Africa Research in Sustainable Intensification for the Next Generation

Sustainable Intensification of Key Farming Systems in East and Southern Africa

Technical Report,
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The Africa Research In Sustainable Intensification for the Next Generation (Africa RISING) program comprises three research-in-development projects supported by the United States Agency for International Development (USAID) as part of the U.S. Government's Feed the Future initiative.

Through action research and development partnerships, Africa RISING is creating opportunities for smallholder farm households to move out of hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, particularly for women and children, and conserve or enhance the natural resource base.

The three regional projects are led by the International Institute of Tropical Agriculture (in West Africa and East and Southern Africa) and the International Livestock Research Institute (in the Ethiopian Highlands). The International Food Policy Research Institute leads the program's monitoring, evaluation and impact assessment.

Africa RISING appreciates support from the American people delivered through the USAID Feed the Future initiative. We also thank farmers and local partners at all sites for their contributions to the program.

Contents

Partners iii

Summary 1

Africa RISING ESA project action sites 3

Implemented work and achievements per research outcome 4

Outcome 1. Productivity, diversity, and income of crop–livestock systems in selected agroecologies enhanced under climate variability *4*

Output 1.1 Demand-driven, climate-smart, integrated crop–livestock research products (contextualized technologies) for improved productivity, diversified diets, and higher income piloted for specific typologies in target agroecologies 4

Output 1.2 Demand-driven, labor-saving, and gender-sensitive research products to reduce drudgery while increasing labor efficiency in the production cycle piloted for relevant typologies in target areas 27

Output 1.3. Tools (including ICT-based) and approaches for disseminating recommendations in relation to above research products, integrated in capacity development 29

Outcome 2. Natural resource integrity and resilience to climate change enhanced for the target communities and agroecologies *38*

Output 2.1 Demand-driven research products for enhancing soil, land, and water resource management to reduce household/community vulnerability and land degradation piloted in priority agroecologies 38

Output 2.2 Innovative options for soil, land and water management in selected farming systems demonstrated at strategically located learning sites 44

Outcome 3. Food and feed safety, nutritional quality, and income security of target smallholder families improved equitably (within households) *53*

Output 3.1 Demand-driven research products to reduce postharvest losses and improve food quality and safety piloted in target areas 53

Output 3.2 Nutritional quality due to increased accessibility and use of nutrient-dense crops by farmers improved 55

Outcome 4. Functionality of input and output markets and other institutions to deliver demand-driven sustainable intensification research products improved *58*

Output 4.1 Access to profitable markets for smallholder farming communities and priority value chains facilitated 58

Outcome 5. Partnerships for the scaling of sustainable intensification research products and innovations *66*

Output 5.1 Opportunities for the use and adoption of sustainable intensification technologies identified for relevant farm typologies 66

Output 5.2 Strategic partnerships with public and private initiatives for the diffusion and adoption of research products 89

Output 5.3 Gender-sensitive decision support tools for farmers to assess technology-associated risk and opportunities used by partners ... 99

Output 5.4: A technology adoption, monitoring, evaluation, and learning framework for use by the project team and scaling partners released [led by IFPRI and used by project partners] ... 100

Capacity building ... 103

Challenges and actions taken ... 107

Lessons learned ... 107

Communications and knowledge sharing ... 108

Selected reports and publications ... 109

Peer reviewed journal articles ... 109

Reports, training material, and briefs ... 110

Partners

ADD	Agriculture Development Division, Malawi
AGRA	Alliance for a Green Revolution in Africa
ARI-Naliendele	Agricultural Research Institute, Naliendele, Tanzania
ARI-Hombolo	Agricultural Research Institute, Hombolo, Tanzania
ARI-Selian	Agricultural Research Institute, Selian, Tanzania
CIAT	International Center for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Center
DALDO	District Agriculture and Livestock Development Officers (Malawi)
ICRAF	International Center for Agroforestry Research
ICRISAT	International Crops Research Institute for the Semi-arid Tropics
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
LUANAR	Lilongwe University of Agriculture and Natural Resources, Malawi
MSU	Michigan State University
MAFC	Ministry of Agriculture, Food, and Cooperatives, Tanzania
MERU- AGRO	MERU-AGRO Seed Co
MMFL	Minjingu Mines and Fertilizer Co
NAFAKA II	Cereals market system development (Tanzania)
SAIOMA	Strengthening Agricultural Input and Output Markets
SFHC	Soils, Food, and Healthy Communities, Malawi
TLC	Total Land Care (Zambia, Malawi)
UDOM	University of Dodoma, Tanzania
ZARI	Zambian Agriculture Research Institute
WU	Wageningen University, The Netherlands
WorldVeg	The World Vegetable Center

Summary

The field crop experiments established and reported in the last report had their intended data captured. Data of some of the studies have been analyzed and trends are given for the main four studies below.

Local adaptation of new crop varieties (Tanzania). The generated 2020-2021 cropping season data provides a comparison with that of the 2018-2019 cropping season. For legumes, the late planted shorter duration Spanish groundnut, Kongwa 560 (ICGV-SM 05650), still performed well compared to the local check variety, again confirming that promotion of short duration genotypes is the best option. For cereals, the late planted sorghum variety, IESV 23010 & pearl millet - P 8774, also performed well in the moderate potential areas in intercropping systems. This is critical to inform technology deployment in a production zone that receives intermittent to low rainfall. The seed value chain of these crops under-invested in by both private and public sectors and the informal seed systems predominate. The groundnut seed value chain study indicates that the key areas of intervention to revolutionize the chain include: strategic partnerships with key stakeholders linking farmers to markets to stimulate demand; provision of necessary basic infrastructure; innovative options to access credit; and strengthening of community institutions involved in seed production.

Long-term impacts of crop rotation (Malawi). Twelve (12) long-term on-farm cereal legume/rotation field experiments, some dating back to the 2012/2013 cropping, were maintained during the "legume phase" 2020/2021 cropping season. Maize grain yields for the continuous unfertilized maize were generally less than 1500 kg/ha, despite excellent non-nutrient related agronomic management practices. Maize yields were largest for both NPK and NPK+manure treatments, with no significant differences between these treatments. The traditional maize/pigeonpea treatment had significantly larger maize yields compared to the unfertilized maize, confirming this intercropping practice as a viable intensification strategy for resource constrained smallholder farmers.

Innovations of crop spatial arrangement (Tanzania). This involves growing of maize among either pigeonpea and/or beans in rotation. The yield of maize grown as pure crop after double-up legume was more than that in the intercropping systems, consistent with the improved nitrogen fixed of about 60 kg/ha in the double-up. Majority of men and women farmers rated Mbili Mbili as the best technology due to its profitability, increased household food security because of the different crop maturity periods, fodder provisioning from residues derived from the three crop species, fuel, and improvement of soil fertility by the legume component. Farmers that did not rate Mbili Mbili as the best considered two maize plants per hill (and topped at physiological maturity) as the best technology due to ease of weeding operations (due to 50 cm between plants instead of 25 cm in other systems). Toppings contribute to livestock feed.

Conservation Agriculture (Malawi and Zambia). All trials were harvested on time and results analyzed and summarized. Harvest results from Eastern Zambia clearly showed superior yield of the rotation treatments, which outperformed other treatments. In Central and Southern Malawi, the influence of heavy rains at the onset of cropping season, followed by an early tailing-off in February 2021, affected crop performance as grain filling was compromised. Detailed early, mid-season, and end-of-season evaluations were performed across five farming

communities. From the evaluation scores, there is a clear preference for CA systems with the more diversified CA+Maize/Pigeonpea-Groundnut/Pigeonpea rotation being the overall favourite. Trials were further used to calculate key performance indicators on productivity, profitability, social, and human indicators in collaboration with the agronomic and socio-economic teams. Soil analyses and infiltration measurements results are available but not yet analyzed. We expect to have all the data analyses finalized by end of October 2021 for the development of a five-domain manuscript for publication.

Several studies were survey-based. COVID-19 national standard operating procedures (SOPs) affected field survey operations leading to postponement or delays in delivery of planned outputs. In some cases, phone surveys were used to complement in-person interviews. Some of these studies are now being implemented presently after the ease of SOPs restrictions and will be continued during the 2021-2022 project year. Similarly, short-term capacity building and technology scaling operations were minimized.

The ESA Project committed 2020-2021 as a year of documentation, being a legacy of its achievements. There were 32 journal publications committed as deliverables in the year's project workplan. As of this report, 24 manuscripts have been published (13 during this reporting period) and 13 are to be submitted before the end of 2021. Where some of these were not reported in the last report, their abstracts (for published papers) and working abstracts (for those in the pipeline) are presented in this report. The low number of training and extension materials and briefs produced (only three) during this reporting period is offset by the significant progress towards the production of the "*Sustainable Agricultural Intensification: A handbook for practitioners in East and Southern Africa*". This handbook has been submitted to CABI's production department.

The project held a successful virtual review (2020/2021) and planning (2021/2022) meeting from 14 to 16 September 2021. In the review session, presentations were made for each of the project's sub-activities, based on the achievements toward the sub-activity deliverables and plans to address gaps, if any, to ensure completion. Plenary discussions followed each group of sub-activity presentations that formed an activity. During the planning session, teams were formed to plan and implement project-level cross-cutting research and review activities that mainly address evaluation of the project's impacts, including identifying priorities and gaps for guiding future SI research in ESA. Details of the meeting may be accessed at [ARESA2021 - africa-rising-wiki]

Africa RISING ESA project action sites

The East and Southern Africa (ESA)-wide geo-referenced sites are shown where Africa RISING was implementing either research activities or technology dissemination over the project time, updated to the current reporting period (Figure 1).

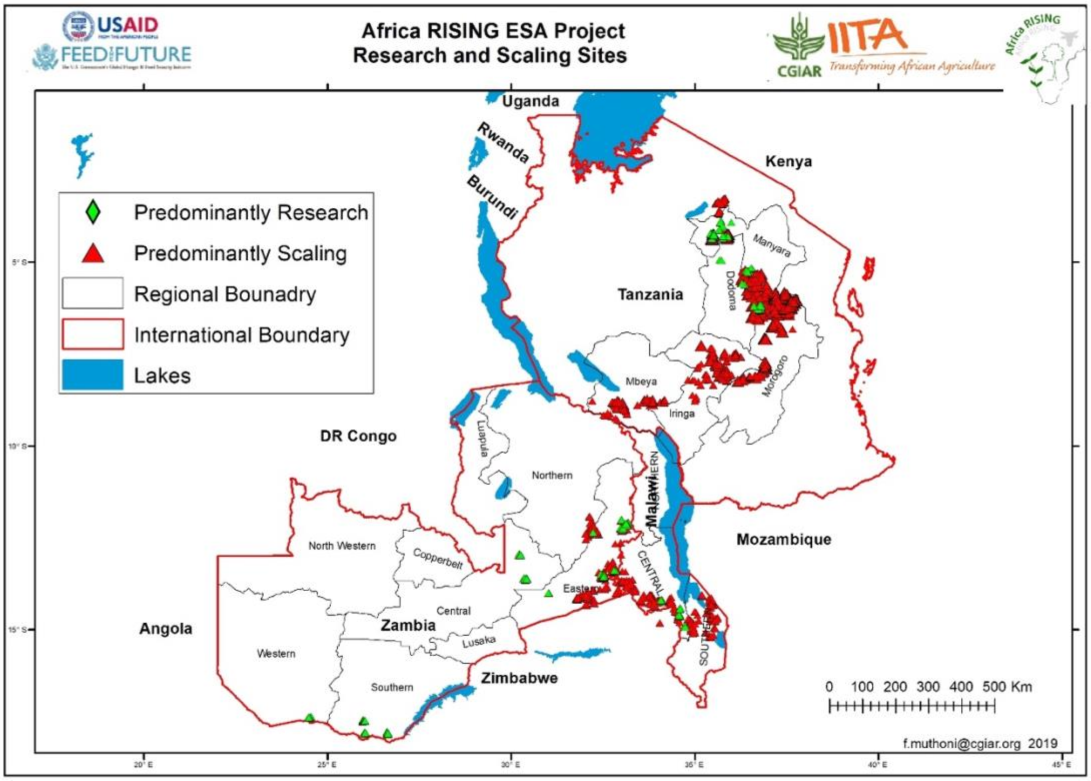
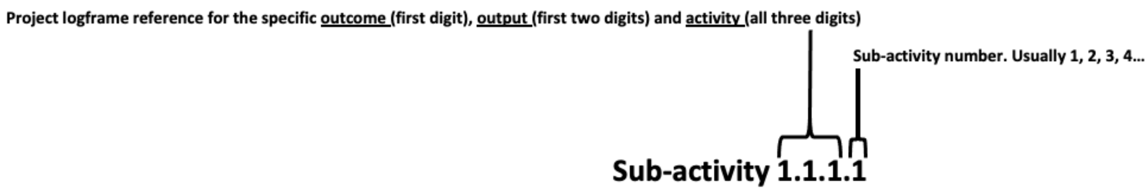


Figure 1: Locations where the Africa RISING–ESA Project has conducted research (green diamond) and scaling (red triangle).

Implemented work and achievements per research outcome

Each sub-activity in the report is preceded by a label code that is meant to help the reader to gain context about its alignment with specific outcomes, outputs and activities within the project logframe - https://hdl.handle.net/10568/82852. This label code is interpreted as shown below.



Outcome 1. Productivity, diversity, and income of crop–livestock systems in selected agroecologies enhanced under climate variability

Output 1.1 *Demand-driven, climate-smart, integrated crop–livestock research products (contextualized technologies) for improved productivity, diversified diets, and higher income piloted for specific typologies in target agroecologies*

Activity 1.1.1*: Assess and iteratively improve resilient crop-crop and crop-livestock integration systems*

Sub-activity 1.1.1.1: Validation of drought-tolerant maize (DT) hybrids under on-farm conditions in central Tanzania

The sub-activity evaluated 18 DT hybrids under on-farm conditions, from which four best performing hybrids were selected based on their yield and agronomic performance. These were also recommended to seed companies (who are key for scaling) to push for their release, targeting the drought-prone areas. Also, seven new Quality Protein Maize (QPM) were evaluated for their yield and agronomic performance under optimal and stress conditions (random stress). The new QPM hybrids proved to be good candidates to address biotic and abiotic, as well as nutritional challenges faced by the resource poor communities in central Tanzania. Field activities were concluded during the 2019/2020 period. The development of manuscripts for publication, which has been reported in previous reports, continued but progress has been slow. Consequently, new target dates for submission of these manuscripts to journals are proposed (see table below).

Targeted deliverables for 2020/2021 and status on achievements

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
Manuscript on new DT hybrids	Draft is ready; resolution of figures to be made before submission	Target submission date is 30 June 2021.	Recommended major revisions are being addressed. New target submission date: October 2021
Manuscript on QPM (from previous AR research)	Draft ready and under internal review	Target submission date is 30 June 2021.	Delayed, same reason as for DT hybrids. New Target submission date: October 2021
Superior DT hybrids suitable for farm-level production confirmed	Relayed in 2020 report to IITA	Activity completed	Information materials (brochures, leaflets) are under development, to be completed by March 2022.
Data uploaded to DataVerse	Delayed	Delayed	Upload targeted for October 2021
FtF indicators data upload	Data for 2020 submitted to the M&E Officer	No field activities; no set targets	NA

Sub-activity 1.1.1.2: Investigations on the medium to long term impacts of SI technologies on crop productivity at multi-locational fields

Twelve (12) long-term on-farm cereal-legume rotation experiments, some dating back to the 2012/2013 cropping were maintained for (a) investigating the medium to long-term impacts of SI technologies (i.e., improved soil fertility management, ISFM), improved germplasm, crop combinations, and nutrient and water management) on crop productivity on multi-ecology field sites; and (b) as a source of data for "water-limited yield potential" study, being required for the Case Studies' SI analyses on the Africa RISING impact – investigated under Sub-activity 5.1.1.4. The 2020/2021 season cropping activities were implemented successfully. Trials were established in December 2020 and harvested during April/May 2021.

The 2020/2021 cropping season was a 'legume phase' – meaning there are no data that show rotational effects. Data are, therefore, presented for the treatments that have maize each year since 2012. Maize grain yields for the continuous unfertilized maize were generally less than 1500 kg/ha, despite excellent non-nutrient related agronomic management practices. Maize yields were largest for both NPK and NPK+manure treatments, with no significant differences between them (Figure 2). The traditional maize/pigeonpea treatment had significantly larger maize yields compared to the unfertilized maize, confirming this intercropping practice as a viable intensification strategy for resource constrained smallholder farmers. As expected, the largest maize yields were obtained at the Linthipe site, which has the most favourable temperature for maize biomass accumulation and subsequent grain productivity. Yields of groundnuts ranged between 1300 and 1800 kg/ha while the yields of soyabean ranged 1112—1585 kg/ha, with Golomoti (least agroecological potential) achieving the lowest yields.
Two manuscripts relating to this study were published during this reporting period (see Deliverables Table below). It is expected that more papers will be generated from this long-term field study in the future.

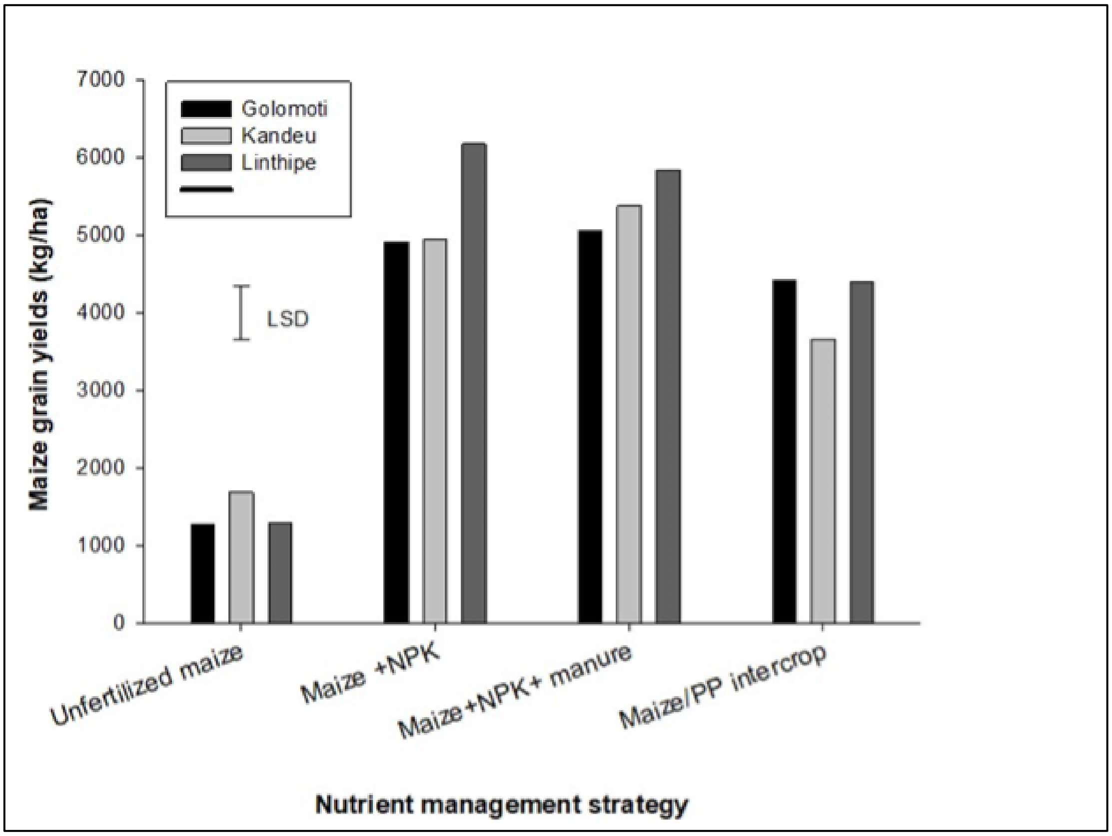


Figure 2. Maize productivity following different soil fertility management strategies across three locations that represent an agro-potential gradient, mostly defined by rainfall received and potential evapotranspiration (high rainfall, moderate evapotranspiration = high crop productivity potential). Golomoti is in the hot lakeshore zone, associated with high evapotranspiration and erratic rainfall; Linthipe is at high altitude with cooler temperature and reliable rainfall; and Kandeu has comparatively intermediate climatic conditions.

Targeted deliverables for 2020/2021 and status on achievements

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
Benefits of SI technologies evaluated across sites and documented.	Analysis of the generated data is ongoing. Some results are presented in this (2019/2020) report.	*Marginal more than mesic sites benefit from groundnut diversification of maize: increased yield, protein, stability, and profits:* submitted	Manuscript published. https://doi.org/10.1016/j.agee.2021.107585[1]
		Broadening farmer options through legume rotational and intercrop diversity in maize-based cropping systems of central Malawi: submitted	Manuscript published. https://doi.org/10.1016/j.fcr.2021.108225
Data uploaded to DataVerse	All data for 2020 uploaded.	NA	Data for 2021 to be submitted by October 2021
FtF indicators data submitted to M&E/IFPRI for upload	All FtF indicators for data for 2020 provided to M&E officer.	NA	Data for 2021 to be submitted by October 2021

[1] For more reference details on manuscripts published during this reporting period, please go to the Communications and Knowledge Sharing Section.

Sub-activity 1.1.1.3: Determining the productivity of groundnut as a function of seed generation × variety × density interactions in two contrasting agroecologies, and rotational benefits to maize

The objective of this work is to evaluate the effect of groundnut seed quality and plant density on groundnut productivity and quantify the rotational benefits to a subsequent maize crop in high and low potential agricultural zones in central and southern Malawi, respectively. Jester Kalumba successfully defended his MSc thesis '*Effect of seed generation, rhizobia inoculation and plant density on productivity and seed quality of soybean [Glycine max (l.) Merril] and groundnut [Arachis hypogea (l.)] in Dedza and Machinga districts of Malawi*'. The thesis abstract is given below. Drafting of a manuscript based on the research has been initiated, with June 2022 as the target date for publication.

Thesis abstract. Two on-farm, researcher-designed, farmer-managed trials were arranged in split-plot in a randomized complete block design (RCBD) with seed generation as main plot factor while inoculation and plant density were subplot factors for soybean and groundnut trials, respectively, in Dedza and Machinga districts in the 2017/2018 season. Following the field trials, screenhouse experiments were conducted at the Crop and Soil Sciences students' research farm at Bunda College to evaluate the effect of mother environment on seed quality of soybean and groundnut. This study was laid out in a completely randomized design (CRD). The overall objective of these trials was to investigate effects of seed generation, inoculation, plant density, and mother environment on soybean and groundnut productivity and seed quality.

In Machinga, soybean response to inoculation for BNF and grain yield was 67 percent ($p=0.002$) and 27 percent ($p=0.016$) higher in recycled than certified seed, respectively. In Dedza inoculating soybean significantly increased BNF by 74 percent ($p=0.004$) and grain yield by 21 percent ($p=0.029$), while planting certified soybean increased grain yield by 18 percent ($p=0.031$).

In Dedza, planting groundnut in twin rows increased BNF by 38.5 percent ($p=0.004$) and grain yield by 145.8 percent ($p<0.001$). In Machinga, planting groundnut in twin rows increased BNF by 32.5 percent ($p=0.025$) and grain yield by 87 percent ($p<0.001$). Because of poor germination for certified seed, a covariate analysis controlling plant density revealed that use of certified seed increased BNF and yield of groundnut ($p<0.001$). Results of screenhouse experiments showed that seed handling under different conditions significantly affected seed quality for soybean and groundnut. This indicates that appropriate seed production practices and handling are crucial for the successful production of grain legume crops.

Sub-activity 1.1.1.4: Exploring productivity of goats under controlled breeding and feeding regimes among young breeding female goats in the crop–livestock system in Malawi

The livestock component field activities run from 2016-2019. A summary from the MSc thesis of Charles Mkchutche is found in the last report. A manuscript has been published (http://www.lrrd.org/lrrd33/1/dmase3302.html), and the abstract is given below.

Abstract. Range forages consumed by free-range goats are commonly deficient in protein, energy, and minerals resulting in low productivity of the goats. The main objective of this study was to evaluate the effect of whole pumpkin seed meal supplemental diet on growth performance and semen quality of free-range goats. Thirty (30) Malawian local bucks, with an initial weight of 12.4±0.3 kg, aged six months were studied in a CRD. The treatments used were free grazing with supplemental diet of either pumpkin seed meal or soybean meal and grazing only. The supplementing diets were mixed with maize bran to make them comparable. These were offered to goats (500 g each goat) before grazing (7:00 am) in individual pens followed by free graze for 7 hours. The experiment ran for 150 days. The measurements included feed and refusals of the supplementing diet, live body weight, scrotal circumference, and semen quality characteristics. The intake of supplementing diets was high in bucks consuming soybean supplementing diet than pumpkin seed meal supplementing diet ($P = 0.0489$). Bucks supplemented with either soybean or pumpkin seed meal had higher final weight and average daily gain ($P < 0.05$) than the non-supplemented goats. However, the final live body weight and average daily gain did not differ ($P = 0.639$) between goats on soybean and pumpkin seed meal supplementing diets. The bucks supplemented with pumpkin seed meal had the widest scrotal circumference ($P < 0.05$) of all the treatments studied. Those fed with supplementing diet containing pumpkin seed meal had higher semen pH ($P < 0.05$) than bucks on sole grazing group and soybean supplementing diet. Bucks on pumpkin seed supplementing diet had the greatest scores ($P < 0.05$) on total sperm motility and progressive motility; and sperm concentration followed by the bucks on soybean and the bucks on grazing only had the lowest score. The whole pumpkin seed meal could be used to improve productive performance and semen quality characteristics of free-ranging bucks.

Sub-activity 1.1.1.5: Determining the productivity and resilience benefits of Gliricidia-based cropping systems

The main aim of this sub-activity was to assess crop yield, nutrient uptake, and resource use (fertilizer and rainwater) efficiency and profitability of maize/gliricidia intercropping in semi-arid conditions. Two manuscripts were published and presented in the last report. During this reporting period, one has been submitted (abstract/summary given below) and three are at different stages of development. A total of 30 000 seedlings of *G. sepium* has been produced and distributed to farmers in partnership with lead farmers and scaling partners (LEAD foundation and Farm Africa).

Hafner et al. 202x: Allometric equations for estimating on-farm fuel production of *Gliricidia sepium* and pigeonpea in semi-arid Tanzania: An abstract

Background: Fuelwood is the primary source of cooking energy in Tanzania. Due to deforestation, access to fuelwood is becoming more difficult. On-farm agroforestry systems can reduce dependency on off-farm fuel; however, the output of on-farm produced fuel is typically uncertain as production potentials are often not known. In this paper, we developed allometric equations to model absolute dry woody above-ground biomass (WAGB) production from intercropped *Gliricidia sepium* (Jacq.) Kunth ex Walp (Gliricidia) shrubs and *Cajanus cajan* (L.) Millsp. (pigeonpea) plants.

Methods: A destructive sampling approach was used, measuring the dendrometric characteristics root collar diameter at 20 cm stem height (RCD_{20}) and stem height to estimate WAGB. The models were based on 112 Gliricidia and 80 pigeonpea observations from annually pruned plants. Seven (7) allometric equations were fitted to derive best-fit models for WAGB production.

Results: We found that using a natural log-transformed linear model with RCD_{20} as a single predictor variable provides the highest explanatory value to estimate WAGB production (Gliricidia: $R^2 = 95.7$ percent, pigeonpea: $R^2 = 91.4$ percent), while meeting Ordinary Least

Square (OLS) estimator requirements. Adding stem height as an additional variable to predict WAGB production does not improve model accuracy enough to justify the extra work to include it.

Conclusions: While on-farm pigeonpea plants produce a stable amount of woody biomass per annum, annual fuelwood production from Gliricidia shrubs increases over the years. Compared with annual fuelwood consumption data from literature, our results show that on-farm produced fuelwood can substantially offset demand for off-farm fuel, potentially resulting in household fuelwood self-reliance.

Targeted deliverables for 2020/2021 and status on achievements

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
Manuscript on the nutritional interactions and resource-use efficiency in *G. sepium* intercropping	Collection of data on maize and pigeonpea grain and *G. sepium* wood is completed. Processing of soil fertility and pigeonpea wood data is in progress.	Data analysis and manuscript development	Manuscript is still under development. Proposed submission date: April 2022
Manuscript on intercropping performance under drought conditions (new)	Submitted	Published https://doi.org/10.3389/fsufs.2020.562663	NA
Manuscript on profitability of *Gliricidia* intercropping experiment at Manyusi	Data processing and manuscript development are in progress (by a PhD student)	A draft manuscript "***Ex-ante modelling: Profitability of Gliricidia-Maize system in selected dryland areas of Dodoma region in Tanzania"*** has been completed and shared with co-authors for comments. Submission target date: 30 September	Delayed submission. New proposed date is December 2021.
Data on the adoption and socio-economic impacts of agroforestry technologies	Paper on predicting agroforestry adoption using the ADOPT model was published https://doi.org/10.3390/agriculture10070306	Processing and analysis of data for follow-on paper on adoption is in progress	Target submission date: April 2022
Data and manuscript on the biomass equation for predicting wood and foliage biomass in intercropped *G. sepium* and pigeonpea	Data processing and manuscript development	Continuing manuscript development	Accepted for publication in Journal of Energy, Sustainability, and Society. Abstract is presented above.
Manuscript on cooking energy security (new)	Submitted	Published: https://doi.org/10.1016/j.esd.2020.10.012	NA

Two flyers on "Productivity and Economic benefits of maize-*Gliricidia* intercropping" and on "Integration of agroforestry and efficient cooking stove to enhance biomass energy security" were produced in English and Swahili	Preparation starts during next reporting period	Drafting in progress	Draft flyers are available in both English and Swahili. Final versions to be produced by May 2022.
Data uploaded to DataVerse	Data for 2020 was uploaded		Data for 2021 targeted for October 2021
FtF indicators data submitted to M&E/IFPRI for upload	Data for 2020 was submitted		Data for 2021 targeted for October 2021

Sub-activity 1.1.1.6: Assess the yield, economic and BNF benefits of innovative approaches addressing the pigeon pea and common bean productivity within maize-based cropping system and variable weather

This study aimed at determining the effects of different crop spatial configurations on the productivity of pigeonpea and beans within the three eco-zones of Babati district, Tanzania, as well as assessing the uptake and adaptations of *Mbili-Mbili* technology by farmers in the same district. The fourth season field experiments were implemented successfully, data analysis is ongoing, and preliminary observations are presented in this report.

Innovations of crop spatial arrangement involving maize among either pigeonpea and/or beans, and maize stripping and topping practices, all result in generally the same maize yields (i.e., no negative effects on final grain yield). Maize grown as sole crop after doubled-up legume produced more yields (e.g. by 0.5 t/ha in Riroda village) compared to maize in intercropping systems (Figure 3). This is consistent with the improved fixed nitrogen of about 60 kg/ha in the double-up. With topping, maize stover biomass averaging 2.1 t ha^{-1} is obtained. On the other hand, stripping the four lower maize leaves from *Mbili Mbili* resulted in 0.7 t ha^{-1} of biomass, which is good for livestock supply in case of short supply from other sources. While the maize and pigeonpea yields are statistically similar across the intercropping treatments, Mbili-Mbili system (Plate 1) has the advantage of an additional 0.5 t ha^{-1} obtained from common beans.

Therefore, *Mbili Mbili* was rated as the best technology by men and women in Gallapo (Table 1 - showing rating and reasons) and in Riroda villages due to its profitability, increased household food security because of the different crop maturity periods, fodder provisioning from residues derived from the three crops, fuel, and improvement of soil fertility by the legume component. Groups that did not rate *Mbili Mbil*i as the best (i.e., both men and women in Sabilo, and women in Riroda) rated two maize plants per hill (topped at physiological maturity) as the best technology due to ease of weeding operations (50 cm between plants instead of 25 cm in other system). Economic analyses are underway to compare the different systems in monetary terms.

In all cases, legume productivity is high under doubled-up legume cropping (e.g., bean production was 1.4 t ha^{-1}). Doubled-up legume also allowed for a second legume (bean) phase producing up to 1.2 t ha^{-1} of bean. Although not rated highly by farmers, the doubled-up legume could be profitable in some cases, also considering the rotational benefits to the cereal.

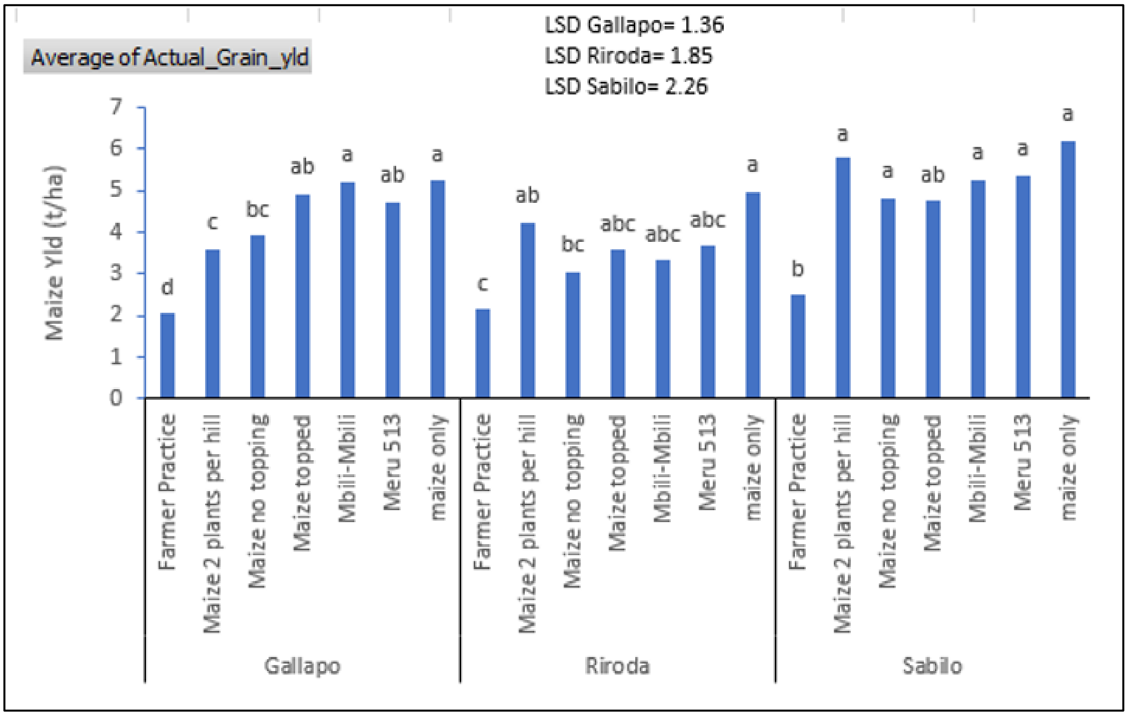


Figure 3. Maize grain yield across three sites of Babati during the long rains of 2020/2021. Maize yield is analyzed at site level. All maize planted was Dekalb 8031, except in cases where Meru 513 was planted. Treatments with different letters are significantly different.

Plate 1. Doubled-up legume system (foreground) and a Mbili-Mbili system with a good canopy (background). Photo credit: Michael Kinyua/CIAT.

Table 1. Absolute ranking of treatments in different villages of study

Technologies	Rank	Remarks
Sabilo		
Maize only	5	This system lacks pigeonpea, which is a major source of income for households; has big cob and plants associated with high maize yield
Maize no topping	7	Low food security of the households
Maize topped	3	High plant biomass
Double-up Legume	6	This system is not preferred because it lacks maize, which is important for food and income
Maize 2 plants/hill	1	Has big cobs and plants associated with high maize yield; has moderate labor requirement
Mbili-Mbili	4	The two intercropped legumes and maize enhance household income and food security
Meru 513	2	Has high maize yield; enhances household income and food security
Gallapo		
Maize only	5	It does not guarantee household food security; lacks legumes
Maize no topping	7	Average yield of maize and pigeonpea
Maize topped	2	Guarantees food security for the household
Double-up Legume	6	Does not guarantee household food security; lacks maize
Maize 2 plants/hill	3	Results in high maize yields and increased income
Mbili-Mbili	1	Ensures food security and profitability because legumes fetch high price in the market; low weeding labor requirement hence, reducing production costs
Meru 513	4	Has moderate maize and pigeonpea yields
Riroda		
Maize only	4	Has high maize yield but does not guarantee household food security since it lacks legumes
Maize no topping	3	Ensures household food security
Maize topped	7	Small plant and cob sizes; hence, low yield
Double-up Legume	5	Has high maize yield but does not guarantee household food security due to lack of maize
Maize 2 plants/hill	2	Prospects for high household income
Mbili-Mbili	1	Ensures food security for the household, provides enough fodder, fuel, and improves soil fertility
Meru 513	6	Maize variety is not good

Targeted deliverables for 2020/2021 and status on achievements

Deliverables	Status (September 2020)	Status (September 2020	Status (September 2021)
Six on-farm trials, two in each of three eco-zones of Babati District, successfully implemented	Maize was harvested but pigeonpea is yet to be harvested.	Second cycle of six on-farm demonstration trials were successfully initiated as planned. A total of 225 baby farmers were successfully trained on establishment of baby trials for testing Mbili-Mbili.	Field activities are completed. Data for four seasons are being analyzed to be used for manuscript preparation. Submission targeted for June 2022.
BNF of pigeonpea quantified	Sampling done according to plan, samples prepared, and ready to send to Europe for 15N analysis.	Samples to be collected when the crop attains 50 percent podding	Sampling for the 2021 season is done; samples are being prepared for analysis
150 farmers trained (during field days)	Field day was conducted before beans were harvested for farmers to identify with Mbili-Mbili. Other field days cancelled because of COVID-19.	A mini-field day was conducted in Sabilo, Riroda, and Gallapo Eco-zones between 22 and 24 March 2021. About 36 percent of the 143 participating farmers were women. Full field day report is attached on the custom indicators. Farmer Attedance List.xlsx Field day report.docx	A second field day was conducted prior to maize harvesting where 103 farmers participated. Report is under preparation.
Manuscript on aspects around Mbili-Mbili based on available data	NA	Plans of writing the paper will be initiated after completion of data collection for this season.	Data analysis considering all four seasons has been initiated. Draft manuscript is expected in November 2021.
Data uploaded to DataVerse	Completed for 2020	NA	Target upload date: October 2021
FtF indicators data submitted to M&E/IFPRI for upload	Completed for 2020	NA	Target upload date: October 2021

Sub-activity 1.1.1.7: Monitoring the impact of weather and climate variability on the productivity and resilience of maize–legume cropping systems of Kongwa and Kiteto, Tanzania

Collection of monthly weather datasets from automated weather stations in Kongwa and Kiteto districts in Tanzania has continued. The datasets were shared with partners on DataVerse. Preparation of a manuscript out of a survey to establish farmers' perception of weather variability and associated on crop production was initiated but progress during this reporting period has not been submitted by the PI (Shitindi Mawazo – SUA).

Targeted deliverables for 2020/2021 and status on achievements

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
Establish farmer's perception of weather variability & associated impacts on crop production: Manuscript	Survey with 147 farmers involved completed	Data cleaning and analysis completed. It will be used to prepare a manuscript for publication.	No progress reported
Monthly weather data off-loaded from weather stations in Kongwa and Kiteto districts	Submitted for 2020	Weather data with its metadata was submitted to M&E officer for uploading to DataVerse.	No progress reported

Sub-activity 1.1.1.8: Explore, document, and assess the sustainable intensification pathways of 3 farming system case studies in Tanzania to inform scaling potential.

This study was to be driven by compiling existing data on the three farms from researchers and filling data gaps where identified. At the end of 2020, a household survey was conducted in Tanzania (with focus on adoption of postharvest technologies) in which the three original farms were included. Progress on the three farm case studies has not been provided as the researcher has been on extended sick leave.

Targeted deliverables for 2020/2021 and status on achievements

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
Interviews and surveys with three farmers as case studies conducted and data gaps filled. Produce a manuscript.	Interviewed two of the three case studies (during previous reporting period). Systems diagrams developed and elaborated. The farm case studies were included in recent household survey (led by C. Mutungi and J. Manda).	Third farmer interview still not conducted due to COVID-19. It is considered that the data generated in the survey by Mutungi and Manda is sufficient to inform the case study analysis.	No progress reported on data analysis and manuscript development.
MSc Thesis on Farming systems analysis with Sustainable Intensification Assessment Framework (SIAF) and FarmDESIGN	MSc student finalizing thesis (analysis utilizes ARBES data from farms but not including the case study farms)	MSc thesis titled *"Scenarios for assessing and improving performance of smallholder farms in Tanzania affected by economic and climatic disturbances"* submitted	MSc study completion by Evelin Massop and thesis summary is presented under sub-activity 2.1.1.1.
Data uploaded to DataVerse	Recorded interviews being transcribed; data from recent household survey still being processed	Recorded interviews have been transcribed; household survey data processed and is being analyzed	Report not available

<u>Sub-activity 1.1.1.9:</u> Assessing the impacts of Africa RISING technologies on the performance and resilience of multi-location and differentially exposed farming systems case studies in Malawi.

In an activity that started in 2020, it was hypothesized that crop productivity on mother trials typically represent water-limited yield potential for the different agroecologies. Crop yield for these trials would be used as benchmarks to assess the level of intensification at farm-scale for other farmers' groups (mother trial host farmers' fields, baby trial farmers, and farmers not directly participating in Africa RISING activities). Mother trial farmers are more likely to adopt more technologies as they more closely interact with a range of SI technologies on the mother trials. The objectives of this sub-activity are to: (i) determine the adoption and impact of SI technologies for the differentially exposed farming systems; (ii) predict different farming systems' performance when subjected to scenarios of shocks; and (iii) identify the contribution of Africa RISING technologies to shock resiliency. The FarmDESIGN modeling framework was proposed to be used for analysis. The MSc work addressing the first objective has been completed and a thesis submitted (reported under Sub-activity 2.1.1.1). Report of progress on the other two research questions has not been provided by the PI who is on extended sick leave.

Targeted deliverables for 2020/2021 and status on achievements

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
Data from 2020 surveys processed and exchanged among team	New activity	Completed	
Missing data (mainly on yields) collected	New activity	Data collection is ongoing	
Farming systems analyzed with FarmDESIGN	New activity	Exploratory analysis is ongoing with available data	
Adoption and impact of SI technologies for differentially exposed farming systems assessed and documented	New activity	Exploratory analysis is ongoing with available data	MSc Thesis submitted and defended. See report under sub-activity 2.1.1.1

Activity 1.1.2: *Evaluate and implement pathways that are effective at improving access to seeds and clonal materials of modern varieties of legumes, cereals, vegetables, forages, and livestock*

Sub-activity 1.1.2.1: Assessment of the benefits of management technologies on the performance of improved vegetable varieties

This study utilized data from 64 demonstration plots in eight villages of Karatu District in Tanzania. Crop growth, yield, and economic data were collected to assess the impact of good agricultural practices (GAPs) on vegetable production. The GAPs included implementation of environment-friendly practices that conserve the soil fertility and health, use of eco-friendly approaches to control pests and diseases, and efficient use of water in agriculture.

A summary of the results was given in the last report. A paper on adoption of SI technologies of vegetable production has been published (https://doi.org/10.1080/14735903.2021.1943235), and the summary is given below.

"Sustainable agricultural technologies have impacted positively on staple crop yields in Asia and some parts of Sub-Sahara Africa. However, the adoption of similar technologies in vegetable subsector is still low among small-scale farmers in Tanzania. Several efforts aimed at promoting the adoption of the technologies such as improved vegetable varieties, mineral fertilizers, manure and pest management practices to raise output, have not yielded the desired impacts. We examine dynamics of farmers' adoption of these technologies and the factors influencing technology choice. We also predict the peak level and speed of adoption of these sustainable technologies. Findings show that complementarities exist among improved varieties, fertilizers, and pest management practices, while trade-offs exist between manure and mineral fertilizers. These complementarities and trade-offs should be sufficiently exploited for farmers to adopt technologies that are suited for their specific circumstances. Better knowledge, access to credit, group membership, farmer participation in demonstration trials, and more substantial livestock holdings drive technology adoption decision. Technologies have different peak levels of adoption, which are reached at different time intervals. The policy option is to strengthen collaborative efforts to scale out sustainable agricultural technologies to respond to the increasing demand for nutrient-dense vegetables for income, food, and nutrition security."

Summary of other work. Profitability analysis on the production of three vegetables with introduced GAPs revealed that nursery management and manure costs accounted for over 80 percent of the total variable costs in the three vegetable crops (Table 2). The highest quantity sold was recorded by the tomato-producing households, followed by Ethiopian mustard, and African nightshade. Lower marketable yields were observed from the plots with normal farmers' practices for crop management. Vegetable production was generally more profitable in all the participating villages when GAPs were applied. Although vegetable production was profitable in the three crops, the highest profit (gross margin) and returns per US$ invested were earned from the African nightshade cultivation (Table 2).

The ANOVA analysis of the gross margin between the farmers' practices and GAPs indicates a significant variation in the profitability of tomato (F=109.93, p<0.001), Ethiopian mustard (F=81.81, p<0.001), and African nightshade (F=182.06, p<0.01). This implies that although vegetable production is profitable, there is a significant difference in the profitability between the treatments; thus, the use of GAPs should be recommended for adoption.

Table 2. Average costs and returns (profitability) of vegetable production per hectare

Item (costs)	TOMATO (64)		AFRICAN NIGHTSHADE (64)		ETHIOPIAN MUSTARD (64)	
	Mean±SE		Mean±SE		Mean±SE	
	GAP	FP	GAP	FP	GAP	FP
Nursery management (USD/ha)	1543±16	1818±176	1490±19	1867±25	1493±15	1821±18
Manure (USD/ha)	2875	0	2875	0	2875	0
Irrigation (USD/ha)	751±9.5	754 ±9.9	732±12	775±9.4	665± 12	724±11
Transport (USD/ha)	210±8.4	219±9.4	229 ± 9.3	230±9.8	241±11	298±16
Harvest (USD/ha)	278±11.2	267±11.2	282±8.5	263±10	250 ±11	258±11.2
Returns						
Quantity sold(kgs)	25687±853	18952±736	6751 ±184.4	1761±108	7191 ±207	4932±186
Gross Income (GI)	25000±1004	9463±685	28785±1203	8205±615	15795± 604	6809±399
Gross Margin (TR-TVC)	19342±1015	6406±702	23176±1196	5028±615	10271± 605	3709 ±400
Returns per 1 USD invested (GM/TVC)	3.4	2.2	4.12	1.6	1.9	1.2

Notes: Data are means (±S.E., N = 64). Key: **FP:** Farmers' practice; **GAP**: Good agricultural practices.

Targeted deliverables for 2020/2021 and status on achievements

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
Adoption of sustainable agricultural technologies for vegetable production in rural Tanzania identified and documented	Manuscript under development	Manuscript submitted and under review by the International Journal of Agricultural Sustainability	Published (https://doi.org/10.1080/14735903.2021.1943235)
Paper on the impact of improved vegetable management practices	Requires end-line survey data to be collected at end of project	NA	End-line data will be collected in early 2022; manuscript submission by September 2022
At least one success story published	One success story published and can be accessed at https://africa-rising.net/worldveg-and-africa-rising-serve-up-an-exciting-improved-vegetables-exhibition-at-the-tanzania-agribusiness-forum-2020/	Completed	Completed
Data uploaded to DataVerse	Data not yet uploaded	Upload completed for 2020	Data for 2021 to be uploaded in October
FtF indicators data submitted to M&E/IFPRI for upload	FtF indicators were submitted	Upload completed for 2020	Same as above

Output 1.2 *Demand-driven, labor-saving, and gender-sensitive research products to reduce drudgery while increasing labor efficiency in the production cycle piloted for relevant typologies in target areas*

Activity 1.2.1: *Support local partners through training on appropriate drudgery-reducing technology delivery. No sub-activity was planned for 2019-2020.*

Activity 1.2.2: *Co-adapt existing mechanization options with target communities*

Sub-activity 1.2.2.1: Use of tractor mounted ripper tillage implement for enhancing soil water infiltration and moisture conservation in semi-arid areas of Kiteto

This study was initiated during the 2018/2019 cropping season to determine the potential benefits of rip tillage (RT) in semi-arid agroecologies of Central Tanzania. Collection of data was continued during 2019/2020 season. Analysis of the two seasons' data is contributing to drafting a manuscript for publication, with a working title "*Use of tractor mounted ripper tillage implement for enhancing soil water infiltration and moisture conservation in semi-arid areas of Manyara Region in Tanzania". It's target* submission date is in November 2021. The abstract of the draft is given below.

"The occurrence of hardpans due to the continuous use of primary tillage implements such as the disc plough have a negative influence on soil hydrological properties and crop performance. RT can reduce this effect. To determine the extent of the benefits of RT in the semi-arid areas of Tanzania, a combination of one researcher-managed and 10 farmer-managed trials were installed in the semi-arid Kiteto district in Tanzania. RT was compared with the conventional tillage (CT) that uses the disc plough. Two contrasting maize varieties, DKC9089 (a commercial variety commonly grown in the area but succumbs to drought) and WE2109 (a drought-tolerant variety) were used as test crops. Data on soil water content, cumulative infiltration, and maize grain yield were collected; and water use efficiency, calories production, and economic performance were calculated. On the average, RT gave maize grain yield advantage of 24 percent over CT; a result of higher cumulative water infiltration (564 mm for RT vs 314mm for CT) and better rainwater use efficiency (10.3 kg grain ha^{-1} mm^{-1} for RT vs 7.5 kg grain ha^{-1} mm^{-1} for CT. Calories and protein produced followed the same pattern. Average gross margin for RT (TZX 2,398,201) was 35 percent higher than that of CT. Productivity performance of both maize varieties was not significantly ($P<0.05$) different, and they equally succumbed to drought when rainfall was extremely low (72 mm). In the normal semi-arid rainfall distribution, RT is the recommended land preparation practice, especially on farmlands that have been under CT for a long time.

Targeted deliverables for 2020/2021 and status on achievements

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
Manuscript on use of the tractor-mounted ripper tillage implement for enhancing soil water infiltration and moisture	Productivity, socio-economic, environment, and food security data for second season cropping were collected and assembled for analysis	First draft is under preparation	Responding to internal review comments is in progress; Target submission date: November 2021
Data uploaded to DataVerse	In progress and will be submitted not later than 18 November 2020	Completed for 2020	NA
FtF indicators data submitted to M&E/IFPRI for upload	FtF data was submitted to M&E	Completed for 2020	NA

Output 1.3. *Tools (including ICT-based) and approaches for disseminating recommendations in relation to above research products, integrated in capacity development*

Activity 1.3.1*: Conduct extrapolation domain analysis based on GIS, agroecology, and crop model-generated information to establish the potential of technologies for geographical reach*

Sub-activity 1.3.1.1: Farmer/Extension messaging (forage production and use, crop residue processing and use and feed rations) using the MWANGA ICT-Platform

MWANGA ICT – Messaging Platform has been described in previous reports. The platform was not used during this reporting period. An end-line survey report to identify its influence on knowledge, attitudes, and practice (KAP) from target livestock farmers showed that the MWANGA platform can be a valuable extension approach of reaching out to as many farmers as possible. The results showed that farmers need to be prompted and reminded to share information with other farmers during the duration of disseminating messages to widen the reach of the information. One of the key recommendations by farmers on the platform is to make it more interactive. Farmers would wish to interact with the platform and ask questions and/or share their experiences on crop and livestock production challenges. To address these observations, a proposal to renew activities is being prepared.

Sub-activity 1.3.1.2: Produce regionally relevant extrapolation domain maps for validated conservation agriculture (CA) practices

The current study applies maize grain yield data and remote sensed layers as input to an ensemble machine learner to predict the spatial variability of the maize grain at field scale for different combinations of conventional practice (CP), conservation agriculture (CA) and agronomic management practices for 16 growing seasons (2004/2005 to 2019/20). A total of 34 552 geotagged datapoints were obtained from CIMMYT CA trials database for four countries (Figure 4). An ensemble of three ML algorithms [i.e., the random forest (RF), eXtreme Gradient Boosting (XGboost), and spectral vector machines (SVM)] were evaluated together with a spatial-temporal cross-validation procedure to train the ensemble ML models. Spatial feature selection was employed to eliminate variables that do not lead to better spatial predictions of maize grain yields beyond the training sites. The robustness of the spatial predictions of maize yields was evaluated using the concordance correlation coefficient (CCC).

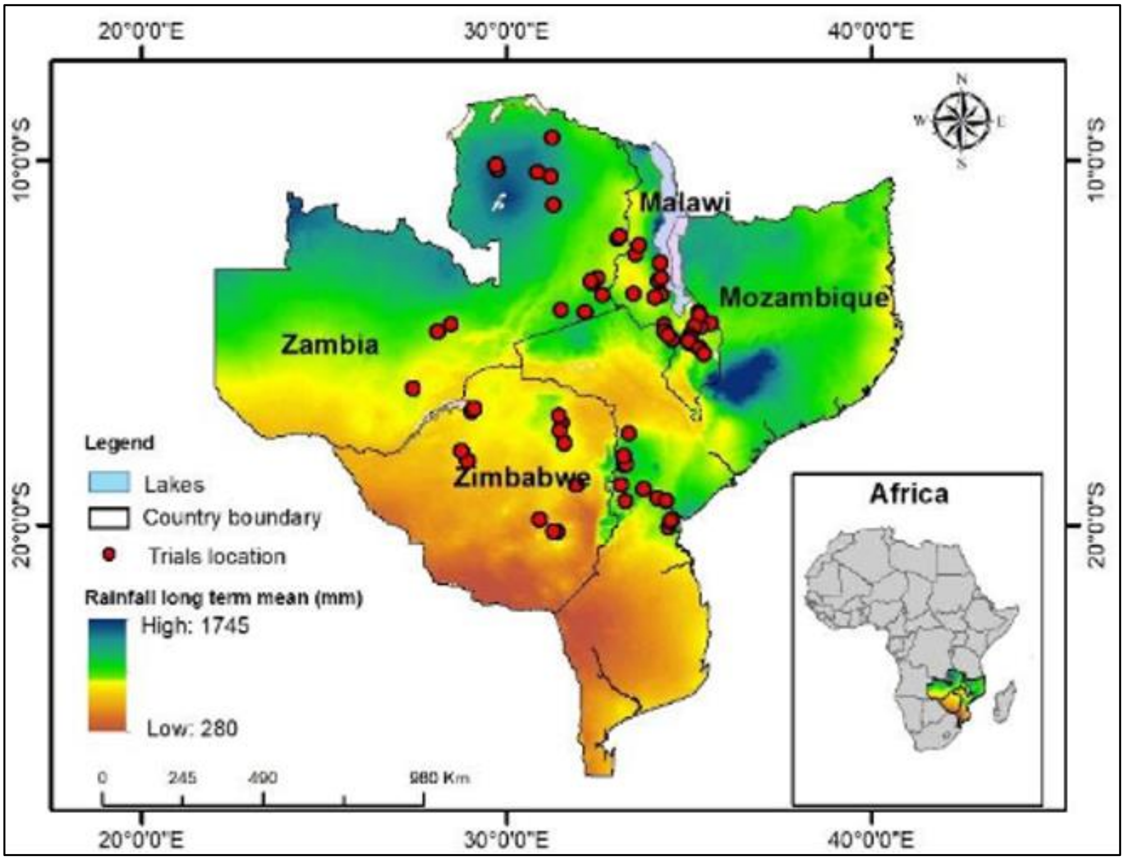


Figure 4. The geolocation of CP and CA trials in southern Africa for 16 growing seasons from 2004/2005 to 2019/2020.

Relationship between observed and predicted grain yield. The concordance correlation of the predicted vs measured maize grain yield was 0.773 (Figure 5). Generally, the variable importance revealed the temperature, and precipitation related variables were the most important in predicting the grain yields (Figure 6). The highest 5 percent night-time land surface temperature in October was the most important predictor. This was followed by reflection from the LANDSAT shortwave infrared band for January to March. The accumulated precipitation in December emerged the 4th most important variable. Lobell et al. (2011)[2] observed that each degree day spent above 30^0C would reduce maize yields by ~ 1 and 1.7 percent under optimum rainfed and under drought conditions, respectively. Climate projections suggests likelihood of warmer temperatures and increased frequency and intensity of droughts in study area. Warmer temperatures accentuate soil water loss through evapotranspiration; thus, increasing moisture stress. Our results highlight the need for increased investments in breeding drought and heat-tolerant maize varieties in this region.

[2] Lobell, D.B., Bänziger, M., Magorokosho, C., Vivek, B. (2011) Non-linear heat effects on African maize as evidenced by historical yield trials. Nature Climate Change 1, 42

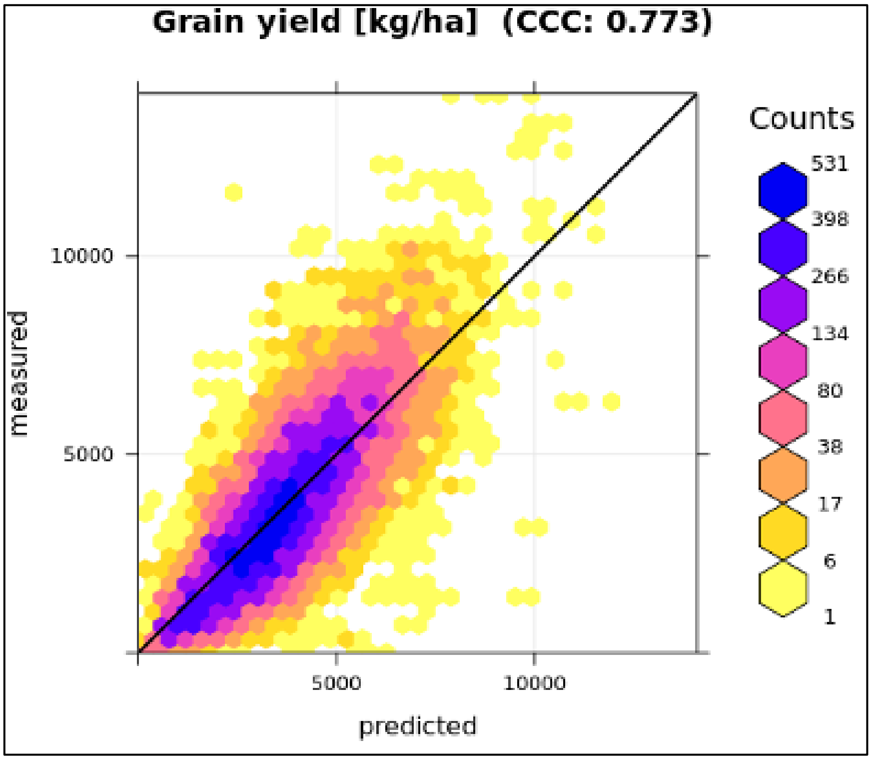


Figure 5. Agreement between the observed and predicted maize grain yield (kg/ha) for agronomic trials in southern Africa.

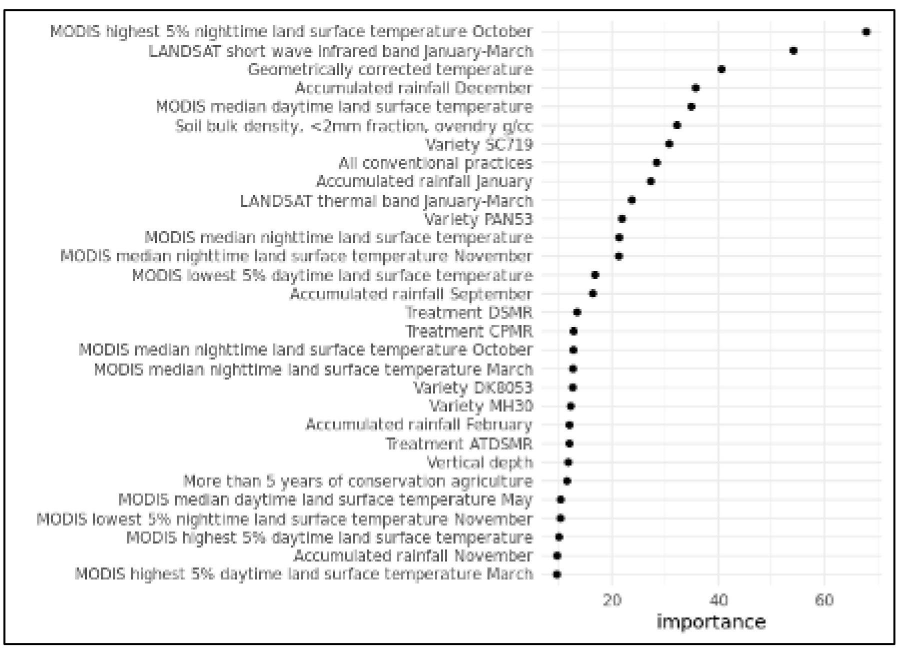


Figure 6. The importance of the variables generated from the ensemble machine learning model. Only the top 30 variables are shown.

Yield predictions and gain in CA and CP scenarios: The validated machine learning model was applied to predict grain yields over space and time. Figure 7 shows an example of predicted maize grain yield from CP and CA scenarios during different seasons with dry or wet conditions. The predicted yield during wet season for CP (Figure 7b) and CA with over five years (Figure 7d) are demonstrated over Machinga district in Malawi. Comparison between Figures 5i and 5j reveals that that the scenario with over five years of CA had higher grain yields compared to CP attributed to benefits of CA (i.e., increased soil organic carbon that consequently improves soil fertility and moisture retention). The 2016 harvest year was the warmest El-Niño on record in southern Africa and comparisons of Figures 7i and 7j shows that CA was more resilient to drought compared to CP. Therefore, investments in CA for over five years enhances yield stability in smallholder systems in Malawi.

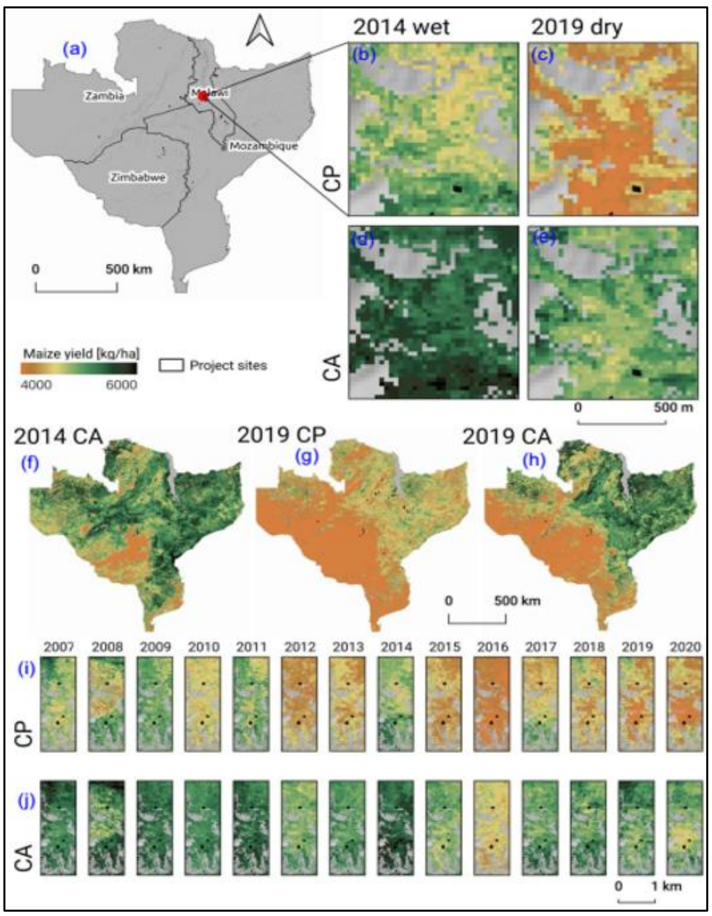


Figure 7. Predicted maize yields at field scale (30 m) for different growing seasons in four southern Africa countries, with a zoom in at project area in Machinga district of Malawi, from conventional practice (CP) and CA treatments. Comparison of yield between wet (b, d) dry (c, e) seasons revealed that CA treatments were more resilient to droughts. Seasons are labelled based on harvest year; therefore, 2016 represents the 2015/2016 growing season.

The percentage uncertainty of the predicted yields was lower than 20 percent over the large proportion of the study area. However, uncertainties above 40 percent were observed in northern and western Zambia due to the low sample size of agronomic trials over the relatively wet agroecology in that area (Figure 4). The uncertainty maps help to identify where the model results should be interpreted cautiously.

Targeted deliverables for 2020/2021 and status on achievements.

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
Extrapolation domains for CA practices documented	Manuscript preparation initiated	Manuscript titled "Spatiotemporal modelling and prediction of maize yield at farm-scale in South-East Africa (2007–2020)" in preparation	Target submission date: December 2021
Maps: Inter-annual maize yields from CA and CP systems	NA	Processing agronomic and remote sensing data	Maps have been generated and are uploaded at: https://envirometrix.direct.quickconnect.to:5001/fsdownload/aFpXfPTsH/R-code
Maps: Yield advantage of CA systems at different seasons	NA	Calibration and accuracy assessment of ML models	
Publication on spatial variability of maize yields under different CA and climate variability	In preparation	Manuscript titled "*Remote sensing and machine learning identify where and when CA increases maize yield in Southern Africa"* in preparation	Submitted to *Agriculture and forest meteorology Journal of clean production;* under revision now
Tutorial for space-time machine learning crop yield prediction	NA	Drafting of tutorial is ongoing	Draft at: https://gitlab.com/openlandmap/africa-rising
Data uploaded to DataVerse	Utilizing data previously uploaded on Dataverse by CIMMYT	NA	

Sub-activity 1.3.1.3: Produce regionally relevant extrapolation domain maps for validated soil and water conservation practices

This research was initiated during 2019-2020 to map the hotspots of land degradation using high resolution (30 m) remote sensing data in Kongwa and Kiteto districts of Tanzania. We monitored the indicators of land degradation in Kongwa and Kiteto districts to guide future investments of soil and water conservation practices. The trends of land productivity, land cover, and soil organic carbon as proxy of land degradation were monitored from 2001 to 2019. Following the success at local scale (see manuscript at https://www.mdpi.com/2072-4292/13/9/1754), we expanded the study to cover the East and Southern African regions.

A paper focusing on the ESA region is in preparation (80 percent completed) and will be submitted for publication in January 2022. This study applies the Normalized Vegetation Index (NDVI), which is a surrogate for vegetation productivity, to investigate the following: (1) degree of change in vegetation productivity over the ESA region over the past three decades (1983 - 2015); (2) quantify the relative importance of climatic and human disturbance factors on the NDVI trends; (3) types, causes, extent, and intensity of land degradation at local scale in a typically degraded landscape in Kongwa district of Tanzania assessed from field surveys; and (4) assess the type, extent, purpose, and effectiveness of the sustainable land management practices (SLM) applied in Kongwa district.

Targeted deliverables for 2020/2021 and status on achievements

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
Produce regionally relevant extrapolation domain maps for validated S&WC practices	Maps on hotspots of land degradation in Kongwa and Kiteto have been produced	Completed https://cgspace.cgiar.org/handle/10568/113186?show=full	NA
Land degradation neutrality results disseminated – Manuscript	Draft manuscript in preparation (delayed because of COVID-19 pandemic)	Manuscript titled “*Assessment of Land Degradation in Semiarid Tanzania—Using Multiscale Remote Sensing Datasets to Support Sustainable Development Goal 15.3*” submitted	Manuscript published https://www.mdpi.com/2072-4292/13/9/1754
New manuscript	NA	“*Monitoring the trend and drivers of land degradation in the ESA region with remote sensing*”: a working title of the manuscript in preparation	To be submitted January 2022

Sub-activity 1.3.1.4: Ex ante impact assessment with Trade-off Analysis Model for Multidimensional Impact Assessment (TOA-MD) for regional relevance of Africa RISING technologies.

The Trade-off Analysis Model for Multi-Dimensional Impact Assessment (TOA-MD) was applied for Africa RISING validated technologies to *ex ante* assess potential impacts of adoption at the regional level, as presented in the last report. This approach, when combined with sensitivity checks and scenario analysis, allows an estimation of likely adoption rates of improved agricultural technologies by Africa RISING. Progress on this work during this reporting period lacks clarity on way forward with the production of the manuscript for publication (no info due to extended sick leave of researcher).

Targeted deliverables for 2019/2021 and status on achievements

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
Ex-ante impact assessment implemented, analyzed, and documented	The TOA-MD framework applied for AR validated technologies (focus on fertilizer applications and hybrid maize seeds) for Tanzania	Data from different AEZs (Kongwa, Kiteto and Babati) identified in DataVerse and analyzed; manuscript preparation has been initiated	Progress has not been clarified

Outcome 2. Natural resource integrity and resilience to climate change enhanced for the target communities and agroecologies

Output 2.1 *Demand-driven research products for enhancing soil, land, and water resource management to reduce household/community vulnerability and land degradation piloted in priority agroecologies*

Activity 2.1.1: *Characterize current practices in ESA through identifying formal and informal arrangements for access to and use of water and land resources*

Sub-activity 2.1.1.1: Assessing buffer and adaptive capacity to harness resilience of different farm types

Vulnerability and resilience are two crucial attributes of smallholder farming systems that can be used for analyzing the response to disturbances. This sub-activity assesses these properties in relation to the buffer and adaptive capacity, which depend on the 'window of opportunities' of possible changes in terms of productive, socio-economic, and environmental performance indicators (i.e., the 'solution space'). The vulnerability of the system can be quantified as the distance of selected performance indicators between original and disturbed systems. The buffer capacity will be derived from the size of the solution space that could be obtained after reconfiguration of farm components (crops, animals, fertilizers, etc.) that were present on the original farm, whereas the assessment of adaptive capacity was derived similarly but after allowing innovation by introducing new components to the farm.

MSc students were engaged to conduct this work (one completed and presented in the last report and the other two and have completed their theses contributing to systems synthesis activities in Tanzania and Malawi). In both cases, analyses were conducted on how selected Africa RISING beneficiary farmers performed at multiple SIAF framework dimensions relative to other farmers in the community. In Tanzania, the focus was on a set of 579 farmers included in a postharvest survey in which positive deviants were identified. In Malawi, farmers involved in mother and baby trials were compared to non-participating control farmers. The summaries of these theses are presented below.

Summary of the MSc thesis "*Farm performance evaluation: Holistic impact assessment of project promoted sustainable intensification innovations at farm-level in Tanzania*" by Eveline Massop.

Smallholder farmers in sub-Saharan Africa are characterized by low inputs and consequently low productivity. They are mostly self-sufficient but struggle to meet their own nutritional demand. With a fast-growing population, there are even more mouths to feed, but agricultural production is threatened by the consequences of climate change. Sustainable intensification (SI) is considered a solution for this complex situation, and Africa RISING is one of several projects promoting SI. This thesis provides a holistic assessment of the project in Tanzania, based on a household survey, which included 579 households in Babati, Kilolo, Kongwa, and Mbozi districts. The aim was to identify whether farms with better SI performance had more innovations implemented and which combinations of innovations could contribute to this performance. Hierarchical Cluster Analysis was used to identify combinations of innovations and based on SIAF, several indicators were used to assess performances per cluster. Positive Deviant Analysis, based on Pareto-optimality and above average performances for selected indicators, was used to identify farms that performed extraordinarily better.

Ten innovation clusters were identified, and the farms in five clusters that used more innovations also had a better performance. A large majority of farms in the better performing clusters made more use of fertilizers, compared with lower performing clusters. There were 52 farms identified as Positive Deviants, and these farms made more use of innovations, which were not widely represented in the innovation clusters. Most of the farms were found in well performing clusters; however, the most of these well performing farms and the Positive Deviant farms still used considerable amounts of pesticides. This conflicts with SI; thus, requires attention for future improvements.

Figure 8 provides the visualizations of farm performances of the three selected farms that have been part of the program for several years (Farm S1, S2, and S3), the comparable farms (Comparable farm C1, C2 and C3), and the dataset mean and modus. The first farm comparison (Figure 8a) shows that Farm S1 performed better for all indicators compared with Comparable farm C1, except farm decision-making and nitrogen efficiency. Farm 1 performed above average for most indicators; however, productivity was slightly lower than the dataset means. Comparable farm C1 performed better than the dataset means for the indicators of household leisure time, erosion, pesticide AI, nitrogen balance, WDDS, and farm decision-making index. However, most of the indicators were around or below dataset mean performance, especially productivity indicators. The second farm comparison (Figure 8b) shows that Farm S2 only obviously performed better than Comparable farm 2 in terms of collective action and education. Comparable farm C2 performed better than Farm S2 in terms of maize productivity and HDDS but had low performance on protein and dietary energy productivity, nitrogen efficiency, education, collective action, farm decision making index, and asset ownership distribution. The nitrogen balance was worse than the dataset mean. Although erosion is a problem for this farm, its magnitude is less than the dataset mean. The third farm comparison (Figure 8c) shows that Farm S3 performs better than Comparable farm C3 for all indicators, except the farm decision-making index. Productivity of both farms is lower than dataset mean. The farms also deal with mild erosion and have a high nitrogen balance. Compared with dataset mean, farm S3 performed better for all indicators, except productivity and nitrogen balance. Women were highly included in farm decision-making and asset ownership distribution. Comparable farm S3 performed below or around dataset mean for most indicators.

Comparing the three selected farms with the dataset modus, Figure 8d shows that all three farms perform better at all domains, except productivity and nitrogen balance. The performance of farm gross margin, HDDS, WDDS and collective actions is far above the dataset mean.

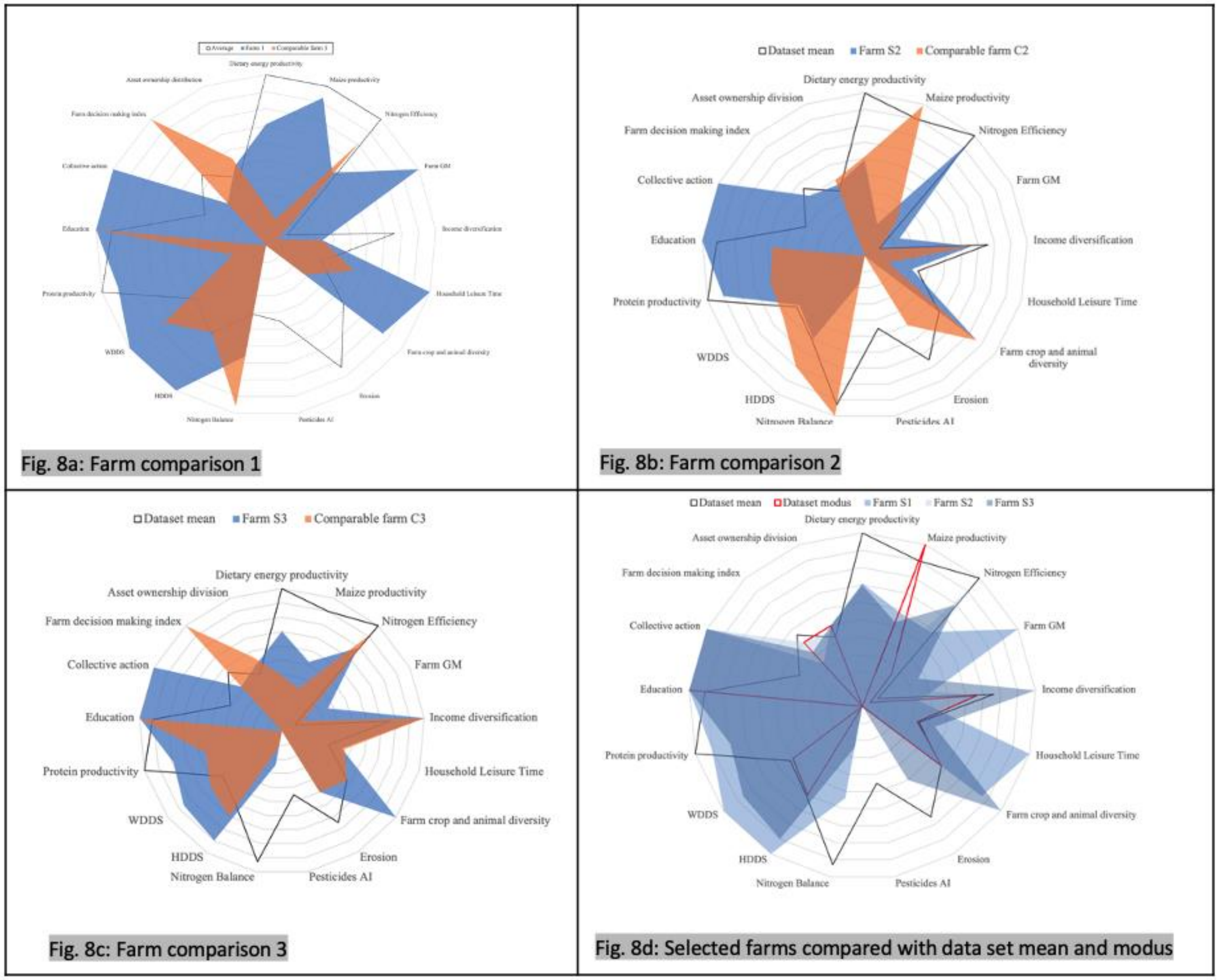


Figure 8. Visualization of farm comparisons. For all indicators, a higher score represents a better performance, except for the indicators of erosion, pesticide AI, and nitrogen balance. For these indicators a low score is preferred. Farm decision-making and household asset distribution more than half means that women are more included; however, half is also considered as good performance.

Summary of the MSc Theis "*Healthy soils, healthy plants, healthy humans: A holistic exploration of sustainable intensification effects on farming systems in Malawi*" by Madeline Mathews

Smallholder farmers in Malawi are faced with resource and space constraints, low soil fertility, and vulnerability to climatic shocks. This has led to poor nutritional standing of farmers and their households, and very little ability to break through experienced feedback loops that keep them locked in a state of food and resource insecurity. The connection between soil-land and the human-health axis is only recently gaining momentum; however, promising programs focused on SI have begun to be implemented in sub-Saharan Africa to address root causes that lead to multi-dimensional poverty. Approaches such as SI, aim to provide farmers with low-cost accessible technologies that have the potential to optimize spatial resource allocation, increase production, and harness natural processes to mend degraded soils.

This research aimed to understand the holistic effect of integrating biologically nitrogen-fixing legumes within crop configurations on a farm system. Specifically, we looked at the differences in space allocated to legume intercropping in the form of legume-legume, maize-legume, and doubled-up legume rotations (DLR).

Due to the complex and dynamic nature of farming systems, one change in management may lead to spillover effects throughout the entire farming system. Therefore, it was essential that a systems approach was used to analyze not just lower scale processes within the soil, but also higher-level analysis at the household and farm level. To do this, the application of an innovative bio-economic model, FarmDESIGN was employed, which allows for the integration of data at multiple levels.

A case study approach was taken between two treatment groups (a mother and baby farm) in Central Malawi, with an additional exploration component carried out to understand potential opportunities, trade-offs, and synergies that exploratory farm configurations could generate. In the case study analysis of the two treatments, a clear trade-off was seen between farms that adopt more space for cash crops, and those that adopt more space for legume-intercropping. A greater area dedicated to cash crops was associated with increased financial standing, but less improvement in soil organic matter and dietary energy yield. On the other hand, the farm with more space allocated to legume intercropping was associated with increased levels of environmental and nutritional standing, which is evidenced by the indicators of increased soil organic matter and increased dietary energy yield.

In exploratory runs, the results show that when optimizing holistic objectives of nutrition, economic, environment, and social standing, the model allocates increased space to legume intercropping configurations. For the mother farm, this was seen in increased area to DLR and for the baby farm, legume-maize area. It was concluded from this that as a farm's holistic standing increases, more area is likely to be dedicated to legume intercrops.

For optimizing dietary energy yield, this was focused on feeding as many people as possible (i.e., based on just calories). Therefore, the model allocated almost all the space to maize. However, this misses out on other important micro-nutrient indicators such as protein, iron, and Vitamin A. Due to these results, a nutrition focused scenario that focused on optimizing the production of not just calories, but also protein, iron, and Vitamin A (commonly cited indicators for what household members are lacking in their diet - FAO et al., 2017[3]) was run. However, the variation was not as great as expected (Figure 9).

For optimizing both dietary energy yield and household free budget, the best performing farms in the economic indicator were mostly allocated to cotton and maize. This is not surprising as both crops have proven to fetch high prices, and a way to produce the greatest number of calories.

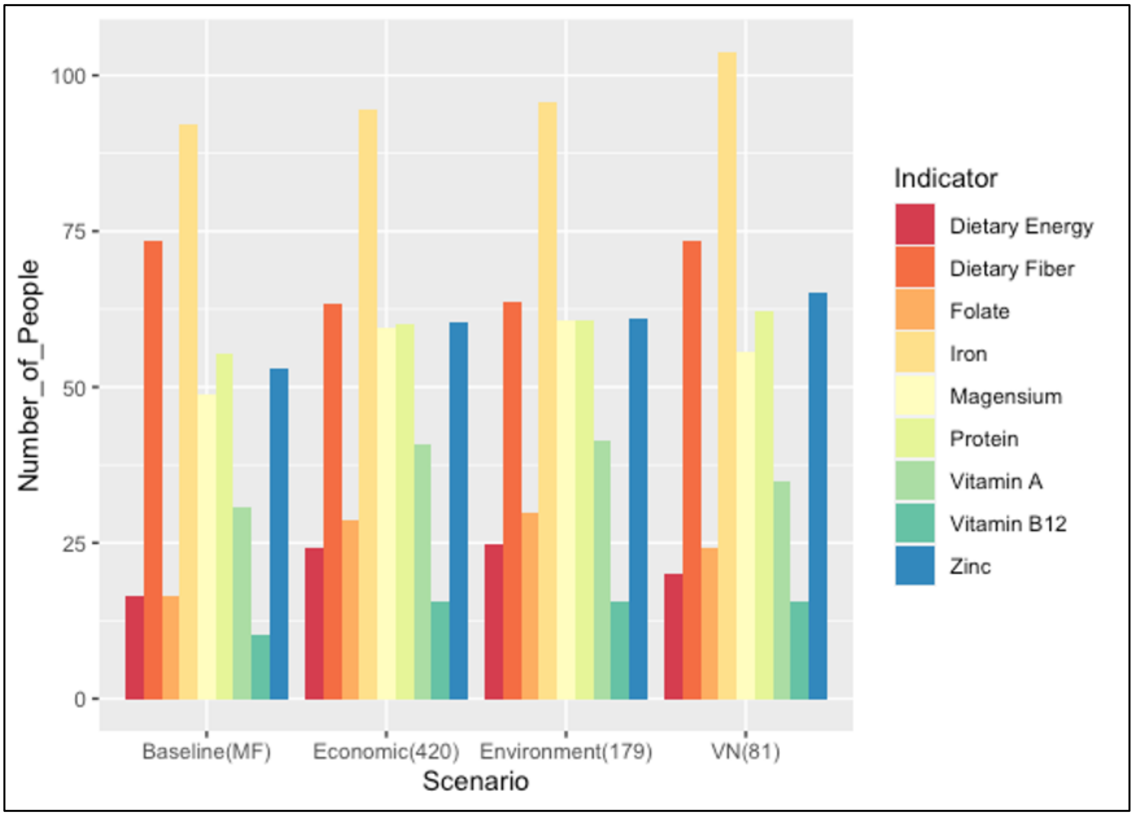


Figure 9. Mother Farm generated scenarios for economic and environmental best performing farm configurations. The selected configurations "Economic" and "Environment" were the best performing categories in each of the farms. The nutrition focused scenario analysis showed that, between the two categories, there were (unexpectedly) relatively similar levels of dietary energy and micronutrients.

[3] FAO, IFAD, UNICEF, WFP, and WHO, 2017. The State of Food Security and Nutrition in the World 2017. Building Resilience for Peace and Food Security FAO, Rome. https://www.fao.org/3/a-I7695e.pdf

Targeted deliverables for 2019/2021 and status on achievements

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
MSc Thesis (Eveline Massop)		Started November 2020; expected completion June 2021	Completed; see thesis summary above
MSc Thesis (Madeline Mathews)		Started November 2020; expected completion June 2021	Completed; see thesis summary above
Journal articles	Not started	We are currently discussing suitability of data	Proposed date of submission – June 2022

Output 2.2 *Innovative options for soil, land and water management in selected farming systems demonstrated at strategically located learning sites*

Activity 2.2.1: *Set up demonstration and learning sites in target ESA communities*

Sub-activity 2.2.1.1: Lessons from long-term on-station Conservation Agriculture (CA) trials in Zambia

All long-term on-station trials were successfully completed by the end of June 2020. All data were summarized, analyzed, and submitted for upload into DataVerse by August 2020. The deliverables under this sub-activity relate to publishing the results of this study, as follows:

- Improved nutrition and resilience will make CA more attractive for Zambian smallholder farmers (https://bit.ly/3cS9B8B);
- Intensifying cropping systems through doubled-up legumes in eastern Zambia https://doi.org/10.1038/s41598-021-87594-0;
- The crucial role of mulch to enhance the stability and resilience of cropping systems in southern Africa https://bit.ly/3fWecZC;
- Long-term CA improves water properties and crop productivity in a Lixisol https://bit.ly/3uAXbbw;
- Short-term gains versus long-term sustainability - evidence from long-term CA research in Southern Africa (under review); and
- Economic assessment of Zambia CA systems (to be out by April 2022).

Sub-activity 2.2.1.2: Assessing the benefits of nutrient and water management for climate resilience in Malawi

For several years now, we have implemented trials in Machinga district that investigated the interactions between nutrient and water management. The main plot factor was water management (tied or no-tied ridges), while sub-plots factors were N and P fertilizer management: (1) continuous non-fertilized maize; and (2) maize fertilized at 35 or 70 kg N ha-1 [maize @50 percent F or maize @100 percent F]. Only three field sites were established during 2020/2021, which were intended to be a platform for conversations around adaptation and resilience building with partners. Sadly, we could not hold any field days as the COVID-19 pandemic persisted throughout the cropping season. We have since harvested the crops for yield data.

Contrary to the previous years where severe dry spells would disrupt normal crop growth, the 2020/21 cropping season had near perfect rainfall with no recorded dry spells, likely resulting in leaching in sandy soils. Consequently, introducing tied-ridging water conservation and management resulted in depressed maize productivity when less fertilizer at 50 percent of recommended rate was used (Figure 10). Interpretation of the results on this experiment must be in the context of the probability of occurrence of seasons such as was experienced during the 2020/2021 cropping season. In general, such rainfall seasons are very rare in drought prone areas of southern Malawi. Therefore, as a risk-averse strategy, farmers are encouraged to use water conservation measures, especially when they also apply fertilizers.

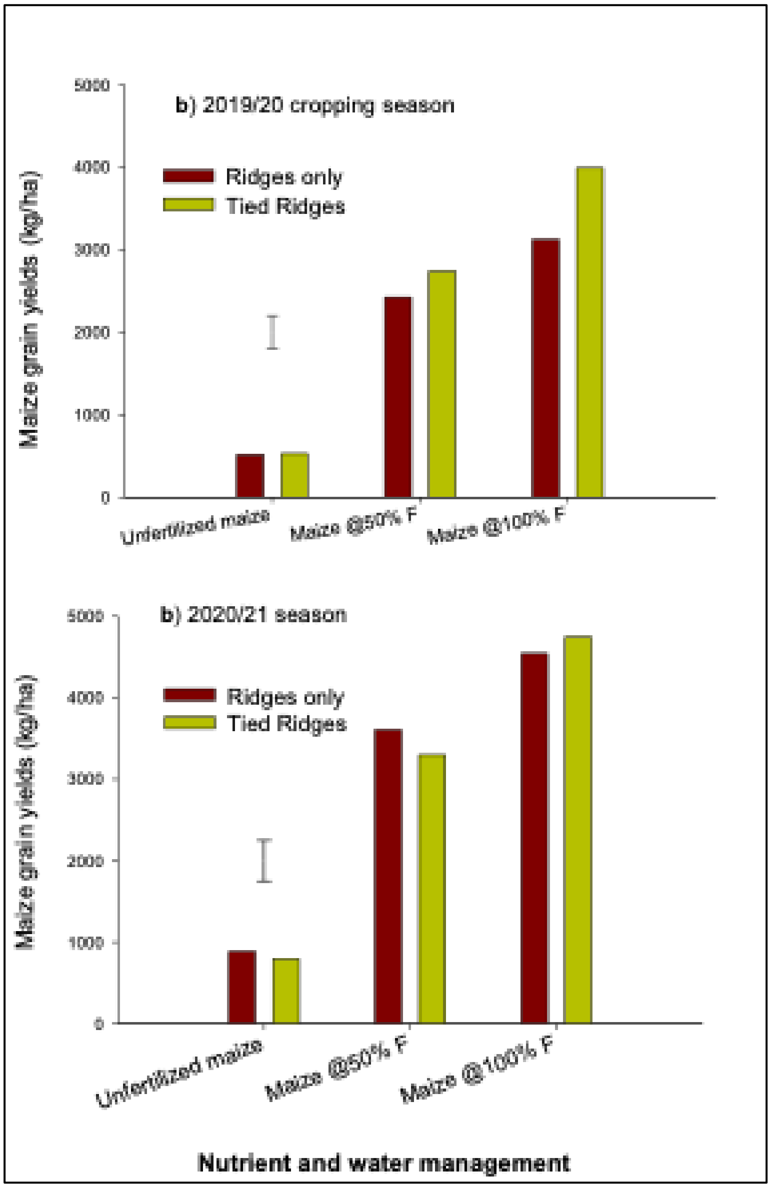


Figure 10. Nutrient and water management effects on maize productivity in drought-prone southern Malawi.

Targeted deliverables for 2020/2021 and status on achievements

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
Soil water and nutrients use interactions determined	All trials were harvested during March and April 2020; all data processed	Three repeat field trials successfully established in Ntubwi, Nsanama, and Nyambi as planned in January 2021	Data is collected and will be analyzed and used for preparing a manuscript; target submission date: June 2022
Data uploaded to DataVerse	All data for 2020 uploaded to DataVerse	NA	All data for 2020 uploaded to DataVerse
FtF indicators data submitted to M&E/IFPRI for upload	FtF indicators were submitted	NA	FtF indicators were submitted

Sub-activity 2.2.1.3: Climate-smart farming practices (soil water micro-catchments, weather-informed varieties, cover crops integration [cowpea]) for increasing productivity of the maize-legume system under variable weather conditions.

This study addresses the need to provide options that help farmers manage challenges related to weather variability in crop production. Options being tested include utilizing weather forecasts information in making decisions on planting dates, integration of *in situ* water harvesting, cover crops, and improved fertilizer management. The study addresses the response of crops to the combined application of these technologies and includes participatory evaluation, with a gender perspective, by farmers.

Four trials were set in two villages of Sabilo and Gallapo and established during the short rainy season of 2021. The objective of setting the trials at variable seasons was to establish how agricultural economics of the two systems would vary and examine whether intercropping short-duration maize with beans during the short rainy season followed by a second phase of legumes during the long rainy season is a more resilient strategy relative to a single cropping of maize-bean-pigeonpea during the long rainy season. During the short and long rainy seasons, two varieties of maize and three varieties of beans were planted per each trial. However, pigeonpea was only planted as an intercrop in the maize-bean system during the long rainy season (Table 3).

Table 3. Details on components of different cropping systems established during the short and long rainy season of 2020/2021 in Sabilo and Gallapo villages of Babati

Treatments	SR_Maize	LR_Maize	Bean Var.
Maize - bean intercrop	Seedco 419	Dekalb 9089	Elyamungo 90
Maize choice guided by regional weather forecast	Dekalb 777 in Sabilo Situka M1 in Gallapo	Dekalb 777 in Sabilo Situka M1 in Gallapo	Elyamungo 90
Maize-bean intercrop under tied ridges	Seedco 419	Dekalb 9089	Elyamungo 90
Maize- cover crop intercrop	Seedco 419	Dekalb 9089	Cowpea
Maize-heat tolerant bean variety	Seedco 419	Dekalb 9089	Selian 11
Maize-bean + slow-release N	Seedco 419	Dekalb 9089	Elyamungo 90
Maize-bean + micronutrients	Seedco 419	Dekalb 9089	Elyamungo 90
Maize-bean intercrop	Seedco 419	Dekalb 9089	KAT B9

Note: While maize was intercropped with beans during the short rainy season, maize was intercropped with beans and Mali pigeonpea variety in the long rainy season (SR= short rainy season; LR= long rainy season)

In summary, the climate-smart agricultural options under test includes micro-catchments, cover crops, planting of weather informed varieties, and slow-release N fertilizers. From the data collected so far, the following trends were observed:

- the high chlorophyll content after application of micronutrient fertilizer indicates the need for soil amendment with fertilizer blends containing micronutrients for increased crop production in the area;
- tied ridges have a potential of harvesting and conserving rainwater and providing moisture to maize crop for longer periods, resulting in increased chlorophyll content;

- bean yields were significantly affected by bean variety planted when assessed across fields. Mean yields ranged from 0.44 t/ha under Selian 11 variety to 1.09 t/ha for KAT B9 variety (Table 4). It was established that Selian 11 bean variety does not perform well in seasons characterized by prolonged dry spell because of its late flowering and podding characteristic;
- on the average, cowpea had higher grain yield (1.8 t/ha) than beans (1.2 t/ha). This indicates the multiple values a farmer can get from cultivating cowpea for use as a vegetable, for grain production, and income generation while providing soil cover; and
- soil moisture and soil temperature were significantly affected by sampling time ($p \leq 0.01$) along the growth curve and not by cropping systems.

Table 4. Effect of bean variety on resulting bean yield during the short rainy season of 2020/2021 season in Babati

Cropping system	Bean yield (t/ha)
Conventional maize-bean	0.69bc
Maize guided by weather forecast	0.83ab
Maize - Tied ridges	0.97ab
Maize - Selian 11 bean	0.44c
Maize - slow-release N	0.94ab
Maize with micronutrient	0.78abc
Maize - KAT B9 bean	1.09a
LSD	0.34

Targeted deliverables for 2019/2021 and status on achievements

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
Two technologies (use of micro-catchments and of cover crops) validated, and results documented	Maize harvested; pigeonpea in fields to be harvested in October 2020	Four on-farm trials were successfully initiated as planned (i.e., two trials in Sabilo and Gallapo villages)	Data are being analyzed and results will inform the ISFM system level manuscript (see 4.1.1.3)
Data uploaded to DataVerse	Data for 2019/2020 uploaded as planned	NA	Planned for October 2021
FtF indicators data submitted to M&E/IFPRI for upload	Completed	NA	Planned for October 2021
Publications	Publication accepted	Publication published [Kihara17965.pdf (ajfand.net)]	

Sub-activity 2.2.1.4: Integration of fodder trees and grass forages in dryland farming

Field experiments were stopped after six years of contour farming on the highly degraded soil, in favor of documenting outputs for publication. Data generated from this activity was used to support three publications presented in earlier reports.

Sub-activity 2.2.1.5: Evaluation of land rehabilitation benefits of shelterbelts and contours

No report presented (SUA – Shitindi) for the last and current reporting period.

Sub-activity 2.2.1.6: Validation of residual tied ridging as a labor-saving technology in the semi-arid areas of central Tanzania

Data collection on field experiments comparing utilization of repaired tied ridges from previous operations (residual tied ridges, RTR) with the conventional annually constructed tied ridges (CT) as a labor-saving practice was completed. Data have been analyzed and used to draft a manuscript with a working title "*Validation of residual tied ridging as a labour-saving technology".* It's target submission date is in November 2021. Below is the abstract of the manuscript.

Abstract. The poor and erratic rainfall (300-600 mm annually), high evapotranspiration rates, and frequent droughts are major factors limiting crop production in semi-arid areas. Their effects can be mitigated using physical soil and water conservation measures, which demand high labor input. Annual construction of tied ridges is one such measure. We hypothesized that if tied ridges from one season are repaired for use in the subsequent season, it would reduce the labor requirements of constructing new tied ridges. During the 2018/2019 and 2019/2020 cropping seasons, a study was designed and implemented in three villages to examine the efficacy of reconstructed tied ridges (RTR) as an alternate strategy for managing climate risks associated with high rainfall variability in the semi-arid region of central Tanzania. Treatments consisted of three tillage methods: CT; annually constructed tied ridges (ATR); and previous season's RTR. Improved maize (commercial variety DKC908 and drought tolerant WE2109) and sorghum (varieties Macia and NACO Mtama1) were used as test crops. Data were collected on labor requirements during land preparation and weeding, crop performance, economic benefits, food security, and rainwater use efficiency. RTR reduced the cost of land preparation by 17 and 57 percent over CT and ATR tillage, respectively. Regardless of its frequency, the overall cost of weeding was high for CT (US$ 16.13/ha) compared to those of the RTR and ATR treatments, which were the same (US$ 10.76/ha). Labor days saved with RTR were 9 and 28 manhours ha^{-1} over CT and ATR, respectively. Maize grain yield advantage was 86 and 61 percent over the CT for RTR and ATR, respectively, in part, due to the higher water use efficiency. Respective yield advantage values for sorghum were not significant. The study recommends the use of RTR because it is time saving, has low labor requirement, and ultimately results in higher economic benefits than CT and ATR.

Additional update. An extra treatment was superimposed on this study during 2019/2020 to determine the extent to which crops grown with *in-situ* water harvesting technologies can withstand water stress. Rainout shelters were used to induce the water stress as described in the last report. The 2020/2021 period was a second season trial. Preliminary data analysis showed that maize grain yield under ambient condition was more than 3X than that obtained under imposed drought conditions (Table 5). Both ATR and RTR outyielded CT treatments under ambient conditions, but not so much under drought conditions. Better soil water infiltration and storage appear to explain the observed productivity differences. The lesson confirmed is that drought occurring at flowering stage will have a negative effect on household food security bearing in mind that maize is a staple cereal in the study area. A manuscript for publication is being prepared, but because we want to relate the findings to long-term rainfall data that is still being compiled, the target submission date is extended to June 2022.

Table 5. Maize grain yield (kg/ha) as affected by tillage methods and varieties under ambient and imposed drought conditions at Mlali, Kongwa district during 2020/2021 cropping season. Two maize varieties (DKC9089 and WE2109) were used as test crops.

Treatment	Maize grain yield, kg/ha		
	Ambient rainfall condition	Imposed drought condition	Change (-ve)
CT+DKC9089	4123a	1051a	3072 (75%)
CT+WE2109	4261a	1290ab	2971 (70%)
ATR+DKC9089	5585b	1776b	3809 (68%)
ATR+WE2109	5161b	1390ab	3771 (73%)
RTR+DKC9089	5804b	1785b	4019 (69%)
RTR+WE2109	5654b	1780b	3874 (89%)
Mean	**5098**	**1512**	
SE±	**475**	**270**	
CV %	**9.3**	**17.9**	

Targeted deliverables for 2020/2021 and status on achievements

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
Manuscript on validation of RTR	Yield components, soil water content, and hydraulic potential data were collected; data are being analyzed	Drafting of the manuscript is in progress	Target submission date: November 2021
Manuscript on validating *in-situ* water harvesting technologies under water stress (rainout trial)	Biophysical data collection is completed	NA	Season 2 biophysical data collection is completed; long-term rainfall data are being assembled as they will add value to the study; manuscript target submission date: June 2022
Data uploaded to DataVerse	Done for 2020	NA	Scheduled for November 2021
FtF indicators data submitted to M&E/IFPRI for upload	Done for 2020	NA	Scheduled for October 2021

Outcome 3. Food and feed safety, nutritional quality, and income security of target smallholder families improved equitably (within households)

Output 3.1 *Demand-driven research products to reduce postharvest losses and improve food quality and safety piloted in target areas*

Activity 3.1.1: *Conduct packaging and delivery of postharvest technologies through community and development partnerships with an iterative review, refining, and follow-up*

Sub-activity 3.1.1.1: Impact of nutritional messaging on household nutrition, knowledge, attitude, and practices

Because of the COVID-19 pandemic that restricted the movement and gathering of people, all field trips related to this sub-activity were suspended (from mid-March 2020). To address this, a no-cost extension was granted to complete related activities by March 2021. However, this was also cancelled as the pandemic situation has not improved. Thus, the activity has again been re-scheduled for early 2022.

Targeted deliverables for 2020/2021 and status on achievements

Deliverables	Status (March 2021)	Status (September 2021)
At least 350 households trained on nutrition	Re-scheduled due to COVID-19	Re-scheduled due to COVID-19
At least four food kiosks/restaurants include recipes in their food menu	Re-scheduled due to COVID-19	Re-scheduled due to COVID-19
At least one success/blog story	NA	https://africa-rising.net/worldveg-and-africa-rising-serve-up-an-exciting-improved-vegetables-exhibition-at-the-tanzania-agribusiness-forum-2020/
Partners include nutrition education in their existing/new programs	In progress	Completed http://africa-rising-wiki.net/File:Key_lessons_scaling_veg_in_Karatu_21April.docx
A draft paper "to assess the impact of nutritional education on farmers nutritional knowledge, attitude and practices, income, and nutrition status"	NA	To be drafted using baseline and endline data to be collected in March 2022; planned to be submitted for publication by August 2022
Development partners include nutrition education in their existing /new scaling programs	Report to be presented during the second half of this project year	Completed.
At least one success/blog story produced	Planned for the second half of this project year	Completed.

Data uploaded to DataVerse	To be completed by August	
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August	Completed.

Sub-activity 3.1.1.2: Validating hermetic storage structures and the environment on physical and economic loss abatement in produce

The field component of this study was concluded in 2019. Data collected in an impact survey in mid-2020 were processed and a draft manuscript titled (revised) "*Food security and welfare impacts of mechanized shelling, drying tarpaulins and airtight grain storage among farm families in Tanzania: A comparative assessment*" is near submission (October 2021). The abstract is given below.

"During the last decade, postharvest losses (PHL) reduction has been on top of the agenda of governments and development agencies as a pathway to improving farm productivity and improve livelihoods. We investigated the factors that affect farmers' decisions to adopt farm-level technologies (i.e., mechanized shelling, drying tarpaulins, and air-tight storage) validated as positive strategies for reducing PHL in Tanzania's maize-based systems, and the impacts on farm families' food security and welfare. Mechanized shelling addressed a labor issue, while tarpaulins and airtight storage majorly addressed product quality and quantity losses, which are critical postharvest concerns. We analyzed cross-sectional survey data of 579 households using the endogenous switching regression framework. Results show that there exist some differences in the determinants for adoption across the three postharvest technologies. Demographic characteristics of households are not strong determinants, while large farm size, location in higher production potential zones, and neighbors use of the technology, are universal drivers of adoption. The technologies have positive impacts on food security and welfare. Drying tarpaulins and airtight storage increase food availability (18 to 27 percent), food access (24 to 26 percent), and household incomes (111 to 155 percent). Mechanized shelling improved incomes (68 percent) and food consumption expenditures (49 percent). The share of total household expenditure on food decreased markedly among adopters of mechanized shelling (11 percent), drying tarpaulin (42 percent), and air-tight storage (51 percent) meaning that user households became less vulnerable. Supporting policy for the adoption of these technologies should include frameworks that increase farm yields, off-farm income sources, and financial services access".

A report titled "The role of social capital and networking in relation to the speed of postharvest technology adoption" is scheduled to be submitted in April 2022.

Sub-activity 3.1.1.3: Nutritional value, safety, and processing quality of produce during storage and utilization by households

For sub-activity 3.1.1.2, the field component of this study has concluded and has been reported in the last report. A manuscript titled "*Quality and storability of common beans in smallholders' farm stores in Northern Tanzania: A multivariate analysis of agro-location, variety, and storage method effects"* was published as per last report. https://doi.org/10.1016/j.jspr.2020.101723. It is now a closed activity.

Output 3.2 *Nutritional quality due to increased accessibility and use of nutrient-dense crops by farmers improved*

Activity 3.2.1: *Promote and deploy nutrient-rich crop varieties and livestock food resources in target communities*

Sub-activity 3.2.1.1: Pathways to sustainable adoption of nutrient-dense diets in rural communities of central Tanzania

This work addressed drivers of food choice focusing on new pearl millet and pigeonpea varieties promoted by Africa RISING. The work was implemented by two students (Ms Monica Chande and Ruth Mremi) whose theses were successfully submitted for the award of MSc Degrees of Sokoine University of Agriculture, Tanzania. Theses summaries were given in the last report. A manuscript from the thesis addressing drivers of pearl millet consumption has been published (https://www.frontiersin.org/articles/10.3389/fsufs.2021.694160/full). One manuscript addressing drivers of pigeonpea consumption has been accepted for publication, and the results and conclusion are presented below.

Results: Health value was significantly correlated with health behavior identity (rs=0.63, P<0.001) and significantly predicted health behavior identity (rs=0.49, P=0.001). The constructs cues to action and control belief were significantly associated with intention (β=-0.41, P=0.059 and β=0.06, P=0.019 respectively). Finally, we observed that intention was a significant predictor of behavior (β=1.38, P=0.001). We also observed a significant negative interaction between perceived barriers and intention to consume pigeonpea (β=-0.04 P=0.006) indicating that perceived barriers limit intention to consume pigeonpea.

Conclusion and Implication: Our findings indicated that when the caregiver places increased importance on preventing her school-aged child from being iron or protein deficient or being anemic (health value), it results in a positive evaluation of the effectiveness of giving pigeonpea to address these nutrient deficiencies. Programs and efforts aimed at promoting pigeonpea consumption should focus on educating caregivers on iron and protein deficiency and the role that pigeonpea could play in addressing these. However, perceived barriers (i.e., pest attack on grain) need to be addressed to increase pigeonpea consumption. The involvement of postharvest management specialists to address pest attacks during storage is, therefore, crucial. Along with this, increasing productivity and crop management is also crucial to ensure year-round affordable supply of pigeonpea.

Sub-activity 3.2.1.2: Promoting farmer production of nutrient-dense (Zn, Fe) NUA45 and drought-tolerant SER83 bean varieties in Malawi

Maize occupies a disproportionately 70-80 percent of cropped land in central Malawi, leaving only at most 30 percent of the land for grain legumes and other minor crops. Dietary diversity studies have confirmed the dominant role of maize in diets. Consequently, protein and micronutrient deficiencies are widespread. Over the years, we have advocated for a shift towards intensified scaling of grain legumes on farms. This study was designed to improve nutrition by increasing productivity of intercropped bean without necessarily changing the proportion of land allocated to grain legumes. A manuscript entitled "Productivity of Newly Released Common Bean (*Phaseolus vulgaris* L.) Varieties Under Sole Cropping and Intercropping with Maize (*Zea mays* L.)" has been published (https://doi.org/10.3389/fsufs.2021.741177). Below is the abstract of the manuscript.

“Intercropping maize (*Zea mays* L.) with common bean (*Phaseolus vulgaris* L.) is one of the predominant farming practices in ESA for the effective use of resources and continuous household food supply. The productivity of sole or intercropped crops is subject to variety, location, year, and their interaction. Therefore, the objective of this study was to determine the productivity of newly released common bean varieties NUA45 and SER83 under sole cropping and intercropping with a maize hybrid variety SC672 as a guide to large-scale production. Experiments were conducted at Chitedze Agricultural Research Station (13.85°S; 33.38°E) and Linthipe Extension Planning Area (12.06°S; 33.25°E), and in Malawi in 2019 using a factorial arrangement laid out in an RCBD with four replications. The numbers of pods per plant (NPP) and seeds per pod (NSP), grain yield (GYD), and 100-seed weight were collected for common bean included, while GYD was recorded for maize. The main effects for genotype, location, year, and intercropping system were significant ($p < 0.05$) for GYD in common bean. The effects of the year and cropping system and location by intercropping system interaction were significant for maize GYD. The maize yield did not vary between sole cropped and intercropped systems. The total land equivalent ratios (LERs) for NUA45 and SER83 were 1.59 and 1.77, respectively. The LER-values showed a significant difference ($p < 0.034$), suggesting a considerably higher benefit of maize and common bean intercropping. Overall, intercropping maize with common bean rendered higher yields in the SER83/SC672 intercropping system than the sole crop in the study areas. Therefore, intra-row intercropping of the newly released common bean variety SER83 with a maize hybrid variety SC672 is recommended in the study area and other similar agroecologies for stable and sustainable production of both crops”.

Targeted deliverables for 2020/2021 and status on achievements

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
Nutrient-dense common bean seed distributed to about 500 farmers	Seed was distributed – see list at https://cgiar-my.sharepoint.com/personal/c_mankhwala_cgiar_org/Documents/Documents/MSU/LIST%20OF%20BENEFICIARIES%20MALAWI-2019_20.xlsm	NA	NA
Publication: Estimates of productivity and yield gaps for local and improved bean varieties	Trials (three mother trials and 20 baby trials per mother) harvested as planned; yield data analyzed	Manuscript under preparation	https://doi.org/10.3389/fsufs.2021.741177
Technology label: Nutrient-rich beans for improved nutrition, incomes, and soil fertility	Under preparation	Submitted for upload	https://africa-rising.net/brief-focus-nutrient-rich-beans-for-improved-nutrition-incomes-and-soil-fertility/

Sub-activity 3.2.1.3: Determining quality and safety of locally produced legume grain-derived complementary foods and adoption in Dedza District

Building on the introduction of nutrient-dense common bean varieties (sub-activity 3.2.1.2 above), this study was designed to introduce to the farmers alternative methods of incorporating nutrient-dense common bean varieties in menus as part of their diets, especially to demonstrate how these foods would protect children from undernutrition. Because this is a community engaging activity, its progress was limited by the COVID-19 pandemic. Approval for community engagement activities was granted only in September 2021, and this work is planned to be implemented during 2021-2022.

Sub-activity 3.2.1.4: Assess the contribution of the farming systems interventions in narrowing the food and nutrient gaps in Kongwa and Kiteto, and the probability of smallholder farmer production to meet them

This study aimed to determine the extent to which an integrated delivery of productivity-enhancing technologies (targeting Africa RISING promoted crop and livestock technologies) can increase the probability of meeting dietary diversity and nutrient adequacy of family household nutrition dietary needs. The survey was only implemented in September 2021, the delay being due to logistical challenges linked to the escalation of COVID-19 pandemic in the region from May to August 2021. Data are being cleaned, will be analyzed, and a manuscript written. Target submission date is June 2022.

Outcome 4. Functionality of input and output markets and other institutions to deliver demand-driven sustainable intensification research products improved

Output 4.1 *Access to profitable markets for smallholder farming communities and priority value chains facilitated*

Activity 4.1.1: *Conduct comprehensive value-chain analysis with a specific focus on SI technologies*

Sub-activity 4.1.1.1: Conduct value chain analysis (VCA) for (quality protein) maize seed in Kongwa and Kiteto

The study was completed, and the abstract of the proposed manuscript was given in the last report. However, it was recently agreed that a merged maize and groundnut seed value chain manuscript would make a stronger case. See new abstract under 4.1.1.2.

Sub-activity 4.1.1.2: Value chain analysis of groundnut seed and design of operation enhancement strategies for semi-arid ecologies of central Tanzania

A manuscript from the combined results of sub-activities 4.1.1.1 and 4.1.1.2 is has been drafted with the below working abstract. Submission for publication is targeted for November 2021.

Analysis of the Maize and Groundnut Seed Value Chains in Central and Northern Tanzania

Maize and groundnuts are important staple and cash crops in Tanzania; hence, understanding their seed value chains are critical for stimulating and enhancing productivity. The study aimed at establishing the critical elements for a well-designed maize and groundnut seed value chain that strengthens market systems without distorting the private sector investment. Standard survey approaches were used to conduct the study. The results revealed that there was a weak link between research organizations and farmers. More women were involved in the groundnut seed value chain while men were dominant for maize. It was evident that government policies had failed to offer a conducive environment for the seed value chains to thrive. The seed delivery in central Tanzania is constrained by the absence of prominent seed companies for both crops. The area is drought-prone; thus, a disincentive for seed companies to invest with the need for irrigation infrastructure as a solution. The production of hybrid maize by several seed companies is dominated in the high potential areas, and similarly to groundnut by the few companies. Therefore, most of the seed is accessed through agrodealers for the two crops and informal sources for groundnut through associations engaged in production of quality declared seed (QDS). Community seed banks were found to be an efficient way of promoting and availing improved groundnut varieties to smallholder farmers. Over reliance on farm saved seed was identified as one of the challenges affecting seed demand. The formal seed sector is weak for groundnut with very few private seed companies engaged in production as opposed to hybrid maize. Grain production of groundnut is slowly driving demand for improved seed. Seed production standards exist for both groundnut and maize whereby distinctiveness, uniformity and stability are key. Developing a sustainable seed system for groundnut and drought-tolerant open-pollinated variety (OPV) maize should involve engagement with multiple stakeholders, such as community-based seed producers and seed associations, who seem to have a strong foundation in central Tanzania. The study concludes that a strong network among agrodealers, seed companies, and maize farmers makes most of the maize farmers to adopt certified seed varieties. In addition, a strong QDS system is needed as an alternative system particularly for the drought tolerant OPV that are nutrient dense. The study recommends a strong focus on agrodealers' mobility as they are the players next to farmers".

Sub-activity 4.1.1.3: Assess how livelihoods of farmers are affected by implementation of ISFM practices as a result of Africa RISING activities in Babati

This is a survey and synthesis activity whose data have been used to draft a manuscript for publication (the deliverable) and is targeted for submission in November 2021. The summary of the findings is presented below.

ISFM Component 1 – Improved Germplasm. During the 2020-2021 season, farmers in Babati grew two to four crops including maize, beans, pigeonpeas, sunflower, among others. Ninety-seven (97) percent of the farmers used 17 improved maize varieties and purchased certified seeds. However, a large proportion (70 percent) of the farmers used varieties that were released before 2013. Twelve (12) percent of the farmers mixed new and old varieties, while 18 percent planted new varieties only. The newly released germplasm gave an average yield advantage of nine percent and up to 24 percent when given training through PAR. For other crops, local varieties such as beans (97 percent), pigeonpeas (85 percent), and sunflower (96 percent) were mainly used. The remaining few used recycled improved seed, which is acceptable for OPV.

ISFM Component 2 – Fertilizer application. There has been a large boost in fertilizer application to 15 percent considering that only three percent of farmers used fertilizers in 2013 (Kihara et al., 2015). Farmers that applied fertilizer had yield advantage of 56 percent compared to those that didn't (3170±430 vs 2039±126 kg/ha). Fertilizer use (self-purchased) is at 15 percent among actively engaged farmers (i.e., those who have been involved in mother or baby trials), who received both training and inputs. Similarly, 15 percent of farmers who received only inputs and less intensive training during the NAFAKA out-scaling program used fertilizer. Among non-participants, the use of fertilizer is at 12 percent. Each group applied on average 87, 64 and 55 kg ha-1 of fertilizer, respectively. This is indicative of the positive effects of farmer training and input demonstration. The increased usage among non-participants could be attributed to spillovers through community networks, extension agents, and other agencies who promote GAPs. Along the elevation gradient, farmers in the medium-high elevation used 34 kg/ha more of fertilizer than those on higher elevations, mainly because the higher elevation has high crop yield potential where production risk is reduced.

ISFM Component 3 – Organic resources application. For five years (2016 – 2021), one third of the farmers did not apply manure. Among those who applied fertilizers were non-experimenting farmers (71 percent), experimenters (66 percent), and out-scaling farmers (67 percent). The maize yield difference for these household level assessments was insignificant (manure's 2199±146 vs 2132±229 kg/ha), unlike plot level data where differences have been observed (Kihara et al. 2014; see also Figure 11). Much as experimenting farmers applied comparatively more inorganic fertilizer, non-participants applied more manure. There are notable inter-annual differences as 42 percent applied fertilizer during the 2020-2021 season, 61 percent during 2019-2020, 52 percent during 2018-2020, and 35 percent during 2016-2017. Manure transfer among households is considerable, with 18 percent of farmers getting manure from other households. Almost all those who applied used animal manure, while a few (16 percent) applied compost. A small proportion (16 percent) of the farmers incorporated residues: 28 percent among mother-baby farmers; 17 percent among out-scaling farmers; and 9 percent among non-participating farmers. Residue incorporation leads to a yield difference of one-third ton/ha but not statistically significant (2441±527 vs 2099±112 kg/ha). Majority of farmers (76 percent) take out residues to feed their livestock. A significant proportion (30 percent) do not take out residues, feeding their livestock on site. Farmers who took out residues used it for compost (30 percent), fuelwood (25 percent), construction of fences (9 percent), and gave to other farmers (11 percent).

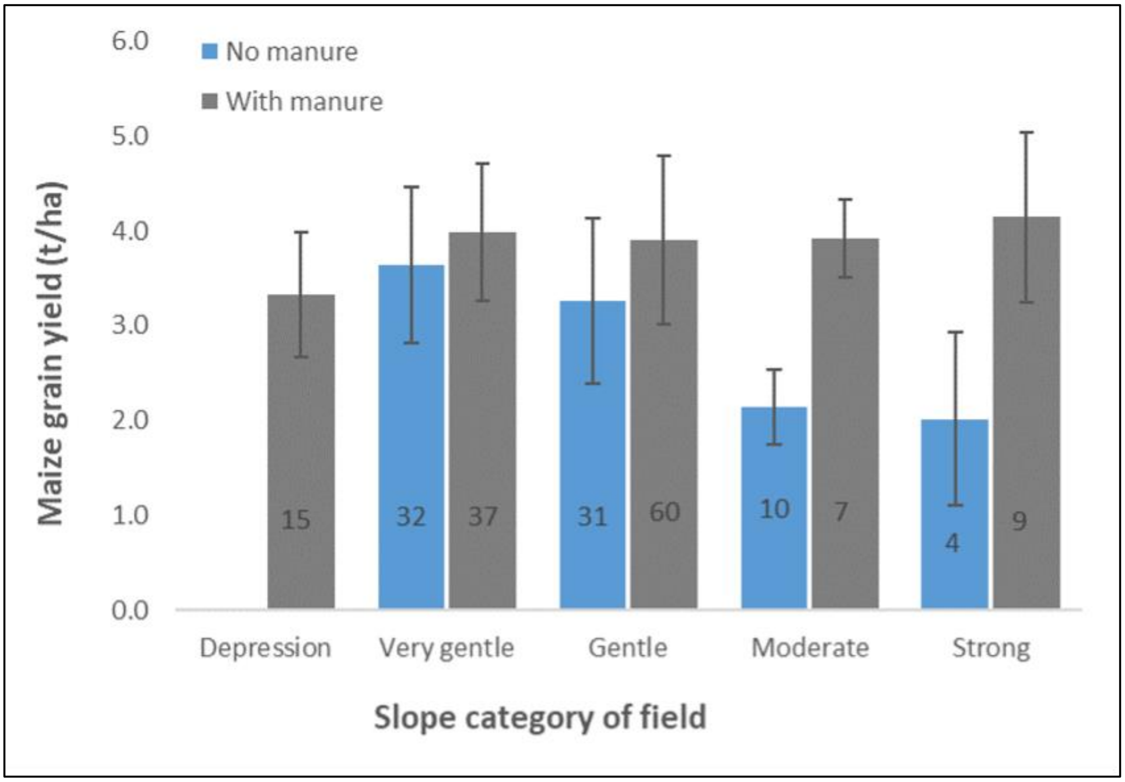


Figure 11. Maize yields observed in 2016/2017 cropping season for farmers' practice in fields under different slope categories with and without manure application in Babati, Northern Tanzania. Error bars are standard deviations from the mean while number of observations are indicated on each bar.

ISFM Component 4 – Local adaptation. Fifty (50) percent of farmers established measures for controlling soil loss and conserving soil moisture. These include terracing (45 percent), contour ploughing (49 percent), earth bunds (41 percent), no animal (35 percent), trees and bananas (32 percent), grass strips (12 percent,) mulching (12 percent), furrow (12 percent), and flood water harvesting (8 percent). For those who previously practiced but stopped, discontinuation rate for terrace was 7 percent, grass strips at 3.2 percent, contour ploughing at 6 percent, trees and bananas at 4.4 percent, and earth bunds at 6 percent. The main reasons for dis-adopting SWC strategies included labor, land, and occurrence of pests and diseases. Though not statistically significant, the measures led to a slightly lower maize yield with an average of 246 (i.e. 2090±182 vs 2336±169 kg/ha).

ISFM Component 5 – Legume integration. Legume integration within the maize cropping systems was done by 94 percent of the households. These are almost entirely grown as intercrops and none of the farmers mentioned rotations, although farmers in Gallapo sometimes plant pure beans.

Component Integration. In the midland and upland project locations, actively engaged households used mostly up to three ISFM components while non-participants used less than 1.5 components. Compared to non-participants, in the midlands, the actively engaged got maize yield advantage of 0.42 to 0.82 t ha^{-1} when both groups used two to three ISFM components (see also complementary data in Figure 12). In the uplands, the yield advantage ranged from

0.39 to 0.63 t ha^{-1} for two or three ISFM components. Diversity in ISFM components leads to yield stability, especially in midlands where yield variability decreased by 20 percent for farmers that employed two ISFM components and were actively engaged in Participatory Action Research (PAR).

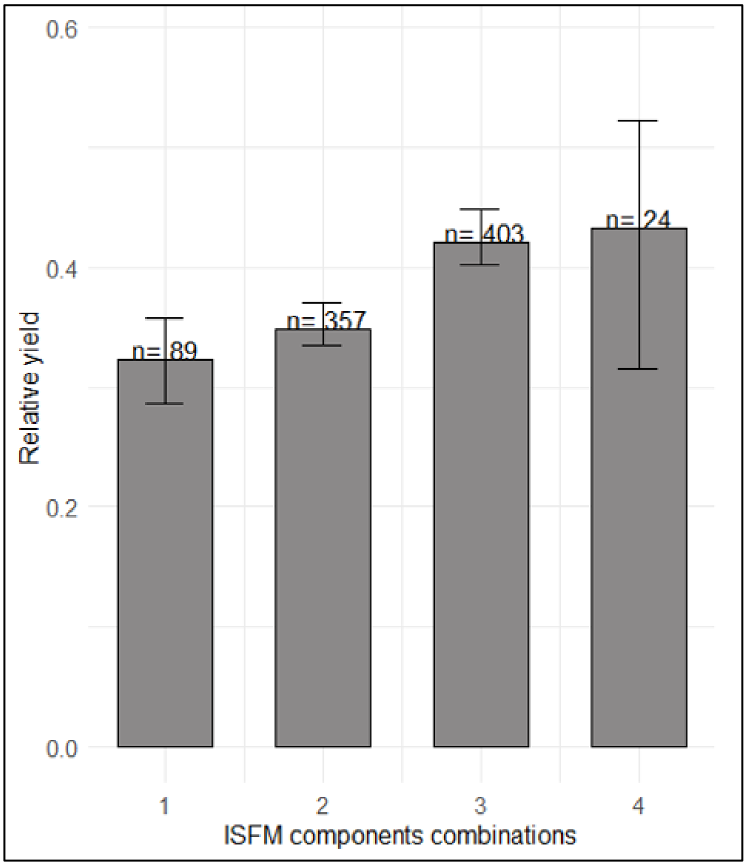


Figure 12. Response ratio of maize grain yield observed for different ISFM components in Babati based on data collected during five surveys conducted in 2013, 2014, 2016, 2017, and 2020. Data used are those from farmer practices. Error bars are bootstrapped confidence intervals.

General recommendation. Africa Rising's PAR approach support led to improved agricultural practices and increased yield advantage among smallholders in the highlands of Northern Tanzania. This was realized through pioneering newly released varieties that are more efficient at utilization of soils and adapted to seasonal weather variability. In addition, the approach promoted increased use of inorganic fertilizers that boost yield. Implementation of ISFM, though having tradeoffs, supports improved crop (maize) productivity.

Targeted deliverables for 2020/2021 and status

Deliverables	Status (March 2021)	Status (September 2021)
Trained enumerators	All activities are to be implemented in the second half of this year.	10 (5M; 5F) enumerators received training and engaged in the survey
Survey conducted		Survey is completed
Manuscript for publication		Data analysis and preparation of manuscript starts during November 2021; target publication date is June 2022

Sub-activity 4.1.1.5: Value chain analysis of nutrient-dense common bean varieties in Malawi

Collection of data for this sub-activity has been concluded. A manuscript is in the early stages of development and is planned for submission by June 2022. Preliminary observations are summarized below.

1. Seed for the common bean value chain originated from CIAT and Malawi Department of Agricultural Research and Services, who produced genetic material and early generation seed (Figure 13). This was in turn bought by seed companies for multiplication and sold as certified seed.
2. There is no specialization – bio-fortified beans are sold to traders who act as wholesalers and retailers for several other varieties.
3. There was no premium price attached to the bio-fortified varieties, with the morphological differences between the bio-fortified and normal varieties so similar in some cases that differentiation was practically nil. The unrecognized/uncelebrated 'quality' of bio-fortified beans is a significant impediment for their wider adoption.
4. Three main opportunities in the value chain were identified: (i) formation of farmer association and cooperatives, which will increase bargaining power, aggregate produce to meet better market, and reduce input costs through group purchases economies of scale; (ii) improved productivity, which can be achieved through improving seed supply chain, capacity building on good agronomic practices, demand creation activities that involve all value chain actors; and (iii) information sharing that can be promoted through creation of stakeholder platforms to ensure demand-oriented production.

Eight main challenges were identified, grouped against three value chain actors, and are presented in Table 6.

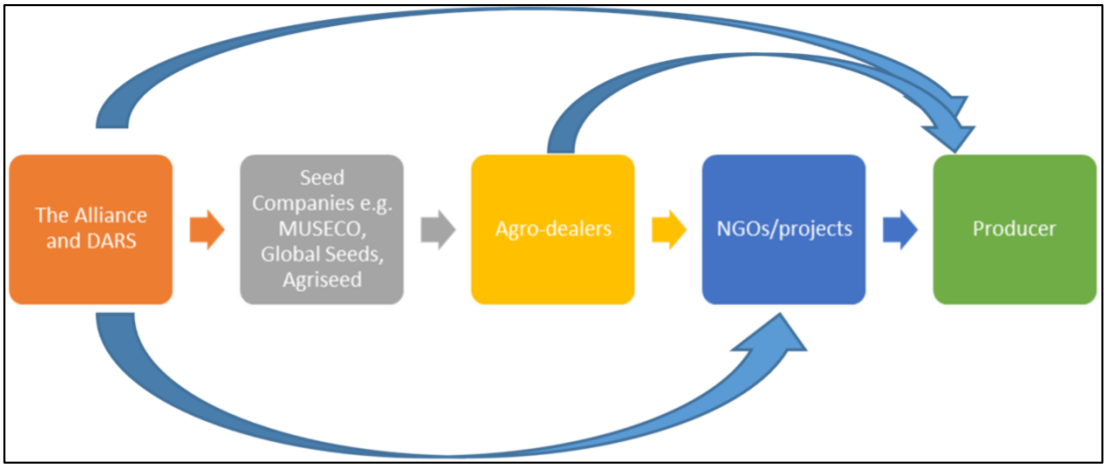


Figure 13. The flow of product in the common bean value chain and actors. The Alliance and DARS produce genetic material and early generation seed, which is bought by seed companies for multiplication, and sold as certified seed.

Table 6. Challenges faced by common bean value chain players

Value chain actor	Challenges	Impact
Input supply	1. Certified seed not available in the area and the far location of agro-dealers who stock certified seed	Farmers are using recycled seed resulting in low yield
	2. Less knowledge on bio-fortified bean varieties	Small agro-dealer shops not stocking certified seed
Producer	1. Small land holding size	Less land allocated to bean production but more on maize
	2. Poor agronomic practices (late planting, planting three seed/station, not applying fertilizer or pesticides)	Low productivity
	3. Unpredictable weather patterns (dry spells at critical stages of bean production	Low productivity
	4. Low bargaining power (farmers have low yields and are not organized into groups to aggregate produce)	Farmers are exploited through low prices and tampered weighing scales
Traders	1.Poor and expensive storage facilities	Loss of beans at postharvest
	2. Poor quality and inconsistent supply of beans (beans are available in March, April, May and January)	High costs of grading to meet market requirement and inability to meet demand locally

Activity 4.1.2: *Conduct a value chain stakeholder analysis (stakeholder mapping)*

Activity 4.1.3: *Develop a value chain enhancement strategy (including collective action approaches, contractual arrangements, and standardization)*

Sub-activities under Activities 4.1.2 and 4.1.3 are addressed by the relevant value chain sub-activities presented under Activity 4.1.1.

Activity 4.1.4: *Identify and evaluate existing mechanisms that inform farmers about dynamic market needs*

Sub-activity 4.1.4.1: Exploring ICTs for linking farmers to markets

The continuing activity with the MWANGA Platform is provision of more visibility to the platform through efforts such as the short blog on the effect of disseminating livestock extension messages using SMS on knowledge, attitude, and practices of smallholder farmers - A case study of using the MWANGA Platform in Tanzania. https://africa-rising.net/disseminating-livestock-extension-information-using-text-messages-in-tanzania/

In the cited blog, the observation is that exposing farmers to agricultural messages over short periods can result in considerable changes in knowledge and attitudes towards various interventions. This indicates that by exposing farmers to messages for a longer period, we may begin to see how these changes translate into improved farmer practices. For this reason, and especially during this COVID-19 pandemic period, when physical scaling interactions are limited, a proposal is being developed to continue the activity during 2021-2022.

Activity 4.1.5: *Conduct an analysis of the existing baseline survey data and supplement them with qualitative surveys from target regions*

Sub-activity 4.1.5.1: Identify the most profitable market channels and welfare effects of participating in the maize, groundnut, and pigeon pea markets in Malawi, Tanzania

A manuscript was the main deliverable in this sub-activity. It was completed and submitted to, and accepted for publication by PLOS ONE. It can be accessed at https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0250848. The abstract is presented below.

Welfare impacts of smallholder farmers' participation in multiple output markets: Empirical evidence from Tanzania (Manda et al., 2021)

A relatively large body of literature has documented the welfare effects of smallholder farmers' participation in single-commodity output markets. However, limited empirical evidence is available when smallholder farmers participate in multiple-commodities output markets. We tried to fill this gap in the literature by estimating the impacts of smallholder farmers' contemporaneous participation in both maize and legume markets *vis-à-vis* in only maize or legume markets using household-level data from Tanzania. Applying a multinomial endogenous switching regression model that allows controlling for observed and unobserved heterogeneity associated with market participation in single-commodity and multiple-commodity markets, results showed that smallholder farmers' participation in both single–and multiple–commodity markets was positively and significantly associated with household income and food security. Moreover, the greatest benefits were obtained when farmers participated in multiple-commodity markets, suggesting the importance of policies promoting diversification in crop income sources to increase welfare and food security. Our findings also signal the complementary–rather than substitute–nature of accessing multiple-commodity markets for enhancing household livelihoods under a specialization strategy. Finally, important policy implications are suggested, from promoting and supporting public infrastructure investments to expanding road networks to reduce transportation costs, especially in remote communities, to enhance smallholder farmer access to profitable maize and legume markets in Tanzania.

Outcome 5. Partnerships for the scaling of sustainable intensification research products and innovations

Output 5.1 *Opportunities for the use and adoption of sustainable intensification technologies identified for relevant farm typologies*

Activity 5.1.1: *Farmer participatory experimentation with crop and soil management and integrated crop-livestock technologies in on-farm situations*

Sub-activity 5.1.1.1: Continued experimentation in six target communities of Eastern Zambia and nine target communities in central and southern Malawi with already established clustered CA trials

drought-tolerant maize varieties and CA practices in 16 target communities of Malawi and Zambia. Throughout the years, these long-term on-farm trials have evolved from simple CA systems trials to more sophisticated CA long-term trials (some more than 16 years) with maize doubled-up legumes. They offer high-quality scientific information for assessing resilience of the CA technologies.

The general performance of trials in all areas continued well after March 2021. They were harvested on time and results analyzed and summarized. Data from the trials were used to calculate key performance indicators on productivity, profitability, social and human indicators in collaboration with the agronomic and socio-economic teams. The project team also conducted soil analyses and infiltration measurements. The results are available but not yet fully analyzed. We expect to have all the data analysis finalized by end of October 2021.

Preliminary harvest results from Eastern Zambia showed superior yield of the rotation treatments (Figure 14,) which outperformed other treatments, except for Hoya. The conventionally tilled control practices are always at the bottom. In Central and Southern Malawi, we noticed the influence of heavy rains at the onset of cropping season, followed by an early tailing-off in February 2021, which affected crop performance as grain filling was compromised (Figure 15). Due to planting of an intercrop in Plot 3, we also recorded yield penalties in the intercropped treatment, partially because the maize is grown at a larger row spacing (90cm instead of 75cm), and partially because the intercrop competed for moisture after February. Groundnut yield in Southern Malawi had record high yields, whereas in Central Malawi, all sites suffered from Rosette disease, which led to low harvests (Figure 16).

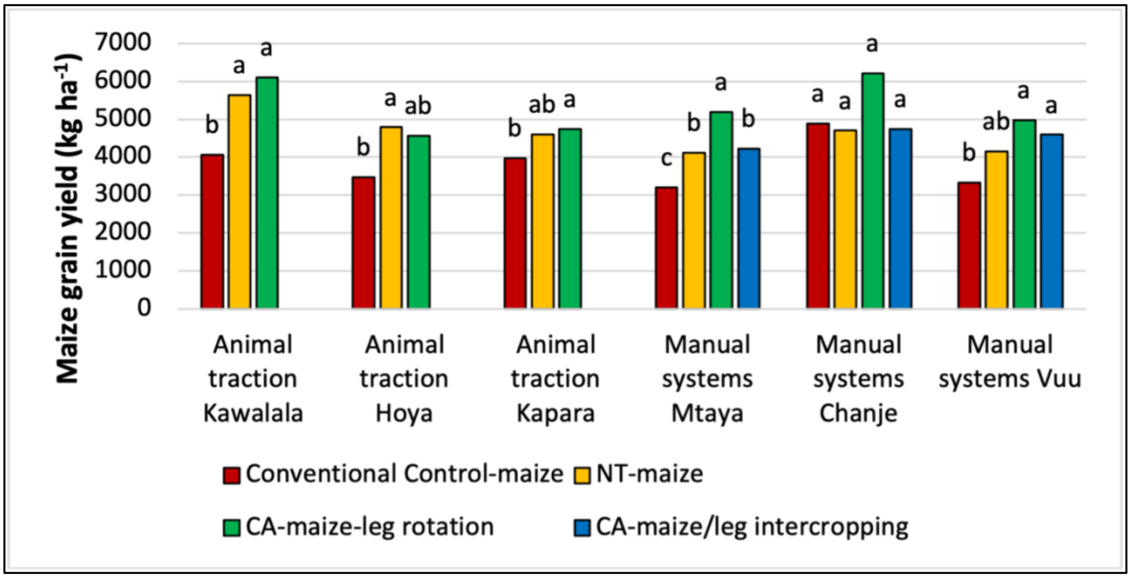


Figure 14. Summary of maize yield data from on-farm communities in Eastern Zambia showing both manual and animal traction seeding systems, 2020/2021. Means followed by different levels above the column are significantly different at P<0.05 probability level.

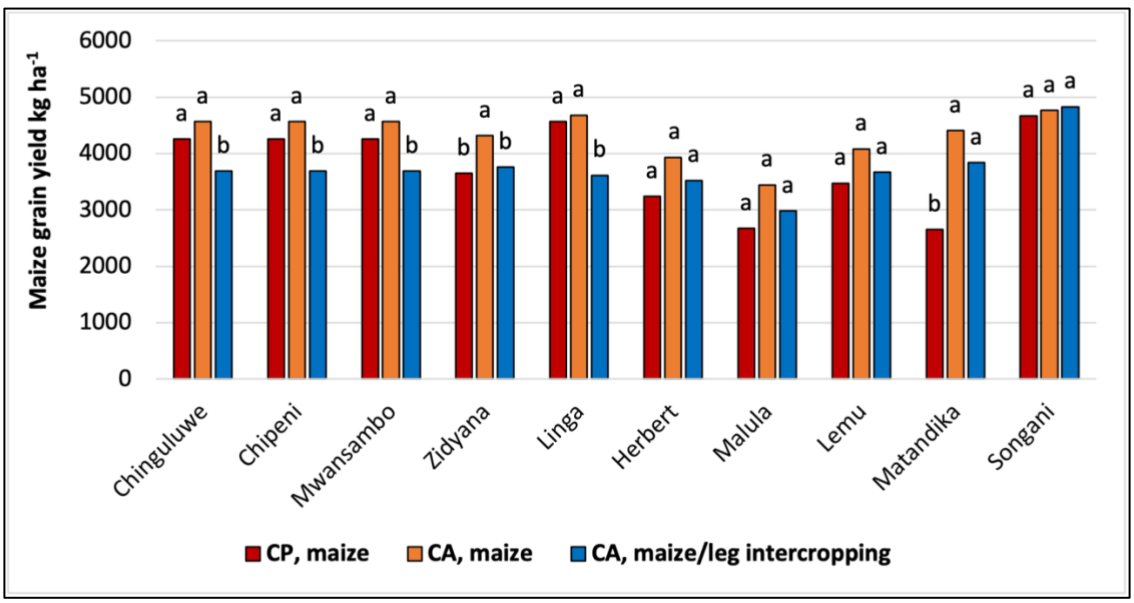


Figure 15. Maize grain yield in target communities of Central and Southern Malawi, 2020/2021. Means followed by different levels above the column are significantly different at P<0.05 probability level.

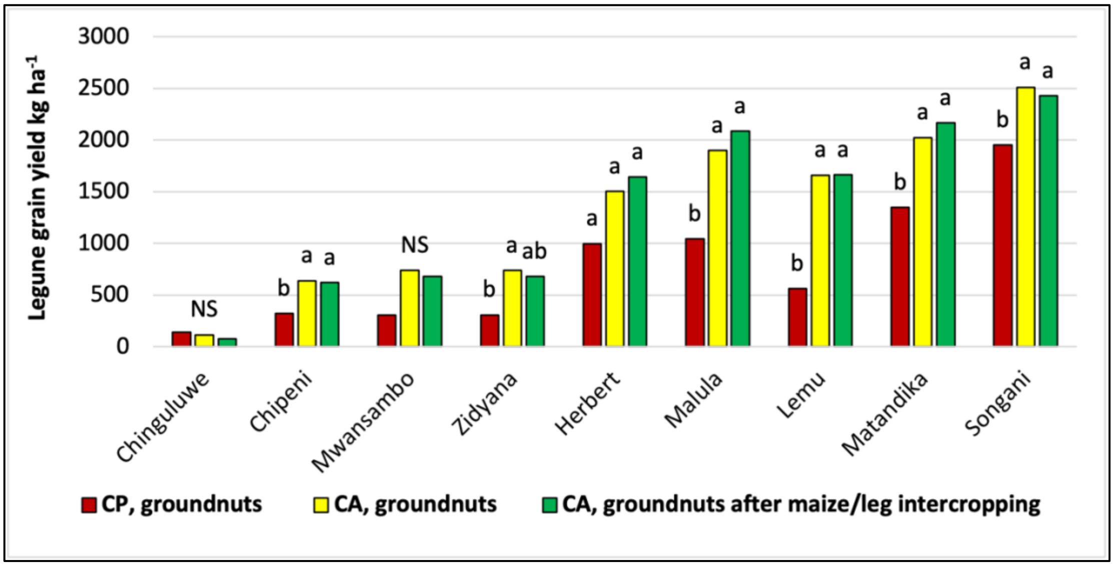


Figure 16. Groundnut grain yield in target communities of Central and Southern Malawi, 2020/2021. Means followed by different levels above the column are significantly different at P<0.05 probability level. Note: sites in central Malawi were heavily affected by rosette diseases; hence, harvest yields were low.

Other observations

- Farmer mid-season and end-of-season evaluations were a clear preference for the two CA systems, with the more diversified CA+Maize/PP-GN/PP rotation being the overall favourite. The conventional practices and the farmer fields alongside the trials got the lowest scores.
- On average, 14-16 percent greater water infiltration was measured under CA. It is the moisture that helps overcome in-season dry spells and leads to greater climate resilience.
- Preliminary analysis of the economics data shows that in Southern Malawi, the intercropping treatment outperformed all other treatments, except for Lemu, which had no differences between the CA system with sole maize-groundnut/pigeonpea rotation. The more diversified option outperformed the conventional practice by 67 percent (US$ 474 ha^{-1}). In Chanje, Eastern Zambia, the CA intercropping treatment had an 86 percent (US$ 491 ha^{-1}) greater net benefit than the conventional practice.
- From 2012 to 2021, severe food insecurity has declined in all sites (Figure17), while food security has increased. Examples are the districts of Dowa in Malawi and Lundazi in Zambia who made huge progress. Results reveal that households implementing SI practices are more likely to have a diverse diet and are also less likely to adopt desperate food insecurity coping mechanisms and strategies.

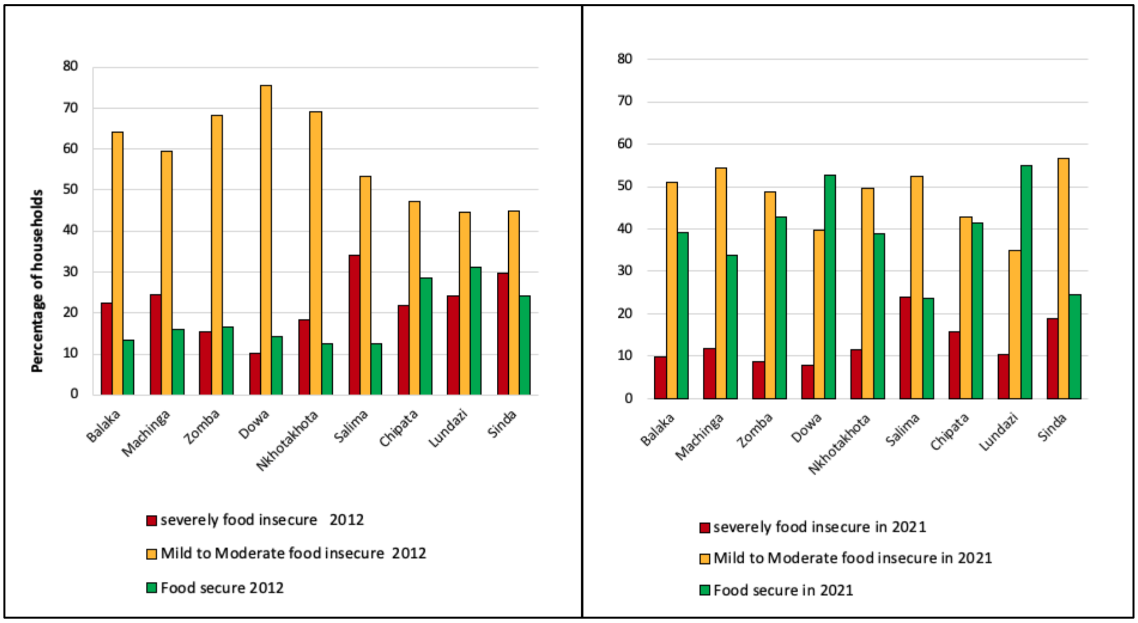


Figure 17. Development of the Household Food Insecurity Access Score (HFIAS) from 2012-2021 in target districts of Africa RISING in Eastern Zambia, Central and Southern Malawi.

Targeted deliverables for 2020/2021 and status on achievements

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
Knowledge products for smallholder farmers	NA	So far, two medicine labels have been drafted and are in their final form or being published.	CA in maize-legume systems medicine labels on CG space https://bit.ly/3cP3gei Animal traction-based maize-legume CA submitted.
FtF indicators data submitted to M&E/IFPRI for upload	Completed for 2020	NA	To be completed by October 2021
Publications		Combining local knowledge and soil science for integrated soil health assessments in conservation agriculture systems. https://bit.ly/3wzJLym	
		Why we should rethink 'adoption' in agricultural innovation: Empirical insights from Malawi https://onlinelibrary.wiley.com/doi/full/10.1002/ldr.3833	

Sub-activity 5.1.1.2: Explore the productivity domains of selected legumes and cereals to elucidate their best fitting cropping system at community/landscape level and their dissemination

This study was designed to validate the adaptation of selected technologies in three sub-ecology domains (low, moderate, and high potential) identified during the 2018-2019 cropping season. In the 2019-2020 season, we identified the best fit cropping systems, management, and planting patterns for each of the three sub-ecologies. At all levels and as expected, early planting had an advantage over late planting. In the 2020-2021 season, three experiments each with the best fit crop combination and planting pattern were deployed, each targeting a given sub-ecology. Preliminary analysis results for the productivity domain is presented. Data analyses for the other SI domains (economic, environment, and social) are in progress and will be utilized at radar chart level to further justify the fit of the technologies in the identified sub-ecologies.

Results of the best fit crop combinations and planting pattern in targeted sub-ecologies

High potential sub-ecology (Mlali and Manyusi both in Kongwa District): Legume-legume (pigeonpea + groundnut) cropping systems using a within row planting pattern (full population of groundnut + half population of pigeonpea planted on the same rows) was the best fit. The experiment was conducted at three levels: Level 1: Researcher designed and managed trial; Level 2: researcher designed farmer managed trial; and Level 3: Counter factual farmers. The groundnut + pigeonpea intercrop is comprised of: (a) within row planting: Kongwa 560 (full pop) + ICEAP 00557 (180 cm-half population) + Tied ridges; and (b) Farmer Practice (Local (pendo) groundnut variety + Mali planted on flat using mixed planting followed by respective pure stands of the crop varieties in the main treatments.

Significant differences were observed for groundnut at all the three levels of experimentation. P<_0.05 implied variation in performances among the different treatments in the experiment, intercrops, respective pure stands: Kongwa 650 and Pendo for groundnut and Ilonga M2 and Mali for pigeonpea (Table 7). While significant differences were observed at Levels 2 and 3 for pigeonpea, there were no significant differences in pigeonpea yield at Level 1. The results further show that the Land Equivalent Ration > 1 for all intercrop, whether using improved varieties or local varieties at all the three levels. This shows intercropping systems provide higher yield advantages than sole cropping. However, even though the LER are > 1 at all levels, the respective yield advantages were different. It was higher at Level 1 followed by Level 2, and the lowest yield at Level 3 (counter factual farmers). This may be attributed to the declining levels of management from levels 1 to 3. Results also show that within levels 1 and 2, the yields are higher using the improved practice (Kongwa 650 + Ilonga M2-within row planting) compared to the farmer practice (pendo + Mali using mixed planting). The experiment draws inference that use of improved technologies is one key to unlocking productivity for the farmers in the semi-arid ecology of central Tanzania.

Table 7. Productivity domain results (grain yield kg/ha)- Groundnut + pigeonpea

Experimental levels:	Level 1					Level 2			Level 3				
Designs	Research designed & managed					Research designed, farmer managed			Control Farmers				
Treatment combination	Groundnut	g/nut Kernel yield (kg/ha)	Pigeonpea	pp grain (kg/ha)	LER	g/nut Kernel yield (kg/ha)	pp grain (kg/ha)	LER	Groundnut	g/nut Kernel yield (kg/ha)	Pigeonpea	pp grain (kg/ha)	LER
Kongwa 650 + Ilonga M2-within row-ridged	Kongwa 650	1583	Ilonga M2	1961	1.89	868	300	1.3	Treatments not with control farmers				
Pure stand	Kongwa 650	1661	Ilonga M2	2103		997	693						
Pendo + Mali-Mixed planting-flat	Pendo	836	Mali	1639	2.03	429	413.33	1.3	Pendo	233	Mali	342.6	1.13
Pure stand	Pendo	756	Mali	1756		523	900		Pendo	444	Mali	563.9	
	Mean	**1325**		**1865**		**704**	**576**		**Mean**	**333**		**553.2**	
	Fpr	0.001		0.47		<0.001	<0.001		Fpr	<0.001		0.001	
	sed	329.9		441		147.5	59.55		sed	120.8		62.89	
	CV%	33.4		29		49.1	23.1		CV%	53.5		41.6	

Moderate potential sub-ecology (Njoro 1 and Njoro 2 both in Kiteto District): Legume-cereal (pigeonpea + sorghum) with an alternate planting pattern (one row of pigeonpea + two rows of sorghum in an alternate manner) was the best fit.

The experiment involved: (a) an improved practice, which had Ilonga M2 planted in an alternate pattern with IESV 23010 + tied Ridges + fertilization; (b) mixed: farmer practice-local sorghum variety + Mali+ planted on flat beds without fertilizer application; and (c) its respective pure stands. There was one mother trial in each village consisting of three replications (Level 1) and a total of 12 baby trials (Level 2), each hosting a single replicate from the mother trial; and 15 counter factual experimental sites (Level 3) only receiving the technology (pigeonpea variety Mali and pearl millet local variety) but producing using their farmer practice.

Results show significant differences in yield, P<_ 0.05, for both sorghum and pigeonpea entries at both levels 1 and 2 (Table 8). Significant differences in yield were observed only for pigeonpea at Level 3. IESV 23010 and Ilonga M2 gave a yield advantage >19 percent, whether in an intercrop or sole cropping at both levels 1 and 2. The improved practice (IESV 23010 + Ilonga M2 +ridge +fertilized) gave a higher yield than the farmer practice at both levels 1 and 2. However, results show LERs > 1 at all levels. Performance of the farmer practice gave a similar yield trend at all the three levels.

Low potential sub-ecology (Laikala and Moleti, both from Kongwa District): Legume-cereal (pigeonpea + pearl millet) was identified as the best fitting cropping system.

The experiment included: (a) an improved practice, which had Ilonga M2 planted in an alternate pattern with IP 8774 + tied Ridges + fertilization; (b) mixed: farmer practice-local pearl millet + Mali+ planted on flat beds without fertilizer application; and (c) respective pure stands. There was one mother trial in each village consisting of three replications (Level 1) and a total of 12 baby trials (Level 2), each hosting a single replicate from the mother trial; and 20 counter factual experimental sites (Level 3) only receiving the technology (pigeonpea variety Mali and pearl millet local variety) but grown under farmer practice.

Table 8. Productivity domain results (grain yield kg/ha) - sorghum + pigeonpea

Experimental levels:	Level 1 Research designed & managed					Level 2 Research designed, farmer managed			Level 3 Control Farmers				
Treatment combination	**Sorghum**	**sorghum grain yield (kg/ha)**	**Pigeonpea**	**Pigeonpea grain (kg/ha)**	**LER**	**sorghum grain yield (kg/ha)**	**pp grain (kg/ha)**	**LER**	**Sorghum**	**sorghum grain yield (kg/ha)**	**Pigeonpea**	**Pigeonpea grain (kg/ha)**	**LER**
ICEAP 23010 + Ilonga M2-alternate +ridge +fert	ICEAP 23010	1009.26	Ilonga M2	648	1.16	836.42	555.56	1.13	Treatments in these rows not with control farmers				
Pure stand	ICEAP 23010	1376.63	Ilonga M2	1500		1240.74	1209.8						
Local Sorghum + Mali-mixed +Flat+ no fert	Local	472.22	Mali	552	1.49	533.95	472.22	1.26	Local mixed	376.74	Mali	512	1.58
Pure stand	Local	513.89	Mali	963		703.7	925.93		Local pure	380.21	Mali	866.67	
	Mean	**843.75**		**911**		**828.7**	**790.9**			**378.47**		**689.8**	
	Fpr	<0.001		<0.001		0.001	<0.001			0.965		0.022	
	sed	178.16		125.4		162.8	135.73			79.2		146.48	
	CV%	36.6		23.9		41.7	36.4			59.2		57.8	

Table 9. Productivity domain results (grain yield kg/ha) - pearl millet + pigeonpea

Experimental levels:	**Level 1**					**Level 2**			**Level 3**				
	Research designed & managed					**Research designed, farmer managed**			**Control Farmers**				
Treatment combination	**Pearl millet**	**pearl millet grain yield (kg/ha)**	**Pigeonpea**	**Pigeonpea grain (kg/ha)**	**LER**	**pearl millet grain yield (kg/ha)**	**pp grain (kg/ha)**	**LER**	**Pearl millet**	**pearl millet grain yield (kg/ha)**	**Pigeonpea**	**Pigeonpea grain (kg/ha)**	**LER**
IP 8774 + Ilonga M2-alternate	IP 8774	699	Ilonga M2	962	1.28	881	439.29	1.38	Treatments in these rows not with control farmers				
Pure stand	IP 8774	1192	Ilonga M2	1351		1041	630.95						
Local pearl millet+ Mali-mixed	Local	680	Mali	1271	1.42	539	597.22	1.44	Local mixed	512.82	Mali	326	1.39
Pure stand	Local	875	Mali	2049		617	611.11		Local pure	619.4	Mali	572	
	Mean	**862**		**1468.95**		**769**	**569.64**			**566.21**		**449**	
	Fpr	0.481		0.004		<0.001	<0.001			0.206		66.4	
	sed	363		258.7		124.1	75.2			82.19		0.001	
	CV%	53		31.8		44.2	41.3			37		36.2	

Targeted deliverables for 2020-2021 and status on achievements

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
Benefits of SI technologies evaluated across sites and documented	Field data collected and analyzed; the best fit cropping systems, management, and planting patterns for each of the three sub-ecologies were identified	Three experiments, each with the best fit crop combination and planting pattern, were deployed; each targeting a given sub-ecology	Data have been collected and are being processed for development of a manuscript
Manuscripts to be submitted by April 22	1. Yield Advantage of Elite Cereal and Legume Genotypes in Varying Potential Agro-ecologies of Central Tanzania 2. Participatory Variety Selection (PVS) as tool for variety development: A case study for the the Africa RISNG Project in Tanzania and McKnight CCRP Project in Malawi		
Data uploaded to DataVerse	All materials have now been harvested; data is mostly processed; analysis either done or in progress	Completed for 2020	Target date for submission in October 2021
FtF indicators data submitted to M&E/IFPRI for upload	Data are being compiled	Completed for 2020	Data submitted to M&E for uploading

<u>Sub-activity 5.1.1.3:</u> Engage development partners to identify livestock management technologies of interest for partnership dissemination

No follow-up engagement activities were implemented during this reporting period. The sub-activity was terminated due to poor performance.

<u>Sub-activity 5.1.1.4:</u> Case studies: Application of SI technologies use among farmers interacting with Africa RISING at different intensities (MSU/CIMMYT partner study)

In this sub-activity, we are quantifying the farm-scale impact of engaging farmers at different Africa RISING technology access intensities. The hypothesis was described in previous reports. The research team has engaged farmers at three intensities.

i. Mother trial farmers – these are farmers who hosted fully replicated trials with a range of technologies, often more than eight treatments. They are a nucleus group of farmers who anchor the learning process. They are more visited by researchers and often host field days. Farmer interaction with researchers and extension is rated as 'high'. We want to understand how these farmers have applied SI technologies on their wider farms and compare that with productivity on the mother trials that they host.
ii. Baby farmers: These are a selected group of farmers who are associated with a mother trial. These farmers usually participate in field days and engage extension staff.
iii. Local controls: These farmers are located in the same village as the mother and baby trial farmers. They do not directly benefit from Africa RISING but are exposed to Africa RISING technologies through field days. They often do not directly relate with the project.

The study is implemented through three modules: Module 1 – farm characterization; Module 2- farm productivity estimations, and Module 3 – postharvest activities, home consumption patterns, and marketing. During April/May 2021, we implemented Module 2, which principally involved crop yield estimates through yield cut measurements on selected farms (four mother trial host farms, four farms from baby trial farms, and local and distant control farms for each of the six EPAs, for a cumulative 16 farms per EPA). The measurements done were on maize, groundnut, and soybean. In all cases, three replicate yield cuts for each field were carried out to capture in-field yield variability.

Results from Module 1 were presented as part of the March 2021 interim technical report. Here, we present preliminary maize productivity yield gaps by farm category across six sites (Figure 18). In all cases, maize yields from mother trials were the largest. The mother host farms had consistently large yields, but not always significantly larger than all the other categories. The distant control was next best in two of the six sites. This will need to be further investigated to understand if there were no inherent differences between the treated and control sites.

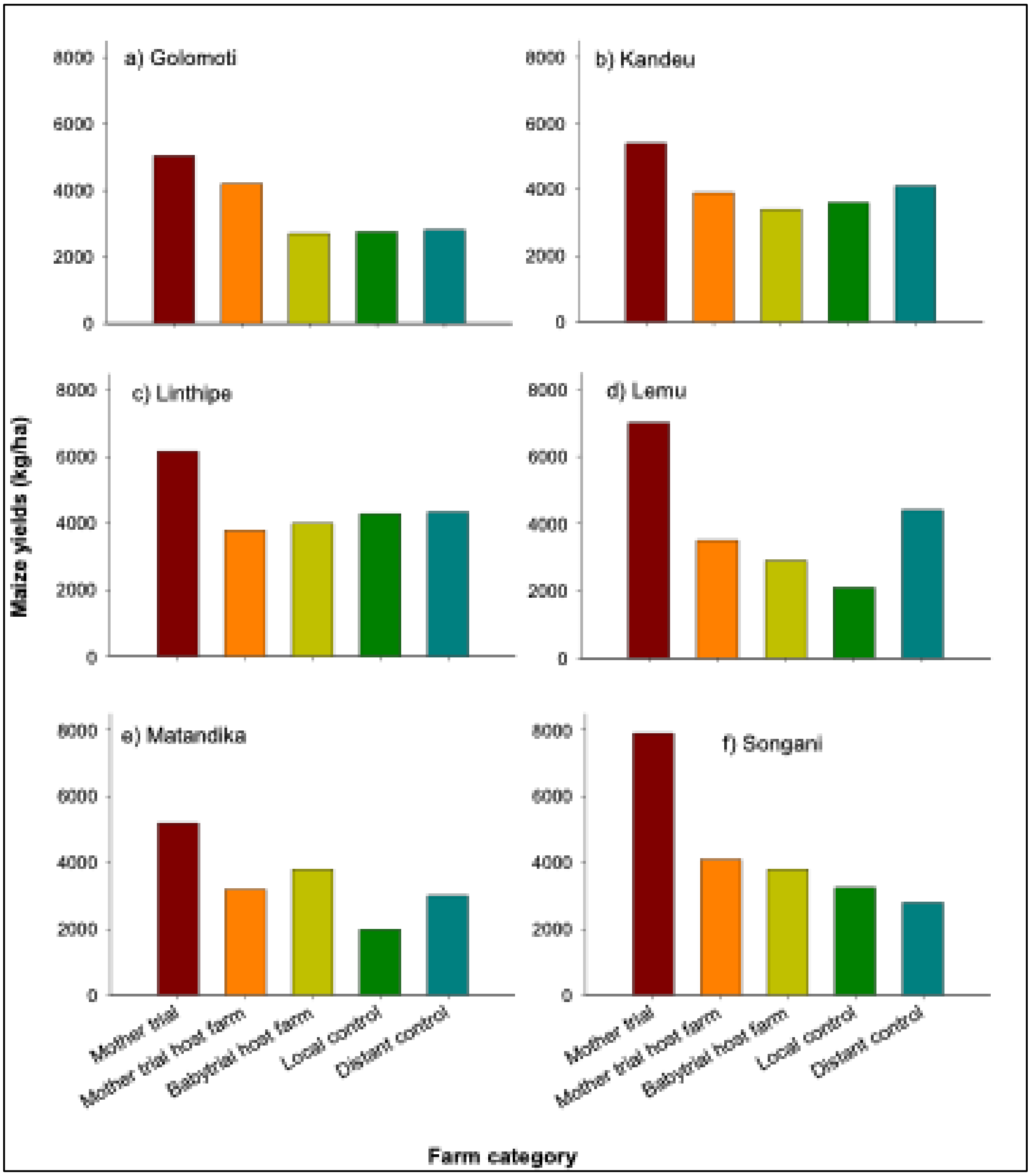


Figure 18. Preliminary results on maize yield gaps for farms interacting with Africa RISING at different intensity across six sites.

Targeted deliverables for 2020/2021 and status on achievements

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
Mother trials for water limited yields established	NA	Trials for 2021 established as planned	Data collected
Detailed farm profiles documented (*Data sets by farm typologies; estimates of yield gaps; farm-scale SI scaling compiled*)	Module 2 was implemented during April and May 2020. There was poor supervision as COVID-19 infections in the region resulted in restrictions.	Data collected from Module 1; electronic survey instrument created using survey stack and used to implement both Modules 1 and 2	Modules 1 and 2 currently being linked for detailed farm profiles
Activities by implementing students monitored	Module 1 (farm characterization) was implemented	Students have begun synthesizing Module 1 data	Data synthesis is continuing
Estimates of yield gaps and farm scale SI scaling compiled	Data for 2020 collected and compiled	Yield cuts data collection for yield estimations currently underway for mother trial host farms, baby farmers, and local controls	Yield cuts data by farm category are being analyzed
Survey instrument verified	NA	Survey instrument was verified in November/December 2020; https://bit.ly/2OoLlBH New sites were selected for the survey	Survey implemented during July and August 2021; data are being cleaned for analysis
Data upload to DataVerse	Data for 2020 uploaded	NA	Target upload date is October 2021
Manuscripts for publication	Drivers of SI technology uptake, implication on adaptive capacity, food security and scaling. Target submission – December 2021		
	In depth study of a subset of intensified and stagnant farms. Target submission – June 2022		

Sub-activity 5.1.1.5: Panel survey, soils processing, and meta-analysis studies for maize-grain legumes sequences and implications for sustainability

This sub-activity has two sets of activities that are critical in bringing to the fore the wider Africa RISING impact in Malawi: (1) analyzing data from the panel surveys carried over the years; and (2) meta-analysis of large agronomic data sets collected over eight years. Key panel survey results related key soil messages, and two publications informed by this research were presented in the last report. One manuscript has been published during this reporting period (https://doi.org/10.1002/saj2.20263). The abstract is presented below.

"Soil C status is a critical component of greenhouse gas mitigation efforts and supports food security through affecting crop growth and management. In much of the world, laboratory-based measures of soil C are expensive and logistically challenging, whereas map-based predictions generated at the continental scale (e.g., African Soil Information Service [AfSIS]; www.soilgrids.org) may be unreliable at the management-relevant, policy-relevant, field, and regional scales. We test whether an US$ 350, open source, field portable reflectometer can provide site-specific estimates of soil C status and predict whether a crop will respond to fertilizer across 1155 sites in central and southern Malawi based on an established threshold of 9.4 g C kg^{-1} soil. When compared with soil C measured by combustion, the scanner calibrated with covariates of field-estimable texture class and slope class provides unbiased (0.42 ± 0.44 g C kg^{-1} soil; p = .06), precise (R^2 = .57), and actionable (area under the receiver operating characteristic curve [AUC] = 0.88) data at the field scale, including at unmeasured locations (relative prediction error 19–23 percent) and at the village scale. The reflectometer outperformed predictions from the continental-scale AfSIS database, which were neither precise (R^2 = .044) nor actionable (AUC = 0.63) at the field scale, and underestimated soil C in the region by 2.5 ± 0.5 g C kg^{-1} soil (p < .001). The reflectometer is an accessible tool to monitor soil C in sub-Saharan Africa to improve field-level management and guide regional policies that support food security while combating climate change".

Targeted deliverables for 2020/2021 and status

Deliverables	Status (September 2021)
Meta-analysis of panel survey data collated to inform manuscript development	Some data fully analyzed; papers published: https://doi/org/10.1016/j.foodpol.2020102002 https://doi.org/10.1111/agec.12601

Activity 5.1.2: *Use farm trial data to apply crop simulation models and assess performance over space and time, including assessment of climate-smart technologies to establish the potential for adaptation and mitigation*

Sub-activity 5.1.2.1: Apply APSIM crop simulation model to assess changes in resource use efficiencies, productivity, and profitability of the different cropping systems in Kongwa, Kiteto, and Iringa in Tanzania.

The objective of the study is to use APSIM modelling to assess the long-term implications of SI options on climate, market risks, and resource use efficiency of smallholder farms in central Tanzania and Malawi. We would identify and propose proven climate-resilient practices, which will be applied to enhance the resilience of the cereal and legume value chains to climate change and help to minimize climate risks and stabilize production and yields. A CCAFS working paper is published at https://hdl.handle.net/10568/114910, and the abstract is presented below.

"Managing climate risk in agriculture requires a proper understanding of climatic conditions, regional, and global climatic drivers, as well as major agricultural activities at the particular location of interest. Critical analyses of variability and trends in the historical climatic conditions are crucial in designing and implementing action plans to improve resilience and reduce the risks of exposure to harsh climatic conditions. However, in Tanzania, less is known about the variability and trends in the recent climatological conditions. The current study examined variability and trends in rainfall of major agroecological zones in Tanzania (1^o - 12^oS, 21^o - 41^oE) using station data from seven locations (Hombolo, Igeri, Ilonga, Naliendele, Mlingano, Tumbi, and Ukiliguru), which had records from 1981 to 2020, and in Dodoma and Tanga with records from 1958 to 2020. The variability in annual rainfall was high in Hombolo and Tanga locations (CV ≥ 28 percent) and low in Igeri (CV = 16 percent). The OND season showed the highest variability in rainfall (34 to 61 percent) as compared to the MAM (26 to 36 percent) and DJFMA (20 to 31 percent) seasons. We found increasing and decreasing trends in the number of rainy days in Ukiliguru and Tanga respectively, and a decreasing trend in the MAM rainfall in Mlingano. The trends in other locations were statistically insignificant. We assessed the forecast skills of seasonal rainfall forecasts issued by the Tanzania Meteorological Authority (TMA) and IGAD (Intergovernmental Authority on Development) Climate Prediction and Application Center (ICPAC). We found TMA forecasts had higher skills compared to ICPAC forecasts. However, our assessment was limited to MAM and OND seasons due to the unavailability of seasonal forecasts of the DJFMA season issued by ICPAC. Moreover, we showed that integration of SCF with SSTa increases the reliability of the SCF to 80 percent at many locations, which present an opportunity for better utilization of the SCF in agricultural decision-making and better management of climate risks".

Targeted deliverables for 2020/2021 and status on achievements

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
Long-term implications of intercropping systems on climate, market risks, and resource use efficiency of smallholder farms established and documented	Simulation studies have been conducted but not completed because some parameters in APSIM are not suitable for the sorghum material used. We have, however, been able to simulate trends.	Meta-analysis of the doubled-up legume systems – influence on cereal productivity and contribution to human nutrition has been delayed due to data analysis.	A manuscript on long-term implications of sorghum-pigeonpea intercropping systems on productivity, resilience, and profitability among smallholder farmers is being prepared for publication in March 2022.

Sub-activity 5.1.2.2: Evaluating potential contributions of integrated soil fertility management around the five SIAF domains with emphasis on Africa RISING interventions in Tanzania

This synthesis activity is aimed at assessing system-wide effects of ISFM on indicators within the five domains of SIAF in Tanzania. A manuscript with a working title "*Understanding potential contributions of Integrated Soil fertility management to various sustainable intensification impact domains*" has been drafted, revised, and shared with the Chief Scientist for final comments. The manuscript is targeted to be finalized and ready for submission to a journal by December 2021. The following are the findings of the synthesis:

- Benefits of ISFM are observed across multiple SI assessment framework domain indicators. These benefits increased as farmers practiced more components. Although the increased use of ISFM components is associated with increased labor, it also leads to higher gross margins/economic gains that often offset the labor costs (Table 10). Decreasing yield variability with more ISFM components points to climate smartness of ISFM. Full ISFM is not practiced by many farmers in the Babati or Kongwa and Kiteto districts of Tanzania, with majority practicing only one or two components.
- There are clear opportunities for increasing the intensity of ISFM through additional ISFM components and promotion campaigns that highlight the finding that the increased application of ISFM results in better yields (Figure 19) and higher gross margins. Government subsidies, where applied, should be expanded beyond improved varieties and fertilizers to other ISFM components including crop diversification (legume integration), local adaptation strategies and utilization of organic resources.
- Research gaps for future studies have been identified, with the environment and social domain identified as being the most deficient of data among the SIAF domains considering the different ISFM components. Although increasing implementation of ISFM by farmers has demonstrated benefits across multiple SIAF domains, it is influenced by socio-economic issues such as affordability, which need to be addressed through other studies and policy interventions.

Table 10. Effects of the number of ISFM components used by farmers on net whole farm income (US$/ca), with standard deviations and number of observations (in brackets)

ISFM component combinations	Babati (N=86)	Kongwa (N = 131)	All (N=217)
0	19.1 **(1)**	40.4±62.1 (**49**)	40.0 ±61.6 (**50**)
1	51.4±40.9 (**8**)	63. 3±148.3 (**46**)	61. 5±137.5 (**54**)
2	140.6±153.1 (**30**)	32.7±71.1 (**21**)	96.1±135.9 (**51**)
3	101.8±129.6 (**26**)	43.6±49.0 (**15**)	80.5±110.2 (**41**)
4	122.6±133.4 (**21**)		122.5±133.4 (**21**)

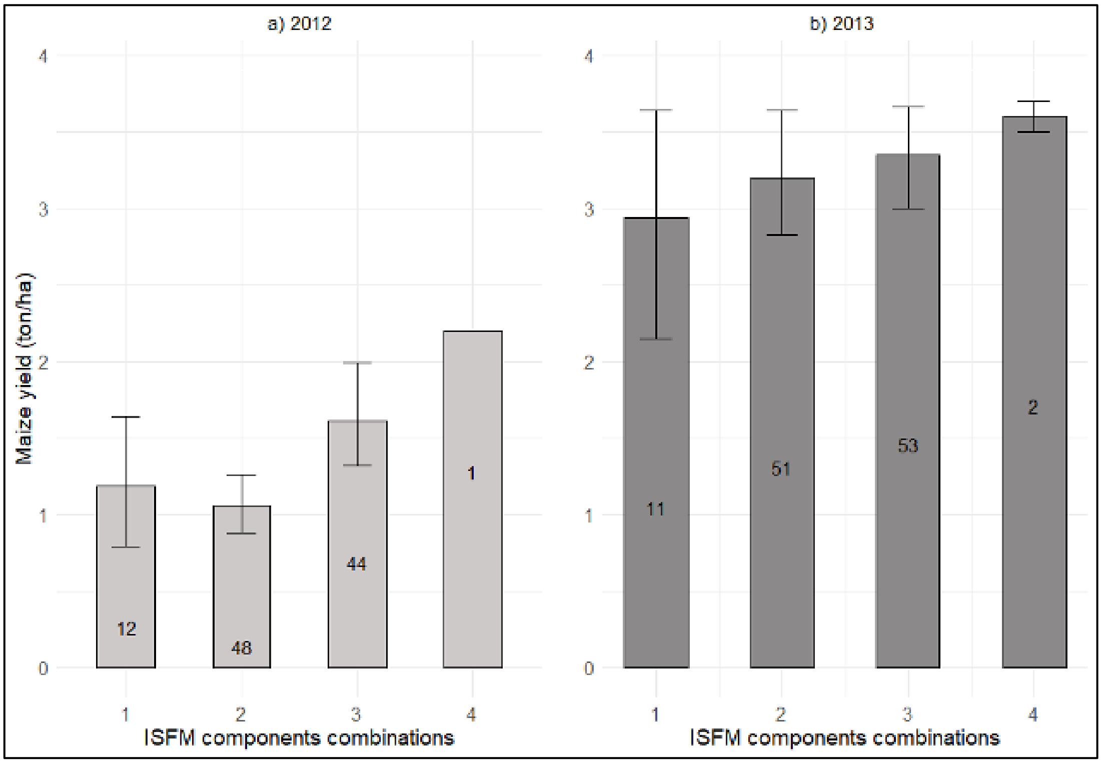


Figure 19. Effects of the number of ISFM components used by farmers on the yield of maize in Babati (a) based on farmer recall in 2012; and (b) based on yield cuts in 2013. The recall data are obtained from surveys conducted in 2013. Error bars are bootstrapped confidence intervals.

Activity 5.1.3: *Establish adaptive field experiments with mineral and crop/animal-derived organic manure*

Sub-activity 5.1.3.1: Rainfall-responsive nitrogen fertilization strategies: in search of increased nitrogen use efficiency by smallholder farmers under rainfed conditions in Malawi

While it is known that nitrogen (N) fertilizers recovery by crops is intricately linked to soil water availability, current N application strategies barely reflect the necessity for reduced N application when rainfalls fail or more N application when the season is favorable. For farmers who invest in N fertilizers, the high risk for financial losses, associated with drought-induced crop failure, is often beyond the threshold that these farmers can absorb. This study aimed to identify financial risk reduction based on formulating innovations around N fertilizer use by smallholder farmers guided by rainfall conditions. To this end, a manuscript titled "A case for green-based vegetation indices: plot-scale sUAS imagery related to crop chlorophyll content on smallholder maize farms in Malawi" (https://doi.org/10.1080/2150704X.2021.1938733) was developed. Its abstract is presented below.

"Predictable outcomes from precision agriculture (PA) solutions require accurate measurements of crop status and a remote sensing knowledgebase that spans ecoregions. This paper evaluates the relationships between 20 multispectral vegetation indices derived from small, unmanned aircraft system (sUAS) image collection, and on-farm measurements of crop chlorophyll content at two smallholder experimentation maize farms in Malawi with varied N fertilizer treatments. Results of this analysis show that prominent, green-based multispectral indices, such as the green normalized difference vegetation index (GNDVI), were among the models with the strongest correlations. This study is consistent with other research in this field, contributes to mounting evidence supporting a shift in status quo for greater adoption of green-based indices in PA, and offers data specific to the semi-arid sub-Saharan context".

Sub-activity 5.1.3.2: Assessing the effect of residue quantity and quality, and water conservation on maize productivity and nitrogen dynamics on smallholder farms in Malawi

Challenges in managing crop residues on the farms have been documented. The trade-offs are rarely used in informed decision-making and indicate that high-quality residues must be preserved for soil fertility gains instead of the easy pathway of land preparation through burning the residues. While the knowledge on N dynamics, following incorporation of different residue quality is fairly documented, what is not clear is the interaction between crop residue quality, quantity, and soil water management on maize productivity, which is the target for this study. In addition to the PhD thesis and one publication that were completed in 2020, a manuscript titled "Crop residue quality and quantity and water management interactions on smallholder farms in Malawi" is under development and planned to be submitted in June 2022 for publication.

Sub-activity 5.1.3.3: Assessing the integrative effect of in-situ rainwater harvesting and fertilizer micro-dosing on crop yield, water, and nutrient use efficiency in Kongwa District

No report was presented for October 2020 to March 2021, and no report has been received for this reporting period (Mawazo Shitindi, SUA).

Activity 5.1.4: Demonstrate the use and impact of crop residues, forages, and other organic resources as animal feed and nutrient resources

Sub-activity 5.1.4.1: Test the effect of feeding Napier grass and Maize stover supplemented with bean haulms at different levels on milk yield under smallholder farmer conditions

Sub-activity 5.1.4.2: Demonstrating the of effect home-made feed rations based on Gliricidia sepium and vegetable waste on the productivity of selected strains of chickens

Both sub-activities ended in 2020 following the non-submission of two consecutive reports even after no-cost contractual extensions were awarded (Ben Lukuyu, ILRI).

Activity 5.1.5: *Use crop-livestock models for trade-off analysis*

No proposal was submitted to conduct research under this activity during this reporting period.

Activity 5.1.6: *Disseminate best-fit integrated crop-livestock technologies to reach and have an effect on small-scale farmers in a landscape context*

Sub-activity 5.1.6.1: Small-scale piloting of FarmMATCH – a framework for typology-based targeting and scaling of agricultural innovations. (Matching Agricultural Technologies to Farms and their Context)

Increasingly, mobile phones and other ICT services are used to provide information and advice to farmers to facilitate learning, but support to targeting and scaling of agricultural technologies through ICT tools is scarce. ICT-based targeting and scaling approaches should not be considered a silver bullet, although they can increase the reach and reduce the costs of technology dissemination compared to traditional village extension services. Within this project, sustainable recommendation domains (SRDs) could be targeted for scaling specific technologies (Muthoni *et* *al.* (2017[4]). The effectiveness of the suitability assessment can be further refined as long as the features of individual farms are considered and directly related to technology characteristics during the targeting phase. This study proposes the use of the FarmMATCH approach to fill this knowledge gap (i.e., facilitating the matching between agricultural technologies to farms and their context).

[4] Francis K. Muthoni, Zhe Guo, Mateete Bekunda, Haroon Sseguya, Fred Kizito, Fredrick Baijukia, Irmgard, Hoeschle-Zeledon, 2017. Sustainable recommendation domains for scaling agricultural technologies in Tanzania. Land use policy 66: 34-48.

Targeted deliverables for 2019/2021 and status on achievements

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
Journal article	Under development	Under development (draft abstract presented above); target date for submission –April 2021	Because no technical assistance was available, a new target date was set – March 2022
MSc student thesis	Under development	No student report because no student was identified. The work is being done by the team.	A journal article is proposed as the deliverable to be published by August 2022 May 2022

Activity 5.1.7: *Conduct cost-benefit and gender analysis coupled with other socio-economic analyses to identify and quantify adoption constraints and opportunities for different farmer contexts*

Sub-activity 5.1.7.1: Socio-economic studies on cost/benefits of CA systems, labor, nutrition, and gender in target communities of Malawi and Zambia

5.1.7.1 Activities were merged with and reported under sub-activity 5.1.1.1.

Sub-activity 5.1.7.2: Farmer application of SI principles in CA long-term trials in Malawi and Zambia, and Sub-activity 5.1.7.3: Socio-economic studies on nutritional benefits of SI practices

These are now presented as Case Studies under sub-activity 5.1.1.4.

Sub-activity 5.1.7.4: Assess the effect of tied ridging, residual tied ridging and rip tillage on maize productivity, net crop returns, household income, and food security

A summary of progress in the study was presented in the last report. Below is the abstract of the manuscript titled "The average and distributional impacts of soil and water conservation technologies on the welfare of smallholder farmers in Tanzania" that has been submitted to the *Energy and Food Security Journal* for publication.

Abstract. "Using recent survey data from over 500 sample households, this study evaluates the adoption (as well as the duration of adoption) and the impacts of soil and water conservation technologies on income and food security in Tanzania. We employ a control function approach and instrumental variable regression models to estimate the average impacts and the instrumental variable quantile treatment effects model to analyze the distributional impacts of adoption. The results show that the adoption and duration of the adoption of soil and water conservation technologies had significant and positive effects on the total value of crop production and household income. Moreover, we find that the adoption and its duration had a significant and positive effect on the food security indicators (i.e., household dietary diversity, household food insecurity access scale, and household hunger scale). The results from the instrumental variable quantile treatment effects model also show that the impacts of adopting soil and water conservation technologies on the outcome variables are positive and significant, although they vary significantly across the income and food security distributions. The results indicate that even though adoption benefits households in both the lower and upper quantiles of the income and food security distributions, the marginal impacts of adoption are generally larger for the households in the upper quantiles. The paper concludes with a discussion of the policy options for increasing and sustaining the adoption and impacts of soil and water conservation technologies in Tanzania".

Sub-activity 5.1.7.5: Determine the effect of the joint adoption of improved maize varieties and maize-legume rotation on maize productivity and crop incomes in Malawi

The data used in this study were collected through surveys conducted in March 2015, May 2015, March 2016, April/May 2016, September 2016, April 2017, February 2018, and April 2018 (Burke et al. 2020[5]). The process of data cleaning, data organization, and variable generation has been completed and data analysis is ongoing. A manuscript for publication will be generated and expected to be submitted to a journal by February 2022.

Preliminary descriptive statistics (Table 11) show that over 70 percent of the households were headed by males. A typical household consisted of four individuals and cultivated 0.23 ha on average. Most of the crops were infested with Striga with slightly over 90 percent of the plots being affected in 2018. Considering that almost 77 percent of the households received a fertilizer subsidy, the fertilizer application rate of 50 kg/ha was relatively high compared to other countries in Africa, south of the Sahara where average fertilizer application rate is less than 20 kg/ha (Africa Fertilizer Map, 2019)[6].

[5] Burke, W.J., Snapp, S.S., Jayne, T.S., 2020. An in-depth examination of maize yield response to fertilizer in Central Malawi reveals low profits and too many weeds. Agric. Econ. (United Kingdom) 51, 923–940. https://doi.org/10.1111/agec.12601

[6] https://www.afap-partnership.org/africa-fertilizer-map-2019/

Table 11. Descriptive statistics by year

Variable	2015 (N= 650)	2016 (N= 617)	2018 (N= 589)	All
Total value of maize productivity (USD/ha)	427.633	279.05	223.12	315.10
Improved maize (1=yes; 0 =otherwise)	0.299	0.3	0.214	0.272
Maize-legume intercrop (1=yes; 0 =otherwise)	0.406	0.414	0.306	0.377
Residue retention (1=yes; 0 =otherwise)	0.86	0.752	0.723	0.778
Organic fertilizer (1=yes; 0 =otherwise)	0.341	0.421	0.304	0.357
Age of the household head (years)	47.607	49.574	54.093	49.648
Sex of the household head (1 = male)	0.758	0.761	0.72	0.747
Household size (number)	2.959	5.219	5.104	4.413
Received fertilizer subsidy (1=yes; 0 = otherwise)	0.842	0.848	0.608	0.769
Size of the plot (ha)	0.234	0.237	0.230	0.234
Striga present (1=yes; 0 =otherwise)	0.553	0.583	0.919	0.681
Market access (minutes)	89.848	90.572	90.394	90.269
Nightlights (W/cms sr)[a]	0.153	0.098	0.35	0.199
Population density (number of persons km^{-2})	406.5	434.2	449.7	429.9
Nitrogen fertilizer application rate (g/ha)	99	41	54	50
Maximum temperature anomalies (^{0}C)	-0.233	1.381	0.057	0.395
Minimum temperature anomalies (^{0}C)	-0.355	0.799	0.919	0.433
Rainfall anomalies (mm)	-0.633	-0.649	-0.517	-0.602

[a] This is a measure of radiance in Watt per square centimeter steradian

The adopters of SI practices had higher mean and median values of total value of maize production (TVMP – Figure 20) than non-adopters. This suggests that SI technologies may be critical in improving maize productivity in Malawi. In addition, the bivariate unconditional relationships between SI adoption and TVMP consistently shows a statistically significant difference between adopters and non-adopters, with the former having more maize income than the latter. The highest returns are observed with improved varieties and the lowest with organic fertilizer. However, observations should be interpreted with caution as we don't have control over other variables, which might affect maize productivity.

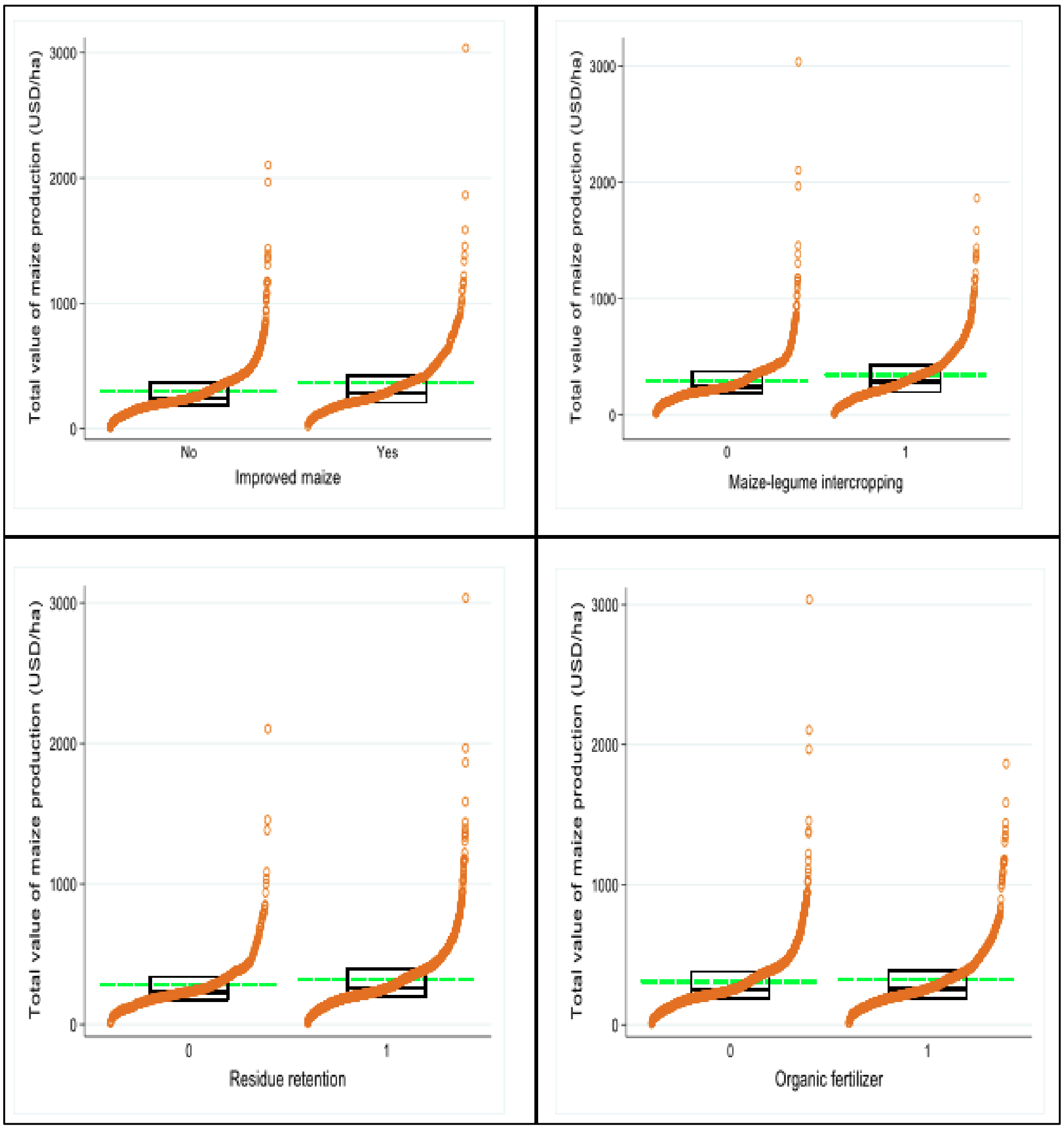


Figure 20. Relationships between TVMP and selected SI technologies. The plots show the distributions of TVMP by each SI technology with the associated cumulative probabilities. The y-axis shows values for the outcome variable while the x-axis shows the adoption status for each SI practice. The dotted lines show the mean values while the solid lines inside the box plots show the median values.

Other preliminary results (data not shown) suggest that the adoption of improved maize varieties significantly increased maize revenue by US$ 58 (p-value =0.00), followed by organic fertilizer application (US$ 31), and lastly maize-legume intercropping with US$ 21. The results also show that low-temperature deviations, relative to long-term averages, is negatively and significantly associated with a reduction in the TVMP. We find that on average, an increase of one percent in minimum temperature during the growing seasons reduces the TVMP by as much as US$ 115. Similarly, a one percent decrease in rainfall reduces the TVMP by US$ 97. It is apparent that climatic factors play a key role in determining the profitability of the maize enterprise in Malawi.

The next steps in the analysis of data include: (a) estimation of the causal impacts of the adoption of SI technologies on maize yield and revenue, using rigorous econometric techniques; and (b) further examination of the marginal impacts of climatic factors on maize productivity.

Targeted deliverables for 2020/2021 and status

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
Manuscript on the yield and income effects of the joint adoption of selected SI practices for maize	Data from the 2015 and 2016 surveys have been cleaned and some variables have been generated	Data from the 2014 and 2018 surveys are being cleaned and variables generated	Data analyses have been initiated and preliminary results presented above; target submission date is February 2022
Data uploaded to DataVerse			Target upload date: November 2021

Sub-activity 5.1.7.6: Determine Africa RISING research on household welfare and return on investment

During the period under review, ACDI/VOCA, in collaboration with IITA, implemented phone surveys and in-person interviews. Initially, it was envisaged that only the phone surveys would be implemented; however, because of the problem of non-response, we complemented the phone surveys with physical person-to-person interviews after the COVID-19 problems had eased. The personal interviews targeted respondents who could not be interviewed through the phone.

The surveys targeted three types of individuals/groups: (1) farmers; (2) village-based extension agents (VBAAs); and (3) producer organizations (POs). Data cleaning and analysis have started on the VBAA'S and Pos, and preliminary descriptive statistics have been generated. A total of 355 VBAAs and 382 POs were interviewed between February and June 2021 from seven regions of Tanzania. The average age of the VBAA's was 45 years, not very different from that of POs at 47 years. Similarly, the household size was about the same (5.43 vs 5.52). Even though the ownership of the phones and mobile money accounts were similar across the groups, there was a clear difference between 2010 and 2020. VBBAs and POs owned more phones and mobile accounts in 2020 than in 2010. The same trend was noted for livestock ownership.

The ultimate objective of the surveys was to estimate the social return on investment (SROI). The SROI goes beyond ROI because it accounts for the social, economic, and environmental value created by a project. The value of sales from the operations of the VBAAs and POs play an important role in the estimation of the SROI. Figures 21 and 22 show the average sales generated by the two groups. The average total sales for the VBAAs TZX 4.1 million in 2018 and over TZX 6 million in 2020. The POs generated on average over TZX 50 million from 2018 to 2020, with the highest being in 2018. The substantial benefits accrued by both the VBAAs and POs across the years may be an indication of the support and knowledge they obtained from the NAFAKA project.

The future plans are to estimate the ROI and SROI for the NAFAKA-AR project, conduct empirical analysis of the impact of the NAFAKA and NAFAKA-AR on the SROI and household welfare, and write a manuscript for publication by April 2022.

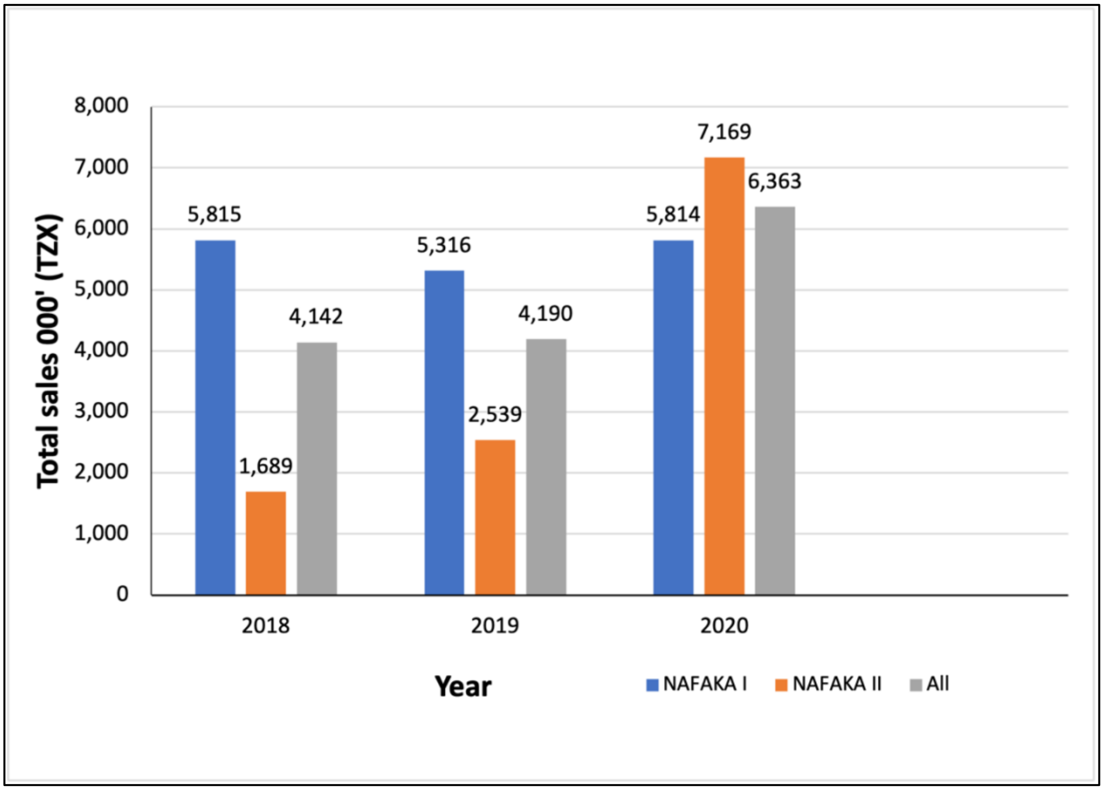


Figure 21. Total sales generated by VBAAs by year of operation. The NAFAKA Project run over two Phases: NAFAKA I form 2012-2015 and NAFAKA II from 2016-2021. VBAAs were recruited during both phases.

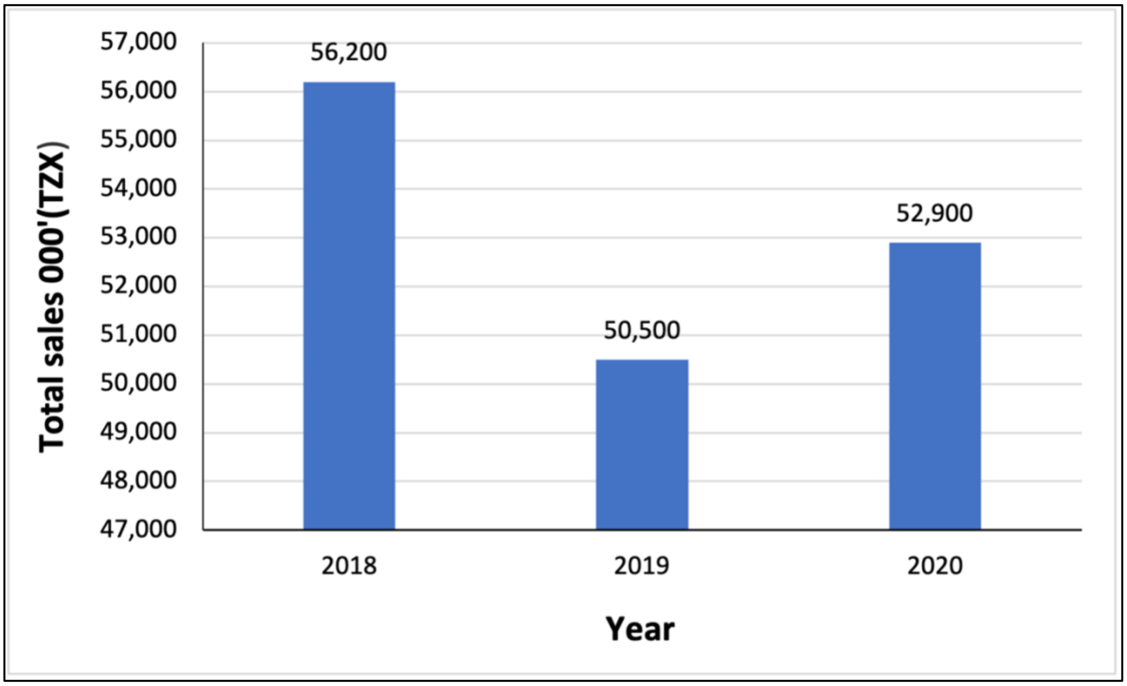


Figure 22. Total sales generated by POs by year of operation.

Output 5.2 *Strategic partnerships with public and private initiatives for the diffusion and adoption of research products*

Activity 5.2.1: *Map and assess relevant stakeholders to establish dialogue for the exploration of mutual synergies for scaling delivery of validated technologies*

Sub-activity 5.2.1.1: Engage able and willing partners to develop a strategy and implementation framework for scaling up intensification technologies in semi-arid ecologies of central Tanzania

Following planning meetings ICRISAT held with Mr Chaula Aithan (DASPA Director) and Mr Msora (KFS Director) in the 2019-2020 season, as well as with farmer groups in the project, MoUs between ICRISAT (on behalf of the Africa RISING project) and these two partners were approved and signed and have been operational since April 2021. Partnership activities were delayed due to COVID-19 and the target of 4000 farmers could not be met. However, DASPA and KFS have worked with three registered seed groups (Umoja ni Nguvu in Laikal, Kwimage in Moleti, and Vidulwe in Mlali) to produce quality seed for new varieties, as well as those proposed for release through the Africa RISING project (Table 12).

Table 12. Seed production of the newly introduced varieties by DASPA

Variety	Variety status	Area (ha)	Actual seeds produced in 2021 (kg)
Mangaka 2009	Released	2.4	3000
Mnanje 2009	Released	3.2	5000
Naliendele 2009	Released	1.4	1500
Nachingwea 2009	Released	0.4	800
Tanzanut 16	Released	1	1500
Kongwa 724 (ICGV-SM 02724)	Proposed for release	1.2	2000
Kongwa 650 (ICGV-SM 05650)	Proposed for release	0.4	600
Totals		**10**	**12100**

Sub-activity 5.2.1.2: Summary from other partner engagements

MSU collaborated with the new Malawi Agricultural Policy Research Institute (MwAPATA) to showcase the soil C reflectometer work in Ntcheu.

- Collaborated with MSU's Alliance for African Partnerships (AAP) who sponsored Dr Innocensia Festo John's postdoc fellowship that was hosted by Africa RISING.
- CIAT worked in partnership with Tanzania Agricultural Research Institute (TARI), Babati District Council (BDC), Seedco, Dekalb Seed Company, and Minjingu Fertilizer Company. TARI-Selian and BDC have been actively involved in running experimental trials, data collection, technology assessments, facilitation of farmer field days and conducting household surveys, especially during the current COVID-19 pandemic period.
- ICRAF is collaborating with the University of Kassel, Germany in supporting the new graduate student, Hannah Graef.
- MSU collaborated with the new Malawi Agricultural Policy Research Institute (MwAPATA) to showcase the soil C reflectometer work in Ntcheu.

Activity 5.2.2: *Leverage/link and integrate (engagement and outreach) with existent initiatives including Government extension systems to support and encourage the delivery pathways*

Sub-activity 5.2.2.1: Engage with seed companies to accelerate QPM seed scaling in Tanzania

The placement of hybrids follows product licensing process, with the hybrids going through national performance trials (NPT) by seed companies or national maize breeding programs. This process has not taken place. Following engagement with seed companies, we anticipated that seed companies would take up the new maize hybrids and plan to place them in NPT during 2021. Unfortunately, two developments are delaying this process:

1. *Change of procedure for seed companies to access new breeding products*. Previously, seed companies used to access the new products through the breeders directly by requesting the new products and testing them in NPT with support of TOSCI (in Tanzania), and then apply for release. This has changed; the seed companies will now be applying for the new products from CIMMYT's Product Allocation Committee (PAC) following a "stage gate process", which is a longer process.
2. *PI departure from the CIMMYT Nairobi Office.* Dr Bright Jumbo who developed the products and had developed a relationship with the seed companies in East Africa is no longer with the Nairobi Office. He presented the trials' data before the PAC and handed

over all the data to PAC before he left. It is now the responsibility of the new breeder to carry the process forward. Africa RISING will engage with the new breeder to determine if, indeed, we can move this process forward.

Sub-activity 5.2.2.3: Support to CRS in scaling and marketing GMCC and grain legume intercropping strategies, and sub-activity 5.2.24: Support to Total LandCare in scaling CA systems in Malawi

These were merged with and are reported under sub-activity 5.2.2.2

Sub-activity 5.2.2.5: Partnership with Islands of Peace for increasing the adoption of postharvest products

As presented in the last report, the partnership period between Africa RISING and Islands of Peace (IoP), Kilimo Endelevu (KE) developed a 2019-2020 strategic plan to expand the scaling of postharvest technologies to reach more farmers in the original villages and in the new action villages. The scaling strategy included specific actions to be implemented by KE with technical backstopping from Africa RISING, to achieve the scaling target of 9120 households by the end of year 2021. The backstopping support by Africa RISING ended during 2020 and IoP was to complete the scaling activity on their own, having gained confidence in their scaling capacity. The sub-activity was ended with laudable success.

Sub-activity 5.2.2.6: Partnership with Islands of Peace for increasing the adoption of good agricultural practices in vegetable production and improved nutrition

This sub-activity is largely on building capacity for the implementing staff of the IoP consortium. Africa RISING is partnering with the KE Project of IoP to scale best bet technologies in Karatu. Other partners are Mtandao wa Vikundi vya Wakulima Tanzania (MVIWATA) and Research Community and Organizational Development Associates (RECODA).

In September 2021, a technology uptake quick survey was conducted in 10 beneficiary villages on 104 beneficiary farmers to assess the uptake of improved vegetable production technologies on vegetable and non-vegetable crops. On average, more than 80 percent of beneficiary farmers acknowledged to have received trainings on improved vegetable production technologies and nutrition information (Table 13) by the partnership. We learned from the focus group discussions (FGDs) that a large proportion of farmers had no knowledge on vegetable production before the trainings. Despite having acquired the new knowledge on improved vegetable production techniques, some farmers still failed to apply the technologies. These farmers reported high prevalence of pests and diseases, and lack of enough water to irrigate the vegetables as the limiting factors.

Practice of improved vegetable technologies has increased yield; thus, assured farmers of food security in their homes. During the FGDs in Rhotia Khainamu village, the farmers were grateful for the trainings because they used to travel long distances and spend money just to purchase vegetables. But now, they grow them in their home gardens and can eat safe vegetables, and generate income, as well.

Table 13. Proportions of trained farmers and who are adopting improved vegetable production technologies and nutrition practices. N= number of farmers interviewed in a village

Village (n)	Improved quality seeds		Nursery management		Good Agricultural Practices		Integrated Pest Management		Good Nutritional Practices	
	Trained	Applied last season	Trained	Applied last season	Trained	Applied last season	Trained	Applied last season	Trained	Applied last season
Changarawe (11)	1	0.82	1	0.64	0.91	0.91	1	0.91	1	1
Glambo (13)	0.92	0.85	0.92	0.69	1	0.92	1	0.92	1	1
Bashay (6)	1	1	1	0.83	1	1	1	1	1	1
Chemchem (7)	1	1	1	0.86	1	0.86	1	0.86	1	1
Bugeri (14)	1	0.86	1	0.79	0.93	0.93	1	0.79	1	0.93
Rhotia Kainamu (9)	1	0.89	1	0.89	1	0.89	1	0.89	0.89	0.78
Kambi ya Simba (11)	1	1	1	1	1	1	0.91	0.91	1	1
Slahhamo (13)	0.92	0.92	1	0.85	1	1	1	1	1	1
Qurus (9)	1	0.78	1	0.89	1	1	0.67	0.67	0.89	0.89
Upper Kitete (10)	1	0.8	1	1	0.9	1	1	0.91	0.9	0.8
Total (104)	**0.97**	**0.88**	**0.99**	**0.84**	**0.97**	**0.94**	**0.96**	**0.88**	**0.97**	**0.94**

Sub-activity 5.2.2.7: Partnership with LEAD Foundation to take to scale soil and water management technologies in erosion-prone areas of Central Tanzania

This is a continuation of the partnership between Africa RISING and LEAD Foundation (a development partner: https://www.leadfoundation.org/), also reported in the previous report. For a scaling partnership, annual plans are usually always different, and so are the deliverables. The 2020/2021 deliverables and achievements are given in the following table.

Targeted deliverables for 2021 and status on achievements

Deliverables	Status (September 2021)
Fanya juu terrace established on at least 20 demonstration sites	Fanya juu terrace demonstrations established at 25 sites during the 2020/2021 season
Fanya juu terrace established on at least 50 ha owned by champion farmers during the 2020/2021cropping season	Fanya juu/chini terrace established on 55 ha in the Singida region during the 2020/2021 cropping season (Figure 23)
At least 100 extension officers across participating districts trained on the use of Fanya juu terrace technology during 2020/2021 through LEAD/Africa RISING partnership	A total of 93 (77M; 16F) extension officers trained. Report has been submitted to comms for uploading
At least 300 farmers exposed to Fanya juu/chini terrace technology during agricultural shows (i.e., Nane Nane ground)	No National Agricultural Show (Nane Nane) was held in 2021. Instead, a farmer field day was held at Nghumbi to showcase best practices on soil erosion control. Report is being prepared.
Validation of Swahili version of SWC training manual	Manual submitted to the AR-ESA Project comms team for further action

Figure 23. Farmers installing Fanya juu terraces in the field at Chemba district in Dodoma Region under Africa RISING/LEAD Foundation partnership in early September 2021. Photo credit: E.Y. Swai/TARI.

Output 5.3 *Gender-sensitive decision support tools for farmers to assess technology-associated risk and opportunities used by partners*

Activity 5.3.1: *Identify and communicate gender-sensitive decision support technologies in the context of different farm typologies*

Sub-activity 5.3.1.1: Gender implications of the introduction of soil and water conservation technologies in the semi-arid Kongwa and Kiteto districts of Tanzania

This study builds on the biophysical research conducted in sub-activity 1.2.2.1. COVID-19 delayed this study's implementation. As a result, the two MA students from the University of Dodoma (UDOM), who were involved in studies on gender dynamics related to RT technology, had to extend the deadline for theses submission. Both students submitted their theses to UDOM and to their IITA supervisors in October 2021. The summaries of their theses will be included in the next report.

For the delayed gender survey, all research preparations have now been completed including literature review, drafting of tools and manuals. Also, the content of all workshops to take place in the field work has been prepared (responsibility: international lead consultant and lead facilitator).

Targeted deliverables for 2020/2021 and status on achievements

Deliverables	Status (September 2020)	Status (March 2021)	Status (September 2021)
Recommendations (fanya juu and tied ridges) in bi-annual reports	Data analysis for the development of recommendations was completed by a team of young social scientists	The results of data analysis, as presented in the draft manuscript, needs to be improved before recommendations can be made.	Re-analysis in process; Recommendations to be submitted in March 2022
Recommendations (RT) in Master of Arts (MA) theses by Oct 2020	Field research completed; data analysis and write-up in process	Progress delayed due to university closure due to COVID-19 pandemic; theses to be submitted in June 2021	Theses submitted including recommendations; a clean summary of recommendations will be submitted March 2022
Manuals on integrated socio-technological decision-support tools for Malawi and Tanzania	NA	Preparation for research is ongoing.	Draft manuals have been prepared for testing
Scientific article	NA	Preparation for research is ongoing	Literature review has been completed; target submission date – June 2022
Blog	NA	Preparation for research is ongoing	Same as for scientific article

Sub-activity 5.3.1.2: Role of gender from farm-to-fork and grain markets of legumes and dryland cereals in Kiteto and Kongwa

The main output of this sub-activity is a thesis with a working title *"Women empowerment and impact on maternal and child nutrition outcomes"*. Thesis write-up has not progressed because of administrative issues relating to student's continued illness. However, data were analysed and drafting of manuscript is under way. Additional data was collected (August-September 2021) and will be combined with previous data sets to strengthen the gender empowerment and nutrition components of the manuscript. We target to submit the manuscript to a journal by June 2022.

Output 5.4: *A technology adoption, monitoring, evaluation, and learning framework for use by the project team and scaling partners released [led by IFPRI and used by project partners]*

Activity 5.4.1: *Monitor and modify the progress of technology adoption process towards scaling*

Sub-activity 5.4.1.1: Populate the Beneficiary and Technology Tracking Tool (BTTT) Tanzania, Malawi, and Zambia with information about AR technologies applied, and farmers/households engaged in validating the technologies

IFPRI, in collaboration with the M&E officer, worked to populate the project Beneficiary and Technology Tracking Tool (BTTT) with information about project technologies applied, and farmers/households engaged in validating the technologies (direct beneficiaries). Figure 24 shows the total cumulative number of farmers directly interacting with project researchers in testing and validation of different project technologies since project inception (10 025) against the cumulative target of 9410 for 2021 (107 percent achievement). Higher shares of direct beneficiaries out of 2021 cumulative targets have been reached in Tanzania, followed by Zambia, and Malawi (153 percent, 104 percent, and 87 percent, respectively).

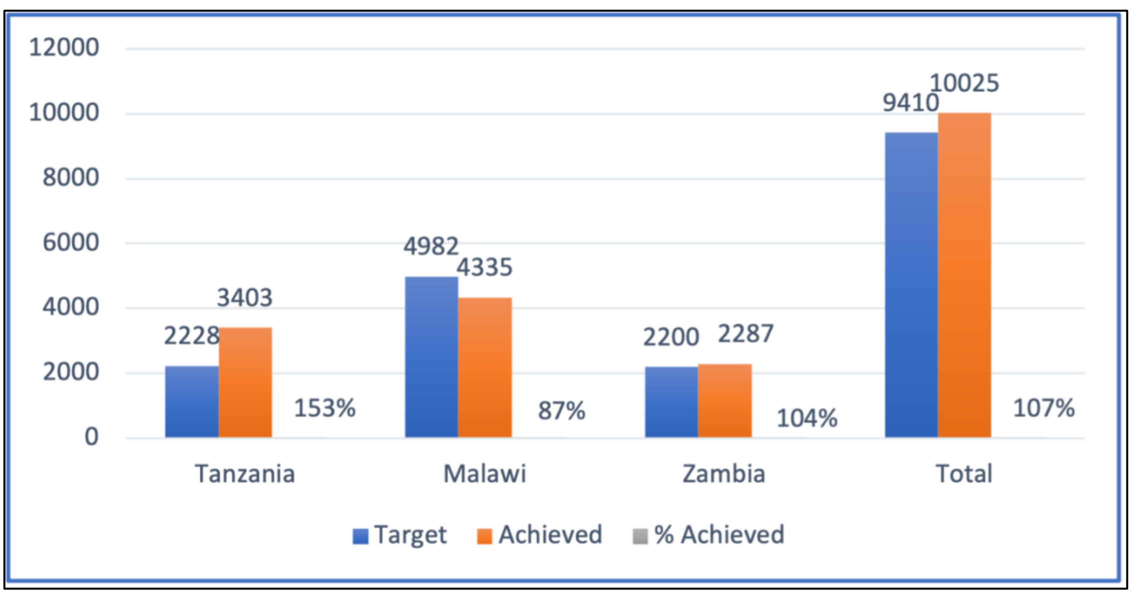


Figure 24. Number of direct beneficiaries reached as of March 2021 (against 2021 cumulative targets).

Sub-activity 5.4.1.2: Populate the technology scaling tool with detailed information on scaling data for Tanzania, Malawi, and Zambia

The M&E officer worked with AR researchers and development partners to populate the technology scaling tool with detailed information on scaling data for Tanzania, Malawi, and Zambia. The tool included the 2021 targets as comparison. Main tasks performed during this reporting period included discussions with development partners to harmonize scaling beneficiary data. Visits were conducted to the selected scaling partners (*Lead Foundation* in Dodoma region and *Island of Piece* in Arusha region of Tanzania) where information about scaling approaches and technologies being scaled-up were compiled. As shown in Figure 25 below, there were 305 201 (102 percent) beneficiaries who have benefited from scaling of validated AR technologies as part of AR collaboration with various development partners in Tanzania, Malawi and Zambia. Higher shares of scaling beneficiaries out of total targeted have been reached in Zambia, followed by Tanzania, and Malawi (182 percent, 106 percent, and 71 percent respectively).

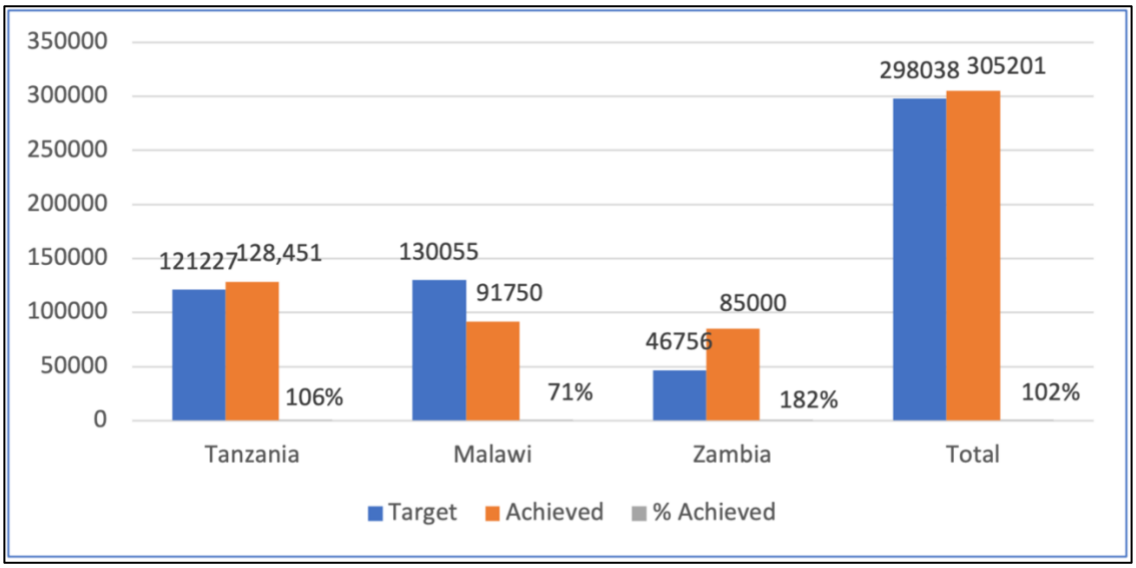


Figure 25. Number of scaling beneficiaries reached as of March 2021 (against 2021 cumulative targets).

Sub-activity 5.4.1.3: Design simple research rack up database and populate it with research rack up data for Tanzania, Malawi, and Zambia)

The M&E officer collaborated with AR researchers to gather research rack up data for submission to USAID research rack up database. Details of research rack up to data for 20 technologies have been submitted by researchers and entered into the designed ODK version of the research rack up database in October. This will allow for easy download of excel file to easily transfer the data into the USAID research rack up system, which is to be completed by 12 November 2021.

Sub-activity 5.4.1.4: Conduct data quality assessment (DQA) to verify number of direct beneficiaries reported against those verified in source data for the selected sites

No activity was implemented during this reporting period because of the COVID-19 situation. The activity should have been implemented in Malawi and Zambia.

Sub-activity 5.4.1.5: Provide additional capacity building to and work with ESA research partners to ensure timely (and complete) submission of FTF indicators data for FY 2021, research rack up data, country narratives, IM performance narratives, compliance with the AR Data Management Plan

The M&E officer continued to work with researchers to ensure quality submission of FtF indicator data, IM activity performance narratives, research rack up data, and dataset to DataVerse. To this end, the M&E officer capacitated researchers in Tanzania and circulated a guide to AR scientists in Malawi and Zambia to assist them in reducing the gaps encountered during submission of FY 2020 data. As of September 2021, IFPRI M&E team is working with the M&E officer and researchers to compile the relevant information for subsequent aggregation and submission onto the new USAID's Development Information Solution (DIS).

M&E targeted deliverables for 2021 and status on achievements

Deliverables	Means of verification	Delivery date	Achievement Status
6.1 Training materials to address gaps associated with FtF and DataVerse submission; IM performance narratives; research rack up prepared; and capacity built to researchers	Report shared with Chief Scientist and uploaded to the AR wiki site	April to June 2021	Partially completed
6.2 Workbook with data summary on 2021 achievements on the five FtF indicators and for each ESA country disaggregated by individual research theme/group who submitted indicator target and additional data as necessary; list of IM performance and country narratives; research rack up data	Activity report, progress report, FtF data, and narratives to be uploaded onto the USAID-DIS system	September to November 2021	In progress as of October 2021; to be completed in November 2021
6.3 Workbook with a list of research themes/groups by country, PIs, and their e-mails, associated to datasets collected and to be collected etc. since 2013 (according to the proposals)	Activity report, progress report,and data submitted to DataVerse	July to October 2021	In progress; to be completed in November 2021

Capacity building

Table 14. Short- and long-term training and field days offered during October 2019–March 2020.

Subject of training/Field Day	Lead institution	Venue	Dates	Participant Category	Number of participants	Percentage of women
Short-term training and Field days						
Use and installation of Fanya juu/chini terraces in the field	TARI	Singida Secondary School	2 to 6 August 2021	Lead farmers, Extension staff	232	46.9
Farmer field days	WorldVeg	Karatu	5 to 11 September 2021	IDP staff, RECODA field technicians, District Government representatives, Extension Agents, farmers, and local leaders from eight villages	257	51
TOTs on vegetable seed production as a business	WorldVeg	Karatu	23 to 27 August 2021	Government extension agents, Island of Peace project (IDP) field technical staff, and Farmer Community Trainers (FCTs)	37	40
Survey solutions software and data collection	IITA	Chipata (Zambia) and Lilongwe (Malawi)	2 to 8 June 2021	Enumerators	24	8
Agronomy and crop protection	ICRISAT	Manyusi, Njoro, Laikala, Moleti and Malia villages in Tanzania	August to September 2021	Farmers	72	44

Subject of training/Field Day	Lead institution	Venue	Dates	Participant Category	Number of participants	Percentage of women
Farmer field days	CIAT	Sabillo and Gallapo villages in Tanzania	14 to 15 June 2021	Farmers and other stakeholders	103	31
Graduate training						
Graduate internship in GIS	IITA	IITA Arusha	November 2020 to September 2021	Graduate Intern, (Francis Msangi)	1	0
Graduate Research (MSc)	University of Bonn	University of Bonn	July 21 to March 2022	MSc. Graduate Research Fellow (Robin Cramer)	1	0
Undergraduate Industrial attachment (BSc. Geoinformatics)	ARDHI University Tanzania	IITA Arusha	14/09/2021 to 20/11/2021	Internship (Jovin Vicent)	1	0
Undergraduate Industrial attachment (BSc. Geoinformatics)	ARDHI University Tanzania	IITA Arusha	14/09/2021 to 20/11/2021	Internship (Darren Mbaga – ARDHI University Tanzania)	1	0
Cases studies expanded framework	MSU/LUANAR	LUANAR	November 2020; ongoing	MSc, Chifuniro Kalawang'oma	1	0
Production economics	CIMMYT	Uni of Zimbabwe	November 2020; ongoing	Tinashe Taringa	1	100
Characterization of households and determinants of adoption of food and nutrition technologies in Ntcheu and Dedza	LUANAR	LUANAR	2017-2021; completed	Raheem Liguluwe Thesis completed, April 2021	1	0
Farming systems ecology	WUR	Wageningen University	November 2020 to August 2021	MSc students Eveline Massop & Madeline Mathews	2	100

Subject of training/Field Day	Lead institution	Venue	Dates	Participant Category	Number of participants	Percentage of women
Graduate internship - GIS	IITA	Arusha	November 2020 to May 2021	Francis Msangi	1	0
Case studies: Application of SI technologies among farmers	CIMMYT, MSU	LUANAR University of Zimbabwe	November 2019 to August 2020. Granted extension	MSc students, Isaac Mavhiko and Tinashe Taringa, Chifunilo	3	33
Gender analysis of RT technology	IITA	University of Dodoma	2019 to 2021	MA students, Julius Anatory and Zamaradi Said	2	50
Profitability of *Gliricidia*-based cropping system	ICRAF/IITA	Sokoine University of Agriculture	October 2019 to June 2021	PhD student, Martha Swamila	1	100
Maize/*Gliricidia* intercropping	ICRAF	University of Kassel	October 2020 to September 2021	MSc student, Hannah Graef	1	100
Human nutrition	LUANAR	LUANAR	2019 to 2021	MSc students, Kondwani Luwe and Sunganani Chowa	2	50
Food Science and Technology	LUANAR	LUANAR	2019 to 2021	MSc student, Melise Mwachu	1	100
Animal science	LUANAR	LUANAR	2019 to 2021	MSc student, Merchious Mpinganjira	1	0
Policy planning and management	ICRISAT	SUA	2019 to 2021	MSc student, Gibson Mulokozi	1	0

Subject of training/Field Day	Lead institution	Venue	Dates	Participant Category	Number of participants	Percentage of women
Crop science	ICRISAT	SUA	2019 to 2021	MSc student, Simon Wabwire	1	0
Socioeconomics	ICRISAT	SUA	2019 to 2021	MSc student, Gloria Kenjawala	1	100
Agronomy	CIAT	Kenyatta University	2019 to 2022	PhD student, Michael Kinyua	1	100

Challenges and actions taken

The COVID-19 pandemic continued to necessitate country lockdowns. Limited movement and gathering, as promotion of social distances, affected field operations, leading to postponement or delays in delivery of some activities and reporting. As a key mitigation measure, the local extension staff guided the lead farmers with the use of mobile phones to collect experimental data. Partnerships for scaling were weakened. For some researchers, they were able to use the additional time to focus more on publication and documentation.

In relation to the above, the project's annual review and planning meeting, which normally brings together the key implementing partners and other stakeholders, was not conducted physically due the COVID-19 pandemic. Instead, a virtual meeting was employed for the implementing partners to interact.

Lessons learned

The COVID-19 pandemic has raised the recognition and importance of e-extension. There is a need to re-invent Mwanga platform to help in linking farmers to produce market. Despite making great strides in improving crop yields, farmer livelihoods are yet to break even because of the low produce prices and exploitation of brokers and middlemen. Increasing the number of farmers reached through Mwanga would also help to create impact on areas that are underserved by physical agricultural extension.

Communications and knowledge sharing

The main communication channels supported during the reporting period were:

- Wiki internal workspace: http://africa-rising-wiki.net/Program;
- Project updates on the program website: https://africa-rising.net/;
- A Yammer network with internal updates.
- Photos: https://www.flickr.com/photos/africa-rising/; and
- Repository: https://cgspace.cgiar.org/handle/10568/16501.

The stories listed below were published and disseminated to stakeholders concerning different project activities and outputs.

- Improving soil carbon measurements to empower African smallholders (25 August 2021)
- BRIEF FOCUS: Nutrient-rich beans for improved nutrition, incomes, and soil fertility (12 July 2021)
- Public and Private Partnerships improve smallholder farmer fortunes in Babati, Tanzania (15 June 201)
- BRIEF FOCUS: Conservation agriculture in maize-legume systems (7 June 2021)
- Disseminating livestock extension information using text messages in Tanzania (19 April 2021)

The following meetings and events were held during the reporting period. The communications team supported some of these meetings and events through materials preparation, and facilitation, among others.

- 14 - 16 September: ESA Project Review and Planning Meeting – virtual, MS TEAMS
- 2 September: ESA Project partners update meeting (with presentations) - virtual, MS TEAMS
- 5 August: ESA Project partners update meeting (with presentations) - virtual via MS TEAMS
- 1 July: ESA Project partners update meeting (with presentations) - virtual via MS TEAMS
- 3 June: ESA Project partners update meeting (with presentations) - virtual via MS TEAMS
- 6 May: ESA Project partners update meeting (with presentations) - virtual via MS TEAMS
- 1 April: ESA Project partners update meeting (with presentations) - virtual via MS TEAMS

Selected reports and publications

The following peer reviewed journal articles and reports were published by the project team during this period.

Peer reviewed journal articles

- Chande, M., Muhimbula, H., Mremi, R., Muzanila, Y., Kumwenda, N., Msuya, J., and Gichohi-Wainaina, W.N. (2021). Drivers of millet consumption among school aged children in central Tanzania. Frontiers in Sustainable Food Systems, 5, 694160: 1-13.
- Richardson, R. B., Olabisi, L. S., Waldman, K. B., Sakana, N., and Brugnone, N. G. 2021. Modeling interventions to reduce deforestation in Zambia. Agricultural Systems 103263.
- Reith, J., Ghazaryan, G., Muthoni, F.K. and Dubovyk, O. (2021). Assessment of land degradation in semiarid Tanzania—using multiscale remote sensing datasets to support sustainable development goal 15.3. Remote Sensing, 13(9), 1754: 1-21.
- Mhlanga, B. and Thierfelder, C. 2021. Long-term conservation agriculture improves water properties and crop productivity in a Lixisol. Geoderma 398:115107.
- Manda, J., Azzarri, C., Feleke, S., Kotu, B., Claessens, L. and Bekunda, M. (2021). Welfare impacts of smallholder farmers' participation in multiple output markets: empirical evidence from Tanzania. Plos one, 16(5), e0250848: 1-20.
- Mhlanga, B., Mwila, M., and Thierfelder, C. (2021). Improved nutrition and resilience will make conservation agriculture more attractive for Zambian smallholder farmers. Renewable Agriculture and Food Systems.
- Nziguheba, G., Adewopo, J., Masso, C., Nabahungu, N.L., Six, J., Sseguya, H., and Vanlauwe, B. (2021). Assessment of sustainable land use: linking land management practices to sustainable land use indicators. International Journal of Agricultural Sustainability, 1-24.
- Mwila, M., Mhlanga, B. and Thierfelder, C. (2021). Intensifying cropping systems through doubled-up legumes in eastern Zambia. Scientific Reports 11:8101.
- Ochieng, J., Afari-Sefa, V., Muthoni, F., Kansiime, M., Hoeschle-Zeledon, I., Bekunda, M. and Thomas, D. (2021). Adoption of sustainable agricultural technologies for vegetable production in rural Tanzania: trade-offs, complementarities and diffusion. International Journal of Agricultural Sustainability.
- Joseph J.E., Rao, K.P.C., Ngwira, A.R., Swai, E., Rötter, R.P., and Whitbread, A.M. (2021). Analysis of rainfall variability and trends for better climate risk management in the major agro-ecological zones in Tanzania. CCAFS Working Paper no. 363. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).
- Hermans, T.D.G., Dougill, A.J., Whitfield, S., Peacock, C.L., Eze, S., and Thierfelder, C. 2021. Combining local knowledge and soil science for integrated soil health assessments in conservation agriculture systems. Journal of Environmental Management, 286, 112192.
- Mhlanga, B., Mwila, M., and Thierfelder, C. 2021. Improved nutrition and resilience will make conservation agriculture more attractive for Zambian smallholder farmers. Renewable Agriculture and Food Systems.
- Maselema, D., Chigwa, F., and Chingala, G. 2021. Effect of pumpkin (*Cucurbita maxima*) seed meal as a supplementing diet to free-ranging goats on growth performance and

semen quality. Livestock Research for Rural Development.
http://www.lrrd.org/lrrd33/1/dmase3302.html

Reports, training material, and briefs

- Muthoni, F., Ochieng, J., Delore, J-M., Lukumay, J. P., and Dominic, I. (2021). Extrapolation suitability for improved vegetable technologies in Babati District, Tanzania. Presented at the Power on Your Plate Summit, Arusha, Tanzania, 25-28 January 2021.
- Mwangwela, A., Mwachumu, M., and Banda, I. (2021). Cooking characteristics and consumer acceptability of bio-fortified beans. Ibadan, Nigeria: IITA.
- Thierfelder, C. (2020). Conservation agriculture in maize–legume systems. Africa RISING Technology Brief. Ibadan, Nigeria: IITA.
- Chirwa, R. and Mankhwala, C. 2021. Nutrient-rich beans for improved nutrition, incomes, and soil fertility. Africa RISING Technology Brief. Ibadan, Nigeria: IITA.

Presentations and posters

- Massop, E. (2021). Farm performance evaluation: Holistic impact assessment of project promoted sustainable intensification innovations at farm-level in Tanzania. Msc thesis in Farming Systems and Ecology. Wageningen, The Netherlands: Wageningen University and Research.
- Mathews, M. (2021). Healthy soils, healthy plants, healthy humans: A holistic exploration of sustainable intensification effects on farming systems in Malawi. Msc thesis in Earth Sciences. Amsterdam, The Netherlands: University of Amsterdam.