Africa RISING

Annual Progress Report
October 2018 to September 2019

The **Africa Research in Sustainable Intensification for the Next Generation (Africa RISING)** program comprises 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 currently in its second phase (since September 2016), the purpose of Africa RISING is 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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This report presents highlights of some activities and outputs that are part of detailed technical reports submitted to USAID by the three Africa RISING regional projects between 1 October 2018 and 31 September 2019. This reporting period is purely meant to align with Africa RISING reporting obligations and not the regular Gregorian calendar. Links to the detailed technical reports are provided in the references section.

Front cover photo: Adane in his cluster wheat farm, Debre Birhan, Ethiopia.

Back cover photo: Women farmers in Ntubwi EPA, Machinga District, Malawi, sing a song in praise of Africa RISING interventions within their community.

Contents

Abbreviations

2WT	two-wheel tractor
ACZ	agroclimatic zone
Africa RISING	Africa Research in Sustainable Intensification for the Next Generation
APSIM	Agricultural Production Systems Simulator
CA	conservation agriculture
CHIRPS-v2	Climate Hazards group Infrared Precipitation with Stations version 2
CIAT	International Center for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Center
cm	centimeter(s)
CRS	Catholic Relief Services
DAECC	Agriculture Extension Coordination Committee (district body, Malawi)
EPA	extension planning area (Malawi)
ESA	East and Southern Africa
ESI	extrapolation suitability index
GMCC	green manure cover crop
ha	hectare(s)
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	information and communications technology
IFPRI	International Food Policy Research Institute
ILRI	International Livestock Research Institute
IMP	improved management practices
IoP	Islands of Peace
kg	kilogram(s)
LDI	land degradation index
M&E	monitoring and evaluation
MnM	Mboga na Matunda project
N	nitrogen
NGO	nongovernmental organization
P	phosphorus; probability
PAR	photosynthetically active radiation
PhD	doctor of philosophy (doctoral degree)
PICS	Purdue Improved Crop Storage
QDS	quality-declared seed
QPM	quality protein maize
SAROS	Smart Agricultural Resources Optimization System
SEEDPAG	Seed Producers Association of Ghana
SIAF	Sustainable Intensification Assessment Framework
SLM	sustainable land management
SMS	short message service
SOM	soil organic matter
sp.	species (singular)
subsp.	subspecies (singular)
t	tons
TLC	Total LandCare
UDS	University for Development Studies (Ghana)
UNCCD	United Nations Convention to Combat Desertification
USAID	United States Agency for International Development
WOCAT	World Overview of Conservation Approaches and Technologies
WorldVeg	World Vegetable Center

Executive summary

Phase II (2016–2021) of the Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) program aims to scale up the innovations validated in Phase I (2011–2016) to at least 1.1 million households, and to implement further research-in-development activities. This report provides some highlights from the third year of Phase II: October 2018 to September 2019.

In East and Southern Africa region, work was heavily impacted by severe drought in the 2018/19 cropping season. For most farmers, this drought adversely affected their crops and consequently served as a reminder of the need for Africa RISING to redouble its efforts to validate technologies that offer farmers resilience against shocks such as drought. In Tanzania, for example, the 18 best performing drought-tolerant and high-yielding maize hybrids were validated for their performance on farm. Of these, four hybrids have now been identified for scaling out, based on their superior yield, agronomic performance, and profitability.

Work to deploy improved crop varieties continued in all six program countries (Ethiopia, Ghana, Malawi, Mali, Tanzania, and Zambia). While farmers continued to be involved in participatory varietal selection for improved varieties of cereal, legumes, and vegetables, much of the focus is now on scaling up, a key ingredient for which is seed. The program is engaging with formal seed companies for drought-tolerant maize in Tanzania. It is also promoting public-sector engagement and revolving seed banks in Ethiopia, quality-declared seed for legumes in Malawi, and community seed banks in Tanzania. Meanwhile, farmers' field demonstrations and seed fairs are being used to reach more farmers, and farmers are being trained in good agricultural and postharvest practices.

The program has also continued to work with farmers in resource-limited settings in all six countries to show how manipulating crop ecology can help to optimize farm outputs and returns. Impressive results were demonstrated through improved management practices, intercropping, and crop rotations. In Karatu District, Tanzania, where vegetable farmers used improved varieties, healthy seedlings, and good agronomic practices, farmers noted positive effects on productivity, profitability, and nutrition, but less effect on the environmental and social domains of the Sustainable Intensification Assessment Framework (SIAF).

To enhance livestock production, project partners worked with farmers to validate various improved livestock production technologies

Soil fertility requires integrated management in order for farmers to get the most from their soils. Nitrogen (N) recovery uptake by crops is closely linked with soil water availability, but N application strategies rarely prescribe reduced application of expensive N fertilizers when the rain fails. In Malawi, the program applied variable, or N response treatment – adjusting the dose of N fertilizer applied to the availability of water in the soil. While it did not give the highest yields, the strategy substantially increased N-use efficiency. In the Ethiopian Highlands, a site-specific decision guide was drafted to enhance yields, reduce input costs, and improve resource management at landscape scale.

Across the six program countries, livestock production remains an important element of sustainable intensification of smallholder farms. To enhance livestock production, project partners worked with farmers to validate various improved livestock production technologies, including forage options, improved feeding practices, feed processing, rations, and other husbandry practices. For example, in the Ethiopian Highlands, new forage options were tested and farmers showed strong interest in fodder beet, and a feeding trial with 10 kg fresh tuber per cow per day, which increased average milk yield by 14–33%. In northern Ghana, since forage shortage in the cropping season is a concern, the program has been experimenting with feeding maize leaves stripped from the plants as feed, with some success. And finally, after showing great success in Ethiopia, the improved feed trough was introduced to northern Ghana. While traditional feeding typically wastes 26–36% of the feed, the new trough has a waste rate of less than 1%, making significant savings on scarce feed resources. Moreover, the trough also reduced feeding time by half (small ruminants typically stop feeding once their nutritional requirements are met).

Reducing soil loss and enhancing water utilization are major concerns across the continent. In program sites in Malawi and Zambia, conservation agriculture has reached a tipping point: more than half of the farmers now use it for their maize, and many have expanded it to other crops, including cowpea, groundnut, and soybean. This expansion has been both effective and profitable. In Zambia, maize–legume intercrops under conservation agriculture no longer experienced reduced maize yield after four years of conservation agriculture, so that the legume crop is purely additional to farm income without any cost in terms of maize.

Contour bunding is also proving its worth in the Ethiopian Highlands: downstream of a contour-bunded sub-watershed, both the number of farmers using irrigation and the area under irrigation increased. Moreover, farmers switched from low-water-demanding crops (e.g., chickpea, lentil) to high-water-demanding, high-yielding, and income-generating vegetables (e.g., carrot, onion). In Tanzania, meanwhile, contours improved maize yield by 200%!

Improving nutrition and food safety, and reducing food waste are essential components of sustainable intensification. In different countries, the program team dedicated efforts and resources to address these challenges. In Tanzania, three technologies for reducing postharvest losses (single hermetic liner bag, double hermetic liner bag, and metal silo) were validated jointly with farmers. In Ghana, a barrier analysis of behavioral determinants (enablers and barriers) of key infant and young child feeding, and maternal nutrition behaviors was carried out. In Mali, training sessions on improved child and family nutrition were organized for farmers and agricultural extension officers.

Livestock farmers at Duko community in northern Ghana express gratitude to Africa RISING

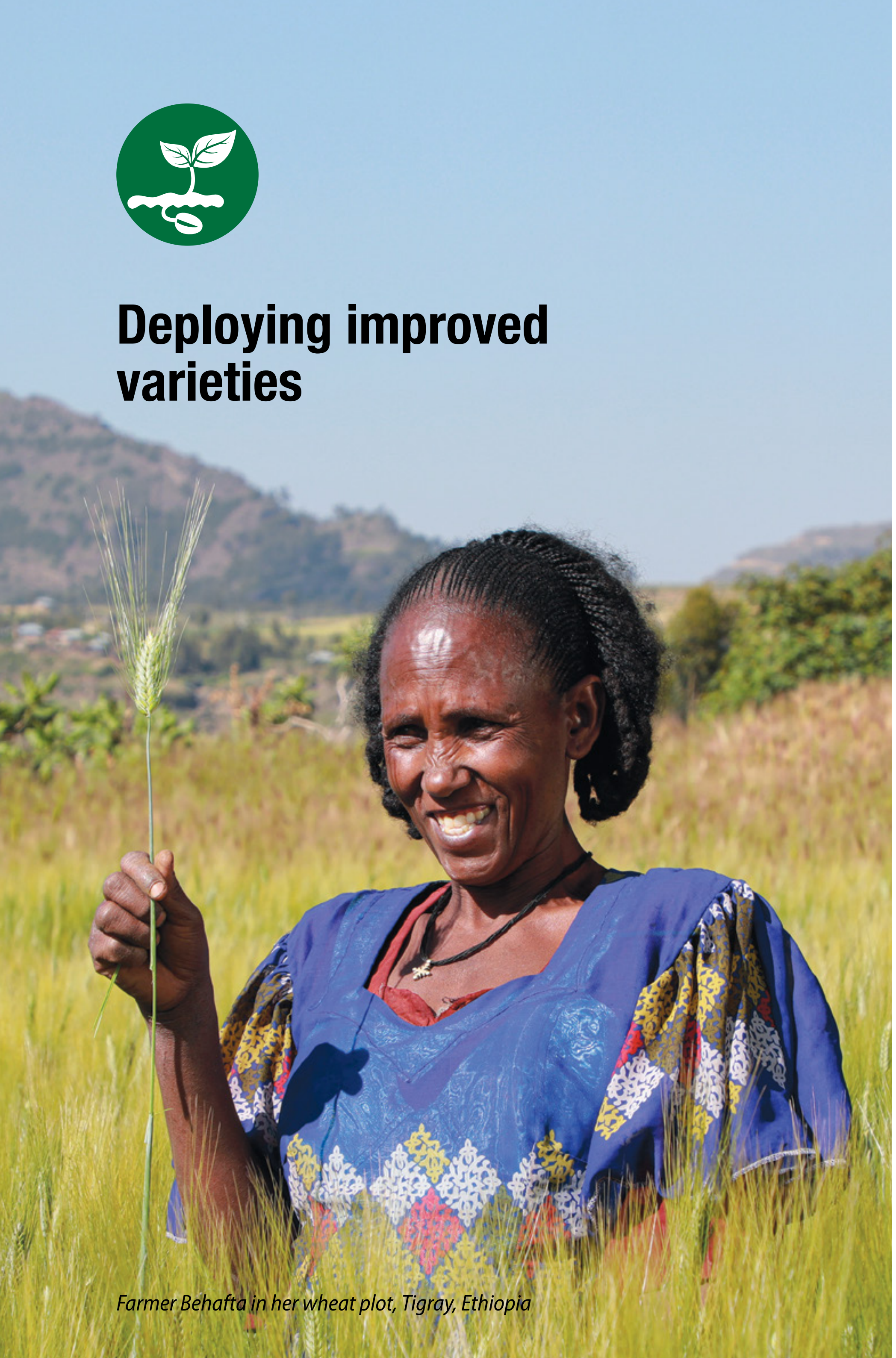
Information and communications technologies (ICTs) are being used to improve the targeting of new technologies, and scaling up is increasing their impact. Among others, FarmDESIGN has been used to determine trade-offs and synergies for the sustainable intensification of smallholder farms. Meanwhile, the simulation model Agricultural Production Systems Simulator has been set up to accurately predict cereal response to intercropping in central Tanzania. Research-established long-term trials, open-source databases, and satellite imagery are providing input data for recommendation domains that will help to guide the scaling out of project efforts.

In terms of capacity building, the program directly trained at least 11,570 people across the six project countries. A total of 15 PhD, 12 Master's, and 4 BSc students are also supported through the program's activities.

While Africa RISING is a program managed by three CGIAR Centers (IITA, ILRI, and IFPRI) and is supported by a major international donor (USAID), the work on the ground would be impossible without the collaboration of research and development partners, including donors, international research and development organizations, international and national non-governmental organizations (NGOs), the private sector, government agencies, and civil society organizations. It is through these partnerships that the program achieves its goals of putting promising technologies and integrated interventions into the hands of millions of rural people in Africa.

It is through these partnerships that the program achieves its goals of putting promising technologies and integrated interventions into the hands of millions of rural people

Deploying improved varieties



Farmer Behafta in her wheat plot, Tigray, Ethiopia

Deploying improved varieties for enhanced farm production, resilience and sustainability involves a number of stages, including variety evaluation and selection, seed production, dissemination or scaling, and ensuring farmers use best practices in growing the new varieties.

In 2018–2019, at various sites across the six program countries, Africa RISING evaluated a wide range of crops that have a critical role in sustainably intensifying smallholder agricultural production systems.

The East and Southern Africa project evaluated groundnut/peanut (*Arachis hypogaea*), pearl millet (*Pennisetum glaucum*), pigeon pea (*Cajanus cajan*), and sorghum (*Sorghum bicolor*) in seven villages with different agroecological potential (sub-agroecosystems) in central Tanzania. In general, the yield of improved varieties was greater than that of the local landraces: some had just one-third of the loss experienced by the landrace under late planting. Spanish groundnut material outperformed Virginia material across sites, especially under stress. While for pigeon pea, medium-duration varieties did best. The differential performance of varieties across sites confirmed the earlier classification of the sub-agroecosystems: the varieties were mapped to these sub-agroecosystems, and the best performers in each identified. Seed production for these crops is through the informal community seed bank approach.

Four selected drought-tolerant maize hybrids will now be scaled out via formal seed companies in central Tanzania

In a season with severe drought that wiped out the trials at four of seven test sites in central Tanzania, four drought-tolerant maize (*Zea mays*) hybrids were selected for superior yield, agronomic performance, and profitability on farm; these will now be scaled out via formal seed companies.

In West Africa, demonstrations of six groundnut varieties were hosted by 18 farmers across three regions of northern Ghana. Farmer preferences varied by gender and whether the farmer was a (direct or indirect) project beneficiary or not; however, three of the six varieties were among the top three selections of more than half of the farmers.

In northern Ghana, 150 farmers were trained in vegetable production, after which they assessed onion (*Allium cepa*), pepper (*Capsicum annuum*), and tomato (*Solanum lycopersicum*) varieties. The preferred onion varieties were high-yielding, large-bulbed, and mild-tasting, while the preferred tomato varieties had many "huge," very hard fruits, and one had bright red fruits.

In Mali, 121 farmers who had taken part in training and exchange visits on good agricultural practices and postharvest practices selected high-yielding, sweet-tasting African eggplant (*Solanum macrocarpon*); high-yielding, hard-skinned (long shelf life) tomato; and vegetable cowpeas (*Vigna unguiculata*) that gave a high yield of fresh pods.

Dual-purpose sorghum (the grain is used as food and the stalk as animal fodder) is being assessed for integration into crop–livestock systems. Three varieties from on-station trials in 2017 outyielded the local varieties in farmers' fields, by 33–58%, and even more so when fertilizers (especially diammonium phosphate and urea) were applied in 27 trials at two sites (three climatic zones) in Mali. This performance was even better than that achieved on station, where the yield advantage was 6–21%. There were clear genotype-by-environment interactions. Four short-stature, dual-purpose sorghum hybrids are now being evaluated by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in four technology parks in Mali.

In the Ethiopian Highlands, the project conducted participatory varietal selection of high-yielding varieties of cereals. Varieties of bread wheat (*Triticum aestivum* subsp. *aestivum*), durum wheat (*T. turgidum* subsp. *durum*), and linseed (*Linum usitatissimum*) were evaluated in 16 farmers' fields across four sites. Two or three varieties of each cereal were selected at each site; one variety of bread wheat and one of durum wheat were selected at all four sites. The bread and durum wheat varieties displayed genotype-by-environment interaction, with four bread wheats producing at least 5 t/ha at one site, and one durum wheat producing over 4 t/ha at a different site. Across locations, bread wheat grain yield was 2.8–4.1 t/ha, rather higher than the national average of 1.7 t/ha. Some of the selected bread wheat varieties performed better under wheat rust (*Puccinia* sp.) and drought stress. Linseed can be used to diversify wheat-based systems in the Highlands, and serve as a source of income, mainly for women farmers.

QUALITY-DECLARED SEED OF GROUNDNUT, COMMON BEAN, AND SOYBEAN IN MALAWI

20 kg of foundation seed given to each of

300 producers

46 tons produced (2018)

distributed to **4,000 farmers** (10 kg each)

50 tons produced (2019)

COMMUNITY SEED BANKS IN TANZANIA

501 seed producers

of which **52% women**

each give back enough seed for **2 new producers**

retains enough to **sow next season**

sells **surplus**

Also in the Ethiopian Highlands, the food oat (*Avena sativa*) variety 'Sorataf' is being grown on 10 farms as a food–feed crop, promoted by the International Livestock Research Institute (ILRI).

The program produced quality-declared seed (QDS) for groundnut, nutrient-rich common bean (*Phaseolus vulgaris*), and soybean (*Glycine max*) in Malawi by giving 300 producers 20 kg of foundation seed each. In the December 2018 harvest, 46 tons of seed was produced and distributed to 4,000 farmers (10 kg each). In the 2019 season, these same producers produced 50 t of QDS. Seed farmers have been linked to the Agriculture Extension Coordination Committee (DAECC) for assistance with marketing their seed production. A study of the viability of this community seed system with real marketing is ongoing.

In Malawi, groundnut seeds were stored in their shells until around planting time. The resulting seed viability was almost 100%, largely surpassing the viability of commercial seeds from agro-dealers, which have their shell removed mechanically before storage.

In Tanzania, community seed banks are being used successfully to promote QDS production for pearl millet, pigeon pea, and sorghum. Each seed producer (501 in the 2018/19 season; 52% women) gives back enough seed to the community seed bank for two new seed producers to be recruited, retains enough seed for the next season, and sells the surplus.

To raise awareness and multiply seeds, 14.15 t of seed of various bread wheat, durum wheat, and food legume varieties were given to farmers across the four project sites in the Ethiopian Highlands. In eight districts across three zones, 250 farmers produced 215.42 t seed of 20 varieties of six crops (bread wheat, durum wheat, faba bean *Vicia faba*, field pea *Pisum sativum* subsp. *arvense*, lentil *Lens culinaris*, malt barley *Hordeum vulgare*) in the 2018/19 season.

SEED MULTIPLICATION IN ETHIOPIA

250 farmers in 8 districts produced

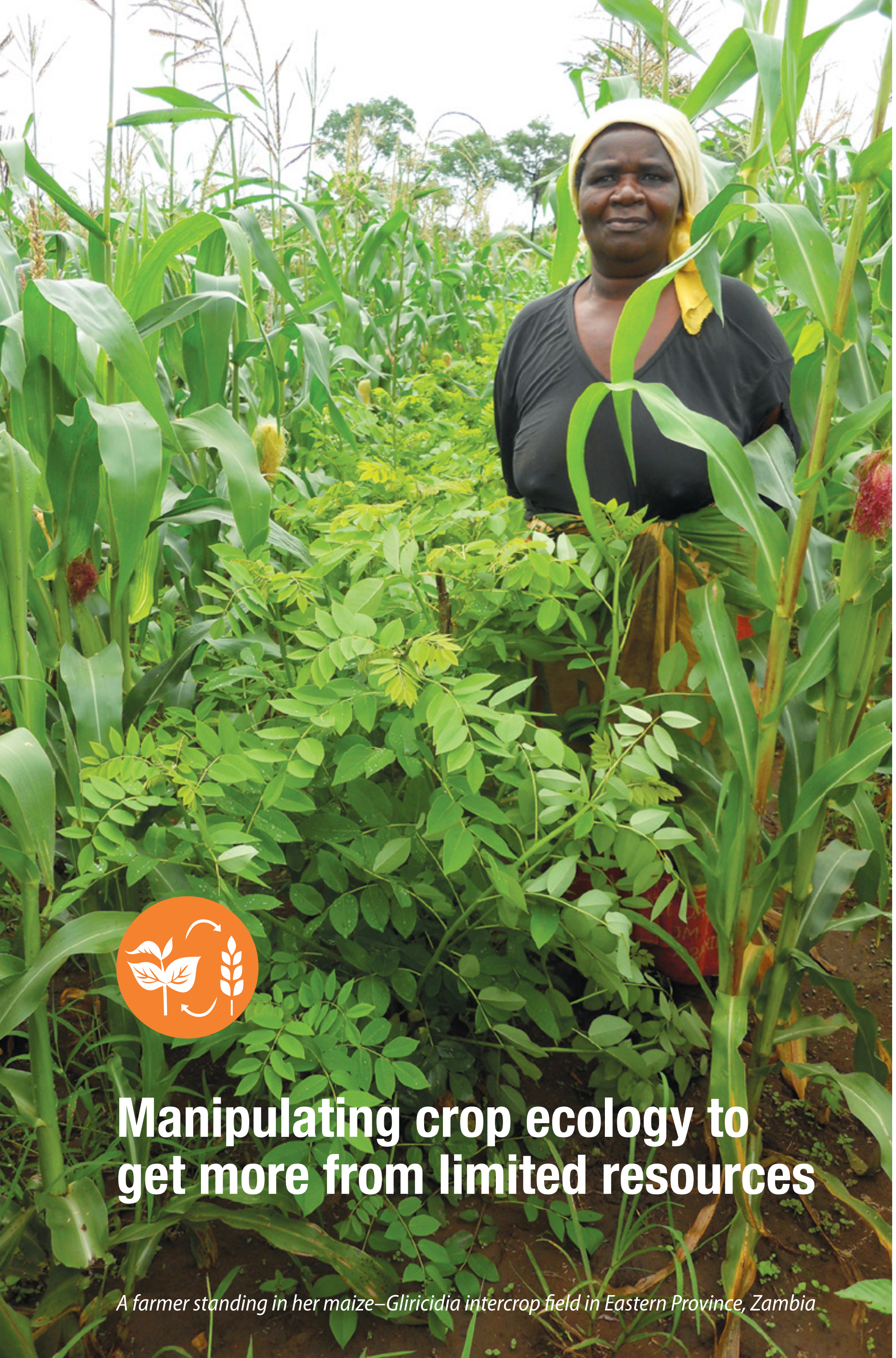
215.42 tons of seeds of

20 varieties of six crops (bread wheat, durum wheat, and malt barley; faba bean, field pea, and lentil)

Outside the project sites, Ethiopia's district bureaus of agriculture scaled out farmer- and industry-preferred varieties of bread wheat, chickpea (*Cicer arietinum*), durum wheat, faba bean, field pea, food barley, lentil, and malt barley from participatory varietal selection and popularization activities to 62,109 households (including 10,192 women farmers), covering 38,897 ha in the 2018/19 season. Overall, 44,593 households (17% female-headed) benefited from Africa RISING outscaling activities for eight crops across four project locations in the 2019 season. Bread wheat reached the most farmers (77% of the beneficiaries), followed by faba bean.

The Ethiopia project provided seeds for revolving banks in its four regions: 9.4 t of pre-basic and certified class 1 faba bean (3 varieties); 0.2 t of breeder field pea (1 variety); 5.7 t of bread wheat basic seed (3 varieties); 2.6 t of durum wheat pre-basic and basic seed (3 varieties); and 4.0 t of pre-basic malt barley seed (2 varieties).

Overall, 44,593 households benefited from Africa RISING outscaling activities for eight crops across four project locations in Ethiopia



Manipulating crop ecology to get more from limited resources

A farmer standing in her maize–Gliricidia intercrop field in Eastern Province, Zambia

This section focuses on manipulation of crop ecology, especially agronomy, to maximize returns on resources invested. Around the world, poor productivity of crops is often blamed on the genetic deterioration of seed as farmers save some of their crop for planting the next season rather than buying certified (or other quality-controlled) seed each year. This is true for groundnut in Malawi, where farmers' yields remain low, averaging 600 kg/ha against yields more than 2,500 kg/ha on research stations. In 2017/18, the project evaluated the effect of seed generation (certified versus farmer-saved) and planting density (double rows versus single row) on groundnut biological nitrogen fixation and grain productivity. Certified seed had relatively larger pod yields; however, its productivity was reduced by poorer germination (compared with farmer-saved seed). This is likely the result of agro-dealers in Lilongwe using machinery for shelling; smallholders keep groundnut in the shell, and hand-shell close to planting time.

Across the three project regions of northern Ghana, six improved groundnut varieties were tested at four plant densities. Results were consistent between technology parks and farmers' fields. The interaction of variety and plant density did not affect grain, fodder, or weed yields. However, groundnut varieties differed in grain and fodder yields, and plant density affected grain, fodder, and weed yields in all three regions. As plant spacing was increased, grain and fodder yields declined while weed biomass increased. The densest planting of groundnut (at 30 × 15 cm spacing) was preferred across the three regions because of its ability to suppress weeds, conserve soil moisture, decrease soil erosion (due to increased ground cover), and increase yield.

The maize–pigeon pea combination also contributes to nutrition security as maize provides carbohydrate and pigeon pea provides protein

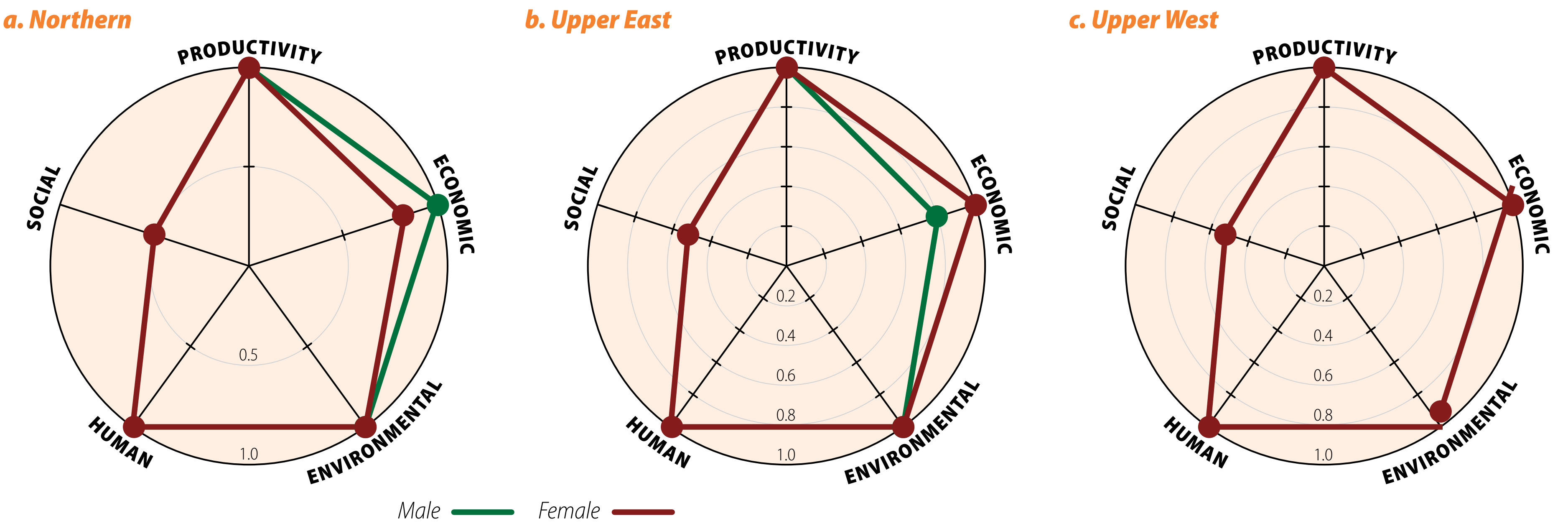
In terms of the Sustainable Intensification Assessment Framework (SIAF), men and women farmers across the three regions scored the densest planting of groundnut higher than the traditional planting method for productivity, economic, environment, and human domains. However, the social domain score for dense planting was lower than that of the traditional method, possibly due to higher labor demands, especially at the time of establishment (Fig. A).

Combining sets of improved management practices (IMP) – typically including good-quality seed of improved varieties, healthy seedlings, and good agronomic practices – is a tried-and-tested route to improved productivity. The first season of IMP for vegetables in Karatu District, Tanzania (64 farmers) increased the yield of tomato by 48%, of African nightshade (*Solanum villosum*) by 30%, and of Ethiopian mustard (*Brassica carinata*) by 28%; and farmers' respective incomes by 57%, 39%, and 40%. IMP also reduced postharvest losses by 86–98% for all three vegetables crops. Market participation increased by 14% for tomato, 36% for African nightshade, and 11% for Ethiopian mustard. Farmers said that IMP had a positive effect on productivity, profitability, and nutrition, but had less effect on the environment and social aspects of SIAF.

Among four cereal–legume intercrop and rotation schemes over three years in central Malawi, maize yield was greatest when it was monocropped after sole pigeon pea; however, groundnut–pigeon pea 'doubled-up' intercrop rotated with maize was the only one to perform, economically, as well as the farmer check. Sufficient economic and environmental returns are required to compensate for opportunity costs associated with maize production limitations due to small farm sizes.

In Mali, intercropping of soybean and sorghum increased sorghum growth and yield. As a monocrop, sorghum yielded 1.14 t/ha, but intercropped with soybean it was 2.325 t/ha. Meanwhile, application of organic manure increased cotton (*Gossypium hirsutum*) yield by 25% and biomass yield by 30%.

Figure A. Farmers' assessment of planting groundnut at 30 × 15 cm spacing relative to traditional method using the Sustainable Intensification Assessment Framework (SIAF) in northern Ghana



Growing-season drought in Babati District, Tanzania, suppressed any effects of novel intercropping technology *mbili-mbili*[1] (no maize grain yield differences across treatments); however, early maturing common bean in the doubled-up legumes system outyielded that under *mbili-mbili* (0.5 t/ha compared with 0.3 t/ha).

During the first half of the grain growth period, maize variety Meru Hybrid 513, selected as best suited to the expected seasonal weather, had higher chlorophyll content than a similar system with 'normal' Meru Hybrid 515, suggesting that Meru Hybrid 513 has improved resistance to soil moisture stress, with consequent yield levels similar to those of sole maize. However, there may have been an effect of slow-release nitrogen (N) fertilizer, possibly increasing N availability after the onset of rain.

Conservation agriculture entails no tillage, crop residue retention as mulch, and crop rotations

The amount of light intercepted by the maize canopy affects the proliferation of the understory legumes in intercrop. Photosynthetically active radiation (PAR) was recorded on pigeon pea after maize harvest. In most cases, doubled-up legumes had the highest light interception and best pigeon pea growth. This system had no maize planted, and common beans matured early, thus increasing light access for pigeon pea. The ability of pigeon pea to maximize use of PAR is associated with improved final yields and enhanced biological N fixation.

Farmers evaluated legume–maize intercrop technologies based on sustainable intensification domains in Nsanama extension planning area, Malawi, where the program had introduced several technologies (fertilized maize, half fertilizer, no fertilizer, legume–maize rotations, doubled-up legumes technology, maize–pigeon pea intercrop, double-row planting of groundnut and soybean), via a structured questionnaire and focus group discussions. The assessment focused on household food production, income generation, and labor requirements (Table 1). Nsanama has limited soil fertility, and household food security is a major concern. For household food production and income generation, most men farmers gave top ratings to fully fertilized maize, maize–pigeon pea intercrop, maize–groundnut intercrop, sole groundnut, sole pigeon pea, maize–groundnut rotation, and maize–pigeon pea rotation. Women gave similar ratings, except that none gave the top rating to sole pigeon pea, and they rated half-fertilized maize highly for income generation. Apart from yielding better, maize–pigeon pea intercrop contributes more pigeon-pea biomass, and maize and pigeon pea together make *nsima* (maize meal) and relish, a major meal in southern Malawi. The maize–pigeon pea combination also contributes to nutrition security as maize provides carbohydrate and pigeon pea provides protein. For input requirements, men rated unfertilized maize, maize–pigeon pea intercrop, sole groundnut, sole pigeon pea,

The maize–pigeon pea combination also contributes to nutrition security as maize provides carbohydrate and pigeon pea provides protein

1 *Mbili-mbili* exploits plant spatial configurations to increase light penetration to intercropped legumes, which are otherwise shaded by the cereal. The name *mbili-mbili* is derived from Swahili word *mbili* meaning 'two'; in Africa RISING, two maize rows are alternated with two rows of a legume.

Table 1. Men's and women's rating of sustainable intensification technologies by food security, income, and production input requirements

Proportion of men and women who rated technology as "best" for particular factor:

Technology	Household food production		Income generation		Input requirement		Labor requirement	
	Men	Women	Men	Women	Men	Women	Men	Women
Maize with half fertilizer	0	0	0	1.0	0	0	0	0
Maize with full fertilizer	1.0	1.0	1.0	1.0	0	0	0	0
Maize–pigeon pea intercrop	0.8	1.0	0.7	0.8	1.0	0	0.1	0.9
Pigeon pea–groundnut intercrop	0.8	0.3	0.9	1.0	0	0	0	0
Groundnut sole crop	1.0	0.6	1.0	1.0	0.8	0	0.3	0
Pigeon pea sole crop	1.0	0	1.0	0.2	1.0	0	0.9	0.1
Maize–groundnut rotation	1.0	0.8	1.0	0.4	0.8	0.4	0.2	0
Maize–pigeon pea rotation	1.0	1.0	1.0	0.9	0.9	0.1	0.2	0

Everyone *Majority* *Less than half*

maize–groundnut rotation, and maize–pigeon pea rotation highly; few women rated any of the options with the top score. On labor requirement, most men rated only sole pigeon pea as top, while more than half the women rated unfertilized maize as top.

To make the best use of the biological N fixation of legumes, the legume may be cut at ground level (ratooned). Trials in Zambia revealed the highest maize yields were in full rotation with pigeon pea (no intercrop), and lowest in sole maize (no rotation) and intercrop uprooted at harvest (farmers' practice). For pigeon pea productivity, ratooning two weeks after maize planting and again during maize harvest seemed to give best results. In terms of whole-system productivity, full rotation was again best, followed by maize with pigeon pea ratooned at harvest and three weeks after maize seeding. The lowest system yields were from sole pigeon pea and sole maize.

Applying integrated soil fertility management

Soil, Long village in Babati, Tanzania: Africa RISING fertilizer research with farmers

Managing soil fertility is a major preoccupation for most farmers. In this section, we look at inorganic fertilizers and legume mulches. Other aspects of soil fertility management include inter- and rotational cropping, reducing soil loss (where nutrients are lost with the topsoil), and managing water to maximize (or optimize) nutrient availability to the growing crops – these are featured in other sections of this report.

Agricultural intensification requires efficient use of resources, especially by resource-constrained farmers in developing countries. Nitrogen (N) fertilizer recovery uptake by crops is intricately linked to soil water availability, but current N application strategies, especially using urea, rarely prescribe reduced N application when rainfall fails. In Malawi, in the year with an extended dry spell, maize grain yields increased from 0.9 t/ha for phosphorus (P)-only treatment, to a maximum of 3.5 t/ha when 92 kg N/ha was applied. The variable (responsive) N treatment received a maximum of only 46 kg N/ha and yielded 3.2 t/ha. The year with excessive rainfall in February had very poor maize grain yields of 0.47 t/ha when no fertilizer was applied; however, there was a large response to fertilizer, resulting in the highest average yields of 4.2 t/ha when 92 kg N/ha was applied. Depending on rainfall received at specific sites, between 69 and 110 kg N/ha was applied for the rainfall-responsive N application strategy, giving an average yield of 3.8 t/ha. The N response strategy does not necessarily result in the highest yields, but it increases N-use efficiency substantially – essential for improved economic gains with the use of expensive N fertilizers.

A total of 262 upscaling trials were established on farmers' fields in northern Ghana from June to August 2019

Low N application rates appeared to reduce utilization of soil water. This is important for water use efficiency as better fertilization is associated with more efficient transpirational water use.

Various combinations of fertilizers have been tested in Africa RISING sites in the Ethiopian Highlands across farming systems, agroecosystems, landscape positions, and soil types, and a draft site-specific decision guide (version 1) was produced to enhance yields, reduce input costs, and improve resource management at the landscape scale. The guides are being validated at scale through various treatments on 648 plots with 216 farmers in three regions. The project will develop a farmer-friendly, targeted decision-support guide (version 2) for fertilizer applications.

Abena Batige, a farmer in Goriyiri Community in Upper West Region of Ghana, testing the cowpea living mulch technology

Various combinations of fertilizers have been tested in Africa RISING sites in the Ethiopian Highlands across farming systems, agroecosystems, landscape positions, and soil types

Living mulch of legumes conserves soil nutrients, increases organic matter, and reduces soil erosion and weed pressure. The interaction of cowpea living mulch and maize maturity-type had no significant effect on grain, stover, or weed biomass yields. However, the living mulch did affect maize grain and weed biomass yields. Planting cowpea living mulch with maize on the same day decreased maize grain yield in all three regions of northern Ghana. Planting cowpea living mulch 1 or 2 weeks after maize increased grain yield in Northern Region but did not affect grain yields in Upper East and West regions. Weed biomass was lower in cowpea living mulch systems in all three regions. Maize maturity-type had significant effect on stover yield in all the regions: the medium-maturity-type variety had higher stover yield than the other maturity-types in all three regions.

Generally, farmers preferred the cowpea living mulch systems (especially planted one or two weeks after maize) over the non-mulch system due to their ability to suppress weeds, and conserve soil and moisture – and the higher yields obtained.

A total of 262 upscaling trials were established on farmers' fields in northern Ghana from June to August 2019: with self-selection, 81% did an N-fertilizer upscaling trial (more men than women), while the remaining 19% did a cowpea living mulch trial (more women).

Enhancing livestock productivity

Africa RISING activities aim to imrpove livestock productivity while reducing crop–livestock conflict within communities

Farm animals are an ancient, vital and renewable natural resource. Throughout the developing world, they are a means for hundreds of millions of people to escape absolute poverty. Livestock sustain most forms of agricultural intensification. Africa RISING is addressing various aspects of feeding livestock, from crop residues, through forage and fodder crops, to improved feed troughs. The West Africa project has also implemented animal health interventions, either alone or in combination with feed interventions.

In northern Ghana, feeding sheep with groundnut haulms from the densest planting to reduced feed intake while increasing overall weight gain and average daily weight gain compared with those from other planting densities, because of reduced deposition of recalcitrant fibers and increased digestibility.

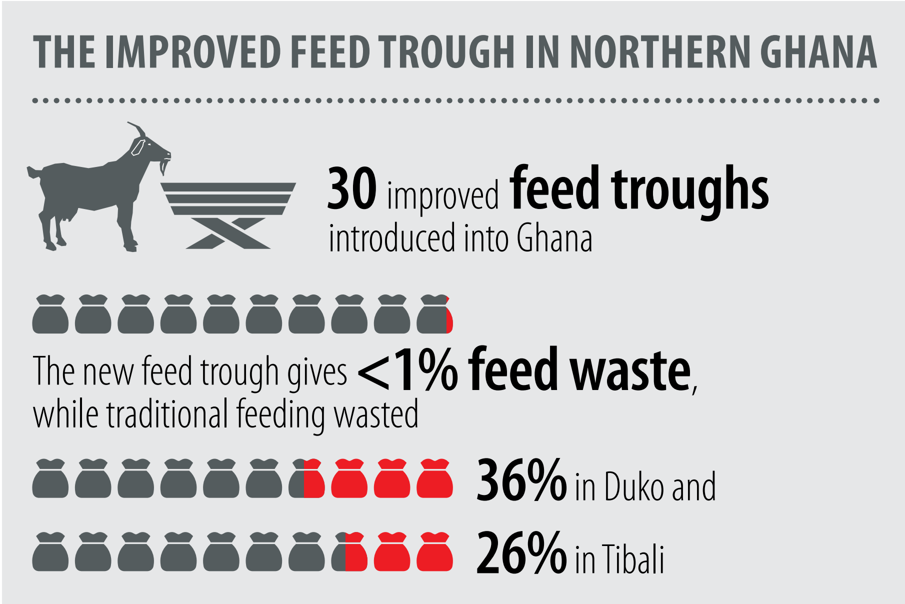
In the Ethiopian Highlands, new forage options validated included lablab (*Lablab purpureus*), phalaris grass (*Phalaris arundinacia*), vetch (*Vicia villosa*) and desho grass (*Pennisetum pedicellatum*) intercropping, and a brachiaria hybrid (*Brachiaria* 'Mulatu II'). And additional observations were made for sweet lupin (*Lupinus angustifolius*), alfalfa (*Medicago sativa*), and fodder beet (*Beta vulgaris* subsp. *vulgaris*) forages to generate multi-season data across the Africa RISING sites. At three sites, fodder beet produced on average more than 112 t/ha fresh biomass. Farmers showed strong interest in the crop – their evaluation was highly favorable. A feeding trial (supplementation with 10 kg fresh tuber per cow per day) showed average milk yield increases of 14–33%.

In the Ethiopian Highlands, new forage options validated included lablab, phalaris grass, vetch and desho grass intercropping, and a brachiaria hybrid

Feed shortages during the cropping season constrain ruminant production in small-scale crop–livestock production systems in northern Ghana. Leaves stripped from maize plants after tasseling or silking could provide feed during the cropping season without compromising grain yield. In the technology parks, the interaction of leaf stripping and maize maturity-type was not significant on grain, stover, and feed yields across three regions. Similarly, leaf stripping did not have any effect on these yields. However, medium-maturing maize had increased stover yield. Most farmers preferred maize leaf stripping at silking, because it is easier to identify lower leaves below the maize cobs and there is already abundant feed for livestock during the rainy season. Most farmers also preferred early-maturing varieties with good grain yield. Generally, results from the farmers' fields were similar. However, for men farmers in Northern Region, stripping maize at both tasseling and silking reduced grain yield, while for women farmers in Upper West stripping maize leaves at tasseling reduced grain yield. This could reflect differences in farmers' management. For example, they might have stripped physiologically active leaves, resulting in less photosynthesis and substrate translocation for grain-filling.

Interaction of leaf stripping with maize maturity-types also had no significant effect on crude protein, neutral detergent fiber, acid detergent fiber, metabolizable energy, and in vitro organic matter digestibility. However, the crude protein content of maize leaf met the minimum crude protein requirement for body maintenance of ruminants, indicating the potential of maize leaf stripping for ruminant feed.

After success in Ethiopia (where they saved 27% of the cereal and legume residues offered to livestock), 30 improved feed troughs were designed and demonstrated in northern Ghana. Fifty-nine people were trained on their design, including selected farmers and 29 youths from Youth Empowerment for Life, a nongovernmental organization (NGO) based in Tamale.



Improved feed rations developed over a number of years by the project have increased reproduction rates, reduced mortality, and increased household income, as a result of farmers' behavioral change in adapting feed rations to their own conditions (which makes the technology more likely to be sustainable).

In Ghana, the improved feed troughs significantly reduced feed waste. Traditional feeding systems wasted about 36% and 26% of feed in Duko and Tibali, respectively. The less than 1% waste from the improved feed troughs therefore offers huge savings. The troughs also reduced feeding time by almost half.

Construction cost is an issue, as each trough costs 1,149 Ghanaian cedis (US$ 194), but use of local materials (especially wood and thatching the roof) could considerably reduce the cost. Moreover, trough construction could provide employment and income for youth.

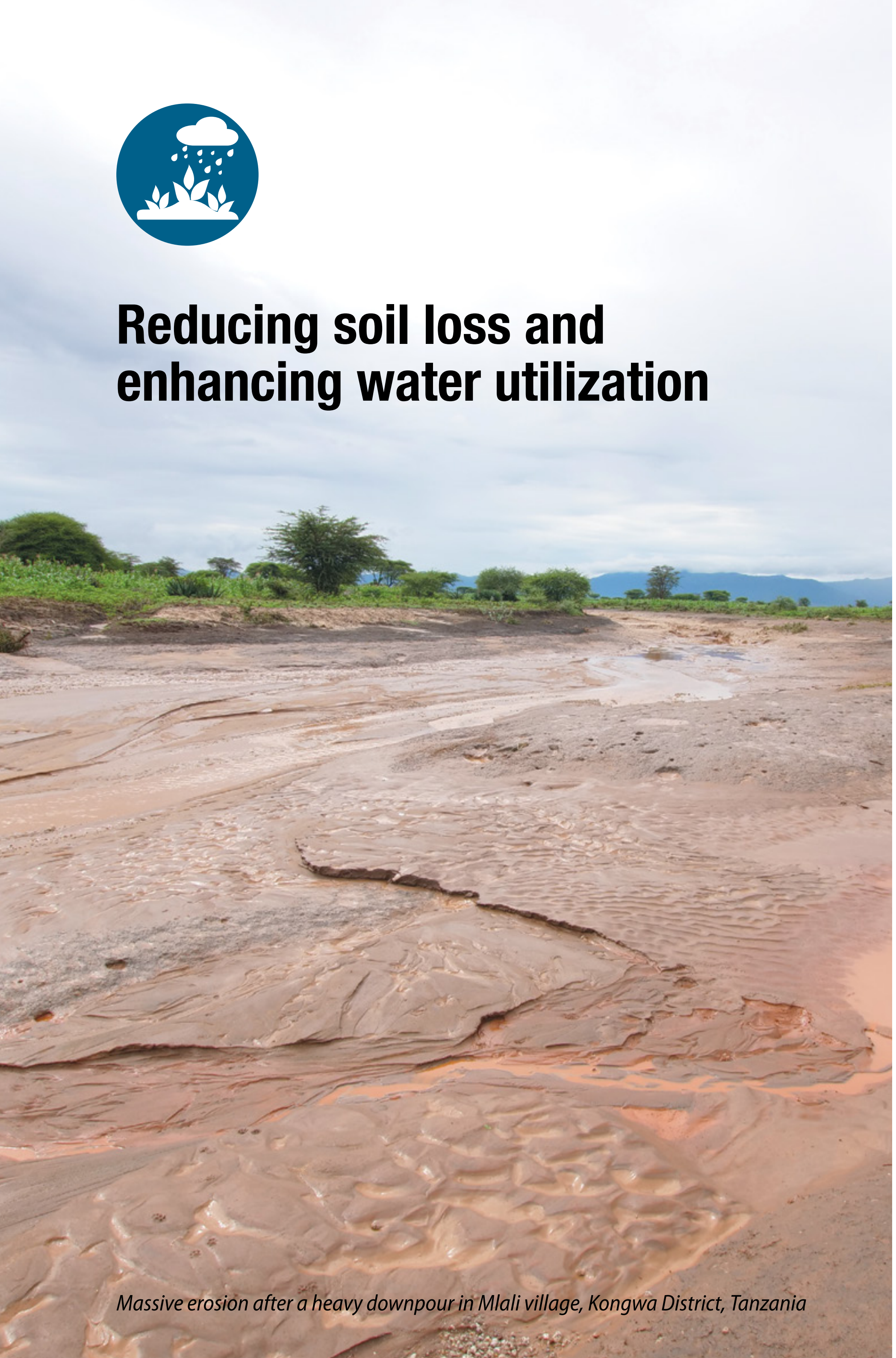
Over a number of years, Africa RISING has worked with small-ruminant farmers in northern Ghana on feed supplementation, improved housing, animal health/veterinary care (chiefly vaccinations and antibiotics), and breeding management. Perhaps the main finding of a farmer survey on this intervention was that improved small-ruminant husbandry contributed to household food security through the sale of the

After success in Ethiopia, 30 improved feed troughs were designed and demonstrated in northern Ghana

animals to buy grains. Healthy sheep and goats were rarely slaughtered for household consumption, while sick animals were. Most households slaughtered small ruminants during religious festivals. Households that received the feed and animal health intervention tended to sell animals more frequently to buy grains and other animal-based food for household consumption than households with no or health-only interventions. Thus, the intervention slightly improved the number of months of household food security, more beneficiary households had "comfortable" food status, they had more animals to sell (because of more rapid growth), and increased dietary diversity.

A farmer in Tibali Community, northern Ghana: his sheep are feeding from a newly constructed feeding trough

Through a plan to scale up jointly prepared and implemented with development partners, a total of 17,578 households benefited from livestock feed and forage technologies in the Ethiopian Highlands. Of these, 21% were female-headed households. Africa RISING helped raise feed seedlings in public nurseries and provided forage seeds for seed multiplication (forage oats, sweet lupin, and vetch) on selected model farmer fields and farmer training centers. Feed and forage technologies being scaled up through development partnerships include oat and vetch mixed forage, pure oat, pure vetch, tree lucerne (*Cytisus proliferus*), desho grass, napier/elephant grass (*Pennisetum purpureum*), and feed trough for cattle and small ruminants.



Reducing soil loss and enhancing water utilization

Massive erosion after a heavy downpour in Mlali village, Kongwa District, Tanzania

Soil and water are of course two of the most important resources on any farm. The soil provides a substrate to support plant growth, and the moisture and nutrients to make it happen. Loss of topsoil and its crop-friendly structure through erosion is a major impediment to farming and a major cause of desertification. Meanwhile, plants need water even more than they need soil (e.g., plants can be grown in hydroponic systems without soil). In many parts of Africa, climate change is altering weather patterns, which were already irregular in many places. Water may be absent when needed (drought during critical parts of the crop season) or arrive in quantities that farmers struggle to manage (e.g., intense rainfall causing floods and effectively drowning crops, and flash-floods causing soil erosion). Water management is therefore key for adaptation to climate change. Moreover, many of the techniques ostensibly used for either soil or water conservation actually do both.

Many of the techniques ostensibly used for either soil or water conservation actually do both

Soil water conservation is important in enhancing water capture and storage during the growth season.

In two sites in East and Southern Africa (Malawi and Zambia), adoption of conservation agriculture (CA) systems has reached the tipping point – more than 50% of farmers are regularly using CA systems and practices in their maize. They have also expanded this to other crops and areas, growing groundnut, cowpea, and soybean under this system effectively and profitably.

After more than four years of CA in Zambia, maize yield is no longer suppressed in maize intercropping trials, so all legumes will be an added advantage to farmers with no penalty. The legumes not only provide an extra crop without additional land, they also improve soil fertility and provide other benefits (firewood, groundcover, etc.). However, to become attractive to farmers, the legumes must also provide sufficient grain to sell.

Long-term, on-farm trials were established in 16 communities of Malawi and Zambia in 2011/12. In 2019 in central Malawi, two CA interventions outyielded the conventional ridge tillage, while in southern Malawi only direct-seeded maize without intercrop did so. In the manual CA system in eastern Zambia, only the maize–legume rotation under CA had a significant yield benefit over conventional ridge tillage. Both CA systems with animal traction ripping yielded more than conventional plowing in eastern Zambia. These results provide strong proof of concept that the sustainable intensification systems promoted have yield benefits. In 2019, maize–pigeon pea and maize–cowpea intercropping in southern Malawi and eastern Zambia had yield penalties, likely due to strong competition effects between maize and legumes in this relatively good cropping season with well distributed rainfall. In rotations in Malawi, both groundnut and pigeon pea yields were higher under CA than under conventional practices. In central Malawi, groundnut farmers harvested 42–57% more grain yield under CA. In southern Malawi, the yield benefit for pigeon pea was 15–17% under CA.

In 2019 in southern Malawi, among maize treatments, CA maize–legume intercropping gave the highest net benefit and return to labor, followed by CA sole maize. In central Malawi, net benefits of intercropping were lower (due to failure of the cowpea intercrop). In central Malawi and eastern Zambia animal traction system, the CA sole maize system outperformed the CA maize–legume system, yielding the highest net benefits among the cropping systems promoted in these target areas. CA maize–legume intercrop gave the highest net benefits and return to labor in the manual systems of eastern Zambia. This is mainly because, in a rotation, the cropped area is divided between both the maize and the legume, whereas in intercropping they share the same space, which has a direct bearing on the gross benefits.

Cost–benefit analysis of CA systems, green manure cover crops, and agroforestry systems in East and Southern Africa revealed that in a normal season (rainfall evenly distributed) in high-productivity areas, all cropping systems will produce positive net benefits.

To illustrate the combined-effect impact of various aspects of CA, the SIAF was applied for central and southern Malawi sites, using the average yields of maize and legumes for the 2018/19 cropping season, net benefits, calculations of protein and calories, reduction in erosion, increase in soil carbon, rating of technologies, and reductions in labor. The improved technologies were improvements over conventional practice, and this was most pronounced in southern Malawi due to harvest from more crops (pigeon pea intercropping and pigeon pea alleys both failed in central Malawi) (Figs. B and C).

Simple tied ridges store excess rainwater, creating more time for infiltration, and so reduce run-off losses.

In semi-arid Tanzania, sorghum on residual tied ridging had poor grain yield, even worse than the control, on sandy clay soils. There were no significant treatment effects on non-sandy soils. Grain yield was not related to soil bulk density, which was greater for conventional tillage. Annual tied ridges and residual tied ridges had more than triple the cumulative infiltration of conventional tillage.

While residual tied ridges required less labor for land preparation, they needed significantly more for weeding operations, possibly because limited soil disturbance means less disruption of weed seed banks, resulting in greater weed regrowth.

Tied ridges without fertilizer did not increase maize productivity; however, water management had more effect with 100% of the recommended fertilizer rates. This suggests that water conservation measure benefits are more pronounced when N and P are adequately supplied.

In matrix scoring exercises, respondents compared maize flat cultivation and maize cultivation with tied ridges in relation to four SIAF indicators. Both men and women perceived tied ridges as more beneficial in terms of soil moisture, productivity, and income from sales. However, for the fourth indicator (labor requirement) mixed views emerged. Flat cultivation was perceived as less labor-demanding during field preparation compared with the construction or maintenance of tied ridges. On the other hand, weeding appeared less labor-intensive under tied ridges than under flat cultivation.

Contour bunding is a holistic landscape approach to managing water and capturing rainfall at the watershed scale.

Figure B. Radar graphs of Sustainable Intensification Assessment Framework (SIAF) indicators of cropping systems of central Malawi

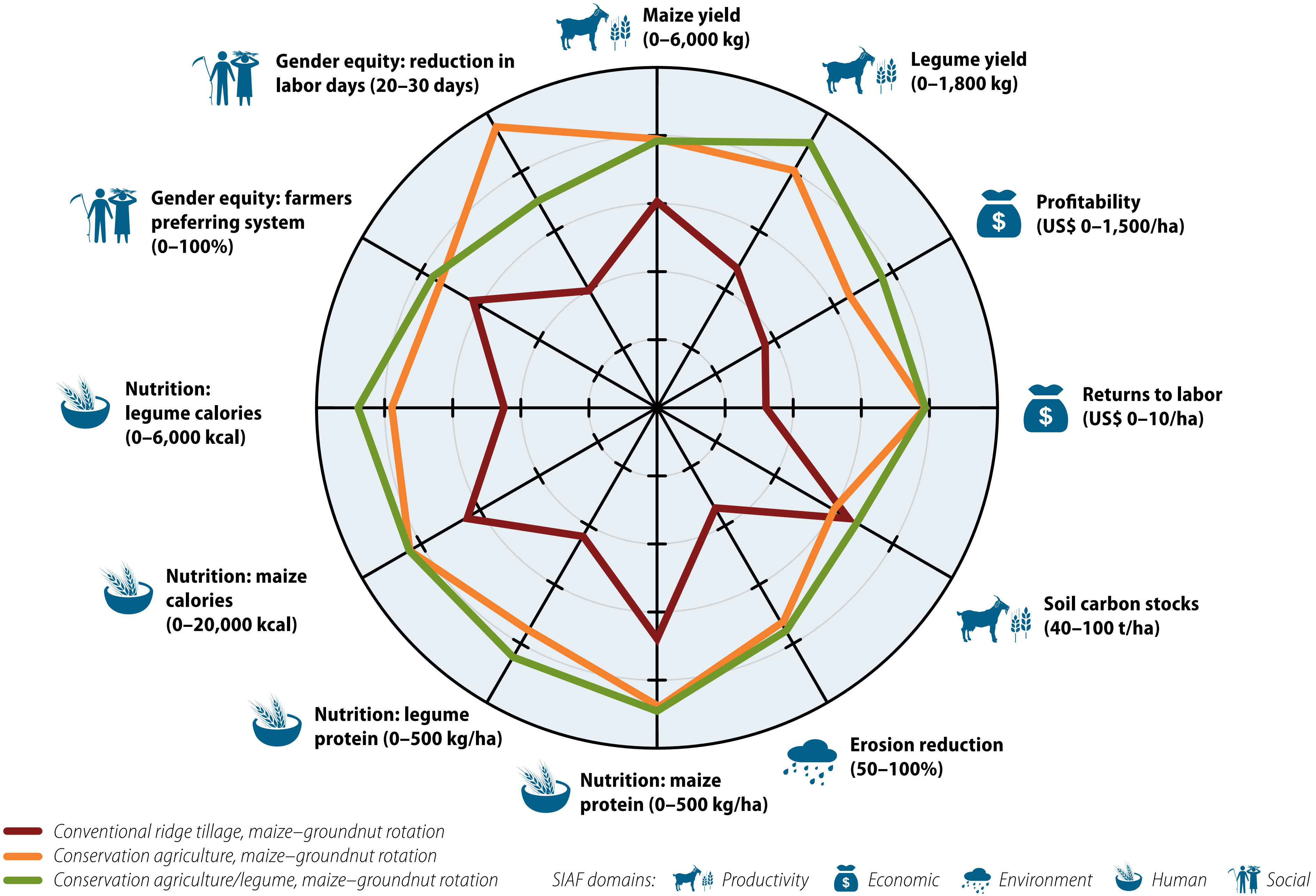
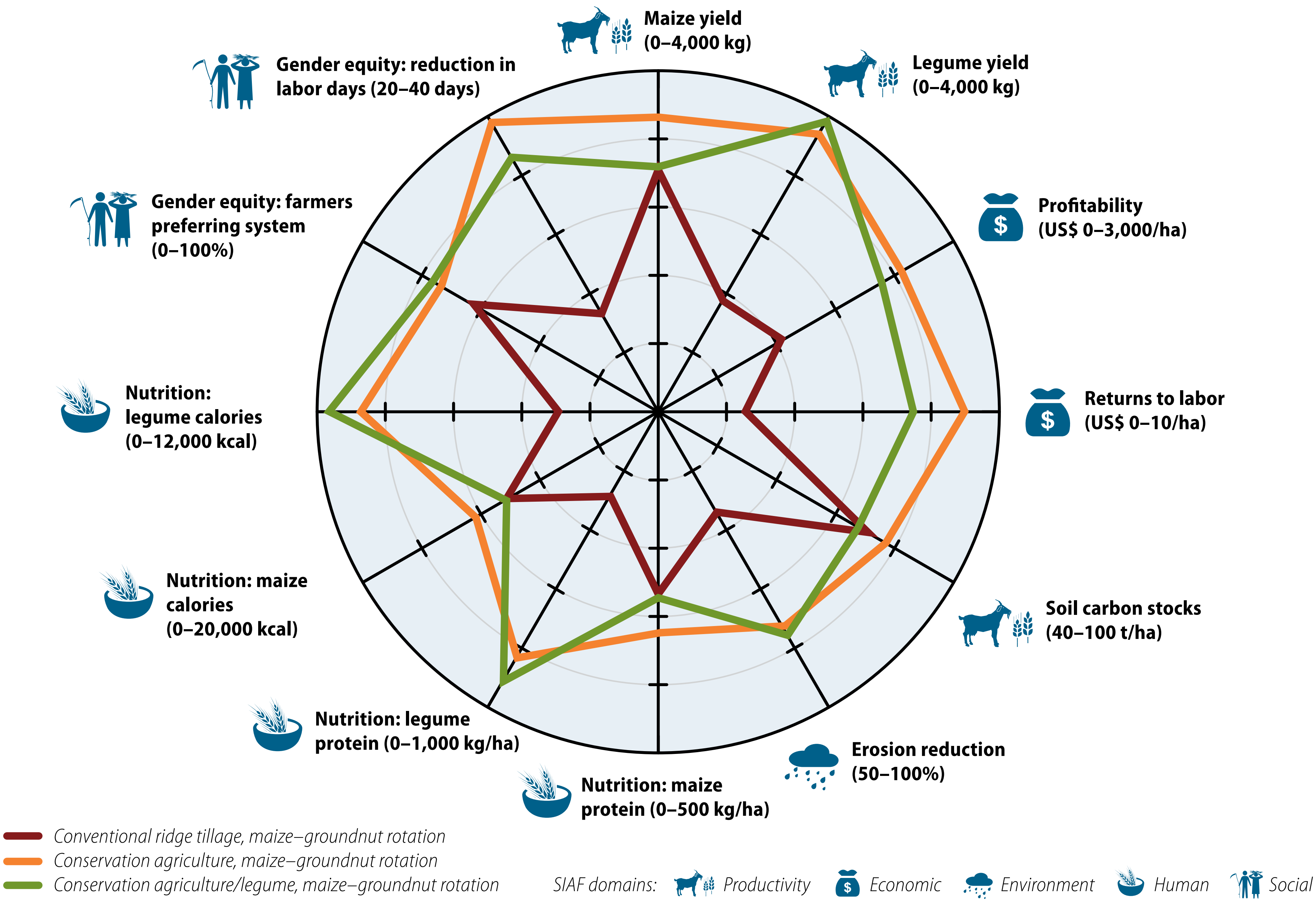


Figure C. Radar graphs of Sustainable Intensification Assessment Framework (SIAF) indicators of cropping systems in southern Malawi

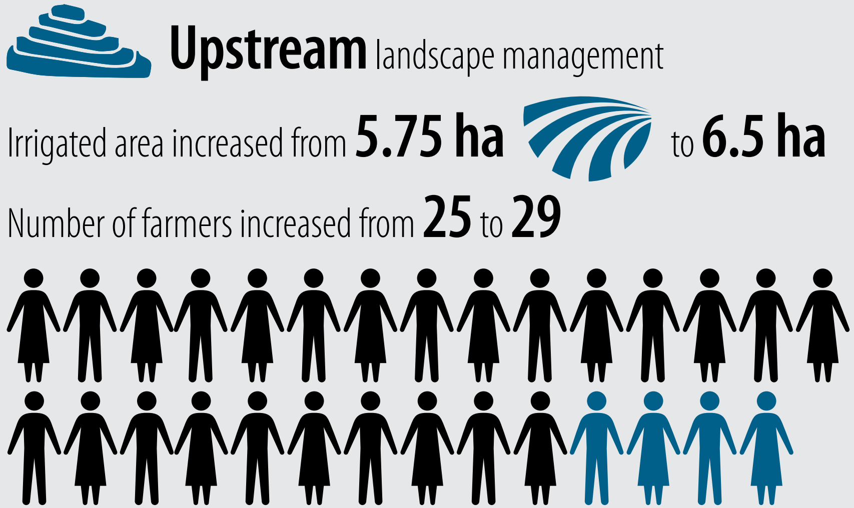


Continuous measurement of subsurface flow was used to analyze the impact of upstream landscape management on enhancing water availability downslope in the Ethiopian Highlands. Downstream of the treated sub-watershed, the number of irrigation beneficiary farmers increased from 25 to 29, and irrigable land from 5.75 ha to 6.5 ha. Five years previously, farmers were using low-water-demanding crops such as lentil and chickpea (*Cicer arietinum*) with a few farmers planting garlic (Allium sativum); now, farmers are using high-water-demanding and high-yielding vegetable crops such as carrot (*Daucus carota* subsp. *sativus*), onion, and garlic, thereby increasing their income. The number of farmers and irrigable land also increased at the untreated sub-watershed, but this was due to the farmers' increased understanding of the benefits of irrigation (a few farmers were able to utilize the small amount of available water from a spring to successfully irrigate pulse crops such as lentil).

In Tanzania, the productivity and economic benefits of contour farming were determined with maize, Guatemala grass (*Tripsacum andersonii*), and *Gliricidia sepium* as test crops. Contours improved maize grain yield 200% over farmer practice during the 2018 cropping season due to improved soil conditions and/or the use of improved maize variety. Low and sporadic rainfall appears to have masked the response of maize to improved soil conditions on contours. Fodder and wood yields were less affected by drought, contributing to higher gross margins (76–112%) and returns to labor (12–74%) in contours. In good seasons, maize contributed 50% of the gross income, while in bad seasons, *G. sepium* wood contributed to 89.7% of the income. The seasonal distribution of Guatemala grass yields and income increase the purchasing power of farmers, improving their access to food during 'lean' periods. These results demonstrate the benefits of crop diversification in contour farming to enhance agroecosystem resilience and the adaptive capacity of farmers.

In Mali, contour bunding reduced run-off (by 56% on farm), raised the water table, and increased moisture in the top meter of soil (maximum 20% more at the end of October compared with not using the approach). In addition, it increased the height, diameter, and crown radius of both *G. sepium* and *Leucaena leucocephala* planted on the crest. Contour bunding increased sorghum plant height, and grain and biomass yields, and pearl millet yield too.

IMPACT OF UPSTREAM LANDSCAPE MANAGEMENT IN THE ETHIOPIAN HIGHLANDS



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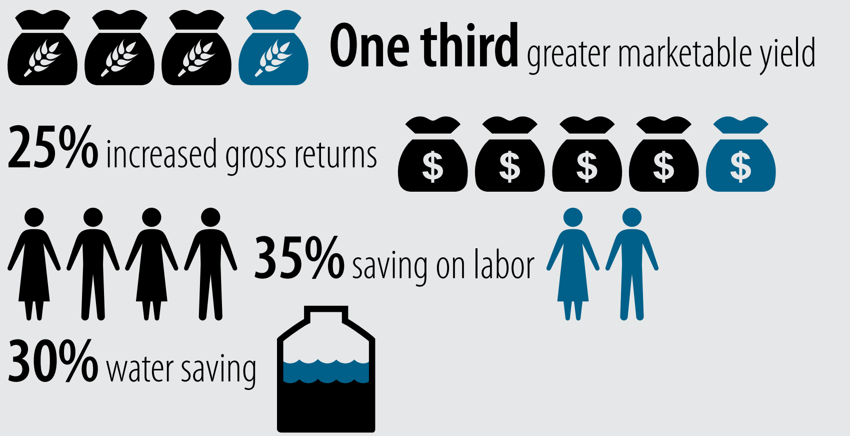
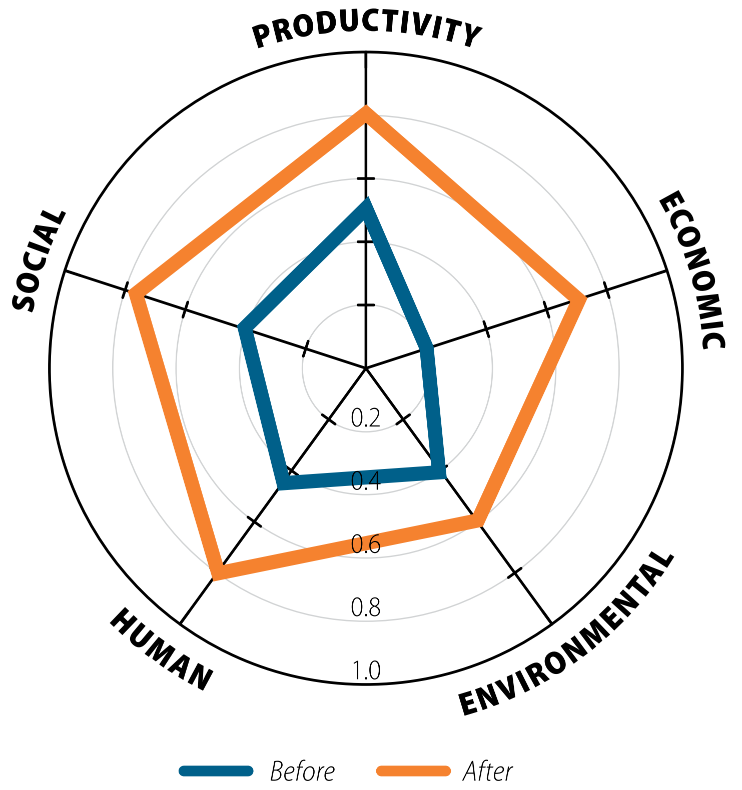


Figure D. Applying Sustainable Intensification Assessment Framework (SIAF) analysis to sweet pepper performance under irrigation, Seloto, Tanzania



The Smart Agricultural Resources Optimization System (SAROS) – a bundled 'smart irrigation' technology comprising improved vegetable varieties (sweet pepper and tomato), an automated drip-irrigation kit (to save on scarce water and labor), and a low-cost screen house (to keep out pests and diseases) – was rolled out to farmers in two village communities in the peri-urban outskirts of Babati town, Tanzania (2 farmers in each village, each with 2 farm trials) for validation. This generated data on soil moisture, irrigation, rainfall trends, water use efficiency, and productivity of vegetable varieties both inside and outside a screen house, as well as the associated cost–benefit analysis around water and labor savings for out-of-season vegetables. After two years, the marketable yield for smart irrigation technology was a third greater than with conventional vegetable production; it gave 25% higher gross returns, saved 35% on labor and 30% on water, and it better protected the soil from erosion. Data analysis to gauge the effect on sustainability was used to generate the standardized SIAF plot (Fig. D), which shows a substantial improvement in all the sustainable intensification domains after the introduction of vegetables.

Solar energy is becoming viable for smallholders, reducing energy costs for irrigation, especially in remote rural areas of the Ethiopian Highlands. Adopters of irrigation tend to produce more products, and improve their land productivity and their resilience to the drivers of food insecurity – even more so with solar power. Many farmers are aware of the benefits of solar, and would be willing to replace their diesel/petrol and manual pump irrigation technologies with solar technology.

Solar technology is new in Ethiopia and expensive for most rural households, so needs to be incentivized – for example, by credit systems. Another constraint is the knowledge gap. Moreover, Ethiopian policies should continue to focus on bridging the gap between those who can afford to invest in irrigation technology and those who cannot, to reduce potentially even greater income inequality that can be created due to irrigation. As irrigation seems closely associated with increases in wealth and income, this gap will only deepen existing inequalities if left untreated.

Solar technology is new in Ethiopia and expensive for most rural households, so needs to be incentivized

Improving household nutrition

*Kocho bread, made from enset (*Ensete ventricosum*), a staple food crop in southern Ethiopia, and eaten with avocado*

Malnutrition is a global issue. Access to nutrient-rich food of all classes is an important component of combating malnutrition – and promoting healthy eating is important for healthy outcomes for all ages, but especially for pregnant women, children, and adolescents. In this section, we look at nutrient loading in maize, and promoting nutritious foods.

At least 13 maize varieties are cultivated by farmers in Karatu District, Tanzania, including mixtures, hybrid, traditional, and open-pollinated varieties, which presents an interesting question for scaling up: how does one successfully penetrate such a farming society with an improved and validated variety? While there are nutritional differences between varieties, the choice of variety is also likely to be influenced by yield and other characteristics such as drought tolerance and resistance to pests and diseases.

Promotion of pearl millet and pigeon pea as nutritional food for schoolchildren in central Tanzania led to increased consumption of these foods.

Farmers still lack knowledge about the nutritional content of vegetables and their health benefits

Messaging on the nutritional value of vegetables, also in central Tanzania, is following a path of awareness-raising and training on nutrition. The project is promoting innovative vegetable recipes through messaging in Karatu District. Farmers still lack knowledge about the nutritional content of vegetables and their health benefits. More than 80% of the households would like to increase vegetable consumption, and 60% plan to increase family vegetable consumption. Against this background, nutrition training was conducted in eight villages involving 332 farmers (52% women), 10 NGO employees, 8 government extension staff, and 16 restaurant/food-kiosk staff, covering knowledge and skills on food groups and better diets to reduce undernutrition, particularly in children under 5 years of age and women of reproductive age. Two new recipes were developed during the nutrition training. Major activities included the provision of information on the importance of eating diverse foods, recipe preparations, ways to add value to farm produce based on the relationship between plant health and human health, and advice on changing diet-related habits to improve nutritional status.

In central Malawi, protein and micronutrient deficiencies are widespread. In maize–bean intercropping using nutrient-dense (iron and zinc) common bean varieties with contrasting growth habits (bush and climbing) at three sites, the mean grain yield of common bean was 298–600 kg/ha. The local climbing variety gave the highest yield in intercrop at two sites, and all intercrops had land equivalence ratios greater than 1 (i.e., more maize and bean produced in intercrop than if they were grown as monocrops on half the land).

In Ghana, tools developed for formative research include barrier analysis to identify the behavioral determinants (enablers and barriers) of five key infant and young child feeding and maternal nutrition behaviors (exclusive breastfeeding, dietary diversity, complementary feeding/food density, joint household decision-making among couples, consumption of fruits and vegetables). The formative research was conducted in partnership and strong collaboration with the Ghana Health Service at the district and subdistrict levels. Results indicate that the role of secondary targets (husbands, friends, in-laws) on the primary target audience (e.g., mothers) significantly affects nutritional problems being addressed – affecting, for example, perceived social norms concerning spending money on the purchase of ingredients such as vegetables, fish, and meat for the household. Husbands are primarily influenced by friends and wives by in-laws. These groups of influential individuals need to be factored into the design of nutrition programs.

For people who already fed fruit and vegetables to their children ('doers') and those who did not ('non-doers'), the only determinant of fruit and vegetable consumption was perceived self-efficacy. Doers were almost three times more likely than non-doers to mention "the availability and/or own production of fruits and vegetables" as a factor that makes it easier to consume fruit and vegetables at least three times a week. Home gardens will therefore contribute to improving the availability of vitamin-rich fruits and vegetables. Meanwhile, non-doers were almost three times more likely than doers to mention "child likes the fruits or has appetite" as a factor that makes it easier for a child to consume fruits and vegetables at least three times a week, implying that they depend on their children liking fruit and vegetables to offer these to them. This is a barrier, indicating that non-doers will not proactively give their children fruits and vegetables. Thus, nutrition education is needed to influence mothers to consciously offer fruits and vegetables to their children.

Perception of positive and negative consequences was not a determinant of consumption of fruits and vegetables; respondents did not often mention the advantages and disadvantages of consuming fruits and vegetables – this finding also calls for nutrition education in this area.

In communities in semi-arid central Tanzania, focus groups indicated that pearl millet grain is largely perceived as food for caregivers (generally female, young, and school-going children), but over 60% of caregivers were unaware of the nutritional health benefits of pearl millet for children (though aware of the benefits of iron and zinc, both present in pearl millet). Pearl millet's iron and calcium could also be of benefit against adolescent nutritional vulnerabilities. While 65% of caregivers were not worried about availability, 30% indicated the time required for processing is a challenge. Medical doctors are trusted and influential in disseminating nutrition and health messages (over 90% of caregivers) – this indicates a key route for nutritional education for caregivers and others.

Nutrition education is needed to influence mothers to consciously offer fruits and vegetables to their children

Improving food safety and reducing food waste

A group of farmers in Nansama village, Kilolo District, Tanzania inspect their maize stored in PICS bags

Food safety and food waste are global issues that require local solutions. In sub-Saharan Africa, postharvest processing and storage are major sources of food losses, both quantitative and qualitative. In this section, we highlight the value of using crop residues and 'waste' as animal feed, and work related to improving storage.

The use of vegetable residues or damaged fruit to feed poultry and small ruminants in Tanzania provides dividends that have not previously been valued. In the test case, damaged fruit and residues each accounted for about 16% of the total biomass produced. This highlights the need for interventions that provide closed loops with little or no waste of byproducts for maximum benefit.

Three products to reduce maize grain postharvest losses – single hermetic liner bag (AgroZ, made of micro-multilayer sheets forming a single hermetic liner), double hermetic liner bag (Purdue Improved Crop Storage, PICS), and metal silo – were evaluated against farmers' storage structures in 39 farmers' stores in Tanzania for context-specific challenges in storing maize and bean grains over seven months.

The profitability of using the PICS bag for bean storage depended on the variety's market value, its vulnerability to damage, and its susceptibility to insects

Grain damage was greater at higher altitude – this is attributed to the interaction effect of temperature and relative humidity on insect population development. Moist grain is softer, and insects bore into it easily to lay eggs; moist grain also favors other forms of biodeterioration. Cooler conditions, however, also encourage mold, which also encourages insect damage. The performance of the different hermetic storage technologies was not significantly different: overall grain damage averaged 8–9% and translated into physical quantity losses of 4.4–4.9% after seven months of storage. These losses can be considered low.

Insect pests survived on maize in all the hermetic containers, but at lower populations than in the farmers' storage facilities. The populations were lowest in the AgroZ bag and highest in the metal silo. Grain damage by insects followed the same pattern. This is attributed to the activity of the insects being reduced at relatively low oxygen levels. Nonetheless, the presence of insect activity highlights the importance of sound handling and management of the technologies by farmers, especially since they would need to open the containers frequently.

Both hermetic bags were perforated by maize insects. About 30% of the double-liner PICS bags had over 20 punctures on the inner liner and half of those had also more than 20 insect holes in the outer liner. About 15% of AgroZ bags had over 20 insect holes. Airtight bags with insect holes are ineffective and no longer attractive to farmers after a single use; airtight bags should be reusable for at least two or three seasons to be economically attractive. The main concern for farmers was the quality consistency of the bags across seasons, which should be followed up with their private-sector manufacturers. If not, a technology that in principle is very useful may disappear from the market.

Hermetic storage (PICS bags) for better postharvest preservation of grains

The PICs bags were not profitable for maize storage, while AgroZ bags were profitable in the second year of use.

Various bean varieties exhibited storability differences both in PICS bags and in farmers' storage. A round yellow variety was the most damaged. The profitability of using the PICS bag for bean storage depended on the variety's market value, its vulnerability to damage, and its susceptibility to insects. Of three varieties examined, the technology was profitable for only one – oval yellow variety 'Mwaspenjele' – which trades off storability, nutritional value, and economic value (i.e., it was neither best nor worst for these traits).

The presence of insect activity highlights the importance of sound handling and management of the technologies by farmers

Mechanization

Bedilu Desta, one of the service providers, familiarizing himself to the two-wheel tractor

Mechanization can be a key part of the sustainable intensification of agriculture at all scales from smallholders to multinational conglomerates cropping thousands of hectares. Tractor-operated implements are key machinery promoted by Africa RISING, especially the versatile two-wheel tractor (2WT).

In Tanzania, tractor-driven rip tillage increased maize grain yield (over 52% yield advantage) irrespective of variety, although biomass yield did not follow this trend. The yield differences are attributed to lower soil bulk density after ripping, allowing better root development, increased infiltration (over 100%), and soil water retention at greater depths. Rainwater use efficiency was increased about 1.4-fold with rip tillage. Generally, low grain yields in 2019 were attributed to prolonged drought spell during the growing season.

Overall, hiring two-wheel-tractor-based services can be profitable for smallholders

The Ethiopian Highlands project demonstrated the use of the 2WT and various accessories, including no-till planters for wheat, teff (*Eragrostis tef*), and maize; wheat harvesters; maize shellers; threshers for wheat, barley, and teff; trailers for transportation; and water pumps for irrigation. Economic benefits were a 78% gross margin increment per hectare for smallholder farmers who hired 2WT-based technologies such as direct planting, harvesting, threshing, and transportation compared with farmers using conventional crop establishment methods (animal draft power and manual labor). Gross margin gains depended on the range of 2WT technologies hired. The gross margin was greater, for example, when farmers hired a combination of four 2WT services (wheat planter, harvester, thresher, trailer), but it decreased to less than 10% for those who hired only one 2WT service.

The 2WT direct-seeded practice gave statistically non-significant (P=0.06) marginally higher wheat grain yield compared with the draft animal conventional plowing across sites, and 10% more wheat grain compared with conventional plowing. The

2WT practice gave 16% more maize grain than the conventional one.

Overall, hiring 2WT-based services can be profitable for smallholders.

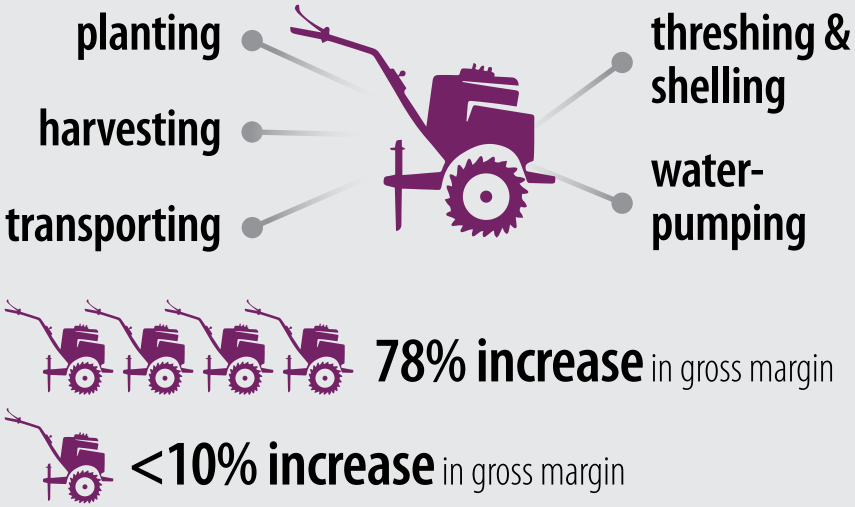
Field days in maize-growing areas and in the wheat belt created awareness among smallholders on small mechanization options available in Ethiopia. The field days also targeted extension agents who work with the farmers. A total of 52 farmers (13 women) participated.

For most youth service-provider groups in Ethiopia, membership has decreased since their establishment in 2017, mainly because of more lucrative employment opportunities elsewhere. Youth employment creation through mechanization service provision has to be competitive to retain youth in agriculture.

Business-minded and enterprising individuals are the best service providers for 2WT-based technologies in rural communities. They invest time in seeking business opportunities, and frequently maintain their equipment.

It is critical to assess which 2WT-based equipment set will make business sense for service providers in the different regions.

TWO-WHEEL TRACTOR IN ETHIOPIA



Demonstration of the maize shelling machine at Duko Community

It is critical to assess which 2WT-based equipment set will make business sense for service providers in the different regions

In Ghana, Africa RISING's mechanization efforts have been through the promotion of small-scale maize-shelling machines to the farmers. The project introduced both diesel (4 hp engine capacity) and electric (1.5 hp) machines to farmers. A socioeconomic study was then carried out for the two machine types and it was established that both increase labor efficiency among smallholders and save costs. Farmers can save up to 36 hours per ton of maize shelled when they use the shelling machines. Africa RISING is building the capacity of farmer groups to be able to use these machines equitably and maintain them well for the longer term, as well as establishing a business model for service provision at community level. Farmers have been trained on the operation, maintenance, and how to put in place and apply collective agreements for sharing maize-shelling machines. While the tradition of sharing tools, seeds, and infrastructure is well established within most African smallholder communities, the reality of farmer group dynamics, rationale for sharing, repair, and maintenance can often derail group aspirations if not handled in an open and honest manner. As part of the mentoring process for the farmers' groups, Africa RISING has advised them on some minimum requirements for the groups receiving the shelling machines. These include the groups having a formal constitution, contributing at least 25% of the machines estimated market value (about 800 Ghanaian cedis [US$ 148]), ensuring gender balance in leadership, and linkage to local artisans who may provide professional support such as maintenance, adaptation, and repair services.

Developing and deploying ICTs, including decision-support tools

Using a drone as a means of quantifying primary productivity and carbon stocks through NDVI imaging to gain deeper understanding of cropping systems beyond the biophysical elements

Information and communications technologies (ICTs) are invaluable in modern agriculture. Computer-based simulation models enable researchers and extension workers to predict how a crop is going to perform under certain conditions, and to predict the best management practices as a season unfolds. Recommendation domains and maps allow development actors to target new areas with proven technologies. Mobile ICTs allow farmers to connect with information on farm management and marketing at appropriate points of the season. And videos are now a proven way of training (especially illiterate) farmers in new techniques. Differential access to ICT between men and women is an important consideration, as is government policy and support for ICT use.

An MSc student from Wageningen University and Research in the Netherlands applied the FarmDESIGN model to explore trade-offs and synergies for sustainable intensification of smallholder farms. Mixed farming systems in Kiteto and Kongwa districts in Tanzania are experiencing the effects of climate variability and change, and a scarcity of farming land due to population growth. The area is affected by soil erosion and prolonged drought periods, which lower crop and animal production. As a result, most farmers experience poverty and food and nutrition insecurity. To improve the situation, Africa RISING introduced the intercrop of maize (Meru Hybrid 513) and pigeon pea, and monocrops of tomato, traditional African nightshade, amaranths (*Amaranthus*, including TZSMN 102-Sel), and *Gliricidia*. The study involved field visits, surveys, and a participatory workshop focused on interactive simulation modeling (FarmDESIGN), and tested the performance of interventions in small, medium-sized, and large farms. The operating profit and vitamin A yield could be improved for small and large farms (but not medium-sized farms), either with or without interventions. Improvements in soil organic matter (SOM) balance and household leisure time decreased when

Differential access to ICT between men and women is an important consideration, as is government policy and support for ICT use

interventions were introduced, due to the strong trade-offs between operating profits and SOM balance, and between operating profits and household leisure time. The adoption of tomato, for example, brings more profits, but it is labor intensive. Conversely, there was synergy between operating profits and vitamin A yield. For medium-sized and large farms, the model adopted tomato as an alternative crop for income generation; for small farms, maize–pigeon pea intercrop and African nightshade were adopted for better SOM balance and vitamin A yield. The number of large ruminants was slightly increased to increase production of milk, meat, and manure on the farm. Farmers were involved in interactive simulation modeling, were free to ask for and make suggestions, and selected their own preferred alternative farm configurations based on their objectives. Model results led to the conclusion that the adoption of interventions depends on the farm's level of resource endowments, and that the model is an effective tool for assessing the performance of interventions and for the redesign of farms for sustainable intensification of farming systems.

For central Tanzania, cereal (sorghum and pearl millet) and legume (pigeon pea and groundnut) grain yields simulated by the Agricultural Production Systems Simulator (APSIM) approximated the observed yields, indicating that APSIM can predict cereal response to intercropping. In low-potential sites, pigeon pea grain yield was reduced by up to 30% in intercrop with sorghum, especially with long-duration pigeon pea. In pigeon pea–groundnut doubled-up cropping systems, the faster-establishing groundnut used up most of the available water resources, especially under drought, resulting in reduced pigeon pea yields.

APSIM modeling showed that adopting pigeon pea–sorghum and pigeon pea–groundnut intercrops in central Tanzania can reduce the risk of crop production. Integrating pigeon pea into the cereal-based cropping systems also increases total soil carbon over time. Practical experimentation with smallholders is advocated to allow resource-limited farmers to determine which cereal–legume systems suit their conditions to build soil fertility while providing immediate household needs.

Africa RISING and partners are developing a crop-planning decision matrix that links soil characteristics and planting dates, to share with end users. The emphasis is on managing the agricultural calendar as a coping mechanism for climate variability. Field observations in recent years show that farmer planning is becoming increasingly haphazard, but if done well, offers numerous dividends (e.g., early crop vigor, drought avoidance, tolerance to pests and diseases).

APSIM modeling showed that adopting pigeon pea–sorghum and pigeon pea–groundnut intercrops in central Tanzania can reduce the risk of crop production

Data on maize yields and agronomic practices from long-term trials on conservation agriculture in Malawi, Mozambique, Zambia, and Zimbabwe conducted by the International Maize and Wheat Improvement Center (CIMMYT); climatic layers, soil chemical and physical properties, and socioeconomic layers from open-source databases; and satellite rainfall data from Climate Hazards group Infrared Precipitation with Stations version 2 (CHIRPS-v2) databases, were used to develop maps on rainfall trends and variability, to be used as inputs to delineate recommendation domains for conservation agriculture practices in East and Southern Africa.

To map fodder trees and grass forage, a spatially explicit land degradation index (LDI) is being developed for two districts of central Tanzania. The LDI map is expected to guide spatial targeting of land rehabilitation programs using agroforestry and other soil and water conservation practices. Over the past 15 years, land productivity has declined for over 70% of the land, and croplands are the most affected by degradation.

Results from maize–legume cropping mapping for central Tanzania show a significant reduction in rainfall for October–May, and a consistent significant warming trend across two districts for nine months (most severe in December); these will increase the moisture and heat stress that could reduce agricultural productivity.

Maps of the extrapolation suitability index (ESI) for Babati District, Tanzania, were generated from 11 biophysical and socioeconomic variables. The ESI maps represent the risk of extrapolating a specific variety with the IMP package to achieve the target average yield and benefit–cost ratio. The lower the ESI, the more similar a particular location is to the reference sites and therefore the more suitable it is for the same package to be applied (i.e., it has a greater potential of achieving the target yield). The ESI maps are necessary to guide scaling up interventions, but do not represent all the variables that may hinder suitability of a given technology package.

A map of agroclimatic zones (ACZs) of East and Southern Africa region was produced using monthly time series of gridded climate layers from the TerraClimate database. The input data included monthly precipitation, actual evapotranspiration, minimum temperature, maximum temperature, and the digital elevation model. The climate layers had monthly temporal resolution for the period 1981 to 2017, giving 444 layers to the time series for each input variable. The long-term monthly time series facilitated the capture of fine-scale climate variability. The dimensions of the time-series variables were reduced using principle components analysis. The refined map of ACZs is expected to improve the spatial targeting of agricultural technology options and other climate-dependent activities.

A map of ACZs has been developed for six west African countries (Benin, Burkina Faso, Côte d'Ivoire, Ghana, Mali, Togo) using long-term (37 years) monthly time-series data (Fig. E). The work delineated 150 distinct ACZs.

The project has produced the first wheat probability map with nitrogen fertilizer application at a fixed rate of 60 N kg/ha as part of the process to produce yield probability maps for selected crops in the Ethiopian Highlands.

To scale out promising technologies to link farmers to markets beyond the Africa RISING target sites in Tanzania, the project is providing advice on agronomy, climate services, and market information via mobile phone. Interactive videos (in the Swahili language) for training were also used to improve knowledge transfer to farmers.

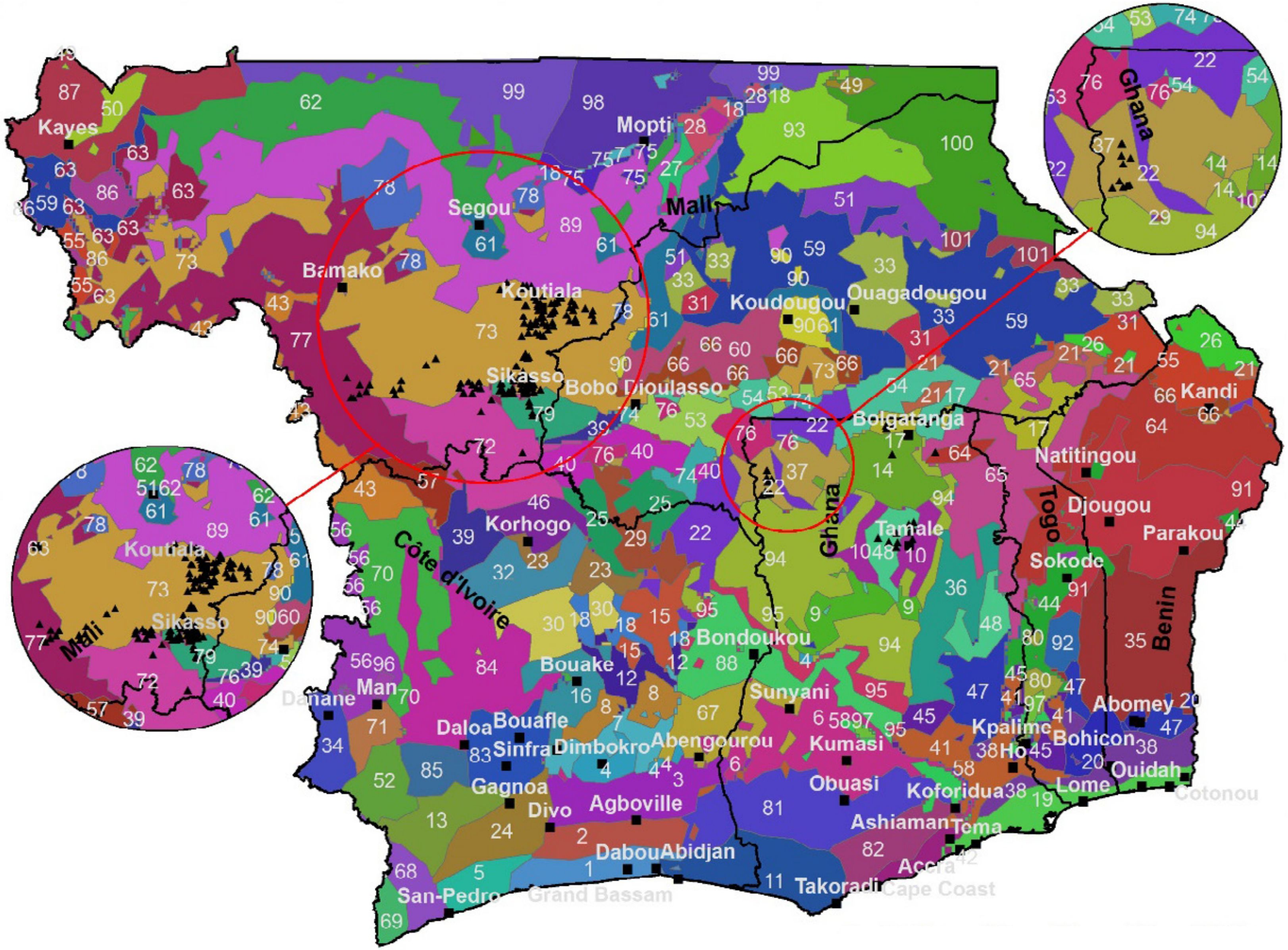
More than 2,200 smallholder farmers (30% women) in Babati District, Tanzania, were reached using SMS information services (agri-tips on harvest, postharvest technologies, and storage and marketing tips). The low number of registered women farmers may be attributed to mobile phone ownership, which is skewed in favor of men by cultural and socioeconomic factors. The project is engaging with partners to tailor messages to the farmers' needs to provide reliable, relevant, and timely information on postharvest interventions and livestock activities.

The refined map of agroclimatic zones is expected to improve the spatial targeting of agricultural technology options and other climate-dependent activities

The project updated the decision-support MWANGA Platform's database with farmers in the Southern Highlands of Tanzania. This now functional Android-based platform hosts educative videos, and links partners in the area with Manyara Region farmers. Some 11,146 farmers have been brought into the database platform.

The World Overview of Conservation Approaches and Technologies (WOCAT) global network was established in 1992 with the aim of compiling, documenting, evaluating, sharing, disseminating, and applying sustainable land management (SLM) knowledge. The United Nations Convention to Combat Desertification (UNCCD) officially recommends WOCAT as the primary global database for SLM best practices. It has various members (individuals, countries, institutes, etc.) that contribute finance and knowledge. Given that a tremendous amount of SLM-related data are available in Ethiopia, EthiOCAT was initiated, but did not materialize. When the International Center for Tropical Agriculture (CIAT) hosted WOCAT, team members from the Sustainable Land Management Program and other institutions agreed to reinstate EthiOCAT. Africa RISING took the initiative to support that exercise, reviewing the WOCAT guidelines with a view to adapting them for the Ethiopian context. The project also initiated discussions on how to migrate some WOCAT content to EthiOCAT. Once EthiOCAT is operational, the project will develop a visualization tool to give users a quick overview of SLM interventions.

Figure E. Map of agroclimatic zones across six West African countries (inset: detail)



■ *Major town* ▲ *Africa RISING demonstration sites* □ *International boundary*

0 100 200 300 400 500 km

Capacity building

EAST AND SOUTHERN AFRICA

Total 5,015 beneficiaries (2,841 women) of short training and field days (farmers, extension workers, IOP staff, councilors, Strengthening Agricultural and Nutrition Extension), plus around 800 farmers at seed and trade fair

1 PhD, 4 Master's, 1 BSc

WEST AFRICA

Total 1,248 beneficiaries (over 450 women) of short training and meetings (farmers, extension, assembly men, chiefs)

8 PhD, 10 Master's, 2 BSc

ETHIOPIAN HIGHLANDS

Total 5,309 beneficiaries (all types)

6 PhD, 2 Master's

Note that total numbers of beneficiaries (especially farmers) are best estimates, as so many have attended open events.

Program monitoring and evaluation, and learning agenda

Monitoring and evaluation (M&E), and more general learning, are key elements of adaptive research for development. We need to know that we are on track with our set targets, be they at program, project, national, district, or farm level. We also need to identify where our protocols and approaches need to be adjusted to improve impact.

Two feedback workshops were held to share results and lessons learned from the 2018/19 on-farm trials and to get feedback from farmers on technology performance in Malawi. Participants included farmers, chiefs, local extension workers, members of the Agriculture Extension Coordination Committee (DAECC), and staff from the District Agriculture Offices of Machinga and Dedza. Giving back results to farmers included presentations by host farmers and researchers. During the presentations, participants asked questions and shared comments on key lessons and observations. For example, farmers were able to express their understanding of the role of legume biomass in improving soil fertility. In particular, double-row planting for both soybean and groundnut resulting in better productivity and improving soil fertility.

The project had increased experimentation by farmers, as former 'baby' farmers considered themselves 'mother' farmers after many years of experimentation. The level of confidence was evident from the coherent explanations given for virtually all the agronomic questions asked.

Men and women agreed that the greatest labor demands were associated with land preparation, principally making ridges. Double-row planting has minimal additional labor, but of more concern to farmers was the additional seed requirements with double-row planting. Farmers welcomed the community seed production initiated by Africa RISING, which had resulted in more quality seed being produced locally.

Women farmers noted increased consumption of healthy foods linked to soybean and groundnut processing – a direct result of Africa RISING interventions.

The International Food Policy Research Institute (IFPRI) organized program-level training in late 2018 for Africa RISING researchers to address three complementary topics related with data management and project monitoring: the system of data management through the program's online platform (Dataverse); data entry and report creation using the online project mapping and monitoring tool; and the use of various offline project monitoring tools, including the Beneficiary and Technology Tracking Tool. IFPRI and the East and Southern Africa (ESA) M&E officer led a discussion on various M&E-related issues during the 2019 ESA Review and Planning Meeting. Topics discussed included 'Feed the Future' and custom indicators, monitoring of different types of program beneficiaries, and program data management.

Women farmers noted increased consumption of healthy foods linked to soybean and groundnut processing – a direct result of Africa RISING interventions

IFPRI continued to manage program-generated data through the program platform, which mainly involved the verification and uploading of data shared by researchers and facilitation of data requests. To further enhance data management and the use of program-generated data by authorized users, IFPRI introduced an online data user agreement through Dataverse using a Google form. The form has enabled data owners and the M&E team to track requests of restricted (non-public) datasets on Dataverse more efficiently. The Africa RISING page on Dataverse has also been linked to the United States Academic Decathlon's Data Development Library. IFPRI collaborated with Africa RISING researchers to compile Feed the Future indicators data for the 2019 financial year that were later aggregated and submitted to the Feed the Future Monitoring System.

On the evaluation side, IFPRI collaborated and Africa RISING researchers in Malawi on the implementation of the Malawi Africa RISING follow-up evaluation survey in late 2019. Follow-up data will be combined with baseline data collected from the same households in 2013 to analyze the impact of the program on long-term agronomic and economic outcomes using panel data technique. The follow-up survey used a streamlined version of models implemented at baseline, including household demographics, agricultural production and sales, food security and consumption, as well as anthropometrics for children under the age of five and women of reproductive age. Special attention was devoted to assessing the plot-level adoption of different sustainable practices in the most recent growing season, and to collecting retrospective adoption data.

In another collaborative work between IFPRI and Zambia Africa RISING researchers, both bottom-up and top-down approaches are used to assess the ex ante effects of conservation agriculture-based systems, taking into consideration both biophysical and economic factors and characteristics of prevailing farm systems (Komarek et al. 2019). The study evaluated the returns to a CA-based system of no-tillage with crop residue retention against returns to a control system of conventional tillage with crop residue removal with an additional spatial farm typology analysis to better understand the spatial variation in field-scale indicators and provide insights into trade-offs and suitability. The study has documented a significant variation in yields from CA-based system, which highlights the need to couple biophysical and economic approaches to a more rigorous assessment of economic returns. Results from the spatial farm typology analysis also highlighted the context specificity of the suitability of CA.

A data collection officer interviews a farmer in central Malawi

EXTERNAL REVIEW

A program-wide external review was commissioned by the Africa RISING Program Coordination Team. A three-member review team comprising Christine Negra (team leader, PhD, plant and soil science), Mark Powell (team member, Professor, soil science), and Nancy McCarthy (team member, PhD, agriculture and resource economics) conducted field visits to Ghana and Mali in September 2019. In both countries, the team visited community technology parks and upscaling fields, and had multiple interactions with partners, including farmer-based organizations, to assess the scientific quality of Africa RISING research and how it is perceived by the end-users (target beneficiaries) and partners. Subsequent visits to Ethiopia, and Malawi and Tanzania took place in October 2019, and January–February 2020, respectively.

PROGRAM-WIDE LEARNING

Two important events aimed at advancing program-wide learning were held: (i) the Annual Africa RISING Learning Event, and (ii) a program-wide partners' exchange visit to Ghana. The Learning Event was held in Lilongwe, Malawi on 5–8 February 2019, attracting the participation of 60 implementing partners from the six Africa RISING countries. Discussions and activities focused on three learning outcomes: sharing experiences on the implementation of the Sustainable Intensification Assessment Framework, gaining common understanding of terminologies used within the Africa RISING program, and sharing experiences about the implementation of systems research for agriculture in practice. The program-wide exchange visit took place on 17–21 June with the objective of exchanging lessons and cross-regional experiences on livestock feeding, human nutrition, irrigated vegetable production, soil and water management, and mechanization. Partners visited project sites in northern Ghana and held discussions with farmers as part of broader reflection and learning. A direct output of the exchange visit was the drafting of manuscripts for cross-regional peer-reviewed journal articles.

Collaborating with development partners

While Africa RISING is a program managed by three CGIAR Centers and supported by USAID, the work on the ground would be impossible without the collaboration of research and implementation partners. These include donors, international research and development organizations, international and national NGOs, the private sector, governmental agencies, and civil society organizations – some of which are highlighted in this section.

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and CARE Mali signed a collaborative agreement to disseminate technologies in 82 villages in 12 watersheds in Mopti Region – after technologies widely utilized by bilateral projects in Mali had been validated by Africa RISING. Technology parks will be established to reach a total of 7,500 farmers. Discussion is ongoing among World Agroforestry Centre, International Livestock Research Institute (ILRI), ICRISAT, CARE Mali, and the United States Agency for International Development (USAID) Mali mission to prepare a long-term research-for-development proposal to scale out Africa RISING-validated technologies widely in Mopti Region.

Lead research partner, CIMMYT, is supporting the scaling up activities of Catholic Relief Services (CRS) in Zambia for green manure cover crops (GMCCs) by providing technical knowledge and building expertise. This year, Africa RISING involved senior agriculture officers and the provincial agriculture coordinators in field tours for new strategies and technologies. A new European Union-funded project will continue to scale up some of the GMCC and agroforestry technologies. A large Green Climate Fund project, in which CRS is a lead designer, will also support scaling out. Over about five years, CRS has reached 4,647 farmers producing pigeon pea in eastern Zambia. More farmers (potentially up to 12,167) were reached through 28 community-based sensitization meetings, community-based training, and 12 field days; and 40 agriculture development agents (8 of them women) were trained in facilitating pigeon pea production and marketing.

In two years of project support given to production and market linkages, farmers on average produced 73 kg of pigeon pea per season, of which 77% (41 kg) was delivered to the bulking centers for marketing. Of the 4,647 farmers reached by the project, 988 (23%) were linked to a pigeon pea buyer. The total quantity of the marketed commodity was 63,827 kg, valued at 214,003 kwacha (around US$ 20,370), and translating into an average net income of 216 kwacha (about US$ 21) per farmer – compared with around 114 kwacha (about US$ 11) pre-intervention.

Africa RISING's work on the ground would be impossible without the collaboration of research and implementation partners

The project is in partnership with **Esoko** (a provider of digital solutions for agriculture) in Tanzania, to take the MWANGA platform (see under 'Developing and deploying ICTs,' p.30) forward, to ensure accurate representation for Tanzania's Southern Highlands farmers.

Partnership with **Islands of Peace** (IoP, a Belgian NGO promoting sustainable family farming and responsible food systems) in Karatu District, Tanzania, is scaling out postharvest management technologies to contribute to food and nutrition security through improved handling, processing, and storage of harvested produce. The partnership transfers validated technologies to farmers, processors, and other stakeholders for improved postharvest management. Some 192 farmers and 21 extension workers in 8 villages were trained on improved postharvest management practices. For details of storage bag trials, see under 'Improving food safety and reducing food waste' (p.23).

Postharvest technologies were demonstrated, and technology briefs and brochures distributed at the IoP-organized Local Seed and Food Fair in Karatu as part of the IoP consortium seed advocacy and sensitization strategy. The aim was to create awareness of the positive qualities of the use of local seed. The fair provided an opportunity to showcase Africa RISING postharvest technologies to more than 800 attendees.

The partnership with IoP in Tanzania also scales out improved vegetable varieties and management practices for improved varieties of tomato, African nightshade, and Ethiopian mustard (see under 'Manipulating crop ecology to get more from limited resources,' p.7). Lead research partner, World Vegetable Center (WorldVeg), conducted awareness-raising meetings, trained IoP staff in raising seedlings for the demonstrations and, together with IoP, identified demonstration host farmers.

Africa RISING conducted postharvest training to equip the 28 IoP staff (11 women) with skills and knowledge for maintaining quality and safety (appearance, texture, flavor, nutritive value) and to reduce losses between harvest and consumption. These technologies will be scaled up to 800 households.

Africa RISING is partnering with **Mboga na Matunda** (MnM) project and **Tanzania Horticultural Association** in Zanzibar and Arusha Region to scale up technologies validated in Babati during Africa RISING Phase I. MnM is targeting 1,000 households in Zanzibar.

ICRISAT AND CARE MALI, MOPTI REGION

82 villages

in **12** watersheds

and using technology parks to reach **7,500** farmers

MARKET LINKAGES, ZAMBIA

73 kg pigeon pea production per farmer, of which

77% delivered to bulking center

4,647 farmers, of which 988 linked to buyers

total **63,827 kg** pigeon pea produced, equating to

$20,370 or **$21** per farmer (net)

Michigan State University implemented the Africa RISING project on global climate change mitigation in Zambia. A participatory system-dynamics model demonstrated that agricultural expansion currently contributes to forest loss, but charcoal production will soon become the primary driver of deforestation. Agricultural expansion is driven by rural population growth, rather than by low yields or land abandonment. Charcoal production is driven by urban population growth and energy demand. Charcoal production dominates in Lusaka Province throughout the 50-year simulation time, primarily as a result of growing urban demand. By contrast, agricultural expansion dominates in Eastern Province until about 2045, at which point charcoal production becomes the dominant driver of deforestation.

There is no evidence of linkages between the adoption of sustainable intensification practices (e.g., conservation agriculture and agroforestry) and landscape-level environmental objectives in terms of climate change mitigation, forest protection, and wildlife conservation. There is theoretical and empirical evidence that agriculture can have negative impacts on wildlife when promoted in areas where human–wildlife conflict is likely, but this is related to the encouragement of agricultural activities in sensitive areas more generally, not the promotion of sustainable intensification or conservation agriculture specifically.

The project is in partnership with **Seed Producers Association of Ghana** (SEEDPAG) and WorldCover to scale out the production of quality seeds of quality protein maize (QPM) varieties at community level through a business model where community seed growers produce certified seeds for SEEDPAG. Africa RISING provided initial inputs (foundation seeds, fertilizer) at a cost that will be recovered during the purchase of seeds for the next cropping season. SEEDPAG trained farmers on seed production, and registered and used them as community out-growers to produce certified seeds. WorldCover insured farmers against crop failure from disaster (e.g., drought) to make farmers less risk-averse. This activity was carried out in three districts of Northern Region with a total of 112 acres (45 ha) of land cultivated for certified seed.

Sustainable Intensification Innovation Lab (Tamale, Ghana) invited the chief scientist of the West Africa Project to a stakeholders' workshop to develop knowledge-sharing centers and learning alliances within existing local and regional institutions. Africa RISING will share past data sets, and intends to use Duko Technology Park, a well-fenced property of more than 10 acres (4 ha), as a one-stop go-to area for the region. The first activity will be to showcase past and current Africa RISING technologies. The irrigation facilities are being revitalized, there are ongoing forage–fodder trials, and demonstrations of sorghum variety 'Soubatimi' and of the use of feed troughs. There will also be dry-season vegetable cultivation once the irrigation facilities are working.

CIMMYT and **Total LandCare** (TLC) have built a strong linkage between research and development for promoting conservation agriculture (CA) systems to smallholder farmers in Malawi, Zambia, and Zimbabwe. TLC is organizing field tours to CA demonstrations and research trials, and features that were broadcast on national radio and Zodiac Radio. More than 200,000 farmers are now practicing various kinds of CA systems thanks to long-term engagement. With support from the **Royal Norwegian Embassy**, CIMMYT and TLC are moving into smallholder mechanization: piloting two-wheel tractors in Mzimba, north-central Malawi.

Collaboration has been initiated with the Youth Mappers from the **University of Cape Coast** to geo-reference all Africa RISING trials in Ghana and map out the activities that help to identify specific crop locations, areas, and farm sizes.

PROJECT REACH IN THE ETHIOPIAN HIGHLANDS

70,172 households reached

of which **14% women**

covering **28,024 ha**

Training of trainers event for scaling of technologies and practices of the Africa RISING project in the Ethiopian Highlands

The Ethiopian Highlands project reached more than 70,172 households (14% female-headed) and covered 28,024 ha of land during the 2019 cropping season.

Africa RISING is engaging with seed companies to accelerate the scaling up of QPM seed in Tanzania, meeting with **Meru Agro Seed Company**, **MAMS Agriculture**, and **Aminata Quality Seeds** in Arusha to discuss partnerships for scaling out new drought-tolerant QPM hybrids. The two released QPM hybrids have already been allocated to Meru Agro, and therefore cannot be marketed by others. Thus, MAMS and Aminata were looking for new drought-tolerant or QPM hybrids; the new drought-tolerant hybrids being tested could eventually be allocated to these companies through the CIMMYT product-allocation process.

The program is collaborating with the **Ghana Department of Agriculture** and **University for Development Studies** (UDS) to train graduate students. The Animal Science Department of UDS is also helping to implement the feeding trial and fodder quality analysis. The project works with farmer groups in all intervention communities. Where such groups do not exist, Africa RISING farmers are encouraged to form one. The farmer groups participate in all the research activities in their communities.

As part of a South–South exchange visit to share experiences on the processes and modalities of landscape restoration, delegates from Makueni County, Kenya, visited landscape restoration sites in Ethiopia in December 2018, including the Africa RISING site in Gule watershed, where the project is partnering with Wukro Saint Mary College and Mekelle University.

EAST AND SOUTHERN AFRICA PROJECT PARTNERS

1. Agricultural Research Institute, Hombolo, Tanzania
2. Agricultural Research Institute, Naliendele, Tanzania
3. Agricultural Research Institute, Selian, Tanzania
4. Agriculture Development Division, Malawi
5. Alliance for a Green Revolution in Africa
6. Aminata Quality Seeds
7. Catholic Relief Services
8. Cereals market system development (Tanzania)
9. District Agriculture and Livestock Development Officers (Malawi)
10. Esoko
11. Grassroots Trust, Zambia
12. International Center for Agroforestry Research
13. International Center for Tropical Agriculture
14. International Crops Research Institute for the Semi-Arid Tropics
15. International Food Policy Research Institute
16. International Institute of Tropical Agriculture
17. International Livestock Research Institute
18. International Maize and Wheat Improvement Center
19. Islands of Peace
20. Lilongwe University of Agriculture and Natural Resources, Malawi
21. MAMS Agriculture
22. Mboga na Matunda
23. Meru Agro Seed Company
24. Michigan State University
25. Ministry of Agriculture, Tanzania
26. Minjingu Mines & Fertilizer Ltd
27. Royal Norwegian Embassy

28. Soils, Food and Healthy Communities, Malawi
29. Strengthening Agricultural Input and Output Markets
30. Tanzania Horticultural Association
31. Total LandCare (Malawi, Zambia, and Zimbabwe)
32. University of Dodoma, Tanzania
33. Wageningen University, The Netherlands
34. World Vegetable Center
35. Zambian Agriculture Research Institute

WEST AFRICA PROJECT PARTNERS

1. Animal Research Institute
2. Association Malienne d'Eveil et de Développement Durable
3. CARE International, including CARE Mali
4. Community-based organizations
5. Department of Agriculture (Ghana)
6. Fédération Nationale pour l'Agriculture Biologique et Équitable
7. Ghana Health Services
8. Innovation Lab for Small-scale Irrigation
9. Institut d'Economie Rurale
10. Institut Polytechnique Rural de Formation et de Recherche Appliquée Katibougou
11. International Center for Tropical Agriculture
12. International Crops Research Institute for the Semi-Arid Tropics
13. International Food Policy Research Institute
14. International Institute of Tropical Agriculture
15. International Livestock Research Institute
16. International Water Management Institute
17. Kwame Nkrumah University of Science and Technology
18. Legume Systems Research
19. Ministry of Food and Agriculture (Ghana)
20. Ministry of Health (Ghana)
21. Peace Corps
22. Science and Technology Policy Research Institute
23. Seed Producers Association of Ghana
24. Soybean Innovation Lab
25. Sustainable Intensification Innovation Lab
26. University for Development Studies (Ghana)
27. University of Cape Coast (Ghana)
28. Veterinary Services Division (Ghana)
29. Wageningen University and Research, The Netherlands
30. WorldCover
31. World Vegetable Center

ETHIOPIAN HIGHLANDS PROJECT PARTNERS

1. Amhara Cooperative
2. Amhara Region Agricultural Research Institute
3. Bioversity International
4. Butajira Fruit Tree Multiplication and Training Center
5. Debere Birhan University
6. Ethiopian Institute of Agricultural Research
7. Government of Ethiopia Agricultural Offices
8. InterAide France
9. International Center for Agricultural Research in the Dry Areas
10. International Center for Tropical Agriculture
11. International Crops Research Institute for the Semi-Arid Tropics
12. International Food Policy Research Institute
13. International Livestock Research Institute
14. International Maize and Wheat Improvement Center

15. International Water Management Institute
16. Madda Walabu University
17. Mekele University
18. Michew ATEVT college
19. Oromia Agricultural Research Institute
20. Oromia Cooperative
21. Oromia Seed Enterprise
22. Raya Brewery
23. Raya University
24. Relief Society of Tigray
25. Saint Mary ATEVT college
26. Send-a-Cow
27. SNNPR Cooperative
28. Southern Agricultural Research Institute
29. Tigray Agricultural Research Institute
30. Tigray Cooperative
31. Wachemo University
32. World Agroforestry Centre
33. World Vision

Publications

EAST AND SOUTHERN AFRICA

- 25 web titles
- 17 journal articles
- 10 reports

WEST AFRICA

- 11 web titles
- 2 journal articles
- 15 reports
- 2 videos
- 1 conference paper

ETHIOPIAN HIGHLANDS

- 12 web pieces
- 4 journal articles
- 4 theses
- 20 posters
- 1 brief
- 1 conference paper
- 9 presentations
- 1 report
- 1 video

References

International Livestock Research Institute. 2019. *Africa Research in Sustainable Intensification for the Next Generation Ethiopian Highlands project, technical report, 1 April–30 September 2019*. Nairobi, Kenya: International Livestock Research Institute. (Available from https://cgspace.cgiar.org/handle/10568/105739) (Accessed 27 May 2020).

International Livestock Research Institute. 2019. *Africa Research in Sustainable Intensification for the Next Generation in Ethiopian Highlands project, technical report, 01 October 2018–30 March 2019*. Nairobi, Kenya: International Livestock Research Institute. (Available from https://cgspace.cgiar.org/handle/10568/101120) (Accessed 27 May 2020).

International Institute of Tropical Agriculture. 2019. *Africa Research in Sustainable Intensification for the Next Generation: Sustainable intensification of key farming systems in the Sudan and Guinea Savannas of West Africa: Technical report, 1 April 2019–30 September 2019*. Ibadan, Nigeria: International Institute of Tropical Agriculture. (Available from https://cgspace.cgiar.org/handle/10568/106493) (Accessed 27 May 2020).

International Institute of Tropical Agriculture. 2019. *Africa Research in Sustainable Intensification for the Next Generation: Sustainable intensification of key farming systems in the Sudan and Guinea Savannas of West Africa: Technical report, 01 October 2018–31 March 2019*. Ibadan, Nigeria: International Institute of Tropical Agriculture. (Available from https://cgspace.cgiar.org/handle/10568/101627) (Accessed 27 May 2020).

International Institute of Tropical Agriculture. 2019. *Africa Research in Sustainable Intensification for the Next Generation: Sustainable intensification of key farming systems in East and Southern Africa: Technical report, 1 April 2019–30 September 2019*. Ibadan, Nigeria: International Institute of Tropical Agriculture. (Available from https://cgspace.cgiar.org/handle/10568/106494) (Accessed 27 May 2020).

International Institute of Tropical Agriculture. 2019. *Africa Research in Sustainable Intensification for the Next Generation: Sustainable intensification of key farming systems in East and Southern Africa: Technical report, 01 October 2018–31 March 2019*. Ibadan, Nigeria: International Institute of Tropical Agriculture. (Available from https://cgspace.cgiar.org/handle/10568/101630) (Accessed 27 May 2020).

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: 505–343. (Available from https://doi.org/10.1016/j.agsy.2019.04.001) (Accessed 27 May 2020).

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ABOUT AFRICA RISING

The Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) program comprises 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 currently in its second phase (since September 2016), the purpose of Africa RISING is 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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ILRI International Livestock Research Institute   IFPRI International Food Policy Research Institute   IITA Transforming African Agriculture