlin]. Berlin, Germany. (https://hdl.handle.net/10568/90680).

42. Peter, B.G., Mungai, L.M., Messina, J.P. and Snapp, S.S. 2017. Nature-based agricultural solutions: Scaling perennial grains across Africa. *Environmental Research* 159: 283–290. (https://doi.org/10.1016/j.envres.2017.08.011).

43. Rajendran, S., Afari-Sefa, V., Shee, A., Bocher, T., Bekunda, M., Dominick, I. and Lukumay, P.J. 2017. Does crop diversity contribute to dietary diversity? Evidence from integration of vegetables into maize-based farming systems. *Agriculture & Food Security* 6(50). (https://doi.org/10.1186/s40066-017-0127-3).

44. Saaka, M., Osman, S.M. and Hoeschle-Zeledon, I. 2017. Relationship between agricultural biodiversity and dietary diversity of children aged 6-36 months in rural areas of northern Ghana. *Food & Nutrition Research* 61(1): art. 1391668. (https://doi.org/10.1080/16546628.2017.1391668).

45. Saaka, M., Oladele, J., Larbi, A. and Hoeschle-Zeledon, I. 2017. Household food insecurity, coping strategies, and nutritional status of pregnant women in rural areas of northern Ghana. *Food Science & Nutrition* 5(6): 1154–1162. (https://doi.org/10.1002/fsn3.506).

46. Saaka, M., Oladele, J., Larbi, A. and Hoeschle-Zeledon, I. 2017. Dietary diversity is not associated with haematological status of pregnant women resident in rural areas of northern Ghana. *Journal of Nutrition and Metabolism* 2017: art. 8497892. (https://doi.org/10.1155/2017/8497892).

47. Samake, O. 2017. *Estimation de l'érosion des sols sous culture en zone soudanienne du Mali : Cas du village de Kani (cercle de Koutiala)*. [Thèse pour l'obtention du diplôme de Master en Sciences Agronomiques. Institut Polytechnique Rural de Formation et de Recherche Appliquée]. Bamako, Mali. (https://hdl.handle.net/10568/101930).

48. Seetha, A., Munthali, W., Msere, H.W., Swai, E., Muzanila, Y., Sichone, E., Tsusaka, T.W., Rathore, A. and Okori, P. 2017. Occurrence of aflatoxins and its management in diverse cropping systems of central Tanzania. *Mycotoxin Research* 33(4): 323–331. (https://doi.org/10.1007/s12550-017-0286-x).

49. Silberg, T.R., Richardson, R.B., Hockett, M. and Snapp, S.S. 2017. Maize-legume intercropping in central Malawi: Determinants of practice. *International Journal of Agricultural Sustainability* 15(6): 662–680. (https://doi.org/10.1080/14735903.2017.1375070).

50. Smith, A., Snapp, S., Chikowo, R., Thorne, P., Bekunda, M. and Glover, J. 2017. Measuring sustainable intensification in smallholder agroecosystems: A review. *Global Food Security* 12: 127–138. (https://doi.org/10.1016/j.gfs.2016.11.002).

51. Tamene, L., Adimassu, Z., Aynekulu, E. and Yaekob, T. 2017. Estimating landscape susceptibility to soil erosion using a GIS-based approach in northern Ethiopia. *International Soil and Water Conservation Research* 5(3): 221–230. (https://doi.org/10.1016/j.iswcr.2017.05.002).

52. Tamene, L., Adimassu, Z., Ellison, J., Yaekob, T., Woldearegay, K., Mekonnen, K., Thorne, P. and Quang Bao Le. 2017. Mapping soil erosion hotspots and assessing the potential impacts of land management practices in the highlands of Ethiopia. *Geomorphology* 292(1):153–163. (https://doi.org/10.1016/j.geomorph.2017.04.038).

53. Timler, C., Michalscheck, M., Alvarez, S., Descheemaeker, K. and Groot, J.C.J. 2017. Exploring options for sustainable intensification through legume integration in different farm types in eastern Zambia. In: Oborn, I., Vanlauwe, B., Phillips, M., Thomas, R., Brooijmans, W. and Atta-Krah, K. (eds), *Sustainable intensification in smallholder agriculture: An integrated systems research approach*. London, UK: Routledge: 196–209. (https://doi.org/10.4324/9781315618791).

54. Thorne, P.J. and Conroy, C. 2017. Research on livestock, livelihoods, and innovation. In: Snapp, S. and Pound, B. (eds), *Agricultural systems*, 2nd edn. Academic Press: 303–330. (https://doi.org/10.1016/B978-0-12-802070-8.00009-8).

55. Yemataw, Z., Mekonen, A., Chala, A., Tesfaye, K., Mekonen, K., Studholme, D.J. and Sharma, K. 2017. Farmers' knowledge and perception of enset *Xanthomonas* wilt in southern Ethiopia. *Agriculture and Food Security* 6: art. 62. (https://doi.org/10.1186/s40066-017-0146-0).

Year 2016

1. Alkhtib, A.S., Wamatu, J.A., Wegi, T. and Rischkowsky, B.A. 2016. Variation in the straw traits of morphological fractions of faba bean (*Vicia faba* L.) and implications for selecting for food-feed varieties. *Animal Feed Science and Technology* 222: 122–131. (https://doi.org/10.1016/j.anifeedsci.2016.10.006).

2. Ayizanga, R.A. 2016. *Phenotypic characterisation and genetic diversity of the local pig of Ghana*. [PhD thesis in Animal Science. Kwame Nkrumah University of Science and Technology]. Kumasi, Ghana.

3. Bezabih, M., Mekonnen, K., Adie, A. and Thorne, P. 2016. *Guidelines on the utilization of cultivated oat-vetch and tree lucerne fodder in the Africa RISING sites of the Ethiopian Highlands*. Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/78175).

4. Bezabih, M., Duncan, A.J., Mekonnen, K., Adie, A., Khan, A.K. and Thorne, P.J. 2016. The role of irrigated fodder production to supplement the diet of fattening sheep by smallholders in southern Ethiopia. *Tropical and Subtropical Agroecosystems* 19(3): 263–275. (https://hdl.handle.net/10568/79450).

5. Birhanu, B.Z. and Tabo, R. 2016. Shallow wells, the untapped resource with a potential to improve agriculture and food security in southern Mali. *Agriculture & Food Security* 5: art. 5. (https://doi.org/10.1186/s40066-016-0054-8).

6. Haile, B., Azzarri, C., Roberts, C. and Spielman, D.J. 2016. Targeting, bias, and expected impact of complex innovations on developing-country agriculture: Evidence from Malawi. *Agricultural Economics* 48(3): 317–326. (https://doi.org/10.1111/agec.12336).

7. Hailu, T., Tessema, M., Fofanah, M. and Lema, Z. 2016. *Nutrition training manual for health and agriculture workers at community level in Ethiopia: Integrating nutrition into crop and livestock farming systems of the Ethiopian Highlands for improved nutrition outcomes*. Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/73670).

8. Hockett, M. and Richardson, R.B. 2016. Examining the drivers of agricultural experimentation among smallholder farmers in Malawi. *Experimental Agriculture* 54(1): 45–65. (https://doi.org/10.1017/S0014479716000673).

9. Kizito, F., Lukuyu, B., Sikumba, G., Kihara, J., Bekunda, M., Bossio, D., Nganga, A., Kimaro, K.W., Sseguya, H., Jumbo, B. and Okori, P. 2016. The role of forages in sustainable intensification of crop-livestock agro-ecosystems in the face of climate change: The case for landscapes in Babati, northern Tanzania. In: Lal, R., Kraybill, D., Hansen, D.O., Singh, B.R., Mosogoya, T. and Eik, L.O. (eds), *Climate change and multi-dimensional sustainability in African agriculture*. Cham (ZG), Switzerland: Springer: 411–430. (https://doi.org/10.1007/978-3-319-41238-2_22).

10. Mponela, P., Tamene, L., Ndengu, G., Magreta, R., Kihara, J. and Mango, N. 2016. Determinants of integrated soil fertility management technologies adoption by smallholder farmers in the Chinyanja Triangle of Southern Africa. *Land Use Policy* 59: 38–48. (https://doi.org/10.1016/j.landusepol.2016.08.029).

11. Mungai, L.M., Snapp, S., Messina, J.P., Chikowo, R., Smith, A., Anders, E., Richardson, R.B. and Li, G. 2016. Smallholder farms and the potential for sustainable intensification. *Frontiers in Plant Science* 7: art. 1720. (https://doi.org/10.3389/fpls.2016.01720).

12. Mupangwa, W., Mutenje, M., Thierfelder, C. and Nyagumbo, I. 2016. Are conservation agriculture (CA) systems productive and profitable options for smallholder farmers in different agro-ecoregions of Zimbabwe? *Renewable Agriculture and Food Systems* 32(1): 87–103. (https://doi.org/10.1017/S1742170516000041).

13. Mzumara, E.L. 2016. *Phosphorus use efficiency and productivity of pigeonpea [*Cajanus cajan *(L.) Millsp.] and soybean [*Glycine max *(L.) Merrill] on smallholder farms in different agro-ecological zones of central Malawi*. [MSc thesis in Agronomy. Lilongwe University of Agriculture and Natural Resources]. Lilongwe, Malawi. (https://cgspace.cgiar.org/bitstream/handle/10568/125473/EDWARD%20LIPENGA%20MZUMARA%20MSc.%20AGRONOMY%20THESIS.pdf?sequence=1&isAllowed=y).

14. Nyangi, C., Mugula, J.K., Beed, F., Boni, S., Koyano, E. and Sulyok, M. 2016. Aflatoxins and fumonisin contamination of marketed maize, maize bran and maize used as animal feed in northern Tanzania. *African Journal of Food, Agriculture, Nutrition and Development* 16(3): 11054–11065. (https://doi.org/10.18697/ajfand.75.ILRI07).

15. Nyangi, C., Beed, F., Mugula, J.K., Boni, S., Koyano, E., Mahuku, G., Sulyok, M. and Bekunda, M. 2016. Assessment of pre-harvest aflatoxin and fumonisin contamination of maize in Babati district, Tanzania. *African Journal of Food, Agriculture, Nutrition and Development* 16(3): 11039–11053. (https://doi.org/10.18697/ajfand.75.ILRI06).

16. Ortega, D.L., Waldman, K.B., Richardson, R.B., Clay, D.C. and Snapp, S. 2016. Sustainable intensification and farmer preferences for crop system attributes: Evidence from Malawi's Central and Southern regions. *World Development* 87: 139–151. (https://doi.org/10.1016/j.worlddev.2016.06.007).

17. Rogé, P., Snapp, S., Kakwera, M.N., Mungai, L., Jambo, I. and Peter, B., 2016. Ratooning and perennial staple crops in Malawi. A review. *Agronomy for Sustainable Development* 36(3): art. 50. (https://doi.org/10.1007/s13593-016-0384-8).

18. Saaka, M., Larbi, A., Mutaru, S. and Hoeschle-Zeledon, I. 2016. Magnitude and factors associated with appropriate complementary feeding among children 6–23 months in northern Ghana. *BMC Nutrition* 2: art. 2. (https://doi.org/10.1186/s40795-015-0037-3).

19. Smith, A., Snapp, S., Dimes, J., Gwenambira, C. and Chikowo, R. 2016. Doubled-up legume rotations improve soil fertility and maintain productivity under variable conditions in maize-based cropping systems in Malawi. *Agricultural Systems* 145: 139–149. (https://doi.org/10.1016/j.agsy.2016.03.008).

20. Tamene, L., Mponela, P., Ndengu, G. and Kihara, J. 2016. Assessment of maize yield gap and major determinant factors between smallholder farmers in the Dedza district of Malawi. *Nutrient Cycling in Agroecosystems* 105(3): 291–308. (https://doi.org/10.1007/s10705-015-9692-7).

21. Tamene, L., Mponela, P., Sileshi, G.W., Chen, J. and Tondoh, J.E. 2016. Spatial variation in tree density and estimated aboveground carbon stocks in Southern Africa. *Forest* 7(3): art. 57. (https://doi.org/10.3390/f7030057).

22. Thierfelder, C., Matemba-Mutasa, R., Bunderson, W.T., Mutenje, M., Nyagumbo, I. and Mupangwa, W. 2016. Evaluating manual conservation agriculture systems in Southern Africa. *Agriculture, Ecosystems & Environment* 222: 112–124. (https://doi.org/10.1016/j.agee.2016.02.009).

23. Waldman, K.B., Ortega, D.L., Richardson, R.B., Clay, D.C. and Snapp, S. 2016. Preferences for legume attributes in maize-legume cropping systems in Malawi. *Food Security* 8(6): 1087–1099. (https://doi.org/10.1007/s12571-016-0616-4).

24. Wieland, B., Alemu, B., Desta, H., Kinati, W. and Mulema, A.A. 2016. *Participatory epidemiology and gender analysis to address small ruminant disease constraints in Livestock and Fish and Africa RISING project sites in Ethiopia*. CGIAR Research Program on Livestock and Fish. (https://cgspace.cgiar.org/bitstream/handle/10568/76685/LF_peg_jul2016.pdf).

Year 2015

1. Chikowo, R., Zingore, S., Nyamangara, J., Bekunda, M., Messina, J. and Snapp, S. 2015. Approaches to reinforce crop productivity under rain-fed conditions in sub-humid environments in Sub-Saharan Africa. In: Lal, R., Singh, B.R., Mwaseba, D.L., Kraybill, D., Hansen, D.O. and Eik, L.O. *Sustainable intensification to advance food security and enhance climate resilience in Africa*. Switzerland: Springer International Publishing: 235–253. (https://doi.org/10.1007/978-3-319-09360-4_12).

2. Eliasu, S. 2015. *Effect of soil and water conservation measures on cowpea and maize performance in the Northern and Upper East regions of Ghana*. [MPhil thesis in Agricultural Engineering. Kwame Nkrumah University of Science and Technology]. Kumasi, Ghana.

3. Maiga, S. 2015. *Effets des amenagements en courbes de niveau sur le ruissellement et la croissance du sorgho dans le village de Kani, cercle de (Koutiala)*. [Thèse pour l'obtention de la Licence en Sciences Agronomiques. Institut Polytechnique Rural de Formation et de Recherche Appliquée]. Bamako, Mali. (https://hdl.handle.net/10568/101929).

4. Mkoma, A. 2015. *Response of maize to phosphorus in sole maize and maize-pigeonpea cropping system in semi-arid areas of Tanzania*. [MSc thesis in Soil Science and Land Management. Sokoine University of Agriculture]. Morogoro, Tanzania. (https://hdl.handle.net/10568/80686).

5. Nassoro, Z., Rubanza, C.D.K. and Kimaro, A.A. 2015. Evaluation of nutritive value of browse tree fodder species in semi-arid Kiteto and Kongwa districts of Tanzania. *Journal of Food, Agriculture & Environment* 13 (3&4): 113–120. (https://www.researchgate.net/publication/283518077_Evaluation_of_nutritive_value_of_browse_tree_fodder_species_in_semi-arid_Kiteto_and_Kongwa_districts_of_Tanzania).

6. Pallangyo, V.L. 2015. *Newly introduced AVRDC vegetable technologies in reduction of income poverty: Babati district, Tanzania*. [MA thesis in Art in Rural Development. Sokoine University of Agriculture]. Morogoro, Tanzania. (https://hdl.handle.net/10568/100240).

7. Saaka, M., Larbi, A. and Hoeschle-Zeledon, I. 2015. Factors contributing to positive nutritional deviance in the growth of children aged 6-36 months in rural northern Ghana. *Jacobs Journal of Food and Nutrition* 2(2): 1 –12. (https://hdl.handle.net/10568/73020).

8. Smith, A., Thorne, P. and Snapp, S. 2015. *Measuring sustainable intensification in smallholder agroecosystems: A review*. Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/67181).

9. Snapp, S.S. and Fisher, M. 2015. "Filling the maize basket" supports crop diversity and quality of household diet in Malawi. *Food Security* 7(1): 83–96. (https://doi.org/10.1007/s12571-014-0410-0).

10. Sobgui, C.M. and Tenkouano, A. 2015. *Guide de nutrition pour travailleurs communautaires*. AVRDC Publication 16-797. Bamako, Mali: World Vegetable Center. (https://hdl.handle.net/10568/72737).

11. Tegbaru, A., FitzSimons, J., Kirscht, H. and Hillbur, P. 2015. Resolving the gender empowerment equation in agricultural research: A systems approach. *Journal of Food, Agriculture and Environment* 13(3&4): 131–139. (https://www.researchgate.net/publication/284748166_Resolving_the_gender_empowerment_ equation_in_agricultural_research_-_A_systems_approach).

12. Waddington, S.R., Zingore, S., Chikowo, R., Wairegi, L. and Snapp, S. 2015. *Integrated fertilizer policy guide for maize–legume cropping systems in Malawi*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/68890).

Year 2014

1. Abass, A., Ndunguru, G., Mamiro, P., Alenkhe, B., Mlingi, N. and Bekunda, M. 2014. Post-harvest food losses in a maize-based farming system of semi-arid savannah area of Tanzania. *Journal of Stored Products Research* 57: 49–57. (https://hdl.handle.net/10568/34458).

2. Kihara, J., Tamene, L., Massawe, P. and Bekunda, M. 2014. Agronomic survey to assess crop yield, controlling factors and management implications: A case-study of Babati in northern Tanzania. *Nutrient Cycling in Agroecosystems* 102(1): 5–16. (https://hdl.handle.net/10568/51658).

3. Lema, Z. 2014. *Manual for innovation platform facilitators in Africa RISING Ethiopia sites*. Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/56720).

4. Lema, Z. and Cullen, B. 2014. *Guidelines on establishing innovation platforms for Africa RISING partners in Ethiopia*. Nairobi, Kenya: ILRI. (https://hdl.handle.net/10568/56736).

5. Mulema, A. 2014. Developing capacities for gender-responsive agricultural programs in Ethiopia. *Brief* 11. [Addis Ababa, Ethiopia: ILRI for] Africa RISING. (https://cgspace.cgiar.org/bitstream/handle/10568/51569/AR_Brief11.pdf).

6. Nassoro, Z. 2014. *Evaluation of nutritive value of browse tree fodder species indigenous to Kiteto and Kongwa districts*. [MSc thesis in Biodiversity Conservation. University of Dodoma]. Dodoma, Tanzania. (https://hdl.handle.net/10568/80691).

7. Rajendran, S., Afari-Sefa, V., Bekunda, M., Dominick, I. and Lukumay, P.J. 2014. Does crop diversity contribute to dietary diversity? Evidence from integration of vegetables into maize-based farming systems in Tanzania. Presented at 88th Annual Conference, 9–11 April 2014, AgroParisTech, Paris, France. Agricultural Economics Society.

Year 2013

1. Snapp, S., Kerr, R.B., Smith, A., Ollenburger, M., Mhango, W., Shumba, L., Gondwe, T. and Kanyama-Phiri, G. 2013. Modeling and participatory farmer-led approaches to food security in a changing world: A case study from Malawi. *Sécheresse* 24(4): 350–358. (https://doi.org/10.1684/sec.2014.0409).

Year 2012

1. International Institute of Tropical Agriculture. 2012. *Mycotoxin fact sheet*. Ibadan, Nigeria: IITA. (https://hdl.handle.net/10568/21187).

About Africa RISING

The Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) program comprised three regional research-in-development projects supported by the United States Agency for International Development as part of the US Government's Feed the Future initiative. Inaugurated in late 2011 and running to two phases (to 2023), the purpose of Africa RISING was to provide pathways out of hunger and poverty for smallholder farm families through sustainably intensified farming systems that sufficiently improve food, nutrition and income security, particularly for women and children, and conserve or enhance the natural resource base.

Women farmers in Ntubwi EPA, Machinga District, Malawi sing a song in praise of Africa RISING interventions within their community. Photo credit: Jonathan Odhong/IITA.

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