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.

ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

IFPRI

IITA Transforming African Agriculture

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

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

In the first report of this project year (1 October 2019 – 31 March 2020), we described the engagement of scientists in establishing crop and natural resource management experiments in the field and hosting early season technology evaluations and field days. These studies constitute more than 40% of the ESA Project research portfolio. As the crops mature around May to June, the biophysical data presented in this report pertain to improved varieties that have been validated to be resilient to drought, pests and diseases and are nutrient-dense, both as sole crops or in different intercrop arrangements, as well as their roles as components in soil and water management. During the planning meeting for the year, we targeted addressing data gaps to wind up the studies that have been conducted over a minimum of two previous years. Most of the data presented are for the current cropping season and we plan to conduct cross-season data analyses and present the outputs in form of publications. In line with this, a few studies are dedicated to cross-discipline analyses to reflect our systems approach.

In respect of improved crop varieties, short duration varieties of groundnut, pearl millet, and sorghum tested in Tanzania (sub-activity 5.1.1.2) were confirmed as best adapted for semi-arid agroecologies but with a proviso that late planting of these materials could result in yield losses of up to 38%. There was no significant difference in the performance of selected four DT maize hybrids under different agronomic management and tillage practices during an unusually good rainfall season in Tanzania (sub-activity 1.1.1.1). Product announcement by CIMMYT is expected in early 2021, paving the way for conducting national performance trials for these hybrids, in partnership with seed companies. CIAT enabled widespread distribution of seed for nutrient dense NUA45 and SER83 bean seed in Malawi through community seed multiplication, (sub-activity 3.2.1.2) but also identified that intercropping both varieties with maize is quite beneficial, with a land equivalent ratio (LER) of 1.57.

Cereal-legume crop arrangements in the field, in time and space, have been investigated quite extensively in the three ESA countries. After legume-maize sequencing for at least five seasons in Malawi, it is concluded that, irrespective of type of legume used, legume – cereal rotations invariably result in better fertilizer use efficiencies (sub-activity 1.1.1.2) and land equivalent ratios (sub-activity 3.2.1.2). In terms of nutrition, groundnut was the better driver of protein production in such systems, with more than double the 300 kg ha^{-1} protein produced in the continuous unfertilized maize monocrop system. It is the short duration groundnut varieties that were found best adapted for doubled-up legume intercropping in the semi-arid ecologies of Tanzania (sub-activity 5.1.1.2). In Babati, Tanzania, the doubled-up legume system performed better than the *mbili-mbili* system (an adapted double-up legume system) in a good rainfall environment, producing 0.4 t ha^{-1} and 0.3 t ha^{-1} higher grain and haulms, respectively (sub-activity 1.1.1.6). This was attributed to reduced interspecific competition for light and nutrients in the doubled-up legume system. Thus, contrary to expectations, the second bean phase in *mbili-mbili* did not establish because of the dense canopy from the maize and pigeon pea crops.

As companion technologies to conservation agriculture (CA), heavy rainfall affected the performance of lablab in the Green Manure and Grain Legume Intercropping trials, whereas, maize/cowpea and maize/pigeon pea intercropping seemed to perform best (sub-activity 2.2.1.1). The intercropping strategy of planting lablab seven days after the maize continues to be the best strategy (at least for the maize) as competition is low. The cowpea in the maize-cowpea rotation had extraordinarily high yields this season. From a sustainability point of view, growing

both maize with cowpea or pigeon pea are the best and logical strategy for farmers in Eastern Zambia and should be recommended. Adding half fertilizer will, of course, improve the final yield. Maize planted with a dibble stick, mulched, and rotated with a doubled-up legume system was the best performing CA treatment in Southern Malawi (sub-activity 5.1.1.1). Growing groundnuts under CA appeared to be the best choice for smallholder farmers in Malawi as it consistently provided greater yields than the conventional system.

Apart from CA, the cereal-legume intercropping has also been tested under other, mainly *in-situ* physical soil and water conservation technologies. With plenty of rains during this season, it was the management of excess water in the troughs of the tied ridges that was unexpectedly wanting. Thus, the moisture content in the water harvesting treatments in Kongwa, Tanzania, was not different from the controls (sub-activity 2.2.1.3). On the other hand, in Kandeu, Malawi, storing more water was associated with yield penalty (sub-activity 2.2.1.2). Such unusual occurrences are documented as “things to worry about” when presenting technologies as having been validated.

The biophysical data were collected when COVID-19 had already presented travel and assembly restrictions to researchers. It is the looking forward ingenuity of the researchers to include local researchers and technicians in their teams that allowed collection of these data. Guidance was through telephone communications. These COVID-19 restrictions affected components of, or whole planned studies that depended on farmer participation (e.g. field days, technology evaluations and household interviews), research partner planning and feedback, surveys, development partner engagement and student mentorship. Thus, several socio-economic and human condition studies are being conducted late or have been postponed altogether. Rather, the researchers put more attention to those activities that could be conducted at desktop level, usually making use of existing data, or through electronic meetings, including drafting of manuscripts for publication. The desktop studies are summarized below.

1. During the current project year, one activity focused on applying the APSIM crop simulation model to the simulation of long-term impacts of cereal-legume intercropping systems on productivity, risk and resource use efficiencies in central Tanzania (sub-activity 5.1.2.1). Preliminary results show that intercropping of cereal and long duration legumes (maize and pigeon pea) is only beneficial in high potential agroecologies.
2. A manuscript addressing the welfare impacts of smallholder farmers’ participation in multiple output markets in Tanzania (sub-activity 4.1.5.1) has been submitted for publication. The study concludes that: (i) improving the functioning of agricultural markets through the facilitation of market access is vital for smallholder farmers to fully reap the benefits of market participation; (ii) and proposes the need to support policy measures that promote the combined production of maize and legumes, as well as strengthen their value chains.
3. Construction of yield maps as decision support tools for guiding extension and development agencies on suitable areas for investment of CA practices showed that the yield advantage from the CA systems covered a large area in Southern Africa but that CA systems are more resilient during seasons with drought compared to the CP (sub-activity 1.3.1.1).
4. Hotspots for land degradation in Kongwa and Kiteto districts of Tanzania were identified that could be prioritized for targeting soil and water conservation practices to reverse the land degradation trends. Results generated from the study will be used for better

targeting of soil and water conservation technologies or practices that are validated by the Africa RISING program (sub-activity 1.3.1.2)

5. Exploration of the ARBES data using the FarmDESIGN model for alternative farm plans revealed that there was room for improvement for both high and low resource endowed farms (sub-activity 2.1.1.1). Substantial synergistic improvements could be obtained before a trade-off frontier would be encountered, particularly for the high resource endowed farm. In contrast, the low resource endowed farm would have considerably less opportunity to improve performance before approaching a trade-off frontier. The trade-off frontiers were apparent for socio-economic indicators of both farms as eventually, more operating profit was linked to less leisure time.
6. A manuscript has been drafted; it is utilising data from different researchers to evaluate potential contributions of integrated soil fertility management around the five SIAF domains with emphasis on Africa RISING interventions disciplines in Tanzania (sub-activity 5.1.2.1)
7. At least ten publications have been developed using field-based data from Africa RISING to be submitted to a variety of high impact factor journals. Some of the manuscripts are cross-project syntheses, i.e. involve researchers from West Africa and Ethiopia. Nine papers were published during this reporting period.
8. Nine of the 11 chapters of our *Sustainable Agricultural Intensification: A Handbook for Practitioners in East and Southern Africa* have been peer reviewed by at least one reviewer, and the review comments are positive.
9. Timely submission of quality reports by partners has come back as an issue affecting the compilation of the progress report to the donor.

Africa RISING ESA project action sites

The 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 (Fig. 1).

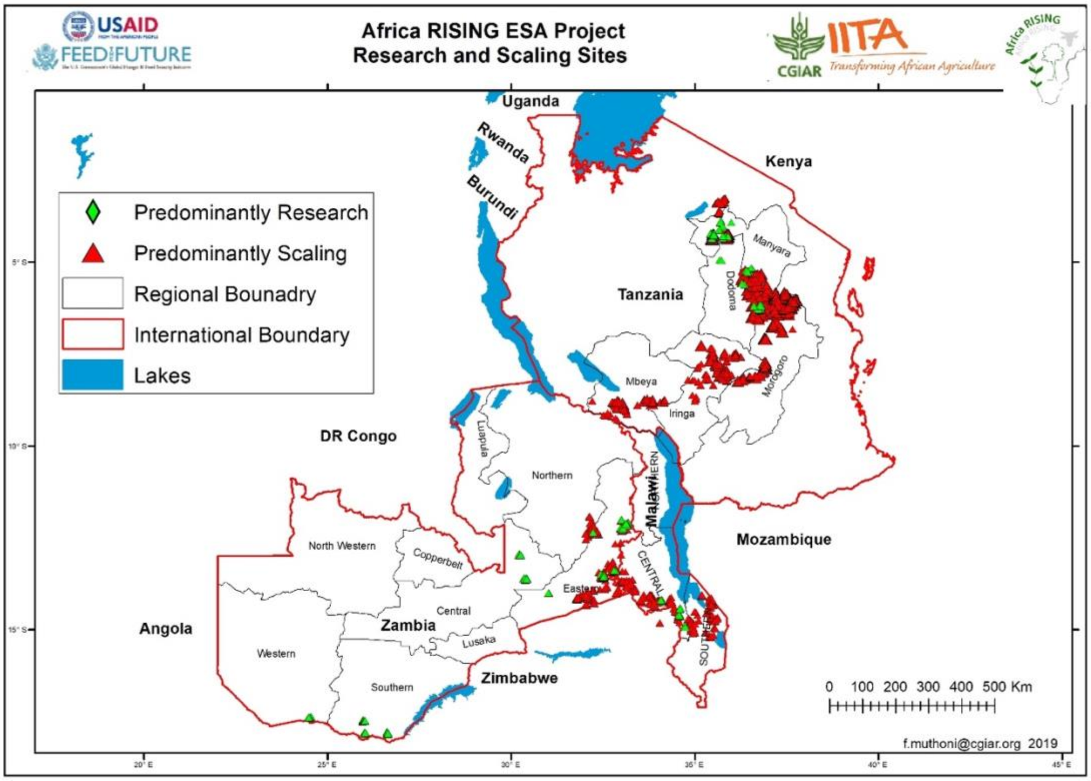
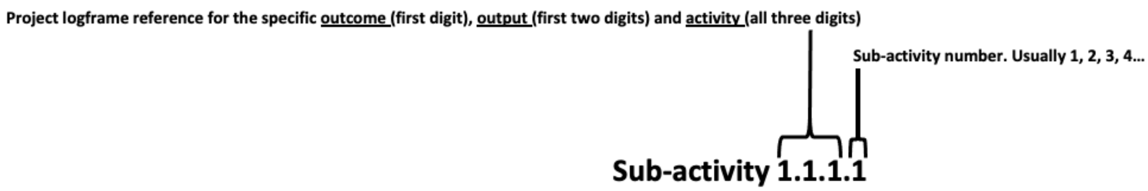


Figure 1: Locations where the Africa RISING–ESA Project has conducted research (green diamond) and scaling (red triangle).

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

Trials to generate extra data for this season were planted at seven sites in the semi-arid districts of Iringa, Kongwa, and Kiteto in Tanzania in January 2020. Four DT varieties were planted on flat fields or tied-ridge fields, with or without fertilizer added at recommended rates. In addition, 28 farmers received seeds of the DT hybrids to try on their farms. Data have been collected, analyzed, and ready to be incorporated in the draft manuscript that also utilized data from previous season trials. The manuscript is targeted for submission in December 2020.

For this season, higher grain yield performance was observed where the hybrids were planted both under flat and tied ridges plus fertilizer applied. The difference in performance between the test hybrids under both tillage practices with fertilizer applied was not significant except for the checks ($P \leq 0.05$). This could be attributable to a good season where the rainfall received during the season was better compared to most previous seasons. Significant differences between tillage practices (i.e., tied ridges vs flat) would be observed when the season is characterized by dry spells. The performance of test hybrids under both tillage practices without fertilizer was not significantly different from the check. This is not surprising because without fertilizer, the potential of the hybrids is not expressed.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
Manuscript on the new DT hybrids	First draft by end of July	Draft is ready. We need to improve on figures resolution to make them clearer before submission	
Manuscript on maize value chain analysis study (2019 activity)	First draft by end of June	Draft is ready and under internal review. See abstract under 4.1.1.1	
Manuscript on QPM (from previous AR research)	First draft by end of July	Draft ready and under internal review.	
Superior DT hybrids suitable for farm-level production confirmed	Report by September 2020	Report link requested.	
Data generated contributing to farm level analysis (Farm Maile)	Report by September, as well as data uploaded to DataVerse	Data available and submitted to IITA M&E specialist in Arusha for uploading to DataVerse	
Profitability of top performing hybrids determined	Report by September 2020	Report link requested	
Community participation enhanced & knowledge about best DT hybrids increased	Framers participate in trial installation and management; field days have been suspended.	Cancelled. Farmer participation in large groups were not allowed due to COVID-19	
Hybrids with high biomass identified as a potential fodder source	Report by September 2020	Report link requested	
Hybrids with high nutrition value identified	Report by September 2020	Grain analysis will be done this quarter because lab service was not ready.	Results by 15 January 2021
Data uploaded to DataVerse	To be completed by August 2020	Data has been submitted to IITA M&E specialist for uploading	
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August 2020	FtF indicators were submitted.	

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

This study investigates the impact of SI technologies that include improved soil fertility management and germplasm, crop combinations, and nutrient and water management. The planned 2019/2020 season cropping activities were implemented in Malawi. We have maintained the on-farm cereal legume rotation experiments, some of which were initiated way back in the 2012/2013 cropping season.

Biological nitrogen fixation. Results were presented in the previous report. Sole groundnut produced the least amount of total N fixed compared to sole pigeon pea, maize/pigeon pea, and the groundnut/pigeon pea intercrops. The doubled-up groundnut/pigeon pea intercrop was effective at cycling the most N.

Maize productivity in legume-cereal rotations. Maize was planted during the 2019/2020 cropping season across six sites that had been under legume-maize sequencing for at least five seasons. Treatments included an unfertilized maize, maize fertilized with recommended NP fertilizer (70N, 10 P) with or without manure, cowpea, soyabean or groundnut-maize rotations, a groundnut/pigeon pea double up systems rotated with maize, and a continuous maize/pigeon pea intercropping. Maize in rotations was always fertilized at 50% of the recommended rate when legumes are not integrated.

While the two NP fully fertilized treatments had larger yields, all legume maize rotations had yields of about 4 Mg/ha, which compared favourably with fully fertilized treatments - yet only 50% fertilizer was used for these treatments (Figure 2). It can be concluded that, irrespective of type of legume used, legume–cereal rotations invariably result in better fertilizer use efficiencies. Also, integrated application of fertilizer and manure resulted in increased maize productivity.

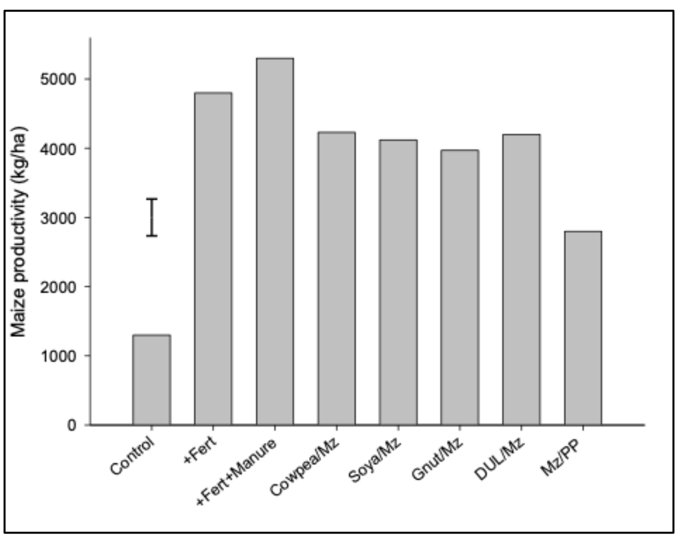


Figure 2. Maize yields after at least three cycles of legume/maize rotations across six sites in central Malawi Africa RISING sites (Fert = fertilizer; Mz/PP = continuous maize/pigeon pea intercropping; DUL/Mz = doubled up legume –maize rotation). Error bar represents the least significant difference among treatments.

Meta-analysis insights on marginal sites legume diversification. The overall objective of the study was to identify SI interventions for marginal areas to address, in a sustainable manner, food security, nutrition, and income requirements for vulnerable households (see Treatments in Table 1). This study explicitly analyses four key research questions: (1) How does the environment interact with performance in SI systems? (2) Specifically, how does grain yield, biomass and soil fertility in maize-based cropping respond to diversification with legumes, for marginal environments? (3) Which SI system is nutritionally superior to other systems in terms of protein produced? and (4) How do SI systems perform economically relative to sole maize?

Table 1. Cropping systems assessed in this study, with their abbreviations. The rotation and intercrop systems received fertilizer rate on an annual basis when maize was present.

System description	Abbreviation	Fertilizer (kg ha^{-1})	Plant population (plants m^{-2})		
			maize	Groundnut	pigeon pea
Continuous maize unfertilized	Mz0	0 N; 0 P	5.3	NA	NA
Continuous maize fertilized	MzNP	69 N + 9.24 P	5.3	NA	NA
Pigeon pea intercropped with groundnut and rotated with maize	DLR	34.5 N + 4.6 P	5.3	13.3	4.4
Groundnuts with maize rotation	GnRot	34.5 N + 4.6 P	5.3	13.3	NA
Pigeon pea with maize rotation	PpRot	34.5 N + 4.6 P	5.3	NA	4.4
Maize and pigeon pea intercrop	MzPp	34.5 N + 4.6 P	4.4	NA	4.4

<u>Grain yield and biomass</u>. Cropping system and environment had a strong influence on grain yield (Figure 3) and biomass. An interaction effect between system and environment was highly observed for grain yield ($p < 0.004$) and for biomass ($p=0.014$). The mean biomass production varied between 4.9 and 15.2 t ha^{-1}, with a systems response pattern that followed closely that of grain yield. In the low (i.e., marginal) environment, any legume system with groundnut (DLR and GnRot) performed better than other legume systems (PpRot and MzPp). Similar patterns were observed in biomass, reflecting differences in growth, which may largely explain the grain yield difference.

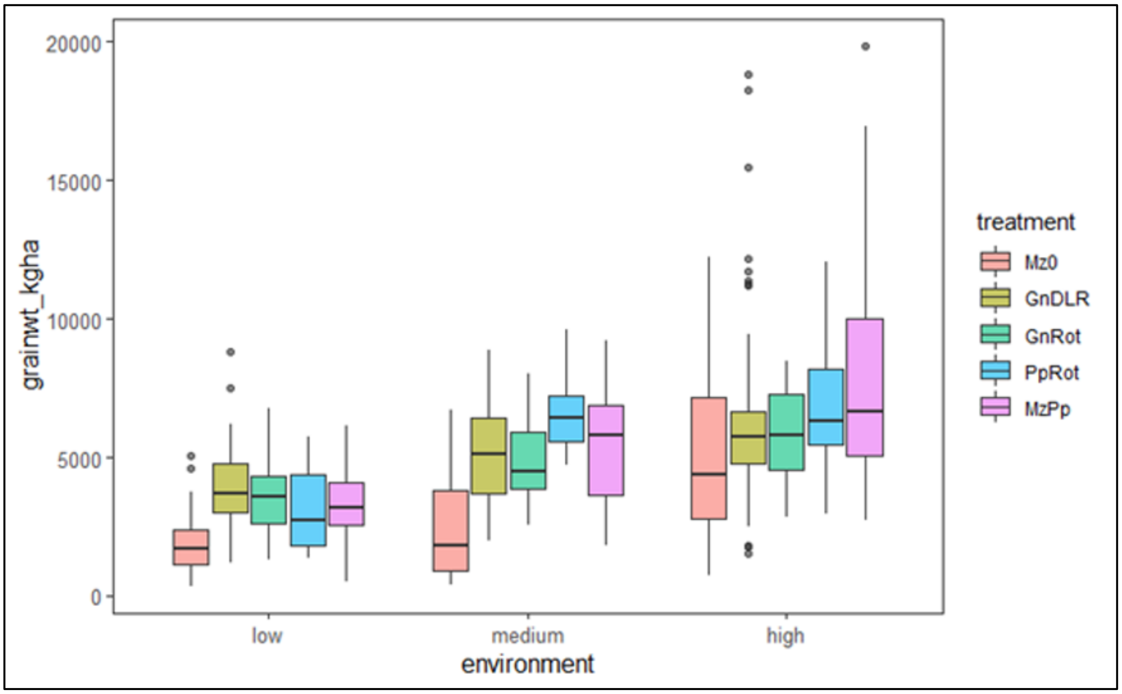


Figure 3. Grain yield (kg/ha) of systems across different environments (low, medium, and high). The mid-line denotes the system's median; the coloured box corresponds to 25% above and 25% below the median and circles show outlier values.

Nutrition indicator – protein. At all sites and for all cropping systems, continuous maize unfertilized (Mz0) system produced the lowest protein (300 kg/ha). Systems with groundnut (DLR and GnRot) produced the largest amount of protein at 758 kg/ha and 682 kg/ha, respectively. Overall, groundnut appeared to be the main driver of protein production. Differences varied across and within environments, with DLR and groundnut rotation producing the most amount of protein in all three environments (Figure 4).

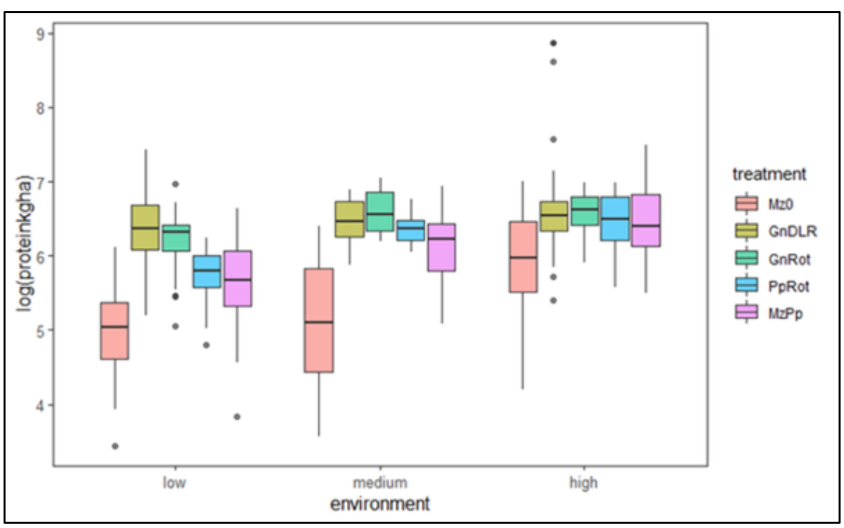


Figure 4. Protein contribution of systems across environments (low, medium, and high). The mid-line denotes the system's median; the coloured box corresponds to 25% above and 25% below the median and circles show outlier values.

Economic Returns. For the economic analysis we used a sub-set of the sites (14), those that included a continuous, sole maize system that was fertilized at the full, government recommended rate of 69 kg N, 21 kg phosphate-P per ha. The farm input subsidy program (FISP) in Malawi enhances access to fertilizers among smallholders, so we wanted to represent this option. The revenue and gross margin results for each cropping system are presented in Table 4, based on average market prices.

Table 4: Economic analysis of six cropping systems in central Malawi at high legume prices. Cropping systems shown are maize unfertilized (Mz0), Maize fertilized (MzNP) doubled-up legume pigeon pea intercropped with groundnut and rotated with maize (DLR), groundnuts with maize rotation (GnRot), pigeon pea with maize rotation (PpRot) and maize and pigeon pea intercrop (MzPp). The cropping systems are assessed over two years. The table includes the gross margins comparisons for the systems.

Cropping system	Units	Mz0	MzNP	DLR	GnRot	PpRot	MzPp
Fertilizer (basal – NP)	$ 50/kg grain	0	80	40	40	40	40
Fertilizer (top – Urea)	$ 50/kg grain	0	80	40	40	40	40
Maize seed	$/ha	18.75	18.75	18.75	18.75	18.75	15.57
Pigeon pea seed	$/ha	0	0	6.6	0	6.6	6.6
Groundnut seed	$/ha	0	0	156.96	156.96	0	0
year 1	$/ha	18.75	178.75	163.56	156.96	6.6	102.17
year 2	$/ha	18.75	178.75	98.75	98.75	98.75	102.17
Total input costs	$/ha	37.5	357.5	262.31	255.71	105.35	204.33
Labour costs	$/ha	91.87	91.872	104.14	93.44	93.44	116.41
Total costs	$/ha	129.4	449.3	366.5	349.2	198.8	320.7
Average Revenue	$/ha	762.9	2567.9	2002.8	2342.9	1663.6	2051.7
Average Gross margin	$/ha	633.5	2118.6	1636.3	1993.7	1514.5	1731.0

Overall performance of cropping systems. Overall, performance was superior for legume SI systems over sole maize, unfertilized. This is shown particularly in terms of performance in marginal environments and stability of production. This stands in contrast with smallholder adoption of legume crops in the region, which is limited, or in some cases, highly variable (Mhango et al., 2012[1]; Silberg et al., 2017[2]). There are, however, many farmer constraints to adoption of legume intercrops and rotational systems, including market access limitations, agronomic challenges and knowledge gaps (Snapp et al., 2002[3]; Waldman et al., 2016[4]). A standout crop within the SI technologies was groundnut, as it was present in the systems, which produced the most protein: the groundnut rotation and the DLR. These systems did well in the

[1] Mhango, W. G., Snapp, S. S., and Phiri, G. Y. K. (2012). Opportunities and constraints to legume diversification for sustainable maize production on smallholder farms in Malawi. Renewable Agriculture and Food Systems, 28, 234–244. doi: 10.1017/S1742170512000178

[2] Silberg, T.R., Richardson, R.B., Hockett, M. and Snapp, S.S. (2017). Maize-legume intercropping in central Malawi: determinants of practice. International Journal of Agricultural Sustainability, 15(6), pp.662-680

[3] Snapp, S.S., D.D. Rohrbach, F. Simtowe and Freeman, H.A. (2002). Sustainable soil management options for Malawi: can smallholder farmers grow more legumes? Agriculture Ecosystems and Environment 91:159-174

[4] Waldman, K.B., Ortega, D.L., Richardson, R.B. and Snapp, S.S. (2017). Estimating demand for perennial pigeon pea in Malawi using choice experiments. Ecological Economics, 131, pp.222-230

low potential environment, which included sites with high evapotranspiration and marginal soils.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & Explanation
SI field trials established for each site	Done during December 2019	All trials established as planned	No deviation.
Baby trials established by at least 3000 farmers experimenting with SI technologies	Done during December–January Only 2500 farmers involved due to reduced budget	Only 2500 farmers involved due to reduced budget	Mangochi sites were not included during 2019/20 cropping season. We worked in three districts –Dedza, Ntcheu, and Machinga
Benefits of SI technologies evaluated across sites	Data will be collected and analyzed for the next reporting period.	Meta-analysis study is ongoing. Some results have been presented.	This will be completed in 2021
At least one field day per EPA conducted	Three field days held; others suspended.	No further field days held during 2020	Farmer gatherings were banned due to COVID19 restrictions.
At least two farmer exchange visits conducted	Suspended due to COVID	Suspended due to COVID	
Africa RISING attends at least one DAECC-led district workshop for SI technologies dissemination	Possibly during August	Bans on meetings remained in place.	
SANE – Africa RISING collaboration extended 2020	The relationship is informal	SANE is closing out	
Data uploaded to DataVerse	To be completed by August	All data uploaded as planned	
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August	All FtF indicators data provided as planned	

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 was to evaluate the effect of groundnut seed quality and plant density of groundnut productivity and quantify the rotational benefits to a subsequent maize crop in a high and low potential agricultural zones in central and southern Malawi.This study was initiated in 2018. Maize was planted, as a test crop, during the 2019/2020 cropping season on plots previously planted to the different interaction groundnut treatments being Certified groundnut seed – double or single rows, and Recycled groundnut seed – double or single rows.

The results in Figures 5 and 6 suggest that in both high and low potential sites, high groundnut density was associated with increased groundnut biological N_2-fixation, as well as yields of the subsequent maize crop. Differences between certified seed and recycled seed were minor, although certified seed had larger biological N_2-fixation and maize response effect in almost all cases. Agroecology had an overriding effect – for example, with double row groundnut cropping, N_2-fixed was about 100 kg/ha N in Linthipe, this being much higher than about 30 kg/ha N in Ntubwi. Agroecology effect was also significant on the yields of the rotational maize crop.

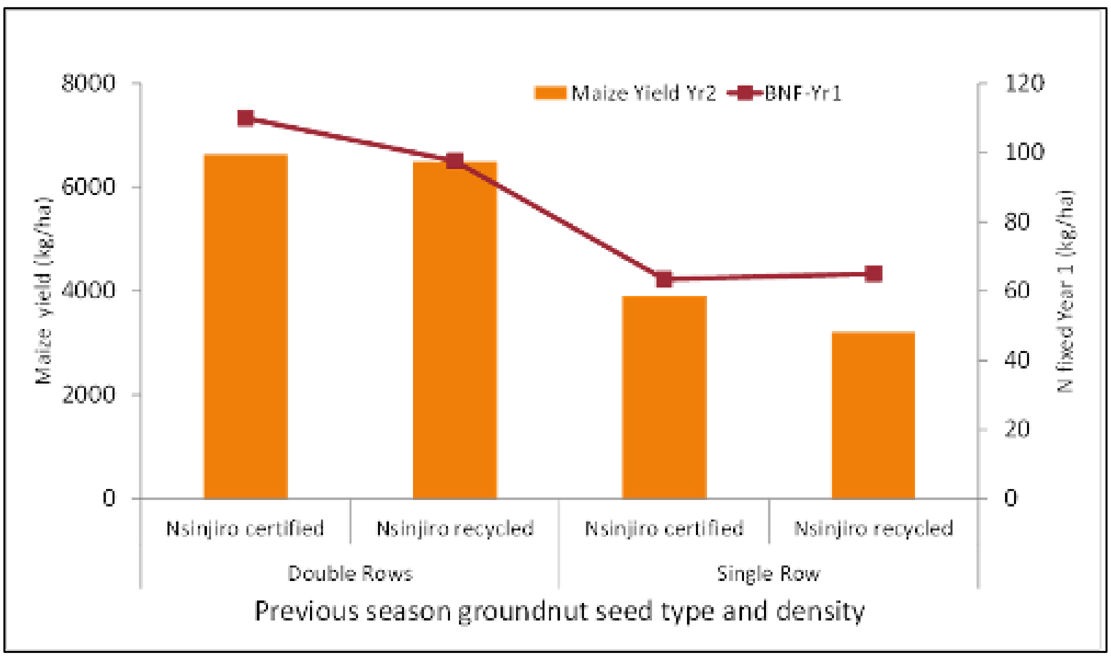


Figure 5. Maize grain yield following certified and recycled groundnut at different densities in Linthipe site, 2019/2020 season. Nitrogen fixed during the previous season is shown on the right Y-axis as represented by a continuous line.

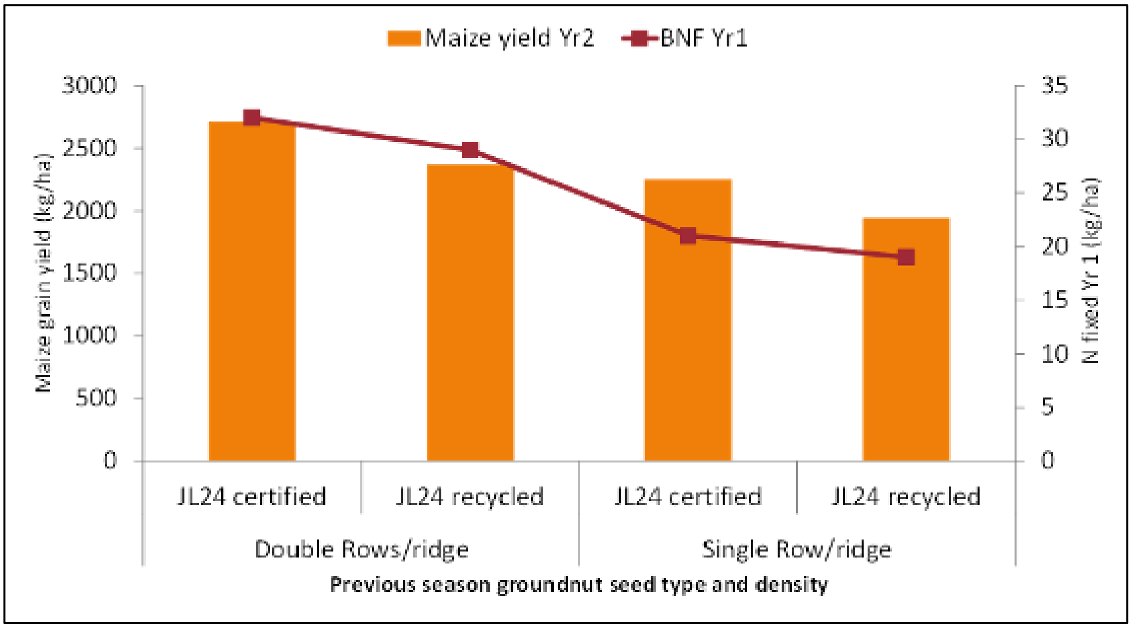


Figure 6. Maize grain yield following certified and recycled groundnut at different densities in Ntubwi site, 2019/2020 season. Nitrogen fixed during the previous season is shown on the right Y-axis as represented by a continuous line.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
SI field trials established for each site initiated in 2018	On-farm trials were established in Linthipe EPA in Dedza District, and Ntubwi EPA in Machinga District	All trials successful, harvested, and data processed	No deviation
Benefits of SI technologies evaluated across sites	To be done after harvest when relevant parameters become available	BNF and productivity have been assessed	
At least one field day per EPA conducted	Cancelled due to COVID-19 pandemic		
At least one farmer feedback workshop conducted in each EPA	Planned for July–August 2020	One feedback meeting held in September with a restricted number of 50 farmers (notes attached)	
District level dissemination of improved groundnut germplasm × density for improved productivity (at least 4000 farmers receive information)	Knowledge products are under development and will be ready for workshops and training after harvest (July–August 2020).	Graduate student currently synthesizing lessons from these experiments for packaging into an extension brief	34-week break from university derailed workplans
Manuscripts		Thesis being developed as all data are now in place	
Data uploaded to DataVerse	To be completed by August	Data uploaded to DataVerse	
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August	FtF indicators data provided	

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

We encountered challenges getting results from the livestock component from April to September. A decision has been made to terminate the contract with Dr Chirwa. However, results from goat supplementary feeding studies documented in Charles Mkchutche's recently completed MSc thesis showed that goats under fodder supplementation had better feed intake, growth rate, improved body, and better carcass characteristics than un-supplemented goats. Table 3 shows improved daily growth rate (DGR) when grazing goats were supplemented with different locally available feed resources.

Table 3. On-station and on-farm DGR of intact local Malawi bucks under free range grazing system

Diet	On-station			On-farm		
	N	DGR (g/day)	SE (±)	N	DGR (g/day)	SE (±)
D_1	8	46^c	11.83	16	46^d	2.35
D_2	8	67^b	3.11	16	52^c	4.41
D_3	8	80^a	3.94	16	61^b	3.16
D_4	8	84^a	3.49	16	68^a	3.59

^{abcd}Means with different superscripts within a column are significantly different at P<0.05

Diets; D_1 = Grazing + 410g Maize bran (MB); D_2= Grazing + 405g *Gliricidia sepium* + 410g maize bran (GLM); D_3= Grazing + 405g *Faidherbia albida* + 410g Maize bran (FDM); D_4 = grazing + 202.5g *Gliricidia sepium* + 202.5g *Faidherbia albida* + 410g maize bran (GFM). DGR=Daily growth rate; SE=Standard error; N = Number of observations.

Targeted deliverables for 2019/2020 and status on achievements

Given that the sub-contract is terminated, the targets are no longer being pursued.

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

The doubled-up legume *Gliricidia* and pigeon pea trials were established in 2015 and assessed for crop yield (maize and pigeon pea grain) for the first three seasons in 2015-2017. The intercropping of maize with *G. sepium* and pigeon pea improved crop yields by up to 33%, but with seasonal variations because this was the establishment phase when tree effects on soil conditions and microclimate modification were building up. We continued monitoring the resilience contribution of this crop arrangement during this reporting period.

Productivity. Maize grain yields varied between cropping systems and cropping seasons (Figure 7) due to the combined effects inter-specific competition and drought linked to low and poorly distributed precipitation. Intercropping maize with *G. sepium* and/or pigeon pea did not significantly supress grain yields even after five years of intercropping under semi-arid conditions. Thus, farmers can diversify their farming systems with grain and fodder legumes without compromising yields of staple food crops like maize.

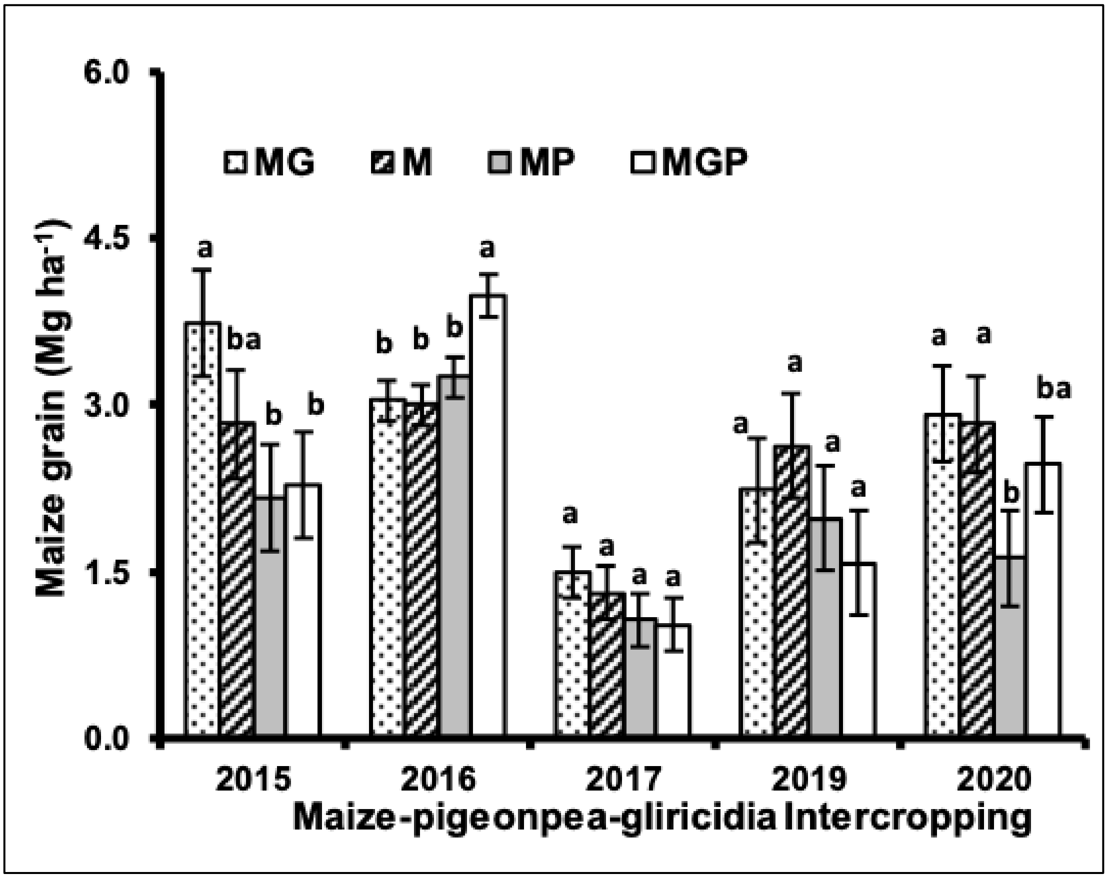


Figure 7. Maize gain yield in *Gliricidia*-based cropping systems at Manyusi village, Kongwa District. Means followed by the same letter within a season are not statistically different at 5% probability level. Vertical bars are stand errors of the difference between means (n=3). M= Maize monoculture; MG=Maize-*G. sepium* intercropping; MP = Maize-Pigeon pea intercropping; MGP = Maize-*G. sepium*-Pigeon pea intercropping.

Economic benefits. The plot level results on crop productivity (Figure 7) are being processed for modelling crops productivity (maize grain and wood yields) in *Gliricidia*-based treatments to generate data for developing a publication on profitability of agroforestry technologies***.***

Nutrition. Caloric yield was used to estimate the food security impacts of tested cropping systems while the impacts on human nutrition was estimated using protein yield. These estimates were obtained using yield data for the years 2019 and 2020 when the cropping systems were also subjected to drought conditions of the rain-out shelter experiments. Maize and pigeon pea grain yields were converted to calories and protein using published conversion factors for Tanzania (Lukmanji et al., 2008). For a given cropping system, calories or protein from both maize and pigeon pea were then summed to calculate total calorie or protein yield per hectare for the cropping system.

Total caloric and protein yields varied significantly between cropping systems, water gradients, and with fertilization. Cropping systems did not affect caloric and protein yields under rainfall gradient conditions in 2019 although ambient rainfall slightly improved nutritional yields compared to drought (Figure 8). Apparently, the prolonged drought and poorly distributed rainfall pattern in 2019 may have masked the response to rainout shelter treatment. In 2020, however, the caloric (p= 0.0412) and protein (p=0.030) yields were improved by induced drought with the highest nutritional value found in maize-*G. sepium*-pigeon pea intercropping system and the lowest values in pure pigeon pea stands. Improved nutritional yields under drought in 2020 reflect favourable rainfall conditions under the rainout shelters on this wetter season with the prolonged and above average precipitations. Lower nutrition (caloric and protein) yields in pure pigeon pea in 2020, reflect poor growth and yield of pigeon pea in this wetter season. Unlike ambient rainfall conditions, induced drought by rainout shelters created favourable conditions for improved caloric and protein yields in 2020.

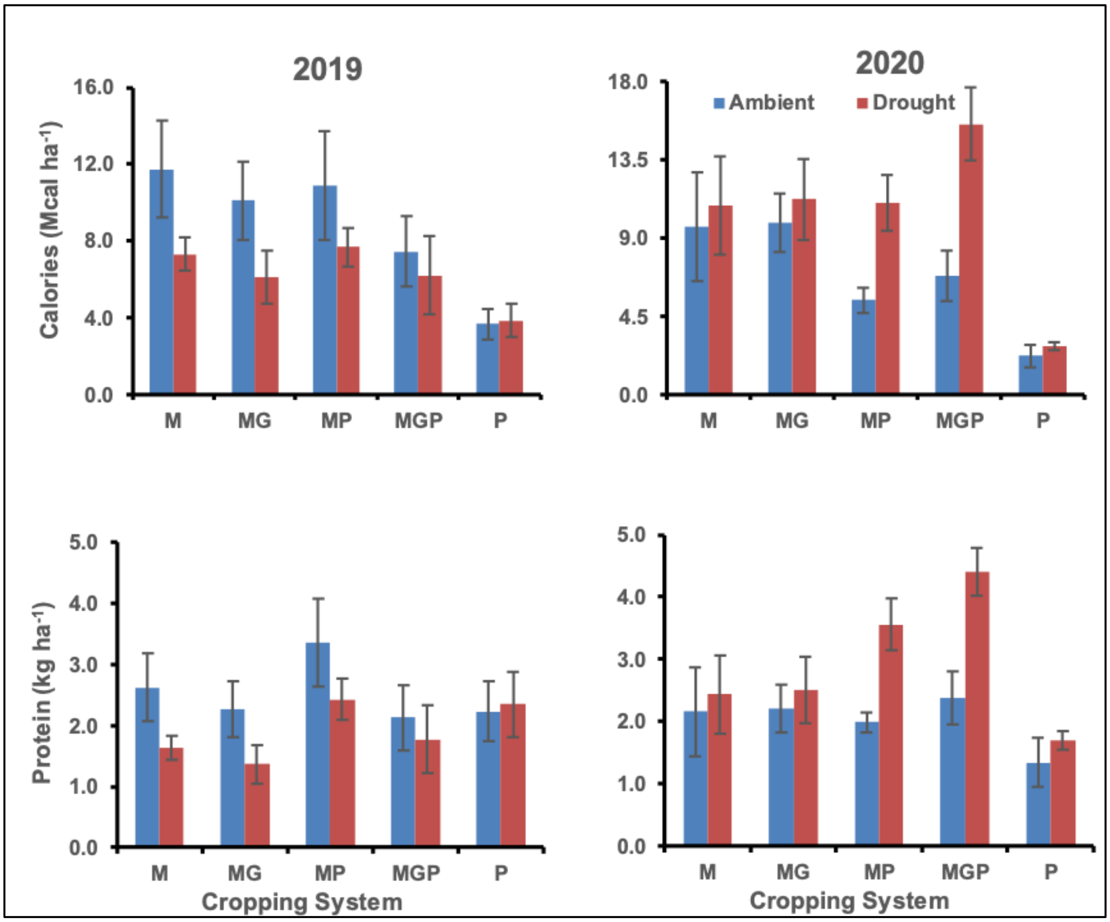


Figure 8. Cropping system effects on caloric and protein yields under ambient and drought rainfall conditions during the 2019 and 2020 cropping systems at Manyusi Village, Kongwa District, Dodoma, Tanzania.

Adoption. A manuscript predicting the adoption of agroforestry was finalized and published during this reporting period (Swamila et al., 2020). Application of the ADOPT predicted adoption of *Gliricidia*-based agroforestry and fertilizer technologies. It was noted that environmental benefits (e.g., soil erosion control and soil fertility replenishment), future profits of agroforestry and trees roles in reducing risks in agriculture are factors likely to drive adoption of agroforestry technologies. However, high initial costs of inputs coupled with the long-term nature of benefits of tree may deter the adoption of agroforestry technologies.

Current work in understanding the process of adoption after the project's intervention will validate these results based on farmer experience in practicing and sharing the technology since 2015. For this, we interviewed 313 farmers (33% women) from six villages in Kongwa and Kiteto districts using the household and focused survey tools, and also held focused group discussions (FGDs) with 90 respondents (56% women) from the same villages. These activities were conducted in September, having been delayed by COVID-19 restrictions. Data processing and analysis is ongoing, and the results will be reported in the next reporting period.

Predicting sustainability using APSIM. Preliminary model calibration of maize grain and *Gliricidia* wood yields has been conducted using the APSIMx using historical data. Results show the higher maize grain yield relative to unfertilized monoculture (Figure 9), reflecting beneficial effects of intercropping on green manure supply and soil fertility, which is expected to increase with years after Gliricidia establishment. Seasonal variation in maize yields is linked to changes in precipitation with the lowest values in 2018/19, which was a drought cropping year.

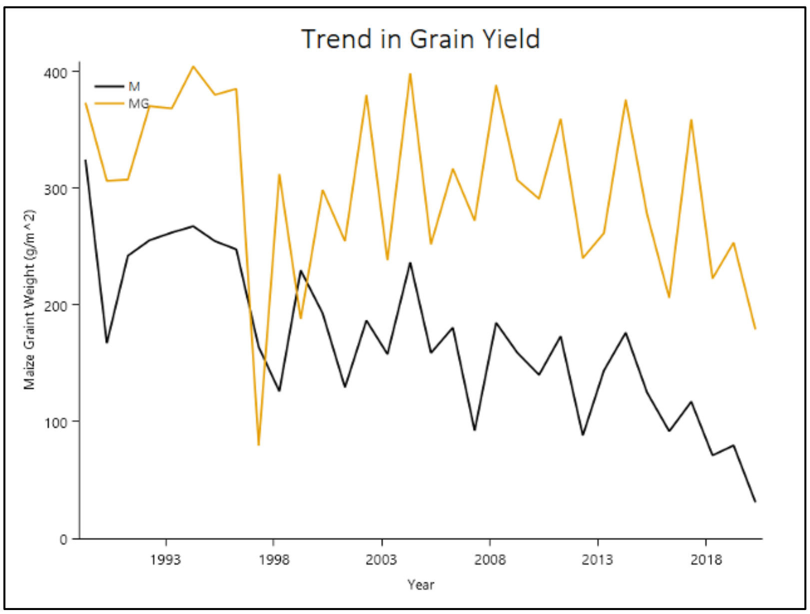


Figure 9. Maize grain yield in *Gliricidia*-maize intercropping based on the APSIMx model. M= maize monoculture; MG= maize intercropped with *Gliricidia.*

APSIM results presented here are preliminary because they are based on past climate data and do not include pigeon pea modelling. We just obtained data for future (2015-2055) climate from Tanzania Meteorological Agency (TMA) to allow forward modelling of maize yield. ICRISAT has just completed the fieldwork to assess bulk density and rooting depth. The next step is processing and analysis of samples as well as model calibration to continue with the modelling and generating results for publication.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
Data and manuscript on the resource use efficiency (nutrients and water) and resilience of *G. sepium* intercropping	Field experiments were established, and data collection is ongoing. Development of the manuscript is completed, and a draft is under internal review before submission by mid-May.	Collection of data on maize and pigeon pea grain and G. sepium wood is completed. Processing of soil fertility and pigeon pea wood data is in progress. Manuscript accepted in Journal of Frontiers in Sustainable Food systems. Title: *Maize-pigeon pea intercropping outperforms monocultures under drought*	Lab results on soil fertility samples came late due to a long queue in the SUA lab. Processing pigeon pea data is delayed as the crop matures in August/September N/A
Data on *G. sepium* intercropping impact on economics, gender, food security, and nutrition generated	Data collection is ongoing	Collection of economics, nutrition, food security, and gender data is complete except for pigeon pea wood component.	
Draft manuscript on economic analysis of agroforestry technologies (using long-term data from APSIM modelling)	Data is being analyzed by a PhD student and a draft manuscript will be ready by September.	Data processing and manuscript development in progress	APSIM modelling to generate long-term data for the manuscript was delayed by technical difficulties in modelling *Gliricidia* effects and staff transition at ICRISAT.
Data on the adoption process and impacts of agroforestry technologies within and outside Africa RISING sites made available	Preparations for the survey and checklist tools for data collection is in progress and it will be finalized by the end of April 2020. Survey will be conducted after the COVID-19 conditions eased.	Data collection tool was finalized, and data collected. Processing and analysis of data is in progress.	The adoption/dis-adoption survey was conducted in September due to COVID-19-related restrictions to hold meetings and/or travel.

Draft manuscript based on the modelling of long-term sustainability	Previous data and data under the current collection will be used for APSIM modelling and manuscript preparation	The APSIM modelling work continues with technical support from CSIRO, Australia (for G. sepium intercropping effects) and ICRISAT for pigeon pea intercropping effects.	Manuscript development is pending for the long-term crops yield data from APSIM.
MoU with Mikumi National Park (MNP) for scaling of agroforestry technologies	Preparatory partnership meeting was held in March 2020; Follow-up physical meetings were interrupted by travel restrictions	• Discussions with MNP have collapsed • New partnership between ICRAF and SAT has been initiated	• Budgetary constraints to scaling activities on the part of MNP.
At least 20 000 tree seedlings delivered for planting in collaboration with extension officers and partners in targeted sites technologies	The target to plant 20 000 seedlings of *G. sepium* was met; beneficiary data are being processed	Collection of beneficiary data from Africa RISING sites completed. Data from scaling sites managed by partner (LEAD foundation) is in progress.	Delayed. Beneficiary data from scaling partner to be collected by December 2020.
Data uploaded to DataVerse	To be completed by August	Data files shared for upload in September 2020	Files for unprocessed data to be shared when analysis is completed.
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August	Data files shared to ESA M&E in September 2020	Files for unprocessed data to be shared when analysis is completed.

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

Selection and establishment of six experimental trials, as well as recruitment of 150 baby farmers for testing *Mbili-Mbili* and doubled-up legume system, was discussed during the last reporting period. During this reporting, results on various field assessments conducted during the season are discussed.

Effect of crop spatial arrangements on biological nitrogen fixation. Samples for BNF analysis were collected at 50% podding. Nodulation of pigeon pea during this period was highly affected by reduced soil moisture content following a long dry spell experienced between maize physiological maturity (R6) and when pigeon pea had halfway podded. The few nodules that had developed before the assessment period were already dry and empty. Biological N fixation sampling was successfully conducted, and samples were shipped to Kenya for pre-processing. Sample preparation is still in progress in preparation for shipping to Belgium for ^{15}N determination by the natural abundance method.

Effect of treatments on leaf chlorophyll. The chlorophyll levels across fields and sampling periods ranged from 45.4 SPAD units in the conventional maize (Syngenta 624) - pigeon pea intercropping system to 50 SPAD units in *Mbili-Mbili* (Tab. 4). Despite *Mbili-Mbili* having significantly low leaf chlorophyll readings at the early stages of crop growth, the levels rose drastically in the period between V8 and V12 stage, to becoming the highest. This indicates that the three crop species in *Mbili-Mbili* does not result in a significant interspecific competition, which may lead to yields penalty relative to crop arrangement under conventional intercrop system.

Table 4. Effect of cropping system of maize leaf chlorophyll during the long rains of 2019/2020 season in Babati

Treatments	<V8	<V12	<R2
Maize monocrop (Control)	45a	49ab	44
Conventional Maize-Pigeon pea- not topped	42b	47b	43
Maize-Pigeon pea- Topped	45a	49ab	44
Maize-Pigeon pea- 2 plants topped	44ab	48ab	43
Mbili Mbili	43b	50a	42
Maize-Pigeon pea- vertical architecture	45a	49ab	42
s.e	0.69	0.88	

Effect of plant spatial patterns on photosynthetically active radiation (PAR). Results on the effects of spatial patterns on PAR from V6 to maize maturity was discussed in the last reporting. Generally, light interception by plant canopy was significantly affected by the plant spatial patterns used when means were averaged across farmer fields and the different sampling dates ($p \leq 0.05$). During this reporting, pigeon pea canopy cover was analyzed from maize harvesting to pigeon pea maturity where means were pooled across cropping systems and farmer fields. The canopy cover ranged from 0.48 $\mu molm^{-2}s^{-1}$ in the system where two maize seeds were planted per hill to 0.58 $\mu molm^{-2}s^{-1}$ in the doubled-up legume system. The dense canopy cover in the doubled-up legume system ($p \leq 0.05$) was observed across the three sampling periods (i.e., at flower initiation, 50% flowering, and 50% podding). The dense canopy cover in the doubled-up legume system is attributed to the absence of interspecific competition from maize compared to maize-pigeon pea intercropped systems. Therefore, light interception by plant canopy was significantly affected by the spatial patterns at planting, during the post-maize harvest growth period of the legume.

***Effects of plant spatial patterns on soil moisture content*.** The effect of the different plant configurations on soil moisture was assessed from the time maize was at eleven leaves (V11) to 50% podding. of pigeon pea. When soil moisture and temperatures were averaged across farmer fields, cropping systems and sampling periods, significant moisture, and temperature differences were observed across the sampling time ($p \leq 0.01$) and not at cropping systems level. This can be associated with the uniform moisture levels due to good rainfall distribution during the cropping season. From V11 to when maize was at dent stage (R4) soil moisture content ranged from 0.21 m^3/m^3 in sole maize system to 0.30 m^3/m^3 in doubled-up legume system (Tab. 5). At this growth period, lower evapotranspiration rate was due to presence of young pigeon pea plants, which had not yet branched, compared to other systems where maize was in active vegetative development (V stages) and reproduction (R stages). The high moisture content in doubled-up legume system at R2 maize growth stage is comparative to the low soil temperature content within the cropping system during the same period. No significant differences in soil moisture content were observed from flowering of pigeon pea to the time it was halfway podded. This could be attributed to the long dry spell experienced during that specific period.

Table 5. Effect of treatments on soil moisture and temperatures during long rains of 2019/2020 season in Babati

Treatment	V11	R2	R4	Flower Initiation	50% flower	50% Poding
Sole maize	0.21c (29.6)	0.28b (31.9a)	0.24ab (36.1)			
Maize-pigeon pea intercrop (Not topped)	0.22b (29.8)	0.29ab 30.5ab)	0.24ab (35.8)	0.26 (33.8)	0.16 (31.7)	0.04 (33.9bc)
Maize-pigeon pea intercrop (Topped)	0.22c (29.6)	0.28b (30.6ab)	0.25a (34.9)	0.25 (35.1)	0.18 (30.4)	0.04 (34.4ab)
Doubled-up legume	0.24a (28.8)	0.30a (29b)	0.25a (34.8)	0.25 (34.6)	0.17(31.5)	0.04 (34.9a)
Maize-pigeon pea intercrop (2 plants per hill)	0.23ab (29.5)	0.29ab (30.5ab)	0.25ab (35.5)	0.26 (34.3)	0.18 (30.9)	0.04 (33.5c)
Mbili-Mbili	0.22abc (29.7)	0.28b (31.6a)	0.25ab (35.1)	0.26 (34.5)	0.17 (31.7)	0.04 (33.5c)
Maize-pigeon pea intercrop	0.22abc (29.8)	0.29ab (30.3ab)	0.23b (36.3)	0.26 (34.4)	0.17 (31.8)	0.04 (33.6bc)
S.E.	0.006	0.006 (0.61)	0.007			(0.30)

Effect of plant spatial patterns on plant physiological growth and cropping systems' production. Pigeon pea branch development was assessed one week before maize harvesting and two months after maize harvest. The different plant spacing patterns significantly affected pigeon pea branch development across the different fields ($p \leq 0.01$). A week before maize harvest, the number of branches per plant ranged from four in the conventional maize-pigeon pea intercrop (not topped) to nine branches under the doubled-up legume technology. An increment in the number of branches was observed one month after maize harvest, which ranged from nine branches in farmer practice, to 15 branches under the doubled-up legume where improved sunlight penetration might have encouraged early branching. Practicing *Mbili-Mbili*, topping, and using maize with vertical leaf architecture also significantly increased the number of branches per plant (i.e., 9, 8, and 8 branches, respectively) compared to the seven branches in conventional maize-pigeon pea system. A similar response pattern was recorded when pigeon pea flowering rate was assessed. Absence of maize in the doubled-up legume system led to early and increased flowering rate compared to systems with a maize intercrop (Table 6).

Table 6. Effect of plant configuration on pigeon pea flowering during the long rains of 2020/2021 season in Babati, Tanzania

Pigeon pea Plant flowering assessment time	Least number of plants flowered per plot	Highest number of plants flowered per plot	Least-flowered treatments	Most-flowered treatments
1 week before maize harvest	1	9	Maize-pigeon pea (not topped)	Doubled-up legume
2 weeks after maize harvest	4	22	Maize-pigeon pea (not topped)	Doubled-up legume
4 weeks after maize harvest	11	64	Maize-pigeon pea (topped)	Doubled-up legume
8 weeks after maize harvest	26	91	Meru H513	Doubled-up legume

Averaged across the three ecozones, topping of maize produced 1.9 t/ha of stover, signifying a potential of animal feed production during periods of fodder insufficiency. Besides, planting of one maize seed per hill produced 0.5 t/ha higher ($p \leq 0.01$) toppings than plant configurations with two maize seeds per hill. This could be attributed to minimal competition for light and nutrients, which might have improved plant nutrient uptake and biomass accumulation.

Across the three agroecologies of Babati, use of improved crop management practices increased maize yields significantly ($p \leq 0.5$, Tab. 7). Thus, beyond using improved seed varieties, it is critical to apply fertilizers and apply proper crop spacing for improved crop production. In low altitude-low rainfall (Farmer A and B), a DT maize variety with vertical leaf architecture (Meru 513) had at least 0.6 t ha^{-1} higher grain yield than the conventional intercropping system, indicating that that DT varieties can also perform well in high rainfall seasons.

Mbili-Mbili produced at least 1.1 t/ha more grain than the convention intercrop system in the medium altitude high rainfall ecozone (Farmers C and D), which could be associated with the presence of a greater inter-row space that might have minimized inter-plant competition for light and nutrients. In the medium altitude-low rainfall ecozone (Farmers E and F), where maize production was more than 6 t/ha, the sole crop system yielded over 0.9 t/ha higher than the conventional intercrop system. The absence of the legume intercrop reduced interspecific competition.

Table 7. Effect of plant spatial configurations on maize grain yield during the long rains of 2019/2020 season in Babati, Tanzania

Treatments	Farmer					
	A	B	C	D	E	F
Sole maize (Control)	5.4a	4.5b	4.1ab	5.3ab	8.7a	9.0a
Maize-pigeon pea intercrop (Not topped)	5.7a	4.0b	3.8ab	4.3b	6.3b	8.1a
Maize-pigeon pea intercrop (Topped)	5.4a	5.4ab	3.6ab	5.5ab	7.1ab	8.0a
Maize-pigeon pea intercrop (2 plants per hill)	5.2a	5.0ab	2.8bc	5.3ab	7.3ab	7.3a
Mbili-Mbili	5.5a	4.0b	4.7a	6.1a	7.7ab	7.5a
Maize-pigeon pea intercrop[€]	6.3a	6.1a	3.4ab	5.2ab	8.3a	7.2a
Farmer practice	1.5b	1.6c	1.2c		1.0c	
s.e.d.	0.64	0.71	0.86	0.7	0.8	1.1

[€] Maize planted in all cropping systems was Syngenta H624 except for this treatment in which Meru H513 was planted

The doubled-up legume system produced 0.4 t/ha and 0.3 t/ha higher bean grain and haulms, respectively, than in *Mbili-Mbili* system ($p \leq 0.01$), attributed to reduced interspecific competition for light and nutrients in the doubled-up legume system. A second bean phase planted in the doubled-up legume system was successfully established at one field in Sabilo and another field in Riroda villages (Photo 1). In the two fields, bean yield ranged from 1.6 t/ha in Sabilo to 2 t/ha in Riroda. The success can be associated to adequate soil moisture and reduced shading associated with pigeon pea intercrop. These results indicate that farmers practicing the doubled-up legume system can gain from reduced risks of weather vulnerability, as well as increased income. Such scenario was evident in Riroda where the first bean phase was destroyed by rains, but the farmer recovered from loss through the second bean phase. Contrary to expectations, the second bean phase in *Mbili-Mbili* did not establish because of the dense canopy emanating from maize and pigeon pea.

Photo 1. A second bean phase under pigeon pea intercrop in Riroda village. Photo credit: Prosper Massawe/TARI.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020	Deviation & explanation
Six on-farm trials, two in each of three eco-zones of Babati District, successfully implemented	Implementation was successful. Also, 150 baby farmers were trained on, and provided inputs for the establishment of baby trials for testing *Mbili-Mbili* and doubled up legumes. Training report available.	Maize harvested and data analyzed; Pigeon pea to be harvested.	None
Three new technologies introduced and tested	*Mbili-Mbili* system, Doubled-up legume and maize topping and stripping technologies have been introduced and data collection for their validation is in progress.	Technologies evaluated as planned.	None
BNF of pigeon pea quantified	The activity will be conducted once pigeon pea attains 50% podding – but also subject to the control of the COVID-19 pandemic.	Sampling done according to plan, samples prepared and ready to send to Europe for 15N analysis	None
150 farmers trained (during field days)		Conducted a field day for farmers to identify with *Mbili-Mbili* before beans were harvested. Other field days cancelled due to COVID-19.	None
Data uploaded to DataVerse	To be completed by August	Data for 2019/20 uploaded as planned.	None
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August	Completed	None

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

Farmer's perception of weather variability associated impacts on crop productivity. From April to July 2020, the work under this sub-activity focused on collection of historical weather and crop yield data. The aim was to verify what farmers perceived about weather variability and associated impacts on crop yield. From the survey data, 100% of farmers reported changes in weather/climatic conditions relative to the conditions experienced in the 1990s. Of all respondents, 98% reported a general decrease in total amount of rains. Majority of farmers (60%) considered that there has been a change in rain pattern within the locality, with rain onset shifting from November to December and January, in recent years. Furthermore, 93% of farmers opined that the amount of rain per season is generally decreasing.

Observed trends of rains recorded from 1996 to 2020 in Kiteto district justified farmers' perceptions on total amount and distribution of rains. Regression analysis of the rainfall data (Tab. 8) revealed that the number of rain days per year have been decreasing at the rate of -.795 ($t = -1.458$, $p = 0.162$), and the amount of rainfall has been decreasing at the rate of -14.234mm per annum ($t = -2.072$, $p = 0.053$). Local knowledge on climate change can guide planning where technical data are not available.

Table 8. Rainfall trends in Kiteto district

Analytical approach		Simple Linear Regression
Rainfall indicator	Number of rain days	Amount of rain per annum
P - Value	0.162	0.053
T - Value	-1.458	-2.072
Regression Coefficients	-0.795	-14.234

During this period, maize productivity decreased slightly, being -0.009 and -0.015 t/ha/yr for Kongwa and Kiteto districts, respectively. Productivity of groundnuts, beans, cowpea, and pigeon pea did not change significantly over time. To meet the demands of the growing population, areas under the staple maize crop increased significantly, from about 2.5 to 4 ha per household, which is not a sustainable approach. This calls for the introduction of sustainably intensified production systems. Areas under legumes did not change significantly.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
Establish farmer's perception of weather variability & associated impacts on crop production	A survey involving 147 farmers from Kongwa and Kiteto districts was conducted in October 2019. Data is being analyzed for report/manuscript production.	Survey report produced	Delayed submission of the report; waiting to compliment survey data with historical yield data
Historical crop yield data for Kongwa and Kiteto districts over the years compiled	Meetings with the Ministry of Agriculture suspended until after COVID-19	Historical yield data collected from district data base and submitted to ESA M&E for DataVerse	
Monthly weather data offloaded from weather stations in Kongwa and Kiteto districts	Ongoing and will be uploaded to DataVerse	October 2019 – April 2020 data collected and shared with KK researchers	Collapse of a computer installed with Watch dog software delayed data offloading beyond April 2020
Data uploaded to DataVerse	To be completed by August	Not uploaded	Delayed completion of data offloading
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August	Submitted to ESA M&E for uploading	

[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.

interventions, which were introduced on three farms to understand better the processes that led to the current successful farm operations. The already available data from the three farms was to be enriched by additional data collection (specifically for FarmDESIGN), which was planned for April-May but couldn't be implemented because of COVID-19. Instead, two alternative farms, which were available in the ARBES database were used to perform the analyses with FarmDESIGN.

SI pathways were explored (baseline vs adoption of AR technologies) and the farming systems were exposed to a drought and price shock. The simulation results show that farmers decrease vulnerability and increase resilience when deploying AR technologies. An illustration of farm performance in the different scenarios for multiple-objective optimization is shown in Figure 10. The objectives chosen for this analysis were operating profit (OP), soil organic matter balance, (SB) and household leisure time (HL). Except for HL (AR technologies generally require more labor than the original farm configuration), farms perform better under shocks when AR technologies are deployed.

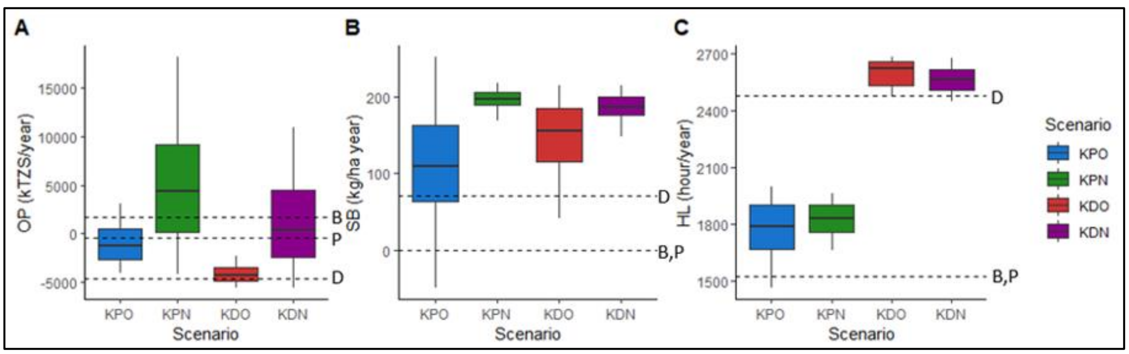


Figure 10. Example of farm performance under different scenarios and multiple-objective optimization. OP: operating profit; SB: soil organic matter balance; HL: household leisure time; KPO: farm K under price fluctuation scenario with original farm configuration; KPN: farm K under price fluctuation scenario with AR technologies adopted; KDO: farm K under drought scenario with original farm configuration; KDN: farm K under drought scenario with AR technologies adopted.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
Inventory of existing data for the three farms	Reports for multiple field visits and meetings with partners to compile existing data and identify gaps available but yet to be uploaded	Interacted with partners to compile existing data and fill gaps. Data complemented by recent household survey (being processed)	
Interviews and surveys with farmers conducted and data gaps filled	Interviews conducted; systems diagrams developed, but these need further quantification	Interviewed two of the three case studies (during previous reporting period). Systems diagrams developed and elaborated. Farm case studies were included in recent household survey (led by C. Mutungi and J. Manda)	3rd interview not conducted due to COVID-19
Farming systems analyzed with SIAF and FarmDESIGN	Work in progress with an MSc student; report to be available in June 2020	MSc student finalizing thesis (analysis based on two alternative farms from ARBES)	Used alternative farms from ARBES because of COVID-19
SI pathways assessed and documented	Work in progress with an MSc student; draft journal article by September 2020	MSc student finalizing thesis (analysis based on two alternative farms from ARBES)	Used alternative farms from ARBES because of COVID-19
Data uploaded to DataVerse	To be completed by August 2020	Recorded interviews being transcribed; data from recent household survey still being processed	
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August 2020	Not applicable for case studies	

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 activity is implemented as a research component of the scaling partnership activity with the development partner, Islands of Peace (IoP), in Karatu District of Tanzania. An experiment, which compared the effectiveness of improved nursery practices (using GAP) compared to farmer practices, indicated higher quality of the seedlings produced following GAP. Overall, the average investment in the GAP nurseries for the three crops (tomato, African nightshade, and Ethiopian mustard) was Tsh 13,546.56 while each farmer spent around Tsh 21,265.16 (Table 9). The differences in the costs are explained by the chemical pesticides and watering bills, which were higher in those nurseries that followed the farmer practices.

Table 9. Average Nursery production costs following the GAP and farmer practices in Karatu

Village	Cost following GAP (Tsh)	Cost following FP (Tsh)
BUGER	13,172.50	22,078.75
CHEM CHEM	14,825.00	20,437.50
GLAMBO	13,693.75	24,705.00
RHOTIA KAINAM	12,737.50	19,641.63
SLAHHAMO	11,560.00	19,647.00
BASHAI	14,306.25	19,237.63
KAMBI YA SIMBA	14,690.00	16,921.25
CHANGARAWE	13,387.50	27,452.50
Average per village	**13,546.56**	**21,265.16**

(1USD = Approx. Tsh 2,300); GAP= good agricultural practices; FP=farmer practice

The baseline insect and pest survey at the onset on the demo trials (64 in total) indicated higher insect incidence on tomato followed by African nightshade. Aphids were more common on Ethiopian mustard and African nightshade while mites were recorded only on the *Solanaceae* crops (tomato and nightshade). The leaf miners were only recorded on tomato. On average, disease prevalence was higher on tomato (28%) and Ethiopian mustard (25%), compared to African nightshade (6%). Early blight mainly occurred on tomato while virus-like symptoms were recorded on Ethiopian mustard and African nightshade.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
Season 2 data on the impact of improved management practices on vegetable production collected	A total of 64 trial-host farmers were identified; activity planning and feedback meetings were conducted; training of farmers on safe vegetable production and GAPs conducted	Data collection in progress	Not yet completed due to delays caused by COVID-19-related restrictions
One farmer field day conducted	Planned for next reporting	Could not be organized due to COVID-19-related restrictions	Cancelled due to COVID-19-related restrictions
One draft paper on the impact of improved vegetable management practices using data from previous studies	To be ready by September	Manuscript is drafted	None
At least one success story published	By August 2020	One success story published and can be accessed at **Link 1**	
Data uploaded to DataVerse	To be completed by August	Data not yet uploaded	Delays caused mainly by the COVID-19-related restrictions
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August	FtF indicators were submitted	None

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

Sub-activity 1.2.1.1: 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 in semi-arid agroecologies of Central Tanzania. The results obtained during the 2019/2020 cropping season are given below.

Effect of rip tillage on dry matter and maize grain yield. The 2018/2019 cropping season was hit by drought (only 72mm of rainfall received) to such an extent that there was no grain yield and treatment effects were hardly significant (Table 10). During the normal cropping season of 2019/2020, rip tillage increased maize grain yield (and calories) by about 21%, with no significant maize variety interaction. Similar results were obtained under farmer management (Figure 11). It is considered that the higher soil water retention in the rip tilled plots and consequent better water use efficiency (averaging 10.4 kg grain/mm rain for RT vs 8.5 kg grain/mm rain for CT) contributed to the higher grain yields. On average, gross margin increased from USD 1324 to 1600/ha.

Table 10. Dry matter and maize grain yields as affected by tillage methods and varieties at Kiperesa mother trials (n=4), Kiteto district during 2018/2019 and 2019/2020 cropping seasons

Treatments	DM yield (kg/ha)		Maize grain yield (kg/ha)	
	2018/2019	2019/2020	2018/2019	2019/2020
CT+WE2109	2932a	15,944a	*	4207a
CT+DCK9089	3043a	15,241a	*	4474a
RT+WE2109	3332a	19,796b	*	5119b
RT+DCK9089	3235a	19,596b	*	5362b
Mean	**3136**	**17644.**	*	**4790**
CV	**25**	**7.8**	*	**7.7**
SE±	**784**	**1372.0**	*	**303**

* No maize grain yield; DM= Dry matter; CT=Conventional tillage; DCK9089= commercial hybrid maize variety called DCK 9089; WE2109 =Water Efficiency Maize for Africa; RT= Rip tillage method. SE± = Standard error; CV = Coefficient of variation; Means followed with the same letter within a column are not significantly different at 5% probability level.

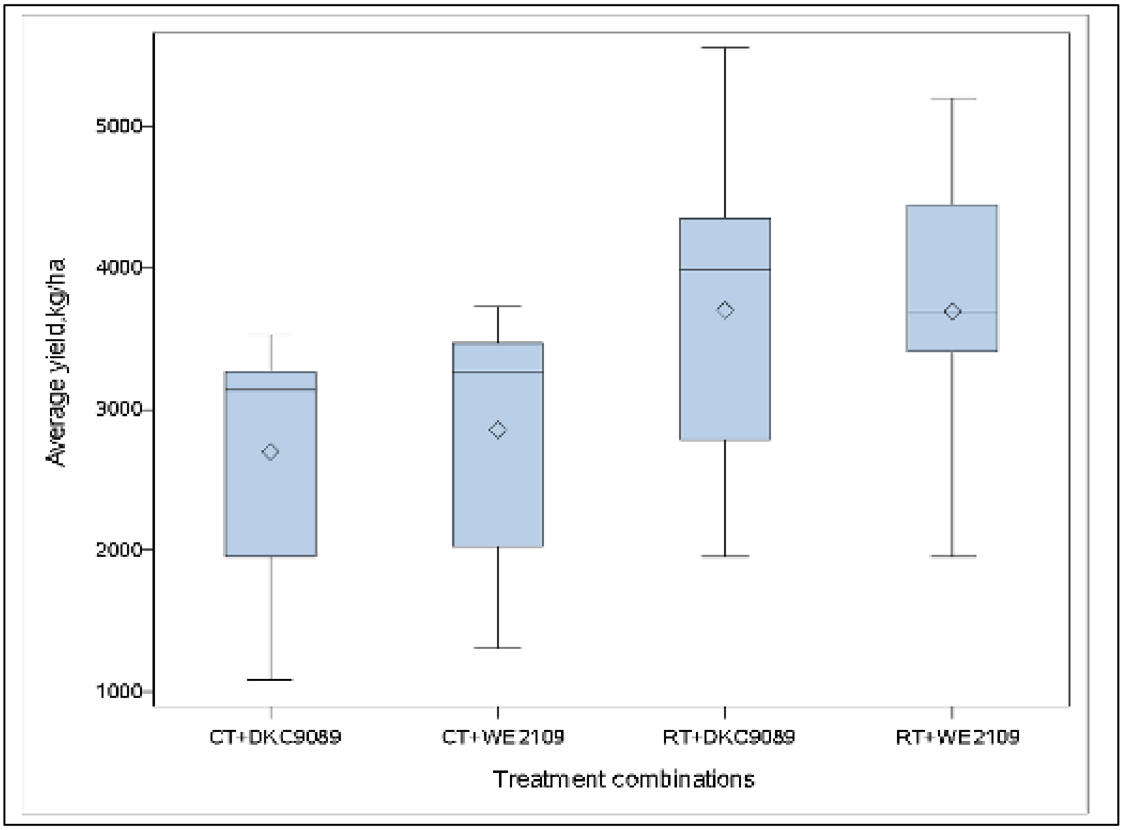


Figure 11. Mean grain yield as affected by tillage and variety at Kiperesa under farmer management (baby trials, n=15) during the 2019/2020 cropping season.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation and explanation
One mother trial and 10 baby trials under rip tillage technique established	One mother trial and replicate trials were established.	NA	The number of baby trials increased from 10 to 40 following request from farmers; We harvested only 15 baby plots because the rest were washed away by the heavy rains.
Socio-economic study on benefits of using rip tillage conducted.	In progress	Gross margin analysis was done	This and the other collected data are being used to draft a manuscript for publication
Accrued benefits on productivity and environment, associated with the use of rip tillage technology quantified.	Data were collected on soil compaction (bulk density), soil water content, and cumulative infiltration	Productivity, environment and economic data were collected and are being analyzed.	
Effect rip tillage techniques on protein content, micronutrient content and food security established.	Lookup table data were identified	Information on food security has been calculated.	
Data uploaded to DataVerse	To be completed by August	In progress and will be submitted not later than 18 November 2020	
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August	FtF data was submitted to M&E	None

Sub-activity 1.2.2.2: Gender and social dynamics analysis of soil and water conservation (SWC) technologies

From May to July 2020, a team of young social scientists from the University of Dodoma (UDOM), together with the consultant Nicolas Patt, prepared a draft article on the results of the gender evaluation of SWC technologies conducted in August 2019. Following a mixed methods approach, descriptive statistics are evaluated against the findings from participatory exercises and qualitative data from FGDs. The draft article will need improving and follow-up data analysis before submission to a journal.

A follow-up question on the drudgery involved in establishing tied ridges was integrated into the survey that the Africa RISING economist conducted on soil and water conservation practices in July 2020. Results will become available in the course of data analysis.

Research on rip tillage in Kiteto district was delayed. UDOM remained closed between mid-March and the end of June 2020 due to the COVID-19 pandemic. As a result, students could not present their research proposals. The closure period was used to prepare tools for field research. After proposal defence in July, students went to the field in mid-September for data collection. Currently, FGDs and key informant interviews are being transcribed, participatory exercises are collated, and survey data are entered and analyzed.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
Recommendations (fanya juu and tied ridges) in bi-annual reports	To be developed by team of social scientists	Data analysis for the development of recommendations was completed by a team of young social scientists	Data analysis needs to be further honed order to arrive at valid recommendations
Recommendations (rip tillage) in MA theses by October 2020	UDOM MA research implementation delayed due to COVID-19 restrictions	Field research complete, data analysis and write up in process	Development of recommendations delayed due to delayed research, analysis, and write-up

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 – Platform is a short message service (SMS) tool described in previous reports. It has been applied to reduce key knowledge gaps among smallholder farmers, improve decision making, and enhance the adoption of technologies. This report highlights results of the impact of disseminating messages using MWANGA to 100 farmers in five villages of Babati District of Tanzania. Results were obtained through FGDs before (baseline) and 14 weeks (end-line) after disseminating the messages.

More than 93% of the farmers were aware of the existence of the Africa RISING project in the study area, and recalled receiving extension messaging through the MWANGA platform. Significant knowledge change resulting from the MWANGA extension messaging was observed in only 3 out of the 10 knowledge areas that were discussed in the FGDs (Table 11). These were areas with initially very low farmer knowledge. So, MWANGA played an important role in these aspects.

Farmers who received extension messages via the MWANGA platform noted that the messages were simple, timely, actionable and in a language they all understood (Kiswahili). But there was minimal sharing of messages with other farmers, only in barazas or during social gatherings. Given that there was no explicit instruction for them to share information, they did not consider it important. Therefore, it is recommended that an initial message should be added to the SMS content at the beginning encouraging farmers to share information with fellow farmers. One of the key recommendations by farmers on the platform is to make it more interactive. Farmers would wish to ask questions and or share their experiences on crop and livestock production challenges.

In terms of attitude, farmers understand that cost and benefits are key factors in technology adoption and that these are positively influenced by keeping exotic breeds and feeding them with better formulated feeds (all significant at 1%).

Table 11. Change in Knowledge and practice among smallholder dairy farmers in Babati, Tanzania

Knowledge area	Proportion		Chi² test (Baseline & End line)
	Baseline (n = 101)	End line (n= 74)	χ2-value
Type Napier grass variety	53.4%	56.8%	0.187
Number of times increasing biomass of Napier grass	89.1%	93.2%	0.879
Forage yield per acre per year for improved Napier grass	9.9%	20.27%	3.750**
At what height should you harvest Napier grass	91.1%	90.5%	0.016
Advantage of planting forages	100%	100%	-
Advantage of chopping forages	100%	100%	-
Advantage of animal housing	100%	100%	-
Three essential nutrients for calf growth	33.7%	63.5%	15.306***
First calving age of a heifer	72.2%	81.1%	1.815
How much water does a high-yielding cow require	21.8%	74.3%	47.851***

***, ** and * represent levels of significance at 1%, 5% and 10%, respectively.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
Baseline survey of current Knowledge, Attitudes, and Practices (KAP) amongst farmers before the intervention	Completed July 2019, report at http://africa-rising-wiki.net/File:AR_Livestock_Research_Activities-July_2019final_.docx	NA	
At least 10 messages to farmers and extension staff about improved technologies disseminated through SMS	Completed and included in the report above	NA	
End-line survey to measure changes in KAP from target farmers, and technical report	Delayed; resulted in a no-cost extension to 2019/2020	Study is concluded and reported in this report	Technical report is under preparation
Data uploaded to DataVerse	To be completed by August 2020	Done	
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August 2020	Done	

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

Extrapolation domain maps for CA practices. The objective of this study was to map out the extrapolation suitability of CA practices in the southern African region based on multi-year and multi-location *in-situ* validation trials conducted in Malawi, Zambia, Mozambique, and Zimbabwe. Though the last two countries are not within the target area of Africa RISING program, they were included because of long-term validation trials that were conducted there following similar protocol from those supported by the program in Zambia and Malawi. Therefore, inclusion of data from the two additional countries helps to capture a wider environmental space where CA can work and therefore improve the model accuracy. A spatial prediction of maize yields from eight CA systems and five conventional practices (CP) was conducted to identify the spatial variation of yield advantage from CA systems. Predictions were done for 2005 and 2017 growing seasons that had below and above average precipitation, respectively (Figure 12). This enabled assessment of performance of CA systems during extreme climatic conditions. The spatial variability of maize yields from different CA and CP systems were mapped.

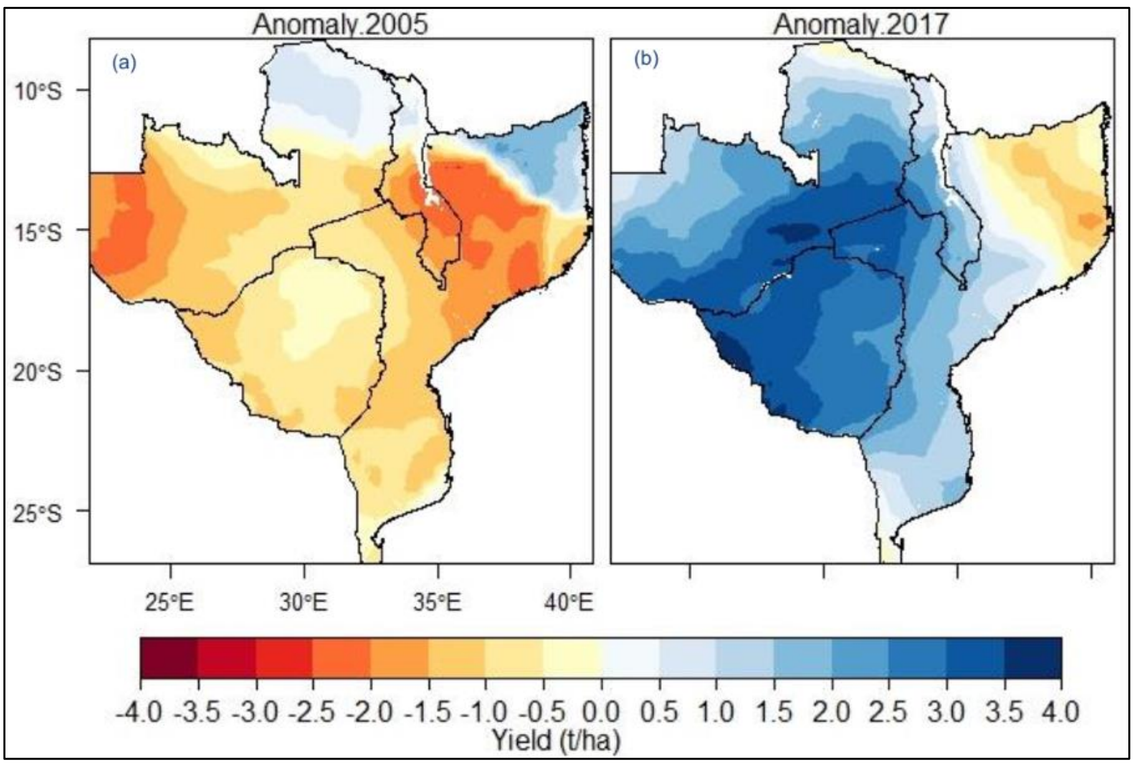


Figure 12. The standardized precipitation anomalies for the 2005 and 2017 growing seasons in Malawi, Mozambique, Zambia, and Zimbabwe. The anomalies indicate the departure of annual rainfall from long-term mean precipitation (1982– 2017). Negative values (yellow-red tones) represent below normal while positive values (blue) represent the above normal precipitation that is associated with droughts and floods, respectively.

The Random Forest (RF) model predicted maize yield with good accuracy R^2 = 0.63 and RMSE = 1.2 t/ha. The elevation and precipitation related variables were the most important in predicting the maize grain yield (Figure 13).

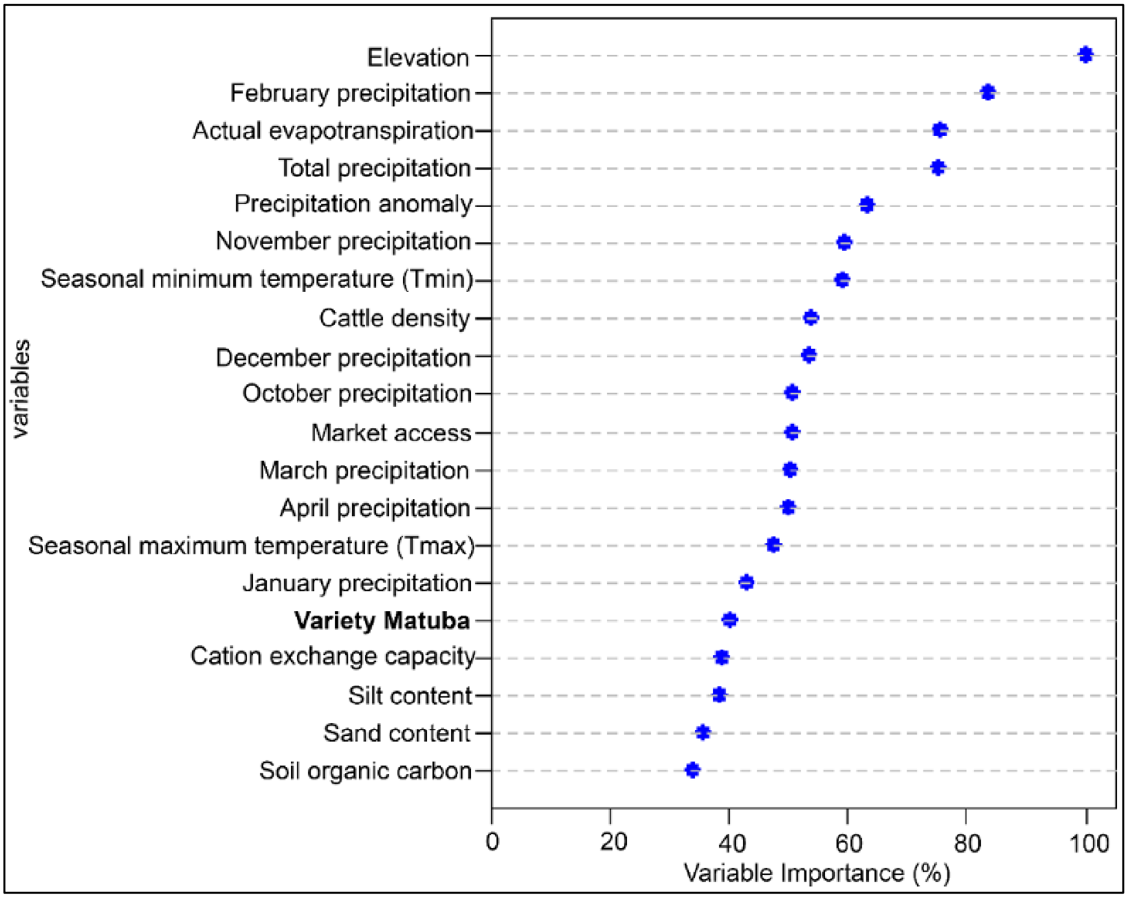


Figure 13. Variable importance plot for prediction of the maize grain yield using the random forests (RF) model

The predictions of maize grain yields and yield advantages for the ZM309 maize variety are shown to illustrate the spatial variability of yields from different CP and CA systems with its complementary technologies. Maize yields were higher during the 2017 growing season compared to 2005 (Figure 14g-h), except in Northern Mozambique where it coincided with negative rainfall anomaly (Figure 14b). The above normal rainfall in 2017 increased maize grain yields in both CPMS and DSMIR systems in an almost similar spatial pattern (Figure 14g-h). The yield advantage from DSMIR CA system (0.5 – 1 t/ha) was recorded in a larger area in 2005 (Figure 14f) compared to 2017 season (Figure 14c). In 2017 season, the CA system in Zambia and Zimbabwe (Figure 14c) recorded yield losses (-0.5 to -1 t/ha) compared to CPMS in areas that have yield advantage during 2005 season (Figure 14f). However, localized yield advantage during 2017 season was restricted to Mozambique (Figure 14c).

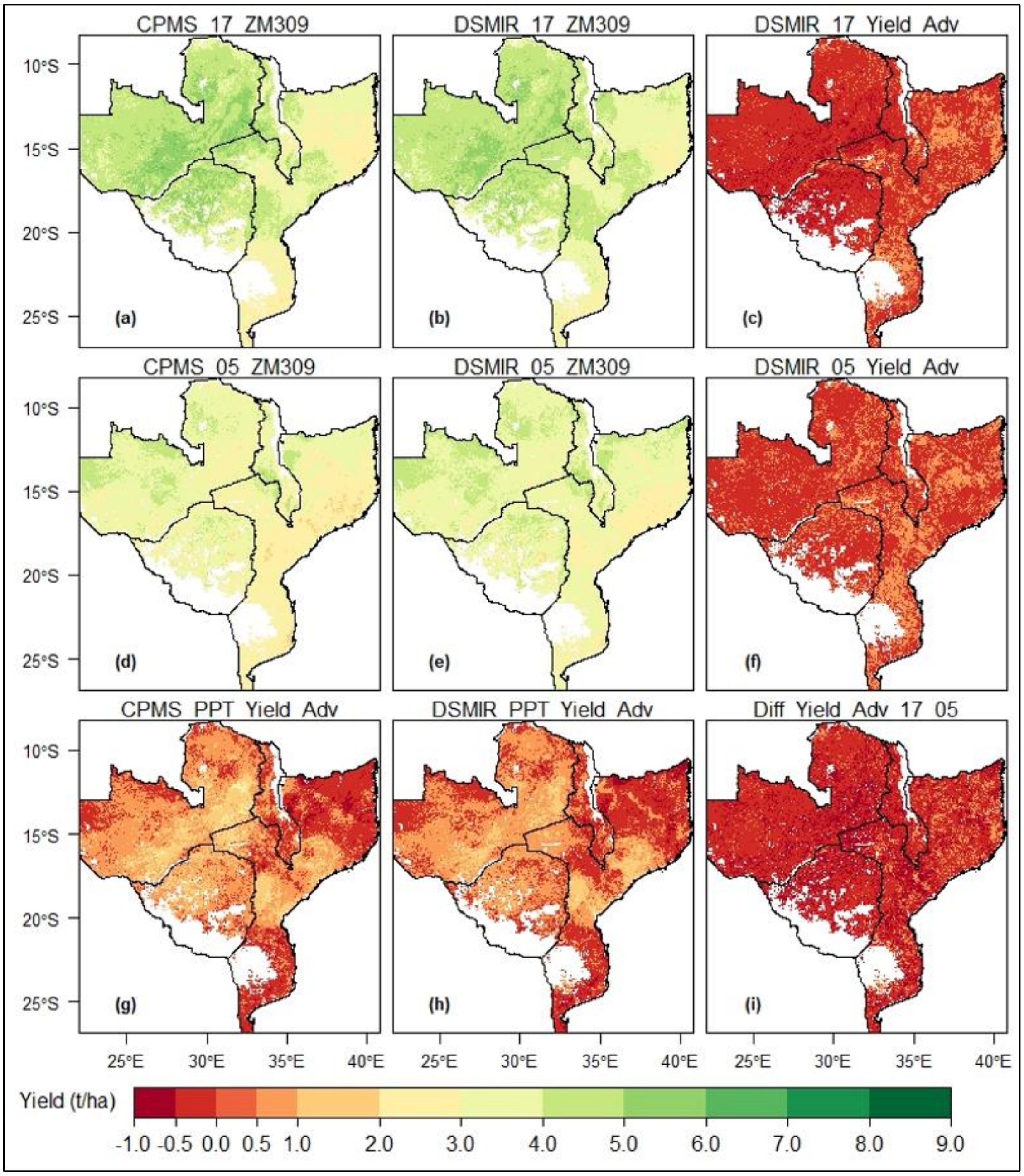


Figure 14. Predicted yield for ZM309 maize variety and yield advantage from CA over CP systems during the 2005 and 2017 growing seasons that had below and above normal precipitation, respectively. The first row shows the predicted yield in 2017 growing season for (a) conventional practice with sole maize (CPMS); (b) direct seeded maize with legume intercropping and rotation (DSMIR); and (c) the yield advantage of DSMIR compared to CPMS in 2017. The second row (d - f) is like a – c but for 2005 season. The third row (g) is yield difference between 2017 and 2005; therefore, yield advantage due to differences in precipitation.

Discussion. The yield advantage from DSMIR CA system covered a large area in Southern Africa during the season with below-normal precipitation (2005) compared to CPMS system. This agrees with recent studies that highlighted that CA practices offer a buffer against yield losses during drought periods (Thierfelder et al. 2015[5], Michler et al. 2019[6]). The finding provides further evidence that the CA systems are more resilient during seasons with drought compared to the CP systems. The yield maps generated from the study are decision support tools that are important for guiding extension and development agencies on suitable areas for investment of CA practices. For governments, these will be critical to define large-scale spatial planning projects and priority locations where CA and its complementary technologies can be extrapolated with lower potential risk of failure. The information can also enhance understanding and improve the uptake and adoption of CA systems among smallholders in southern Africa. The maps inform future selection of appropriate sites and management practices that are suitable for different the CA and complementary practices.

[5] Thierfelder, C., R. Matemba-Mutasa, and L. Rusinamhodzi. 2015. Yield response of maize (*Zea mays* L.) to conservation agriculture cropping system in Southern Africa. Soil and Tillage Research **146**:230-242

[6] Michler, J. D., K. Baylis, M. Arends-Kuenning, and K. Mazvimavi. 2019. Conservation agriculture and climate resilience. Journal of Environmental Economics and Management **93**:148-169

Targeted deliverables for 2019/2020 and status on achievements.

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
Extrapolation domains for CA practices mapped	Processing remote sensing variables on climate and soils has been finalized	Data cleaning and processing completed. Additional GPS data collected from the field in collaboration partners. Machine learning model fitted	Processing and cleaning agronomic data is ongoing, and this is causing a delay in model fitting
Extrapolation domains for CA practices disseminated	Draft manuscript in preparation; Introduction and methods section are at an advanced stage	Draft manuscript is in preparation for submission to journal	Submission of the journal article delayed due to challenges experienced in cleaning the agronomic data. Some GPS data that were missing had to be collected from the field amidst the COVID pandemic. Further delay experienced due to high computational time required to run the model. An expert with experience on virtual machines on the Google-cloud platform was incorporated into the team to speed up the modelling.
Publications		In preparation: Spatial variability of maize yields under different CA systems and climate variability	
Data uploaded to DataVerse	NA	Utilized data were previously uploaded to DataVerse by CIMMYT	
FtF indicators data submitted to M&E/IFPRI for upload	NA	N/A	

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

A study was undertaken to monitor indicators of land degradation in Kongwa and Kiteto districts to guide future investments of soil and water conservation practices. The monitoring compared the default method proposed by the UNCCD that uses coarser resolution gridded time series data on land cover (300 m), with a novel method using higher resolution (20-30 m) remote sensing data. The higher resolution data could identify subtle changes in an area dominated by small-scale farms.

Severe land degradation was recorded in central Kiteto district while the northern section remained stable over a period of 19 years (Figure 15a). The magnitude of land degradation in Figure 15a was aggregated into wards within the two districts to reveal the hotspots. The wards where over 50% of the area was classified as degraded include: Namelok, Partimbo, Engusero, Njoro and Olboroti in Kiteto district (Fig. 15b). Similarly, the Sejeli, Lenjulu, and Hogoro wards in Kongwa districts have over half of area degraded (Figure 15b). These hotspot wards should be prioritized for land rehabilitation measures. Figure 15c shows the main drivers of land degradation in each pixel across the two districts, which range from decline of land productivity (LP), land cover change (LC) and reduced soil organic carbon (SOC) or different combinations of the three variables. Results from this subnational analysis is part of MSc thesis of Jonathan Reith that was submitted at the University of Bonn. A manuscript is being prepared from the thesis for submission in a peer reviewed journal.

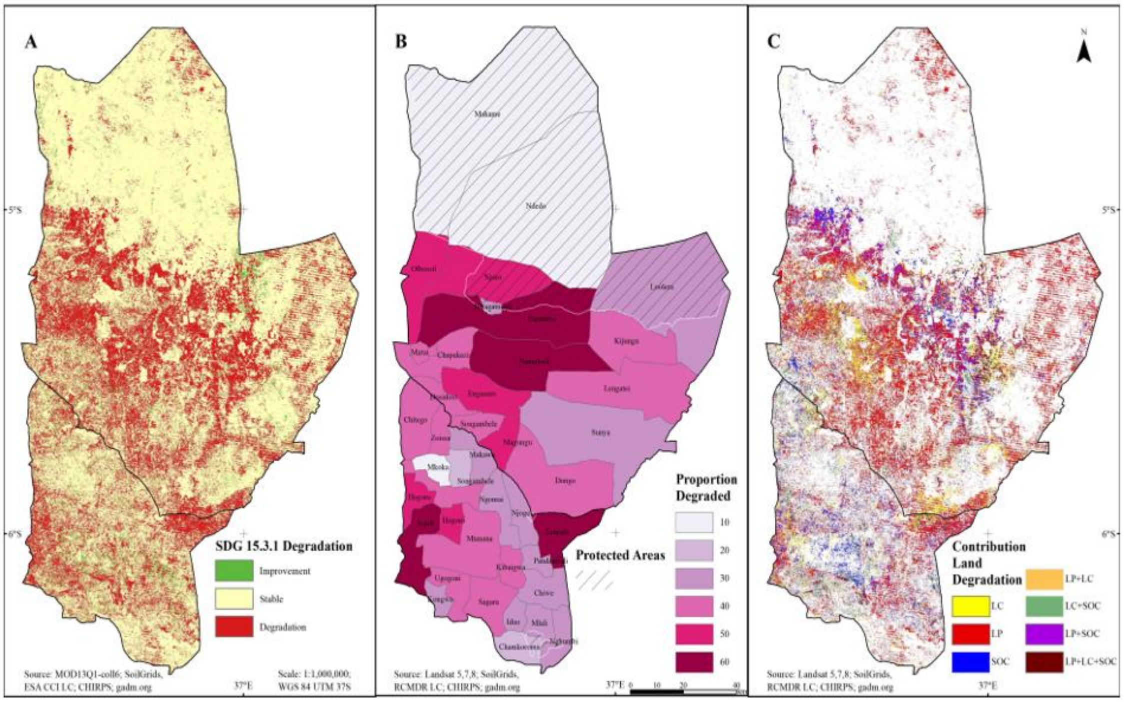


Figure 15. The indicators of land degradation for the baseline period 2000 – 2019: (a) the same data aggregate by wards with darker colors representing higher proportions of degraded area; (b) The per pixel contribution of the three sub-indicators of land degradation; and (C) land productivity (LP), land cover (LC), and soil organic carbon (SOC) and their combined contribution. (Source: Reith 2020[7])

[7] Reith, J. A. 2020. Assessment of Land Degradation in Semi-Arid Tanzania - Using Remote Sensing to Inform the Sustainable Development Goal 15.3. University of Bonn, Bonn.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
Produce regionally relevant extrapolation domain maps for validated S&WC practices	Maps produced on long-term (1981-2015) trends of land productivity while disentangling the effect of rainfall from the influence of anthropogenic activities	Maps on hotspots of land degradation in Kongwa and Kiteto have been produced	-
Land degradation neutrality assessed- Thesis submitted	MSc thesis of Jonathan Reith in progress; to be submitted end of April 2020	MSc thesis submitted to Bonn University in June 2020	
Land degradation neutrality results disseminated- Draft manuscript	Draft manuscript on long-term trends of land degradation and the influence of rainfall and anthropogenic as drivers of land degradation is under preparation	Draft manuscript in preparation	Manuscript delayed because of late submission of thesis due to COVID-19 pandemic
Data uploaded to DataVerse	To be completed by August 2020	Data uploaded to DataVerse	
FtF indicators data submitted to M&E/IFPRI for upload	NA	NA	

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

The TOA-MD model (www.tradeoffs.oregonstate.edu) is being applied to *ex-ante* assess the adoption potential of SI technologies being investigated in Africa RISING and its impacts on farm household income, poverty, food security, and other indicators. The TOA-MD framework was successfully applied for fertilizer applications and hybrid maize seeds technologies for Tanzania, making use of a Worldbank/LSMS household survey of >1000 households across the country.

This study finds that overall, 47-50 % maize farms in sub-humid conditions are likely to adopt seed, fertilizer, and management recommendations (Figures 16 and 17). This analysis shows that Minjingu mazao (MM) fertilizer that is fortified with micronutrients has a marginally higher adoption rate than Diammonium phosphate (DAP). Disaggregation into agroecological zones shows that DAP is relatively more suitable in cool regions while MM is more suitable in warm regions. In the optimistic high on-farm yield scenario, the difference in predicted adoption rates for DAP and MM is small. Under more realistic yield scenarios, DAP fertilizer adoption falls sharply in warm regions (8 - 17 %) relative to MM fertilizer (29 - 36 %). In cool regions, the fall in adoption rate of MM fertilizer under realistic yield scenarios is relatively smaller. These results imply better adoption potential of MM fertilizer across agroecological conditions under realistic yield scenarios. Nevertheless, some farms with higher productivity in cool regions might also benefit from adoption DAP as the source of P.

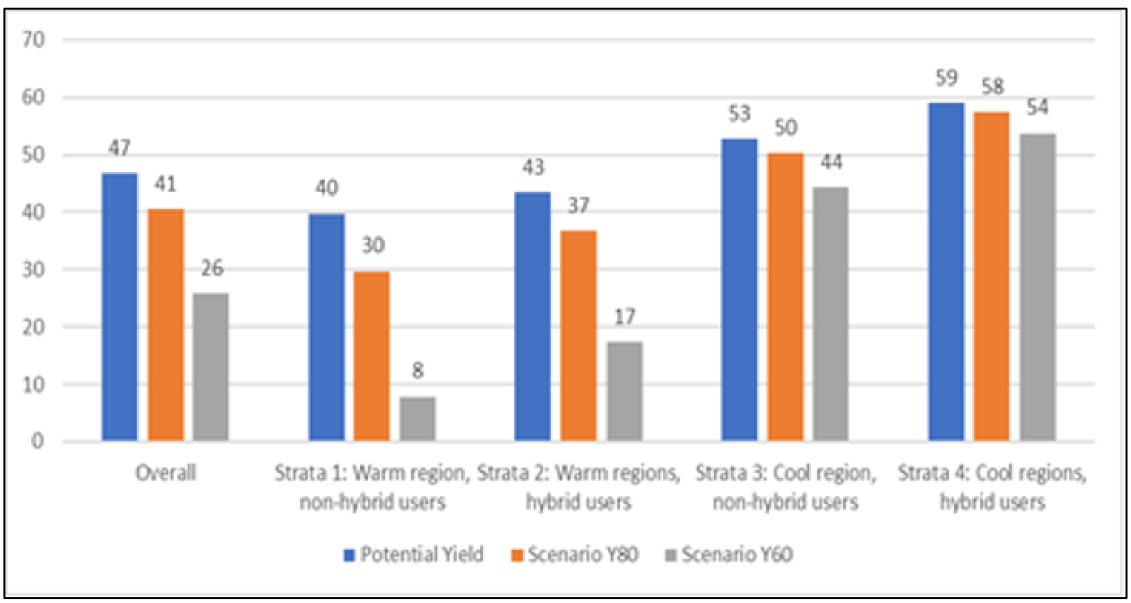


Figure 16. Potential and realistic adoption prediction – System 2-Diammonium phosphate.

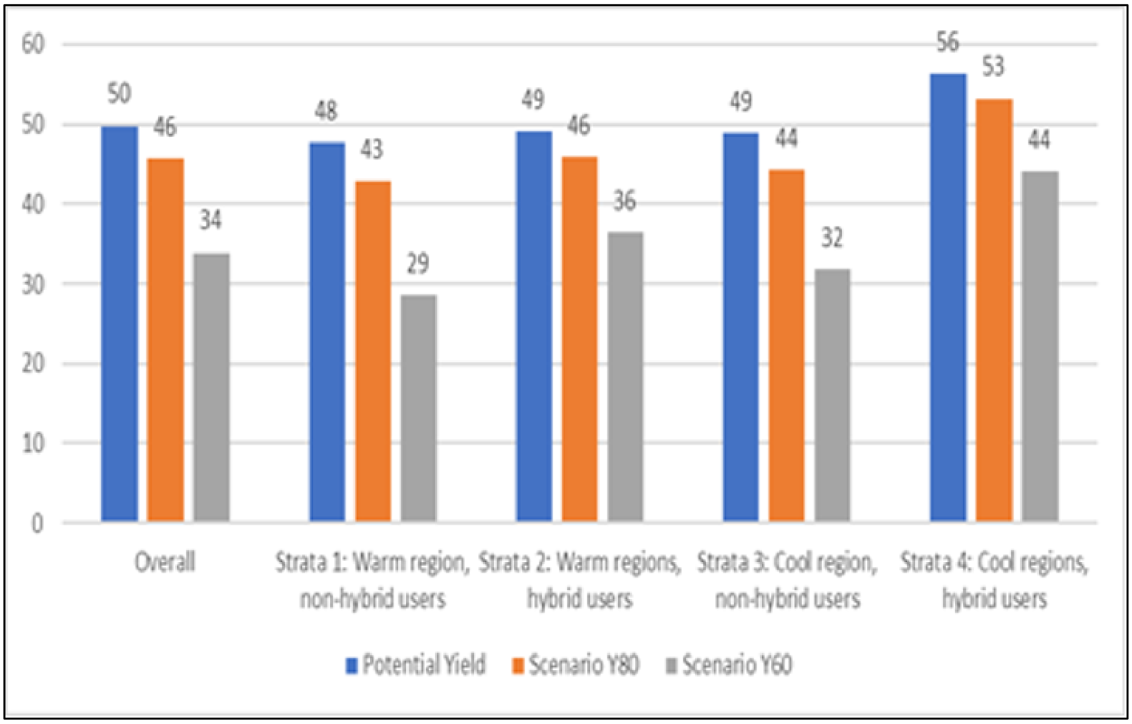


Figure 17. Potential and realistic adoption prediction – System 2-Minjingu Mazao.

While the TOA-MD adopts a partial equilibrium approach, this analysis uses a combination of assumptions about the conditions in output and input markets to estimate the likely range of adoption rates since prices are likely to respond to the yield increase modelled in System 2. This analysis shows that under inelastic input supply and output demand, adoption of DAP fertilizer in warm regions falls to 1-3 % adoption. Under similar conditions, MM fertilizer is likely to be adopted at a higher rate of 19-25 %. These results reaffirm that MM fertilizer is potentially better suited for adoption across agroecological conditions relative to DAP.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
Inventory of existing bio-physical data from Africa RISING experiments.	Data from different AEZs (in Kongwa, Kiteto, and Babati) identified in DataVerse	NA	
TOA-MD model set up for Tanzania	Model setup completed with LSMS data		
Ex-ante impact assessment implemented and analyzed	Model is ready to be populated with Africa RISING data; draft journal article by September 2020	The TOA-MD framework applied for AR validated technologies (focus on fertilizer applications and hybrid maize seeds) for Tanzania	Article available as chapter in PhD thesis of Srabashi Ray, and is being reworked into journal article for submission in December 2020
Data uploaded to DataVerse	To be completed by August 2020	Not applicable (data used are already on DataVerse)	
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August 2020	Not applicable (already submitted and uploaded)	

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*

No activities were implemented during this reporting period.

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 and no further funding is requested from Africa RISING for these trials. All data were summarized, analyzed, and submitted for upload to DataVerse by August 2020. Soil analysis results have recently been received and could not be made available in time for this report but will be analyzed and uploaded.

Results from the trials show that the CA systems were strongly affected by a high rainfall season in 2019/2020, which is usually counter-productive for a drought mitigation strategy like CA. The strongest factor in the Expanded Step trial (Figure 18) was rotation instead of residue retention, which was evident for both tilled and no-tilled systems. As in previous years the no-tillage system without rotation and mulching was the worst performer.

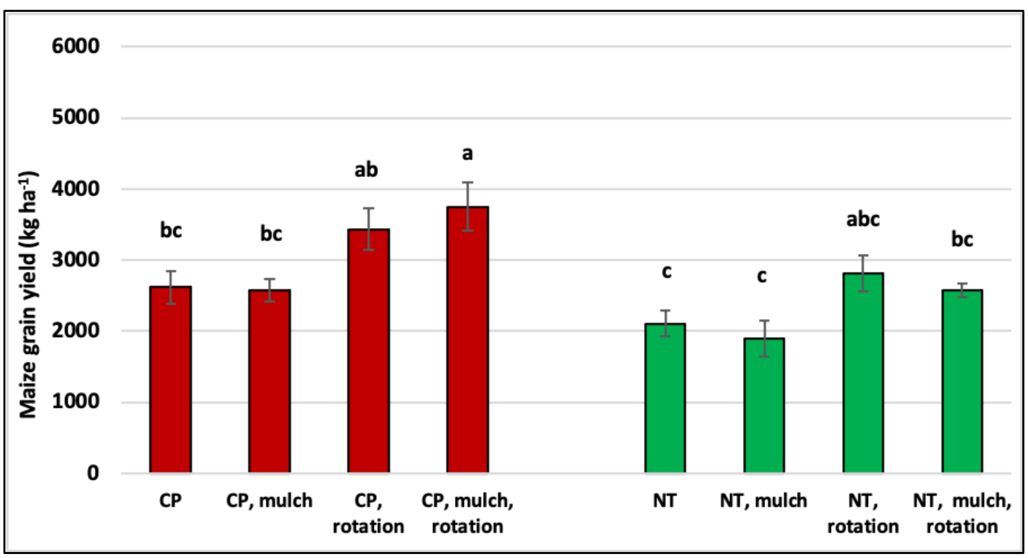


Figure 18. Crop performance at the Expanded Step trial at Msekera Research Station, Zambia 2019/2020. Means followed by a different letter in column are significantly different at P<0.05 probability level. CP=Conventional practice; NT=No tillage

There was no significant difference between maize grain yield in the 3-treatment *Gliricidia* trial (Maize + half fertiliser; maize-*Gliricidia* dense spacing + half fertilizer; maize-*Gliricidia* sparse spacing + half fertilizer), although the 3.4 t/ha average yield level of all treatments with half the fertilization was above the usual mean grain yield for the province of about 2t ha^{-1}. Similarly, the ratooning trial showed variable but not significant yield differences when maize was grown with pigeon pea. As we re-initiated the trial in 2019/2020, no ratooning strategy effect can be measured as the actual yields reported are only from the present year.

Heavy rainfall affected the performance of lablab in the Green Manure and Grain Legume Intercropping trial (Figure 19); whereas maize/cowpea and maize/pigeon pea intercropping seemed to perform best. The intercropping strategy of growing lablab seven days after maize continues to be the best strategy (at least for the maize) as competition is low. The cowpea in the maize-cowpea rotation had extraordinarily high yields in this trial, which was a great outcome. From a sustainability point of view, growing both maize with cowpea or pigeon pea seem to be the best and logical strategy for farmers in Eastern Zambia and should be recommended. Adding half fertilizer will, of course, improve the final yield. The general maize yield level was low due to a maize variety that was later discovered as seed of low quality (fake seed).

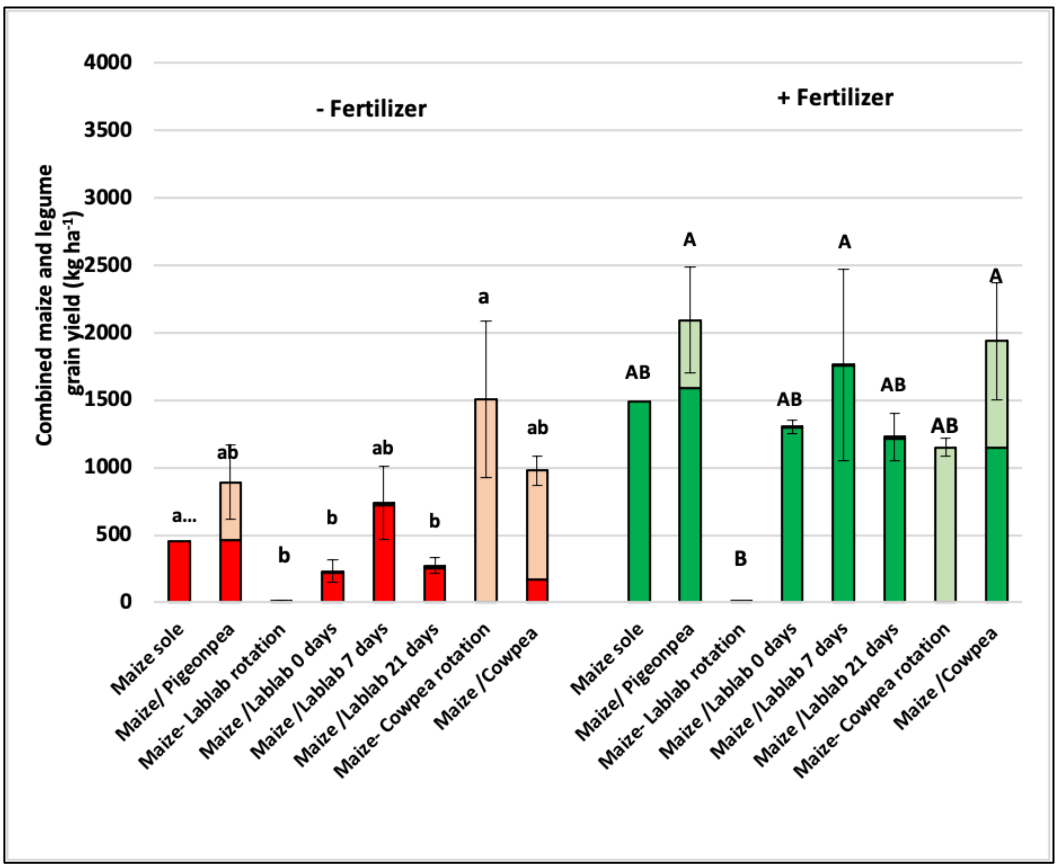


Figure 19: Crop performance at the Green Manure Cover Crop and Grain Legume Intercropping trial at Msekera Research Station, Zambia 2019/2020. Means followed by a different letter in column for each fertilizer level are significantly different at P<0.05 probability level. Bold colors represent the maize yield while light colors represent the legume yields.

The CA long-term trial (Figure 20) continues to show interesting results. The performance of the conventionally tilled systems is heavily dependent on the rainfall season. In high rainfall seasons, (2016/2017 and 2018/2019), the conventional tillage practice outperformed the CA systems. On the other hand, in drought years (2014/2015 and 2015/2016), CA systems were clearly more beneficial. This is an important finding given future projection of climate change. The results also show why long-term trials are critically needed in the assessment of sustainable intensification practices which cannot be judged from a short-term perspective only.

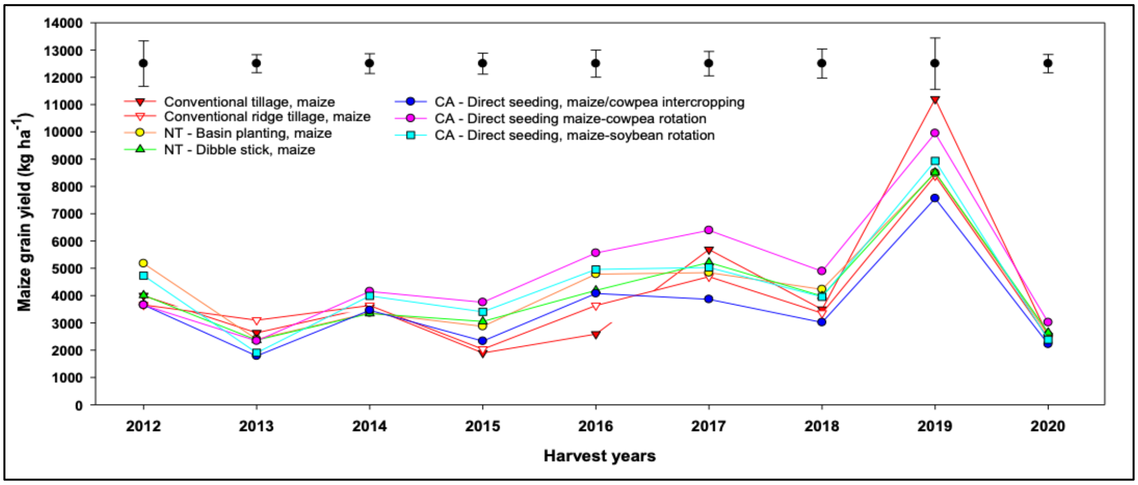


Figure 20. Crop performance at the CA long-term trial at Msekera Research Station, Zambia 2019/2020. Error bars represent the standard error of the difference at P<0.05 probability level.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
At least four field trials established at Msekera	Five on-station trials were established in November/ December 2019. One publication on the longer-term effects of CA is submitted; another on doubled-up legume is under revision	• Completed • Publication submitted on LT effects and still under revision • Publication on doubled up legumes still under revision • Another publication started on GMCCs	Exceeded
Site description details (soils, seasonal rainfall) made available	Soil sampling of on-station trials initiated Seasonal rainfall has been continuously recorded	• Completed • Soil results from on-station trials available • Rainfall data available	No deviation
Report on yield and environmental indicators	Yield data will be collected during April/May 2020 and reported on in the next progress report period	• Completed • Annexed in this report and uploaded	No deviation
Publications	Two manuscripts, one on the longer-term effects of CA and the other on doubled-up legume systems, submitted to journals for publication	• Publication submitted on LT effects and still under revision • Publication on doubled up legumes still under revision • Another publication started on GMCCs	Exceeded
Data uploaded on to DataVerse	To be completed by August 2020	Completed	No deviation
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August 2020	Completed	No deviation

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

Several field sites were established to investigate the interactions of water and nutrient management, especially in the drought prone regions of southern Malawi. The objective is to store as much water in the field (Photo 2) and reduce the severity of dry spells, should they occur as they often do. The key question is: Does *in-situ* water harvesting through tied ridges result in better nutrient use efficiencies across sites? The experiments have a split-plot design with water management (tied or no-tied ridges) being the main plot factor. Meanwhile, sub-plot factors are NP management and cropping sequencing: (1) continuous non-fertilized maize; (2) maize fertilized at 35 or 70 kg N/ha; and (3) sole groundnut or a groundnut/pigeon pea intercrop, both sequenced with maize in Years 2 and 3.

Photo 2. Use of tied ridges to store rainwater in-field so that in field rainwater storage > runoff, where rainfall intensity is often several fold larger than soil water infiltration rates. Photo credit: Sieg Snapp, MSU.

Like previous seasons' data from these experiments, improved water management alone on unfertilized maize will only result in little productivity gains (Figures 21 and 22). This is because most of the soils have poor indigenous nutrient supply capacity. Water and nutrient supply are common co-limitations. In some cases, under ample fertilization, water management accentuates the benefits of fertilization, but in sites with perched water table, storing more water can be detrimental (Figure 22).

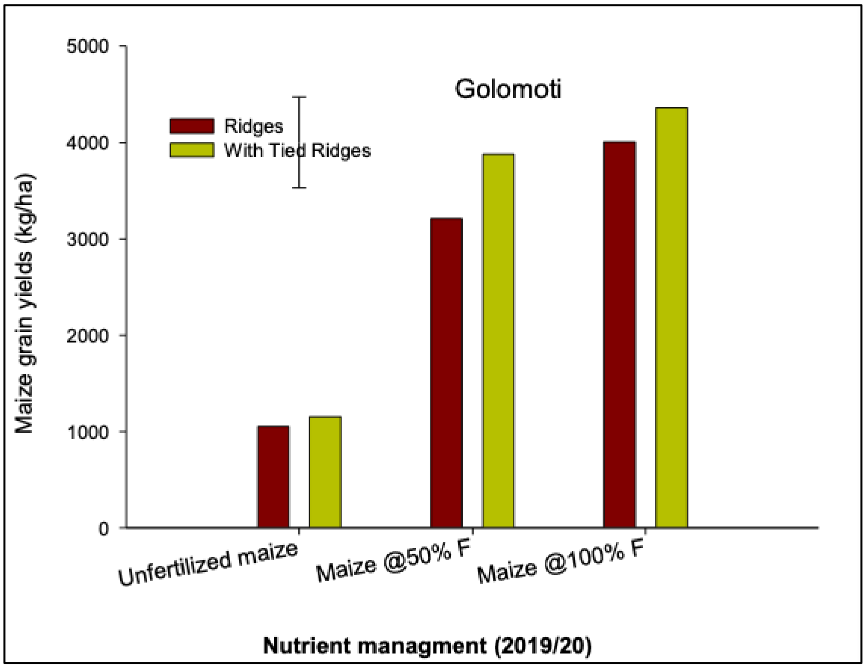


Figure 21. Effect of fertilizer application and water management in Golomoti.

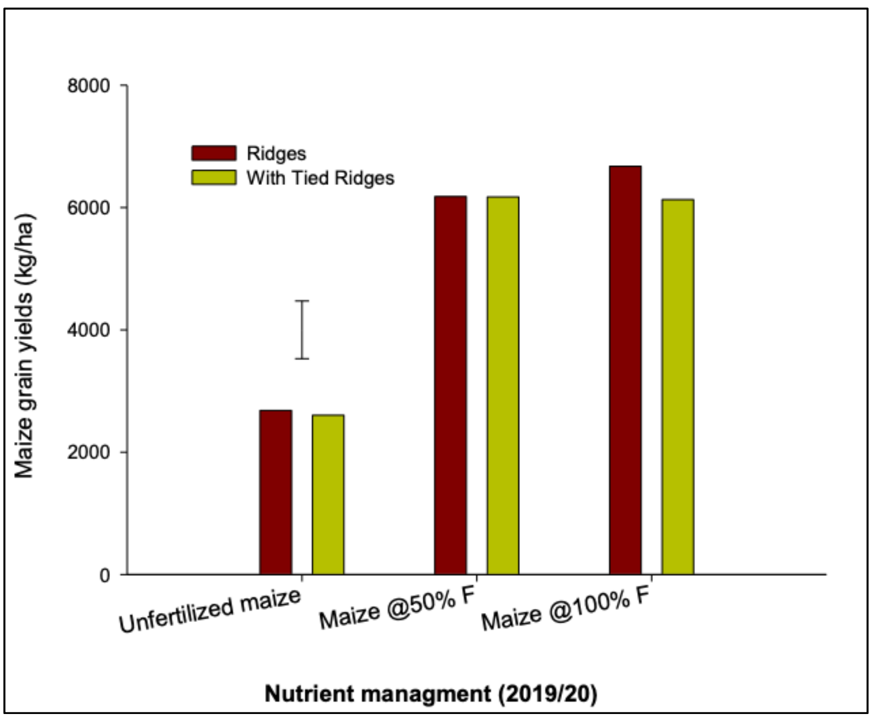


Figure 22. Effect of fertilizer application and water management at a water-logged site in Kandeu.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
At least one nutrient x water management trial established per EPA	Seven nutrient and water management “Mother” trials established successfully in seven sites (EPAs)	All trials were harvested in March and April 2020, and all data processed	
Field days held with partners	Three field days held; reports are yet to be uploaded; other field days cancelled	No further field days were held due to COVID-19-related restrictions	
Soil water and nutrients use interactions determined	Soil water measurements and mineral N soil sampling and extractions are done	Data processed and partially presented here (Figures 20 and 21)	
At least 10 000 farmers practicing tied ridges across projects site; technology dissemination affected by District Ext. Coordination Committees	There was limited engagement due to COVID, but the numbers reached are being compiled	Establishing actual numbers was difficult, but we estimate that we could have influenced 10% of the farmers to adopt tied ridges, especially in Machinga District	
Manuscript	Data collection to be completed	This is still under development	
Data uploaded to DataVerse	To be completed by August	All data uploaded to DataVerse	
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August	FtF indicators were provided	

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.

Report on how the four trials relating to climate smart agricultural approaches in Tanzania (i.e., micro-catchments, planting of weather informed varieties, utilization potentials of slow-release N fertilizer, and how they were initiated) was discussed in the previous reporting. During this reporting period, results from the associated data is discussed. Monthly weather data collection in the two agroecological zones is still in progress.

***Effect of treatments on maize physiological parameters*.** Maize leaf chlorophyll was significantly affected by sampling time and not by treatments or treatment × time interaction. Averaged across cropping systems and time, leaf chlorophyll levels ranged from 43 SPAD units at V8 in control treatment to 51 SPAD units during maize silking in maize-pigeon pea intercrop with slow-release N. The slow N release characteristic might have increased soil N residual time resulting to an extended N uptake period.

When means of maize heights were pooled across cropping systems and farmer fields, no significant differences were observed. The mean maize height ranged from 250 cm under tied ridges to 267 cm in treatment with lablab relay. Tied ridges might have retained high levels of soil moisture, which could have negatively impacted on maize physiological development. On the other hand, lablab establishment was negatively affected by high soil moisture levels and the dense maize canopy, which might have favored maize development.

***Effect of treatments on light interception*.** Light interception by crop canopy was assessed from the time maize was at blister stage to 50% podding of pigeon pea. When averaged across farmer fields and growth stages, photosynthetically active radiation (PAR) level was significantly affected by the different cropping systems ($p \leq 0.05$). PAR fraction ranged from 0.64 $\mu molm^{-2}s^{-1}$ in treatment with conventional maize-bean-pigeon pea intercrop to 0.87 $\mu molm^{-2}s^{-1}$ where a heat tolerant bean variety (Selian 11) was intercropped (Table 12). The climbing characteristic of Selian 11 bean variety provided a greater canopy cover than other legume species (i.e., bean varieties KAT B9 and Elyamungo 90, and lablab) that had been intercropped with maize. Also, Selian 11 had an extended growth period compared to other bean varieties hence a greater potential for its utilization as a cover crop (Photo 3). Lablab relay was expected to have offered an increased light interception capacity compared to beans. However, the dense canopy cover created by maize as a result of the conducive weather conditions and high moisture content in the soil suppressed lablab establishment resulting to low soil cover.

Photo 3. A dense canopy of Selian 11 resulting to soil cover (left) and dry beans of KAT B9 variety on exposed soil surface during similar period of crop growth. Photo credit: Kinyua Michael/CIAT.

Two lablab varieties were tested under split-plot design (in the cropping system with cover crops) and the extent of soil cover formation by the two varieties assessed at pigeon pea flower initiation and at 50% flowering. Averaged across fields and sampling periods, canopy cover under lablab relayed system ranged from 0.66 µmolLm-2s^{-1} under Karamoja red variety to 0.70 µmolLm-2s^{-1} in Eldoret black variety ($p \leq 0.01$). Results indicate that Eldoret Black can be used to provide a denser soil cover compared to Karamoja pigeon pea variety.

Table 12. Effects of treatment on photosynthetically active radiation during long rain season of 2020 in Babati, Tanzania

Treatment	Photosynthetically active radiation fraction (µmolLm^{-2}s^{-1})
Maize- bean- pigeon pea intercrop (control)	0.64^{d}
Maize variety guided by weather forecasting	0.83^{ab}
Maize- bean-pigeon pea on tied ridges	0.86^{a}
Maize- pigeon pea with lablab relay	0.70^{c}
Maize-Selian 11 bean-pigeon pea intercrop	0.87^{a}
Maize- bean-pigeon pea with slow-release N€	0.84^{a}
Maize- bean-pigeon pea with micronutrient	0.82^{ab}
Maize-Elyamungo 90 bean-pigeon pea intercrop	0.76^{b}
S.E.	0.03

All treatments had a uniform application of Minjingu Nafaka during planting and Minjingu Topdressing except € which was top-dressed with slow-release N; beans represent KAT B9 variety, except where indicated otherwise.

***Effect of plant spatial patterns on crop productivity*.** Maize production in medium altitude-low rainfall ecozone (Farmer A and B) varied significantly ($p \leq 0.05$) across the cropping systems, a condition not observed in low altitude-low rainfall ecozone (Farmer C and D). Application of crop micronutrients guided by regional weather forecasting resulted in about 2 t/ha higher maize grain yield than planting of Syngenta H624 under convention maize-pigeon pea-beans intercropping system. This indicates that integrating micronutrients beyond the normal NPK fertilizer recommendation can significantly increase maize production within the region (Table 13).

Table 13. Effect of different climate smart technologies on maize grain yield during the long rains of 2019/2020 season in Babati

Treatments	Farmer			
	A	B	C	D
Maize-bean-pigeon pea intercrop (Control)	4.5	6.5ab	8.1	6.0
Maize variety (SeedCo) guided by weather forecasting	7.4	7.4ab	8.1	5.9
Maize-bean-pigeon pea on tied ridges	5.5	7.8 ab	7.0	5.1
Maize-pigeon pea with lablab relay	5.9	7.0 ab	7.3	5.4
Maize-Selian 11 bean-pigeon pea intercrop	4.9	6.6 ab	7.4	6.0
Maize-bean- pigeon pea with slow-release N€	4.7	7.9 ab	7.3	5.0
Maize-bean-pigeon pea with micronutrient	6.5	8.4 a	7.8	5.1
Maize-Elyamungo 90 bean-pigeon pea intercrop	5.5	6.3 b	7.8	4.9
S.E.D.	1.7	0.89	1.01	0.65

Maize in all cropping systems was applied with Minjingu Topdressing, except in € where slow-release N fertilizer was applied.

Bean production was affected by increased soil moisture content in the low altitude- low rainfall ecozone of Gallapo Village leading to total yield loss. In the medium latitude- low rainfall ecozone of Sabilo Village, planting of the maize-pigeon pea system with Selian 11 bean variety had significantly higher bean yield ($P<0.01$) compared to the rest of the cropping systems. Its developmental characteristic allows it to produce more pods than the common bush bean varieties like Jesika and KAT B9. This would make it produce well even under dense maize canopy because it is able to access more sunlight unlike the bush bean varieties. Indeed, integrating Selian 11 bean variety in maize-pigeon pea system yielded 0.23 t/ha higher beans than conventional maize-pigeon pea-bean intercropping system.

Bean haulms production assumed a similar pattern as the grains where Selian 11 had significantly higher biomass production than the rest of the treatments. Haulms production ranged from 0.7 t/ha in treatment where maize choice was guided by regional weather forecast to 1.4 t/ha under Selian 11. This validates the higher PAR observed under the Selian 11 treatment, which verifies the usability of the bean variety to provide more months of soil cover, more biomass to enrich the soil organic matter, and more foliage to use as animal feed. It is, however, advisable to plant Selian 11 variety in seasons with a prospective well-distributed rainfall if the above-mentioned benefits are to be achieved.

***Effect of different CSA approaches on soil moisture content*.** Averaged across fields and cropping systems, soil moisture and temperatures varied significantly within the sampling periods ($p \leq 0.05$) and not between treatments, which could be attributed to the presence of high soil moisture content in soil (Photo 4).

Lessons learned from 2.2.1.2 (Malawi) and 2.2.1.3 (Tanzania) need to be synthesized and consolidated.

Photo 4. Water accumulation in micro-catchments (left) and saturated conventional practice soils (right) due to prevalence of heavy rains. Photo credit: Kinyua Michael/CIAT.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviations & explanation
Four on-farm trials, two in each of two eco-zones, successfully Implemented	Four on-farm demonstration trials were successfully initiated as planned.	Maize harvested, pigeon pea in fields to be harvested in October 2020	none
Two new technologies validated	The two new technologies (use of micro-catchments and cover crops) are undergoing testing.	The technologies implemented and data collected as planned	Follow-up for cover crops on farms delayed due to COVID-19-related restrictions
Data uploaded to DataVerse	To be completed by August 2020	Data for 2019/20 uploaded as planned	None
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August 2020	Completed	None
Publications	• One publication under revisions • Handbook chapter under review • Plans for ISFM system synthesis made	• Publication accepted • Handbook under review after comments received • ISFM system level draft manuscript developed	None

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

After six years of contour farming on the highly degraded soil, a synthesis of soil fertility variables measured shows an increase by over 20% relative to unprotected control site (Table 15). Most soil quality parameters are still below the optimum for crop production (Landon, 2014[8]), indicating that inputs of high-quality foliage biomass from fodder crops on the contours or manure and retention of crop residues on farm is necessary to complement the benefits of soil and water conservation. We also noted two and three times increases in maize grain (6.8 t/ha) and biomass (33 t/ha) yields on contour relative to non-contour sites, respectively (Table 14). This increase is a result of the combined effects of soil and water conservation and improved soil nutrient levels as noted in previous studies in semi-arid areas (Young, 1997[9]; Birhanu et al. 2020[10]).

Table 14. Selected SI indicator mean values of contour farming at Mlali Village, Kongwa District, Tanzania

Parameter	Control (n=3)[1]	Contour (n=9)	SI Domain	% Change[2]
Soil pH (water)[3]	4.39	5.40	Environmental	23.0
Total nitrogen (%)	0.04	0.07	Environmental	75.0
Phosphorus (Bray-1, mg/kg soil)	13.09	24.50	Environmental	81.5
Organic carbon (%)	0.53	0.68	Environmental	28.3
Sulphur ($SO_4 - S$, mg/kg soil)	13.71	19.93	Environmental	45.4
Cumulative maize grain yield (t/ha)	3.11	6.82	Crop product.[4]	120
Cumulative biomass yield (t/ha)[5]	9.44	32.91	Crop product.	249
Cumulative Gross margin (GM, USD/ha)	649	3,676	Economics	467
Cumulative Return to labour (USD/ha)	771	4,178	Economics	442
Cumulative Caloric yield (kcal/ha)[6]	11,243	24,701	Human Cond. [7]	120
Cumulative Protein yield (kg/ha) [6]	252	553	Human Cond. [7]	120

[1]Control plot without contours
[2]Percentage change relative to the non-contour plot (farmer practice) as a control
[3]Recommended (adequate /medium) levels of soil parameters according to Landon (2014): Soil pH_{water} (5.5 -7.2), Total N (0.2 - 0.5%), OC (> 2%), Olsen P (5 -15 mg P/kg), Bray1 extractable P (15-50 mg P/kg), $SO_4 - S$ (6-12 mg/kg)
[4]Crop product=Crop productivity
[5]Aboveground biomass of maize (grain, stover and cobs) in the control plots and of maize, grass and *G. sepium* in the contour plots
[6]Caloric yield in kilocalories (kcal/ha) and protein yield per ha calculated based on maize grain yield
[7]Human Cond.= Human Condition

Fodder crops (*G. sepium* and Guatemala grass) integrated on contours provided additional benefits of fodder and fuelwood supply, which also contribute to increased income and climate resilience. The proportion of income derived from maize in 2018 averaged 55. 8% (US$1068 /ha) of total income from various crop components in contour farming (Table 15). However, it declined to 26. 3% (US$ 243/ha) in 2019. *G. sepium*-based income was 35.3% in 2018 and 76.7% in 2019, which show increased contribution from wood in 2019 when maize harvest was very poor due to prolonged drought. The percentage of income derived from maize (US$ 751/ha) and

[8] Landon, J.R. (2014) Booker Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. In: 2000 Symposium: Sugarcane: Research towards Efficient and Sustainable Production, Routledge, London, 237-240.
[9] Young, A. 1997. Agroforestry for soil management. Wallingford UK. CAB International in association with ICRAF. 320
[10] Birhanu, B.Z., Traoré, K., Sanogo, K., Tabo, R., Fischer, G., Whitbread, A.M. 2020. Contour bunding technology-evidence and experience in the semiarid region of southern Mali. Renewable Agriculture and Food Systems. 1–9. https://doi.org/10.1017/S1742170519000450

from *G. sepium* (US$ 677/ha) components in 2020 averaged 47.8% of the total income, which reflect increased contributions from the maize component in the season with good harvest. The gross income from Guatemala was comparatively the lowest (7.5%), but steady over the three growing seasons and averaged US$ 25.52/month. These results show the potential for income from various crops in the *fanya juu* contours re-enforced with fodder crops (trees and grass) to increase the purchasing power and access to food, even during the season with short supply. Apparently, diversified and steady income sources from crop components in contour farming act as a safety net against food and income insecurity during seasons with high risk of crop failure due to harsh growing conditions.

Table 15. Average income from crop components in *Fanya juu* re-enforced with grass fodder (*Tripsacum andersonii*) and a fodder tree (*Gliricidia sepium)* at Mlali Village

Farm/Site	Year	Gross Income (USD/ha)			
		Maize	Guatemala	*G. sepium*	Total
Lowland site (n=3)	2018	1027	141	767	1936
Upland site (n=6)	2018	1109	198	587	1894
Lowland site (n=3)	2019	-	88	767	856
Upland site (n=6)	2019	243	92	587	922
Lowland site (n=3)	2020	410	62	767	1239
Upland site (n=6)	2020	1092	67	587	1746

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
Farmer field day held for knowledge sharing	Scheduled for June	Cancelled	COVID-19 pandemic restrictions
Data on the benefits of contour farming (crop productivity & income) collected	Data collection is continuing as planned	Data collection completed	Data used to finalize the contour-based technology in Chapter 4 of the Technology Handbook
Manuscript on household cooking energy security	Manuscript to be submitted for publication in May	Accepted for publication in the Journal of Energy for Sustainable development	
Crop yield (maize, Guatemala), fuelwood and economic data generated as a contribution to the farm systems case study	Data collection is continuing as planned	Data collection completed	Data used to finalize the contour-based technology in Chapter 4 of the Technology Handbook
Determining contour effects: Crop and soil samples collected for submission to SUA for lab analysis	Soil and maize sampling will be conducted at maize harvesting	Soil quality and maize nutrient data received from SUA	N/A
Maps of priority sites for land rehabilitation (IITA-Francis)	A graduate student has been engaged to conduct this activity	Completed and thesis shared by Francis	N/A
Success story on farmer-led technology scaling	To be initiated when farmers are not labor-burdened (e.g., after harvest)	Draft success story developed in September	Final version delayed. To be completed after internal review at ICRAF and clearance by the Chief Scientist
Data uploaded to DataVerse	To be completed by August	Data files shared for upload in September 2020	Files for unprocessed data to be shared when analysis is completed
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August	Data files shared to ESA M&E in September 2020	Files for unprocessed data to be shared when analysis is completed

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

No substantial work was implemented (SUA – Shitindi) and the justification is not clear.

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

Residual tied ridging (RTR) was introduced as a strategy for alleviating the labor bottleneck associated with preparation of fresh tied ridges every season, referred to as annual tied ridging (ATR). RTR are previous season tied ridges that are only maintained to their shape and size ready for planting. It is conducted with two improved test crops (sorghum and maize) that suit different agroecologies.

No significant grain yield differences are observed between RTR and ATR (Table 16) with maize as a test crop, but both performed better than conventional tillage. These trends are also similar in environmental indicators of soil water content/storage and rainwater use efficiency. These point to some economic savings with RTR due to reduced labor. Gross margins for RTR were relatively higher than those of ATR (Tab. 17). Similar results were obtained for sorghum.

Table 16. Maize grain yield as affected by tillage during 2019/2019 and 2019/2020 cropping seasons in Kongwa District (n=9)

Treatment	Maize grain yield (kg/ha)						
	2018/2019 season			2019/2020 season			
	Mlali	Nghumbi	Sagara		Mlali	Nghumbi	Sagara
CT+DKC9089	2159a	92a	*		2697a	2162a	3135a
CT+WE2109	1232a	154a	*		2393a	2195a	3039a
ATR+DKC9089	2389a	159a	*		4453b	3348ab	3858ab
ATR+WE2109	3658a	255a	*		4319b	3378ab	5182ab
RTR+DKC9089	2573a	175a	*		6517c	3665b	5331b
RTR+WE2109	2880a	203a	*		4769b	4014b	5786b
Mean	**2484**	**173**			**4192**	**3127**	**4388**
CV%	**7.1**	**64.4**			**15**	**21**	**17.3**

***=** Location which had complete crop failure; CT= Conventional tillage; DCK9089=commercial maize variety; WE 2109= Water efficient maize variety; ATR= Annual tied ridging; RTR=Residual tied ridging. Means followed by the same letter in the column are not significantly different.

Gross margins for the improved technologies were relatively higher compared to the conventional tillage both with commercial and DT maize varieties during the non-drought 2019/2020 cropping season (Table 18).

Table 17. Gross Margin (US$/ha) by tillage and maize varieties in Kongwa District during 2018/19 and 2019/20 cropping seasons

Treatment	Gross Margin (USD/ha)			
	2018/2019 season		2019/2020 season	
	Mlali	Nghumbi	Mlali	Nghumbi
CT+DCK9089	610.31	134.5	612.78	925.72
CT+WE2109	304.38	164.64	623.42	894.34
ATR+DCK9089	703.63	172.74	986.61	1152.91
ATR+WE2109	1117.96	239.05	988.93	1585.14
RTR+ DCK9089	752.94	149.92	1109.35	1626.84
RTR+WE2109	853.18	253.48	1223.56	1775.24

CT= Conventional tillage; DCK9089=commercial hybrid maize variety; WE2109= Water efficient maize variety; ATR=Annual tied ridging; RTR=Residual tied ridging; and GM=Gross Margin

Superimposition of water stress through rain exclusion. A 100% rainout shelter (described in the last report) was superimposed on the treatments above, 80 days after crop emergence (grain filling stage), to induce drought conditions and determine the extent to which SWM would impact on yield. The rate of drying the soil is generally similar between treatments (Figure 23) but the initial treatment soil moisture differences are maintained. This would probably give the crop a better chance of survival under tied ridging. However, Table 18 shows that under a continued moisture stress, yield reduction is more severe under SWM practiced, with net yield near equal to the conventional practice. Staggered moisture stress periods would indicate the number of drought days that a crop can recover from without experiencing significant yield loss.

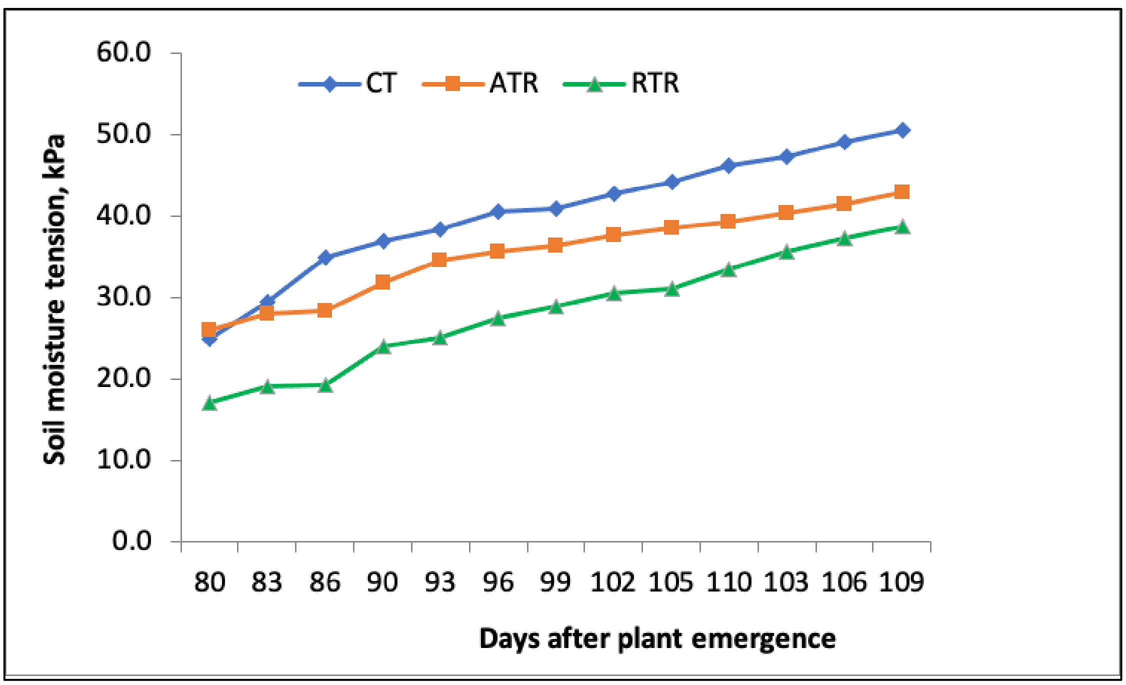


Figure 23. Soil moisture tensions vs treatments; RTR-green line, ATR-red line and CT-blue line

Table 18. Maize grain yield as affected by tillage methods and varieties under imposed drought conditions at Laikala during 2019/2020 cropping season

Treatment	Maize grain yield (kg/ha)		
	Ambient rainfall	Imposed drought	Yield reduction (%)
CT+DKC9089	2697a	908ab	66
CT+WE2109	2393a	827a	65
ATR+DKC9089	4453b	1196ab	73
ATR+WE2109	4319b	1035ab	76
RTR+DKC9089	6517c	1592c	76
RTR+WE2109	4769b	1265bc	73
Mean	**4192**	**1137.2**	
CV %	**15**	**16**	

CT= Conventional tillage; DCK9089= commercial maize variety; WE2109 = Water efficient maize variety; ATR= Annual tied ridging; RTR=Residual tied ridging; CV=Coefficient of variation. Means followed with the same letter within a column are not significantly different at 5% probability level

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
At least three mother trials and 30 baby experimental plots established in three villages with maize as the test crop	Three mother and 62 baby trials were successfully established in the villages of Mlali, Nghumbi, and Sagara	NA	Baby trial increased following demand from farmers
At least one mother trial and 10 baby experimental plots established with sorghum as the test crop	One mother and 26 baby trials were successfully established in Laikala village		Same as above
At least 400 farmers and stakeholders attend farmers' field days	Not implemented	Not implemented	COVID-19 restrictions
Preliminary evaluation on soil water status from induced drought studies evaluated	Data on soil water content and hydraulic potential were collected	Yield components, soil water content, and hydraulic potential data were collected	Data analysis is ongoing
Identified systems analysis data gaps filled from experiments installed at Mr Maile's farm	S&W conservation trial was established, and SI data collection is in progress	Farm level information from Moshi Maile was collected	
Report on the engagement of extension personnel for scaling of *in situ* rainwater harvesting	This will be presented in the next report	Extension officers in participating villages were involved in the implementation of trials as sound strategy for improving rollout of technologies	Report delayed because of COVID-19-related restrictions
Draft manuscript from previous years' data generation	In progress, to be ready by September	In progress	Engagement of statistician for robust data analysis to be done between October and December 2020
Data uploaded to DataVerse	To be completed by August	In progress	Some data were collected late
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August	Done	None

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

The trainings planned under this sub-activity started well before all the field trips had to be stopped mid-March because of the Covid-19 pandemic. A no-cost extension was successfully applied for in order to complete the activities by March 2021.

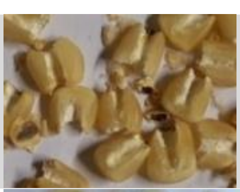
Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
Sensitization meetings in new scaling villages implemented	Meetings were conducted for the farmer groups in the 2018/2019 intervention villages and in the eight new villages. Reports are being prepared for upload.	Concluded. See report at http://africa-rising-wiki.net/File:WvG-IdPfarmerfeedbackmeetings-March2020.docx	none
Baseline data report compiled	A baseline survey was successfully conducted among eight intervention villages and eight control villages.	Baseline report is still under compilation	None
350 farmers trained on nutrition messages	Planned for the second half of this project year	Delayed due to COVID-19 restrictions	No cost extension applied for to finish training by end March 2021
At least two new (additional) vegetable-based recipes developed and promoted	To be developed in time for the nutrition training	Delayed due to COVID-19 restrictions	
At least four food kiosks/ restaurants incorporate one or more vegetable recipes in their food menu	Planned for the second half of this project year	Delayed due to COVID-19 restrictions	

Development partners include nutrition education in their existing /new scaling programs	Report to be presented during the second half of this project year	Delayed: Development partners have included nutrition education in their existing /new scaling programs	Report on this will be available in the next report by March 2021
At least one success/blog story produced	Planned for the second half of this project year	One blog published and can be accessed at [Link 1]	
Data uploaded to DataVerse	To be completed by August	Delayed; Upload to be completed by March 2021	
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August	FtF data was submitted	

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

This study was accomplished and reported in the April–September 2019 report. A manuscript is being prepared for publication during this project year. Table 19 presents a summary of the different kinds of postharvest damage to grain, their causes, and interventions implemented to stop them.

Table 19. Grain defects associated with postharvest losses in maize and common beans, and recommended mitigation practices

Defect	Appearance maize	Appearance beans	Cause	Mitigation practice[1]
Broken			Poor methods of shelling/ threshing	Calibrated thresher; minimum manual methods
Insect damaged			Storage insect pests (maize weevils, grain borers, bean bruchids)	Air-tight storage
Rodent damaged			Rats, mice, and other excavating pests	Rodent traps and air-tight storage
Moldy			Mold growth	Drying on tarpaulin; moisture verification

Rotten/ diseased/ discolored			Fungi, bacteria or other agents of disease/decay	Cob/ pod separation sorting
Shriveled			Poor grain filling	Cob selection/ Sorting
Fermented			Biological activity (enzymes, mold, bacteria)	Proper drying on tarpaulin; verification of grain moisture

[1] The various practices were packaged into two levels: Improved practices and ordinary practices. The improved practices included drying on tarpaulin, cleaning, sorting, and storage in air-tight containers with rodent control traps, where necessary. Ordinary practices included drying, handling, and storage in woven polypropylene bags as customarily practiced by farmers.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status
This study was accomplished and reported in the April–September 2019 report. Deliverable is a publication generated out of the results of the study.	A manuscript is being prepared for publication during this project year
Data uploaded to DataVerse	Data was uploaded during 2018/19
FtF indicators data submitted to M&E/IFPRI for upload	Data was submitted during 2018/19

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

The postharvest losses of maize and common beans are often considered only in terms of quantitative or physical weight loss. Farmers and traders are concerned about the economic losses because the damaged grain will sell at a lower value at the market. However, grain damage also affects the nutritional value, and some components may be impacted more severely than others. In the current reporting season, the postharvest damage levels related to maize and common beans postharvest losses were mapped against nutritional composition and functional characteristics at harvest, mid (3.5 months), and late (7 months) stages of the postharvest season. The aim was to assess how improved practices (i.e., drying on tarpaulins, improved threshing, sorting, and air-tight storage, applied as a package) contribute to the overall availability of essential macro- and micro-nutrients for households and the utilization (processing/cooking) characteristics of the staple food commodities. On-farm data was applied to model the associations and estimate the nutritional gains resulting from the use of improved postharvest practices across locations at different stages of the postharvest period. A manuscript is being prepared for publication. Below are the key findings.

1. The nutritional value of maize grain and dry common beans varied with stage of the postharvest season, and on whether improved or ordinary postharvest practices were applied (Tables 20 and 21).

2. Depending on agro-location, improved postharvest practices of maize resulted in nutritional gains by 21–50% more calories, 32–44% more protein, and 10–65% more minerals at the late stage of the postharvest season (Figure 24).
3. Improved postharvest practices for common beans resulted in significant nutritional gains of 5–21% more protein, 3–22% more calories, and 9–22% more minerals, depending on agro-location (Figure 24). These benefits were seen only when a long postharvest season of about seven months was considered. The average gains are significant (protein + 8 %, calories + 9%; total minerals 12%; Fe + 3%; Zn 19%; Ca 10%).
4. The results of Factor and Principal Components Analysis showed that two component effects were responsible for the observed nutritional benefits: (i) weight loss prevention effect, which comprises measures that mitigate against forms of damage that culminate in the direct loss of dry matter; and (ii) enrichment effect emanating from external factors, such as biological intra-conversions of dry matter into alternate constituents. The first effect was responsible for the content of the macromolecules—fat, protein, fiber, carbohydrates; thus, the gain or loss of calories. The second effect was responsible for specific mineral content. The two effects were opposed to each other, particularly in maize. The weight loss effect was the stronger effect for maize, while the enrichment effect was the stronger effect for the beans.
5. Based on a selected set of processing/cooking quality parameters, maize and common beans under improved postharvest practices demonstrated superior quality.

Table 20. Effects of location, practice (improved or ordinary), and postharvest stage on the nutritional content of maize grain. P values (at 95% CI) are presented, followed by partial eta squared (ηp2) in parenthesis, which is a measure of effect size or relative contribution of the effect to the overall variability observed

Effect	Protein	Fat	Ash	Fiber	CHO[1]	Fe	Zn	Mn	Cu	Ca	Mg	K	Na
Practice	ns	ns	ns	ns	ns	0.000 (.09)	ns	0.031 (.03)	ns	ns	ns	ns	ns
Location	0.000 (.46)	0.000 (.52)	0.000 (.20)	0.000 (.23)	0.000 (.33)	0.000 (.17)	0.000 (.13)	0.000 (.20)	0.001 (.11)	0.053 (.06)	0.015 (.07)	ns	ns
Postharvest stage	0.004 (.06)	0.000 (.32)	0.000 (.20)	0.000 (.19)	0.000 (.30)	0.000(.59)	0.002 (.08)	0.000 (.59)	0.000 (.12)	0.000 (.24)	0.000 (.82)	0.000 (.24)	0.004 (.07)
Location * practice	0.000 (20)	0.007 (.08)	ns	0.027 (.06)	0. 000 (.16)	0.001 (.11)	ns	ns	ns	ns	ns	ns	ns
Location * Postharvest stage	ns	0.000 (.29)	0.000 (.15)	0.000 (.24)	0.001 (.15)	0.000 (.33)	0.034 (.10)	0.023 (.10)	0.000 (.16)	ns	0.000 (.16)	0.002 (.14)	ns
Practice *postharvest stage	0.271 (.02)	ns	ns	ns	ns	0.000 (.16)	ns	0.023 (.05)	ns	ns	ns	ns	ns
Location * practice * postharvest stage	0.000 (.17)	0.006 (.11)	ns	0.032 (.09)	0.004 (.12)	0. 000 (.16)	ns	ns	ns	ns	ns	0.005 (.13)	ns

Notes:

[1]= carbohydrates

- All the main effects were highly significant (Practice: P = 0.006; η_p^2 = 0.18; location P = 0.000; η_p^2 = 0.53; postharvest stage: P = 0.000, η_p^2 = 0.80). From the parameter η_p^2, the postharvest stage had the greatest effect size, followed by location.
- There was no difference between the proximate composition of maize under improved or ordinary practices when the postharvest stage and location were not taken into account.
- Stage in postharvest season and location were significant on all proximate composition parameters. The postharvest stage was significant for all the minerals.

Table 21. Effects of storage duration, practices, and variety on the nutritional content of beans. Significant effects (P values at 95% CI) are presented, followed by partial eta squared (ηp2) in parenthesis, which is a measure of effect size or relative contribution of the factor or factor combinations to the overall variability observed for the particular dependent variable. ns = P value not significant.

Factor	Protein	Fat	Fiber	Ash	Fe	Zn	Mn	Cu	Ca	Mg	K	Na
Postharvest stage	.000 (.31)	.000 (.27)	ns	.000 (.54)	.000 (.52)	.027 (.05)	.000 (.40)	0.007 (.05)	.000 (.16)	.000 (.61)	.000 (.43)	.000 (.26)
Practice	ns	ns	ns	ns	.000 (.11)	ns	Ns	ns	ns	ns	.027 (.03)	.031 (.03)
Variety	ns	ns	.000 (.46)	.000 (.25)	.000 (.18)	ns	Ns	ns	ns	ns	ns	ns
Postharvest stage * Practice	ns	ns	ns	.009 (.05)	.000 (.11)	ns	Ns	ns	.050 (.03)	ns	ns	ns
Postharvest stage * variety	.000 (.10)	ns	.001 (.11)	.018 (.06)	ns	.005 (.11)	.017 (.07)	.001(.10)	.000 (.16)	ns	ns	ns
Practice * variety	.007 (.05)	ns	ns	ns	.000 (.15)	ns	Ns	.032 (04)	ns	ns	.000 (.10)	ns
Postharvest stage * practice * variety	ns	ns	ns	ns	.000 (.15)	ns	Ns	ns	ns	ns	.000 (.21)	

Note: The postharvest stage was significant for all the measured nutritional parameters except fiber. Protein, fat, and total mineral content increased over the postharvest period. Variety significantly influenced fiber content, total mineral content, and iron.

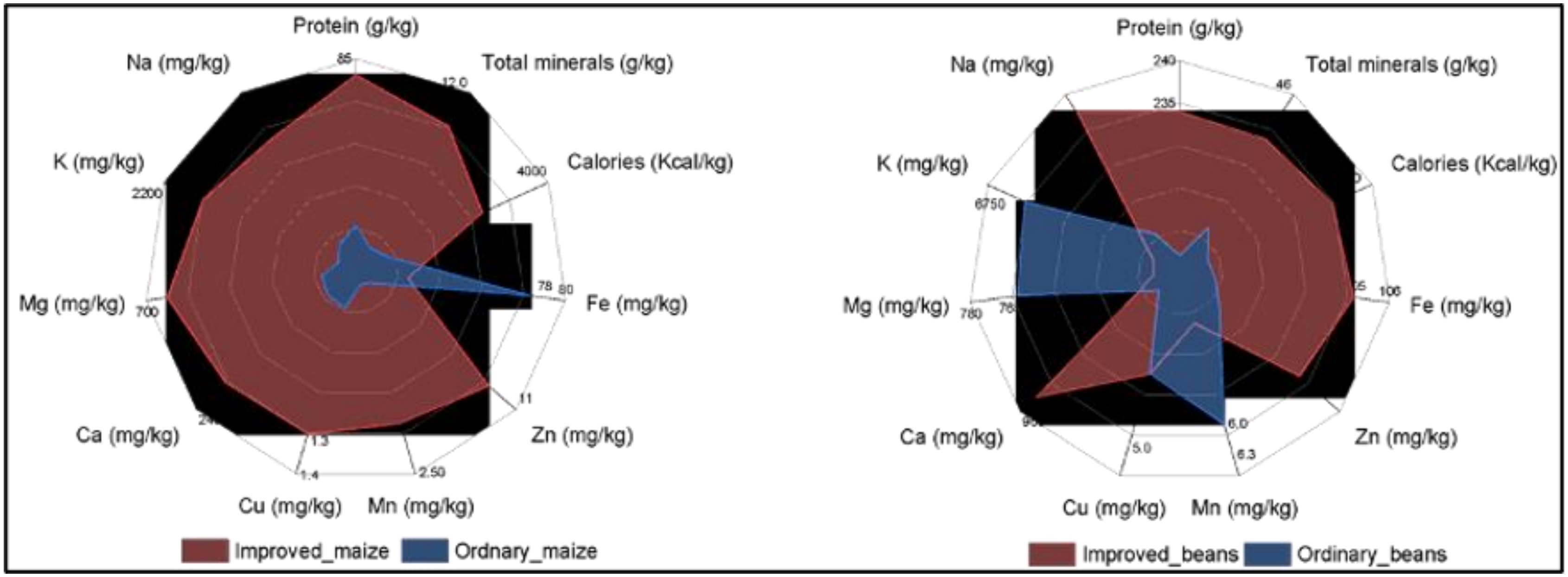


Figure 24. A comparison of the available nutrients per unit weight of maize (left) and common bean (right) stocks from farmers/households at the late stage (7 months) of the postharvest season, following the application of improved or ordinary postharvest practices. The improved practices included drying on a tarpaulin or cleaning, sorting, and storage in air-tight containers while ordinary practices included customary methods of drying, handling, and storage in woven bags. With the improved practices on maize, households have higher levels of all the nutrients except Fe. On the other hand, with improved practices on beans, they have higher amounts of all-important nutrients except Mn, Mg, and K. There appear to be differences related to the performance of individual practices for the different commodities. Nonetheless, the available calories, protein, and total minerals are higher for both commodities.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
Influence of farmer storage structures and environment on physical and economic losses abatement by hermetic storage device evaluated	● An assessment of the nutritional gains of improved postharvest handling and storage of maize and common beans was accomplished using a modelling approach. ● Results are informing the preparation of a manuscript	The report is extracted from the draft manuscript.	Nil
Data uploaded to DataVerse	To be completed by August 2020	Done	
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August 2020	Done	

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 is addressing drivers of food choice focusing on pearl millet and pigeon pea, two of Africa RISING promoted innovations. It is being implemented by two students, Ruth Mremi and Monica Chande, whose studies will lead to the award of MSc Human Nutrition of the Sokoine University of Agriculture. This report includes further advance in analytics of work being undertaken by the students, and the key highlights are given below.

Pearl millet: A total of 128 caregivers with a similar number of children participated in the study. Less than half of the school-aged children included in this study were males (40.6 %) with females as the majority (59.4 %). Overall, the mean age of all children was 7.52 years (7.16, 7.83 years) with the mean age for boys as 7.60 years (7.16, 7.83 years) and girls as 7.47 years (7.06, 8.14 years). The majority of the respondents were married (82.0%), with the rest as single (5.5%) or divorced (12.5%). Only 40.7% of the caregivers had primary or secondary school education. Laikala village is majorly composed of the ethnic tribe of Kaguru (96.9%). In terms of income generating activities, agriculture is the major income source for most of the caregivers (88.3%). In terms of perception, majority of the respondents perceived millet as having a good taste (93%) and as nutritious (83%).

Consumption behavior- Pearl millet. Among households who would intend to consume pearl millet, 48.5% of caregivers indicated price as a barrier (P=0.021), especially during the rainy season, when price is highest due to limited supply of bridging staple cereal grain between cropping seasons (Figure 25). Other barriers identified included: (1) availability of pearl millet (58.6%); (2) quantity of fuel required for preparation (62.6%); (3) short shelf-life of pearl millet flour due to rancidity (64.9%); and contamination with stones (59.4%). There is a need to address postharvest handling and processing of pearl millet to increase adoption and secure food and nutrition needs of these populations. Pearl millet grain contains relatively more fat (7.0–7.9%) than other cereals; hence, subject to lipolysis, which leads to rancidity and deterioration in flour quality. Inactivation of lypase enzyme responsible for lipolysis and subsequently quality deterioration, through pulse-heating of grain, reportedly increases pearl millet flour shelf-life by up to 30 days. This could be substituted by roasting grain. In Kongwa and Kiteto, this would give women, the major caregivers, more time to perform other economic activities, time lost frequently making flour.

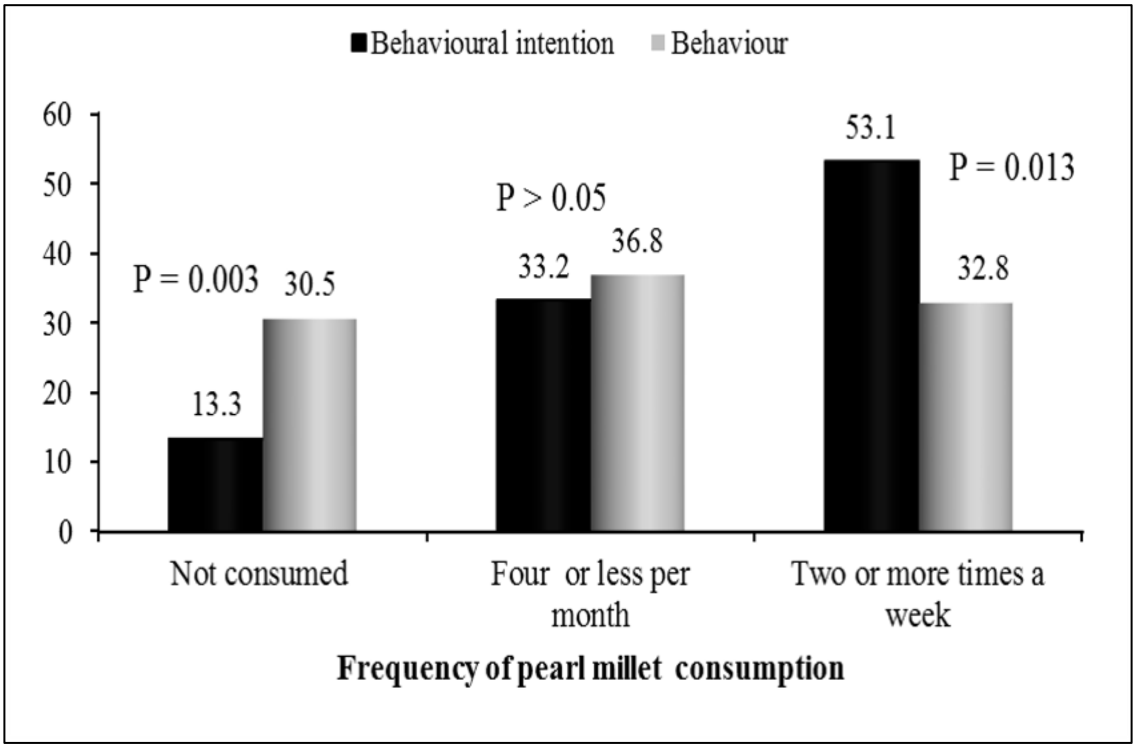


Figure 25. Comparison of intention to consume pearl millet in the coming month and behavior (pearl millet consumption) in the last month (n = 128)

A model investigating consumption behavior of pearl millet in school-aged children tested child age, education, perceived barriers, intention, and the interaction between perceived barriers and intension, found that intention was the most significant predictor of consumption (P=0.04). The model accounted for 20.3% of variance in pearl-millet consumption among school going children. A third model designed to identify predictors of intention show that husbands, mothers-in-law, teachers, and doctors are good triggers of feeding children pearl millet. This has an implication for designing a program to intensify consumption of pearl millet among school going children.

In the previous report, we noted that intention, as a predictor future consumption behavior, was critical. Further analysis was conducted to test this hypothesis. The results showed that intention is a significant predictor (β=0.77; P=0.04) of caregivers giving pearl millet to their school-aged children (Table 22). Through linear regression, we then investigated what factors influence intention and we observed cues to action (β=0.23; P<0.02) and health behavior identity (β=0.34; P=0.000) as significant predictors of caregivers' intention. Cues to action investigates the triggers that stimulate the caregiver to give pearl millet to her child. Specific cues to action identified by respondents were husbands, mothers-in-law, teachers, and doctors. This study indicates that in designing a program to increase consumption of pearl millet among school going children, it is crucial to include husbands, mothers-in-law, teachers, and doctors in the designed approaches.

Health behavior identity that investigates caregiver's opinion of the expected consequence of giving pearl millet to the schoolchild is also a significant predictor of intention. Earlier, we observed that knowledge of the nutrient content of pearl millet consumption and the health consequences was low. To increase consumption, nutrition education should emphasize nutrient content of pearl millet and also the role of nutrients in child health.

Table 22. Factors associated with caregiver health behavior identity and intention to feed pearl millet to school-aged children in Kongwa district

Model Description	Standardized β	P	R2	Adjusted R2
Model 1: Y = Intention			**0.136**	**0.098**
Predictors				
Health behavior identity	0.336	0.000		
Perceived barriers	0.056	0.516		
Attitude towards behavior	-0.095	0.313		
Model 2: Y = Intention			0.115	0.109
Predictors				
Subjective norms	0.158	0.123		
Control belief	-0.089	0.303		
Cues to action	0.231	0.023		
Model 3: Y = Behavior			0.220	0.203
Predictors				
Age of a child	0.043	0.597		
Education	0.025	0.761		
Perceived barriers	0.105	0.646		
Intention	0.774	0.044		
Barriers*intention	-0.375	0.404		

***Pigeon pea**:* Majority of the respondents (n=138), perceived pigeon pea as nutritious (79.7%), tasty (97.8%), and important to attain adequate weight for age (78.3%). In terms of triggers to giving pigeon pea to school children, almost half of respondents reported shortage of food as a cue to preparing pigeon pea (47.8%). This means that almost half of respondents consider pigeon pea as a food security crop. Just as observed in the analyses involving pearl millet consumption, intention was a significant predictor (β=0.25; P=0.00) of pigeon pea consumption.

***Consumption behavior*.** The model testing intention, as a major predictor of behavior, showed no significant difference between intention and behavior among respondents, which are classified as consuming pigeon pea two or more times a week (P=0.874) and those who did not consume pigeon pea (P=0.467). Just like in the case for pearl millet, a model that included intention, perceived barriers, and interactions between them, as predictors of consumption, showed significant interactions (β = 0.268, P=0.001) between intention and perceived barriers. This indicates that perceived barriers influence the association between intention and pigeon pea consumption. To increase consumption, it is important that productivity increases. The new highly productive varieties will do just that. The knowledge needed to sustain consumption is high. Caregivers are aware that pigeon pea is a source of iron (58%), nutritious (79.7%), tasty (97.8%) and important to attain adequate weight for age (78.3%) in children.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
Drivers of food choice in semi-arid central Tanzania established	Research is being implemented by two MSc students ● Theses under development ● Production of guidelines for scaling-out improved nutrition initiated ● Publication on drivers of food choice under drafting	Theses have been submitted for examination at Sokoine University of Agriculture, Morogoro, Tanzania Publications are under development	Nil
Data uploaded to DataVerse	To be completed by August	Data is mostly processed; most of the analysis has been completed; final description of the meta files is ongoing but is affected by delays in receipt of some data sets	Once meta files are completed, we will be able to upload data to DataVerse.
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August	This was submitted separately and is uploaded by IFPRI.	In general, these were positive, with most being over-achieved.

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

During the 2019/2020 season, CIAT distributed NUA45 and SER83 common bean varieties to 500 farmers (314 males and 186 females) in Linthipe EPA. These varieties are nutrient dense (Zn and Fe) and DT. Access to quality germplasm is one of the factors that contribute to poor adoption. Therefore, this approach enhances availability of these varieties from within the community.

Beyond enabling widespread availability of common bean seed for NUA45 and SER83, three mother trials were established, one each in Linthipe and Kandeu EPAs, and at Chitedze research station, to compare performance of these under pure stand and as intercrops. Both varieties achieved yields greater than 1 kg/ha when they were grown as sole crops with, as expected, penalties occurring in the intercrop arrangements with maize. But the large land equivalent ratios indicate preferable benefit of growing both common bean varieties in intercrop arrangement (Table 22).

Table 22. Means of partial and total land equivalent ratios (LER) for maize, SER83, and NUA45 bean varieties

Variety	Partial LER		LER
	Maize	Common bean	
SER 83	0.89	0.75	1.65
NUA45	0.86	0.71	1.57

The determination of labor profiles for these cropping systems showed that: (1) ridging and first weeding were the most labor demanding activities (Table 23); and (2) ridging takes a longer time because it involves re-aligning the ridges to a narrower ridge spacing of 60 cm, compared to the traditional wide ridge spacing of 90 cm.

Table 23. Labor profiling for common bean production in Malawi

ACTIVITY	TOTAL DAYS/ha	TOTAL labor cost/ha (MK)*
Land clearing	12	42,000.00
Ridging	25	120,000.00
Fertilizer Application	5	20,000.00
Planting	4	36,000.00
staking	10	24,000.00
1st weeding	18	90,000.00
2nd weeding	5	40,000.00
1st pesticide application	1	10,000.00
2nd pesticide application	1	10,000.00
3rd pesticide application	1	10,000.00

*1USD=735 Malawi Kwacha

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation and explanation
Nutrient-dense common bean seed distributed to about 500 farmers, listed and disaggregated by sex	Achieved in Linthipe EPA		
At least 3 mother trials and 20 baby trials per mother established	Trials were established at Linthipe, Kandeu and Chitedze. 40 babay trials were established	NA	Only 40 out of the planned 60 farmers offered their land voluntarily to be used for baby trials at the time of planting.
Technical report: Yield distribution/range for common bean production using improved germplasm.	https://drive.google.com/file/d/1a_dAyBkrQyCR9wL1XQBJR-N-CfyyeCV0/view?usp=sharing		Report provided on grain yield distribution
Report: Micronutrient content from produce from 100 farmer fields documented		Not done	Samples were submitted to LUANAR in April and have not been analysed. CIAT has retrieved the samples and will be shipped to MSU early December 2020
At least 3 feedback meetings held with farmers between March and August 2019	Give link to the reports	Information not available	Chifuniro to update
Draft publication: Estimates of productivity and yield gaps for local and improved bean varieties	https://drive.google.com/file/d/1dhWjGZvLpvYWyYdjC7GInjbVFXnlLU7x/view?usp=sharing	In progress	In progress and will be ready end December

Work with the Malawi Government Extension System to reach 5000 farmers in bean growing areas	Information not available	Chifuniro to update
Data uploaded on to Dataverse		Uploaded
FtF indicators data submitted to M&E/IFPRI for upload	Information not available	Chifuniro to update

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

The nutrition studies were earmarked for the postharvest period, as from May 2020. The work was supposed to involve FGDs with clusters of farmers, and evaluation of recipes through targeted feeding experiments. Because of COVID-19, all activities were suspended. Recently, the nutrition team in LUANAR was given permission to resume activities with a limited number of farmers allowed to assemble. Here, we report on a survey on consumption patterns of bio-fortified beans.

Consumption frequency of biofortified beans. A study on consumption of biofortified beans was implemented with 150 participants. The majority of respondents were females (84%) and all the respondents in this study consume common beans. About 84% of the farmers reported having consumed biofortified beans at least once a week (Table 24). The attribute most liked (38%) on bio-fortified beans was taste, followed by the short time that the variety takes to cook. Other attributes that were mentioned included color and grain size. The consumption patterns showed that the respondents were already familiar with bio-fortified beans.

Table 24. Consumption patterns of bio-fortified beans among 150 participants in Linthipe EPA

Variable	Category	Frequency	Percentage
Consumption frequency of bio-fortified beans	Once a week	46	30.7
	Once a month	29	19.3
	N/A	27	18.0
	Others	48	32.0
Last time consumed bio-fortified beans	A week ago	34	22.7
	A month ago	41	27.3
	More than six months ago	26	17.3
	Others	16	10.7
	N/A	27	18.0
Attributes liked on bio-fortified beans	Color	9	6.0
	Smell	19	12.7
	Taste	58	38.7
	Color, smell, and taste	15	10.0
	Color and smell	3	2.0
	Color and taste	4	2.7
	Smell and taste	14	9.3
	N/A	27	18.0
Factors considered when purchasing bean	Grain size	7	4.7
	Color	30	20.0
	Easy to cook	43	28.7
	Grain size and Color	6	4.0
	Grain size and easy to cook	6	4.0
	Color and easy to cook	38	25.3
	Grain size, color, and easy to cook	16	10.7

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation and explanation
Three recipes made available	The three recipes of porridge are proposed and ready for testing with farmer groups during the postharvest stage. These will be documented afterwards.	Testing of recipes has not yet been done but will be implemented in 2020/2021.	Clearance from COVID-19-related ban was only issued in September 2020.
At least two field days, jointly with DNCC, held with nutrition groups, especially HIV/AIDS action groups in Linthipe	These are targeted for the postharvest period when farmers have food supplies, and when COVID-19 conditions are relaxed.	These were suspended	
Improved child nutrition status demonstrated	A report on cooking characteristics and consumer acceptability of biofortified beans using Check ALL that applies (CATA) methodology, is under preparation. Nutrition education and growth monitoring sessions were initiated but disrupted by COVID-19 management conditions.	Collection of extra data was suspended due to COVID-19-related restrictions.	
At least one success/blog story produced	Planned for the second half of this project year	This was not done due to COVID-19 limitations	
Data uploaded to DataVerse	To be completed by August 2020	No data available	Work not done
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August 2020	No data available	Farmers could not be engaged

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

The current COVID-19 lockdown affected the implementation of this survey-based activity. This will then be implemented in 2020/2021.

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. A manuscript has been drafted and is under internal review. It is targeted for submission to a journal in December 2020. The working abstract reads as below.

The study aimed at establishing the critical elements for a well-designed maize seed value chain that strengthens marketplace systems, without negatively distorting or displacing the private sector investment flows in Northern and Central Tanzania and their roles in the input and output markets. A weak link between research organizations and farmers was detected while women had the least number among the key players in the chain. A well-designed chain ensures involvement of more women at every level, increase of information flow, exclusion of Agricultural Seed Agency from seed marketing, and empowerment of a more robust private seed sector for quality protein and Pro-Vitamin A varieties to penetrate dry areas. Limiting policy issues include: (1) failure to regulate retail seed prices; (2) taxing the seed producers; (3) delayed certification of seeds by Tanzania official seed certification institute (4) few quality declared seed (QDS) inspectors; (5) Agricultural Seed Agency's skewed network; and (6) hiccups in land ownership for foundation seed bulking. The study concludes that a relatively strong network between agrodealers, seed companies, and maize farmers would make most of the maize farmers in Babati to adopt certified seed varieties, although a strong QDS system is needed as an alternative system. The study recommends a strong focus on agrodealers' mobility as they are the players next to farmers.

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

The study was completed during the last project year and a manuscript is under preparation. There is an ongoing discussion that results of this sub-activity and sub-activity 4.1.1.1 should be compiled into one publication.

No sub-activities were conducted under Activities 4.1.2 and 4.1.3 during this reporting period.

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

Update on MWANGA. During the previous reporting period, there was an increase in the number of smallholder farmers reached. This was attributed to additional farmer profiling on the MWANGA platform in the Africa RISING–NAFAKA project. An additional 650 smallholder farmers (in addition to the original 2500) were profiled and reached using SMS agronomy, marketing, and climate information. The gender representation for the farmers reached was 68% male and 32% female. The lower number of registered female farmers compared to males may be attributed to mobile phone ownership, which is skewed in favor of men due to cultural and socioeconomic factors.

Presently, the MWANGA Platform continues to be an outlet for the dissemination of agronomic messages on best practices at the farm level and market information at the household and community levels. Follow up studies has been conducted to verify the usefulness of MWANGA messages by the livestock team specifically the impact on farmers' knowledge, attitude and aspirations (see 1.3.1.1). The study noted that the MWANGA Platform has the potential to increase dissemination and adoption of improved forages and feed technologies.

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

The main deliverable, a manuscript entitled "**Welfare impacts of smallholder farmers' participation in multiple output markets: Empirical evidence from Tanzania**", was completed and submitted to PLOS one. The extended abstract reads as follows:

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 most significant 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.

Two main policy implications can be drawn from this study. First, improving the functioning of agricultural markets through the facilitation of market access is vital for smallholder farmers to fully reap the benefits of market participation in rural Tanzania, as is the case in many similar rural settings in sub-Saharan Africa. Despite the recent construction of a promising development corridor in southern Tanzania, the country is still plagued with poor road infrastructure that hinders farmers from accessing profitable maize and legume markets available in urban centers.

Hence, development programs and policies promoting the improvement of the road network in rural communities are important for smallholder farmers to prevent their economic isolation. Second, our findings suggest the need to support policy measures that promote the combined production of maize and legumes, as well as strengthen their value chains. These interventions should follow diversification as opposed to specialization strategies, given the empirical evidence towards value chain complementarity rather than substitutability of the most important commodities in the country. Besides, diversification would also smooth the negative effects of seasonality both in production and in marketing given the different growing periods. In areas where vulnerability to climate change and shocks is relatively high, as in most sub-Saharan Africa, participation in multiple-commodity markets under a diversification strategy would also provide a potential hedge against the risk of crop failure or price shock.

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

In all 16 on-farm target communities, we planted, maintained, and harvested the trials. We also collected weather data, which allows for further analysis. We further conducted a range of evaluation meetings where farmers could report their views about different Africa RISING technologies. Acceptance of technology and prioritization is a key step for further scaling by smallholder farmers.

The yield results from 2019/2020 show that rotation was the strongest factor in the manual and animal traction systems of Eastern Zambia (Figure 26). Maize planted with a dibble stick, mulched, and rotated with a doubled-up legume system was the best performing treatment in Southern Malawi. The conventional ridge and furrow systems was the worst in almost all communities. Growing groundnuts under CA seemed to be the best choice for smallholder farmers in Malawi as it consistently provided greater yields than the conventional system, except for one (out of 10) site, Malula. Not surprisingly, farmers rated the two CA systems highest (Figure 27), which was also in line with the yield levels. Farmers also liked the “improved” conventional practice more than a farmer field alongside the trials most likely due to good management and adequate fertilizer levels that our control received.

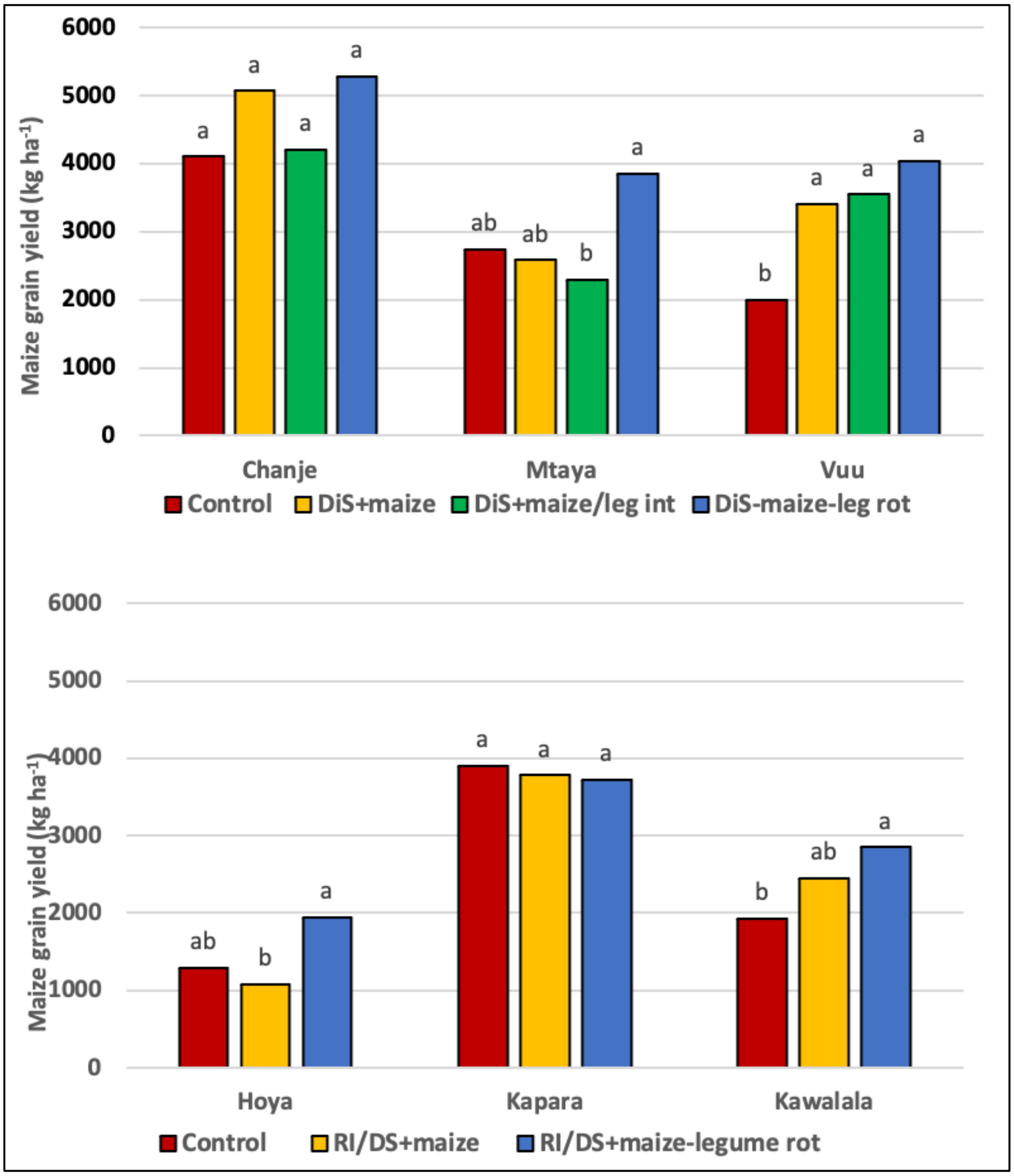


Figure 26. Crop performance at the CA long-term on-farm trials (manual systems) in target communities of Eastern Zambia, 2019/2020. Means followed by a different letter in column for each fertilizer level are significantly different at P<0.05 probability level. Note: Control = conventional tillage; DiS = Dibble stick planting under no-tillage; leg int = legume intercropping; leg rot = legume rotation.

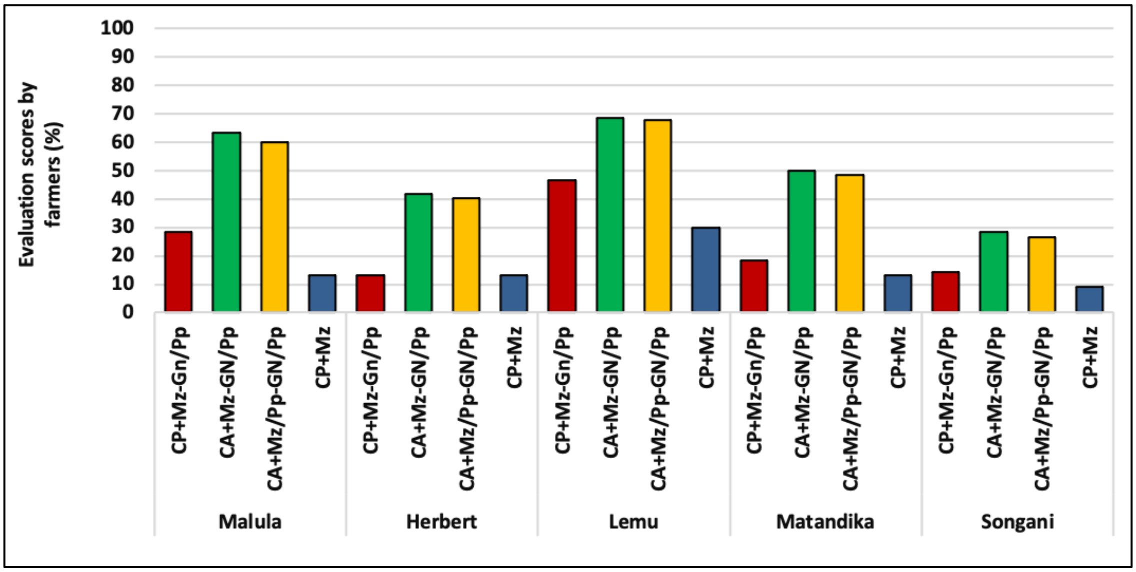


Figure 27. Perception by farmers about Africa RISING technologies in Southern Malawi, 2019/2020. Evaluations are a mean of four different evaluation events carried out during the cropping season representing different stages of crop development. CP = conventional control; CA+Mz-Gn/Pp = CA with a maize groundnut/pigeon pea doubled up legume rotation; CA+Mz/leg-Gn/Pp = CA with a maize/legume intercropping; and groundnut/pigeon pea doubled up legume rotation.

Socio-economic assessments of the profitability of these cropping systems is ongoing but some preliminary analysis shows strong economic benefits of growing crops under CA due to reduction in farm labor for planting and for weed control. Other key economic indicators show higher rates of return, increased returns to labor, and a shorter payback time.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation and explanation
Field trials established	Trials were successfully established in all on-farm communities. Field implementation reports have been received. https://bit.ly/2Rp7T3B	Completed	No deviation
Field monitoring implemented	One field monitoring tour was implemented and reported. https://bit.ly/2Rp7T3B	Completed	No deviation
Data generated and uploaded to DataVerse	To be done once yield data is available	Completed	No deviation
About 10 000 farmers actively participating in promotion and extension activities	So far, 5121 farmers participated in promotion and extension activities. The achievement of the deliverable	In total, 6412 farmers participated in different events.	64% of target; final number was affected by COVID-19

	is likely to be affected by COVID-19.		
Data uploaded on to DataVerse	To be completed by August 2020	Completed	No deviation
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August 2020	Completed	No deviation

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-agroecologies (low, moderate, and high potential) identified during the 2018-2019 cropping season. The candidate varieties represent two crop phenology groups: (1) short and medium duration (legumes and cereals); and (2) long duration only for pigeon pea. For each of the phenologies, the farmer land race was included as a control. Results' highlights are described below.

Performance of improved varieties under farmer and researcher management

Groundnut: Adaptability of new materials***:*** The 2019-2020 cropping season was unique, receiving above average precipitation. Kongwa district received >7000 mm of rainfall in October, while the rest of the season had evenly distributed precipitation (69-120 mm and 74-180 mm for Kongwa and Kiteto, respectively). No significant differences ($p \geq 0.05$) was found for Sub-agroecology x Management x Variety interactions (Table 1c) and this may be due to above average rainfall received during the cropping season.

i. *Researcher versus farmer practice:* Farmers, in general, plant their legume crop late, usually after cereals which are considered as staple crops. We find that irrespective of crop phenology (maturity groups), grain yield in late planted crops was most compromised. A comparison of the short duration – Spanish botanical group of elite and farmer landraces grown using farmer practice (late planting) validated the superiority of the elite material. The two new varieties performed best in the moderate potential sub-agroecology (Table 25). Kongwa 560 was the best performing improved variety, whose productivity in the moderate sub-agroecology was 2907.41 kg/ha, compared to 2574.07 kg/ha and 1518 kg/ha for the medium duration variety Kongwa 724 and the local landrace, respectively. Kongwa 724 was best adapted for the moderate to high potential sub-agroecologies; but for a good year (such as the 2019-2020 cropping season) it, too, does well, better than the farmer material even under their own practice. Yield gains in Kongwa 724 of 9.37 % were observed in the high potential sub-agroecology when planted early over the late planted crop, indicating a penalty of nearly 10% in a bad year. Kongwa 724 has relatively large seed size, that inadvertently increases grain yield compared to the small-seeded short duration Kongwa 560.

ii. *Conclusion and recommendation**:*** This evaluation confirms that the moderate potential sub-agroecology is the most suitable micro-environment in the semi-arid ecologies of central Tanzania for groundnut production. Given that in this location, a good production year (such as the one experienced in 2019-2020 cropping season) occurs once every 4-5 years, it is recommended that farmers plant short duration materials early. The yield advantage is projected to compensate for other household and production risks given that groundnut is a high value crop.

Table 25. Groundnut variety x ecology x management interactions in Kongwa and Kiteto districts during the 2019-2020 cropping calendar

Ecology	Management	ICGV-SM 02724 (Virginia)	Yield gains at each interaction level (%)	ICGV-SM 05650 (Spanish)	Yield gains at each interaction level (%)	Local Check (Spanish)	Yield gains at each interaction level (%)
High potential	Early planting	2390.67	9.37	2740.74	4.05	1448.15	19.44
	Late planting	2166.67	0	2629.63	0	1166.67	0
Low potential	Early planting	2333.33	3.52	1777.78	-1.04	1685.19	13.19
	Late planting	2250.00	0	1796.3	0	1462.96	0
Moderate potential	Early planting	2574.07	6.47	2907.41	38.22	1518.52	6.10
	Late planting	2407.41	0	1796.3	0	1425.93	0
	Mean					**1963.27**	
	Fpr					0.128	
	sed					631.48	
	CV					32.2	

<u>Sorghum</u>: <u>Adaptability of new materials</u>***:*** Significant interactions ($p \leq 0.05$) were found for variety x management by sub-agroecology. As expected, higher yields were observed in the early planted crop than the late planted crop.

i. *Researcher versus farmer practice:* A yield penalty of up to 38% occurred in the late planted crop (Table 26) while the highest yield gains occurred in the moderate potential sub-agroecology. The GxE biplot shows that the variety Gambella 1107 is the most stable (Figure 28) with yield losses stabilized around 22-24 % in high and moderate sub-agroecologies. This variety also had relatively lower yield loses of up to 35% when planted late in the low potential agroecology compared to the other test material. Overall, the materials evaluated performed best in the moderate potential sub-agroecology. In the moderate sub-agroecology, productivity was 3694.44 kg/ha, 2796.30 kg/ha, 3564.81 kg/ha and 1583.33 kg/ha for Gambella 1107, IESV 23010, IESV 92028 DL, and the local landrace, respectively.

ii. *Conclusion and recommendation:* In general, planting sorghum early is a beneficial management action; however, this is often in competition with maize generally planted first. With exception of Laikala village, where sorghum and pearl millet are premium food security crops, and therefore are planted early, we find the moderate potential sub-agroecology most suitable for sorghum production, but it could also sustain maize production. The critical issue is the opportunity cost of producing sorghum that experiences less yield penalty under stress compared to maize. The dry heat in these semi-arid agroecologies also reduce flareup of grain infection by fungi, compared to when sorghum is produced in humid high potential areas. Under such circumstances, therefore, it is possible to produce high quality grain free of mycotoxins (i.e., aflatoxins and fumonisins) that are common on sorghum produced under humid conditions.

Table 26. Sorghum variety x ecology x management interactions in Kongwa and Kiteto districts during the 2019-2020 cropping calendar

Ecology	Management	Gambela 1107	Yield gains at each interaction level (%)	IESV 23010 DL	Yield gains at each interaction level (%)	IESV 92028 DL	Yield gains at each interaction level (%)	Local Check	Yield gains at each interaction level (%)
High potential	Early planting	2777.78	21.67	2444.44	17.42	2175.93	34.04	1259.26	13.24
	Late planting	2175.93	0	2018.52	0	1435.19	0	1092.59	0
Low potential	Early planting	2611.11	34.75	1509.26	15.95	1972.22	38.97	1398.15	36.42
	Late planting	1703.7	0	1268.52	0	1203.7	0	888.89	0
Moderate potential	Early planting	3694.44	26.32	2796.3	29.14	3564.81	20.26	1583.33	-6.43
	Late planting	2722.22	0	1981.48	0	2842.59		1685.19	
Mean								2033.56	
Fpr								<0.001	
sed								416.86	
cv								20.5	

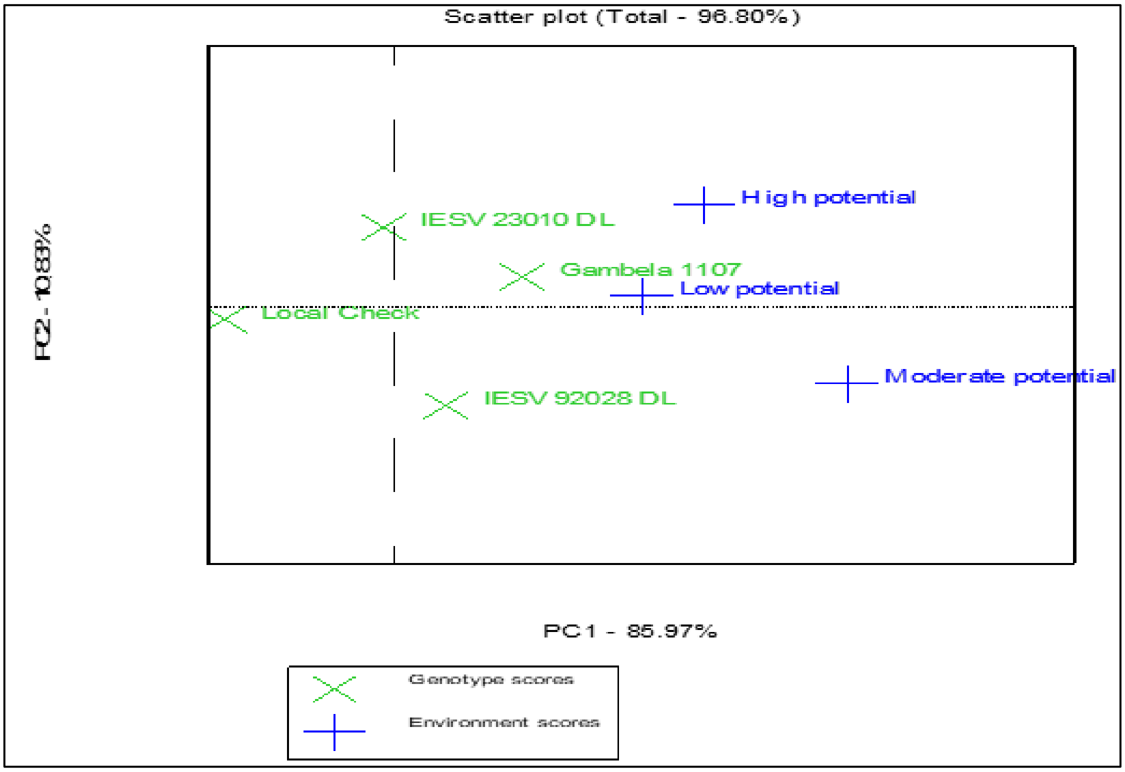


Figure 28. G x E biplot for sorghum across three sub-ecologies (high, moderate, and low potential).

<u>**Pearl millet**: Adaptability of new materials</u>***:*** These studies were conducted in Laikala and Moleti Kongwa District. Both villages are in the low potential sub-agroecology but have pearl millet as a staple crop. Since evaluation was only done in one sub-ecology (low potential), comparisons were made only at management level (early vs late planting).

i. *Researcher versus farmer practice:* Significant differences ($p \leq 0.05$) were found in Management x Variety interaction (Table 27). Planting early had good yield advantage with yield gain of 28-45% observed between early and late planting crops among test varieties. IP 8774 and SDMV 94005 were the most stable genotypes. The yield gain between the best elite material SDMV 94005 and the landrace was 44% when planted early and 28% when planted late, as farmers usually do by taking chances with maize first.

ii. *Conclusion and recommendation:* Clearly, pearl millet (a crop generally grown in constrained environments) offers opportunity to close yield gaps and secure both food and nutrition security. Planting early is strongly recommended, especially, if it is early for the extra-early maturity varieties.

Table 27. Pearl millet variety x ecology x management interactions in Kongwa and Kiteto districts during the 2019-2020 cropping calendar

Ecology	Management	IP 8774	Yield gains at each interaction level (%)	SDMV 94005	Yield gains at each interaction level (%)	SDMV 96053	Yield gains at each interaction level (%)	Local Check	Yield gains at each interaction level (%)
Low potential	Early planting	2092.52	28.32	2981.48	45.34	1888.89	30.39	1666.67	30.00
	Late planting	1500	0	1629.67	0	1314.81	0	1166.7	0
	Mean							1780.09	
	Fpr							0.005	
	sed							396.42	
	cv							22.3	

Pigeon pea: Adaptability of new materials**:** Three released/commercialized varieties were introduced in Kongwa and Kiteto, Mali- (long duration), Ilonga 2 and Ilonga 1 (medium duration). These were evaluated in the three sub-ecologies: (1) high (Mlali and Manyusi villages); (2) moderate (Njoro I and 2 villages); and (3) low potential (Laikala and Moleti villages). Mali, a long duration variety, was used as commercial check being the oldest variety and standard check for pigeon pea, especially long-duration material.

i. *Researcher versus farmer practice:* No significant differences ($p \leq 0.05$) in interactions were found. However, a yield gain of up to 37% was found in early over late planted crops in the high potential sub-agroecology. Ilonga 1 had relatively higher productivity (1986 kg/ha) compared to 1752 and 1310 kg/ha for Ilonga 2 and Mali, respectively. The difference in productivity between the long duration and the two medium duration varieties was 676 and 442 kg/ha. This yield difference is significant given the shortage of proteins in drylands, which pigeon pea grain could easily fill.
ii. *Conclusion and recommendation:* It is recommended that these new varieties, that previously have not been available to smallholder farmers in Kongwa and Kiteto, be scaled-out to close the yield gap and unlock opportunity for farming communities in three districts of central Tanzania. Additionally, planting early will enhance their performance, especially in the dryer sub-agroecologies.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Explanation for deviation
SI field trials established for each site	Done during December 2019	All trials that were established were harvested, data processed, and summaries generated	In the 2018-2019 season, Kiperesa (moderate potential) was one of the sites in Kiteto. This site was not used in the 2019-2020 season because at the time of planting, all roads to the site were cut off. To cover for this, two sites were identified in Njoro; hence, Njoro 1 and 2.
Baby trials established by at least 3000 farmers experimenting with SI technologies	Done during December 2019-January 2020; only 2500 farmers involved due to reduced budget	In this reporting period, we have worked with the seed bank farmers from Laikala, Moleti, and Mlali while graduate farmers had members from Manyusi and Njoro, too. These farmers planted the improved crop varieties, including pigeon pea variety, ICEAP 00040 (Mali), Sorghum varieties (Gambella 1107 and SDMV 23010), and groundnut varieties [(Mnanje, ICGV-SMs 05650 (Kongwa 650), and 02724 (Kongwa 724)].	Seed bank farmers in Manyusi and Njoro planted ICEAP 00040 (Mali). Seed bank leaders have been contacted to verify the data among others due to COVID- 19 limited travel guidance.
Benefits of SI technologies evaluated across sites	Data will be collected and analyzed for the next reporting period	Most data on SI technologies have been collected (i.e., pod yields, grain yields, crop biomass, disease, and other plant parameters) that are useful in the characterization of the different varieties. Crop sales data from baby farmers is yet to be collected.	Most farmers had not sold produce while others were still processing their produce
At least one field day per village conducted	Three field days were held; others suspended	No additional field days were conducted due to COVID-19 pandemic	Report will not have a component for farmer preferences and numbers

			reached with messages on SI technologies through this avenue
At least two farmer exchange visits conducted	Suspended due to COVID-19	No exchange visits were conducted due to COVID-19 pandemic	
Africa RISING attends at least one DAECC-led district workshop for SI technologies dissemination	Possibly during August	There was no DAECC-led district workshop held for SI technology dissemination due to COVID-19 pandemic	
SANE –Africa RISING collaboration extended 2020	The relationship is still informal	Two MoUs were signed with: a) Dodoma Agriculture Seed Producer's Association (DASPA). The agreement of the collaboration is to build capacity of smallholder farmers for seed and seed production to increase profitability. Contact person is Mr Aithan Chaula; and b) Kibaigwa Flour Supplies (KFS). The collaboration aims at building capacity for smallholder farmers for seed, seed production, and marketing. The contact person is Mr Sebastian Abdala Msola. These collaborations have also resulted into successful registration of farmers groups to improve their functionality.	None

		Below are three Community Seed Bank groups: a) Laikala (*Umoja ni Nguvu*); b) Mlali (*Vidulwe*); and c) Moleti (*Kwimage*). Registration was done by the Department of Community Development, Kongwa District. These farmer groups are now officially recognized as seed production groups.	
Data uploaded to DataVerse	To be completed by August	All materials have now been harvested, data is mostly processed, analysis either done and/or in progress and ready for uploading. Final description of the meta files is ongoing, which has been affected by delays in receipt of some data sets.	All explanations have been provided separately in FTF reporting document. Generally positive, with most over-achieved.
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August	This was submitted separately and is uploaded by IFPRI.	
Publications	MS are being drafted at various stages of review	These will be submitted latest by Q1 2021	

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

No follow-up engagement activities were implemented during this reporting period.

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

In this sub-activity, we are quantifying the farm-scale impact of engaging farmers at different intensities. This research is basically testing the hypothesis depicted in Figure 29 and implemented through three modules: (1) Module 1 – farm characterization; (2) Module 2- farm productivity estimations; (3) and Module 3 – postharvest activities, home consumption patterns, and marketing. We were able to implement Modules 1 and 2 only during this COVID-19 period.

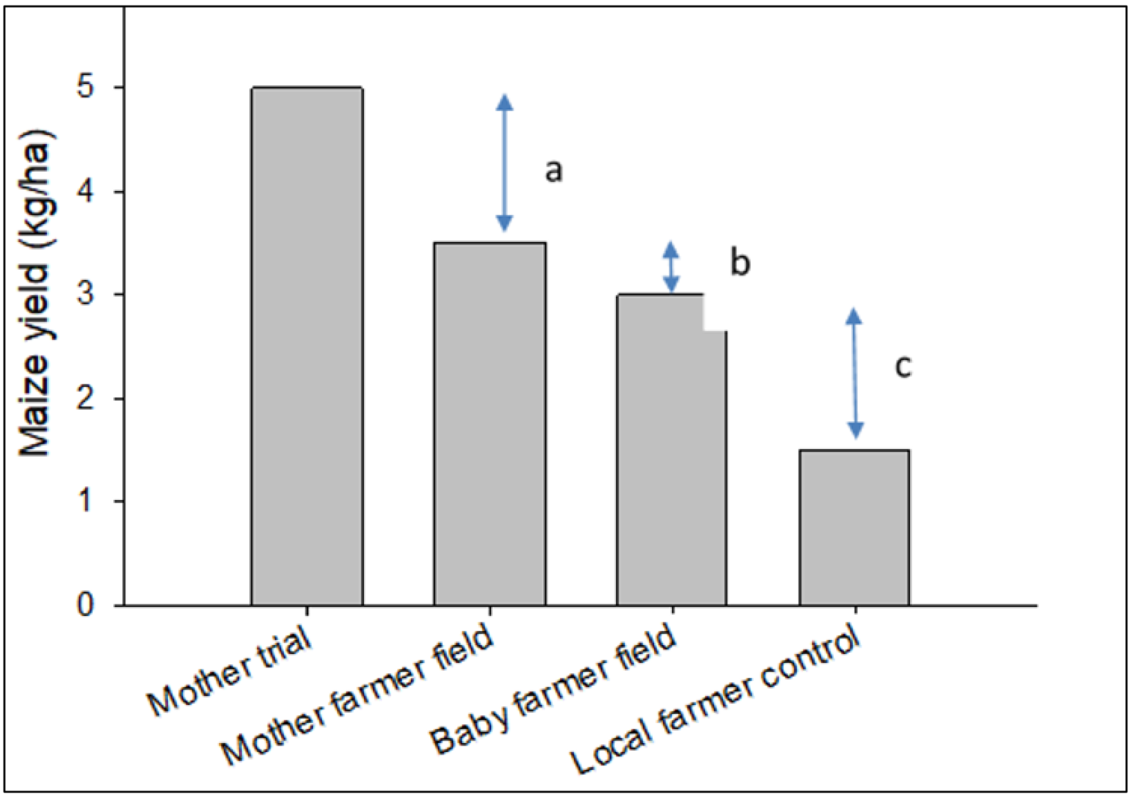


Figure 29. Conceptual framework for assessing the impact of Africa RISING interventions through yield gap analysis for farmers interacting with Africa RISING at different intensity. Yield gap '**a**' illustrates the difference between optimized use of NP (water-limited yield) and knowledgeable farmer adapted SI; '**b**' is a function of knowledge intensity gap between mother and baby trial farmers; and '**c**' is yield that non-participating farmers forfeit. The y-axis variable is given as maize but could be any other crop. This analysis is true for farmers in similar resource endowment group.

Module 1: Highlights from farm profiling work

- No major differences in demographics – age, household size
- More small ruminants in low potential areas – Balaka, Golomoti, and Machinga – average two goats/household
- Small landholdings in high-potential areas – Linthipe
- Maize & legume intercrop common in both low- and high-potential areas

- Relay cropping of beans dominant in Linthipe
- Farm-scale use of SI technologies beyond trials limited (fertilizer, CA)

Module 2: Highlights from quantifying the differentials among Africa RISING 'boundary partners'

- Large difference between maize yields from mother trials and from fields of mother host farmers, baby farmers or controls. No significant maize yield differences among mother, baby or control farmers within a village (Figure 30).
- Productivity of groundnut or soyabean was different among mother and control fields, with the trend following expectations based on intensity of interacting with Africa RISING project (Figure 31).

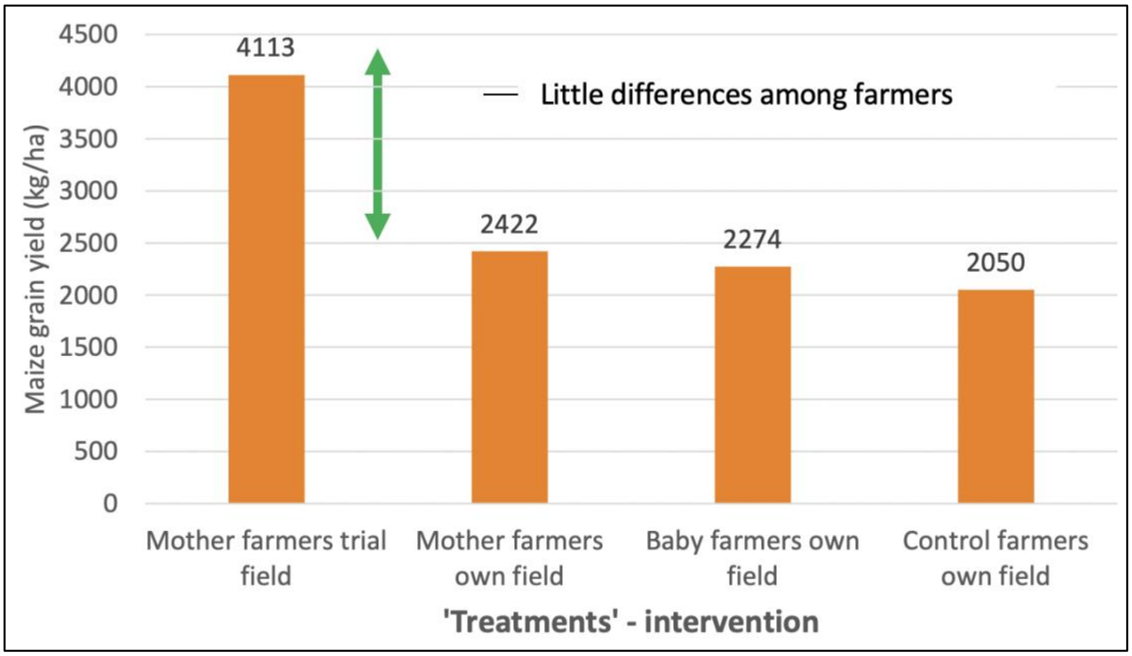


Figure 30. Productivity of maize on mother trials and on farmer's own fields.

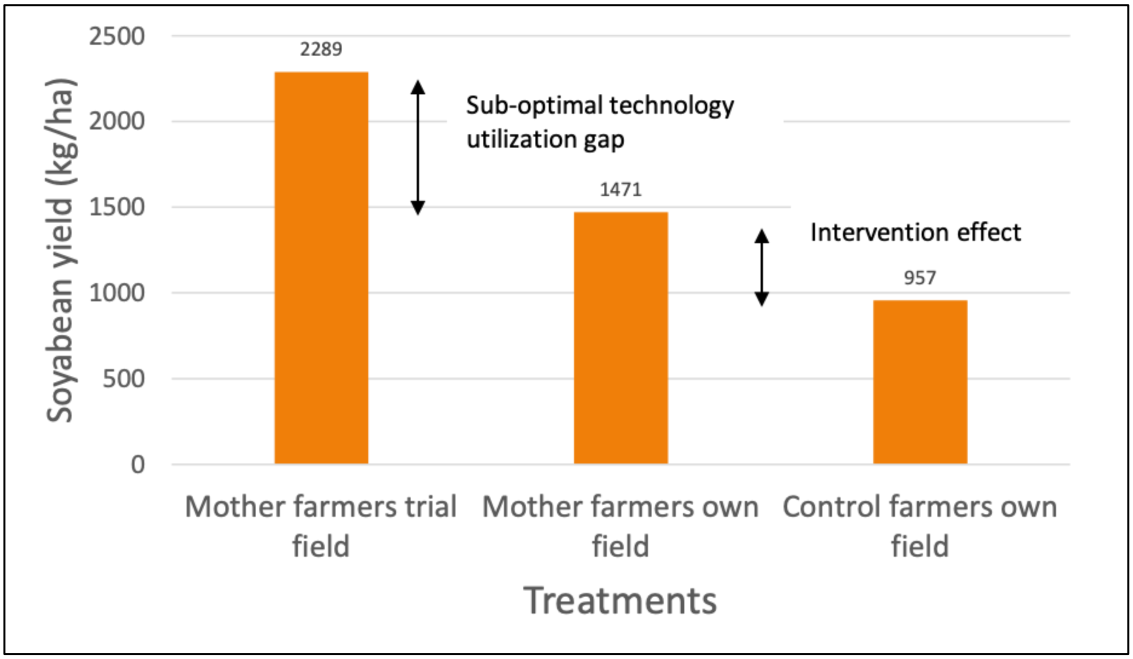


Figure 31. Productivity of soyabean on mother trials and on farmer's own fields.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
Trials established	Trials were established as planned		
Activities by implementing students monitored	An instrument for data collection was developed. Two MSc students are using the instrument to collect data from 54 households for whole-farm analysis in the selected AR districts (Dedza, Golomoti, Machinga, Ntcheu, Zomba Linthipe, and Kandeu).	Module 1 - Farm characterization was implemented	
Data sets by farm typologies; estimates of yield gaps; farm-scale SI scaling compiled	Yield cuts data collection for yield estimations currently underway for mother trial host farms, baby farmers, and local controls.	Module 2 was implemented during April and May 2020. There was poor supervision as COVID-19 infections in the region resulted in restrictions.	Data quality poor
Data uploaded to DataVerse	To be completed by August 2020	Available data uploaded to DataVerse	
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August 2020	This was a monitoring study. Farmers involved are included in counting for other sub-activities.	

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.

This activity combines on-farm research and cropping systems simulation modelling to develop agronomic packages and targeted recommendations for crop traits. Central to the application of cropping simulation models are the biophysical (e.g., soil, crop, and met) and structural (e.g. intercropping, cropping system, etc.) parameterization information, available to realistically simulate on-farm scenarios. The activities in 2019/2020 focused on the simulation of long-term impacts of cereal-legume intercropping systems on productivity, risk, and resource-use efficiencies in central Tanzania.

Soils**:** The soils database was built using the reconnaissance soil survey of Tanzania, 1983 soil report. Recently, soil survey conducted on selected districts in Tanzania under AFRICA project was obtained and used, while a protocol for the development of APSOIL[11] parameter values for use in APSIM was used to estimate parameters not available in the survey.

Meteorological data: Long-term weather data (rainfall, Tmin, Tmax, solar radiation) collected by the Tanzanian Meteorological services and validated by on-farm weather data in the study agroecological zones in the districts of Kongwa and Kiteto were extracted from gridded Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) and subsequently used modelling in APSIM.

Crop data**:** The crop dataset under researcher and on-farm management (location, sowing date) for the new sorghum variety (IELSV23010) and two pigeon pea varieties, Mali (ICEAP00040) and Ilonga 2 (ICEAP00557), were assembled. However, the sorghum variety attributes available in APSIM are not compatible with the material used in this study (i.e., day-neutral and photoperiod-sensitive). For this study, selected sorghum varieties whose crop phenology was similar to the test material were used. The attributes used in the experiments were days to flowering, days to physiological maturity, and grain and biomass yields. The agronomic data from on-farm trials were used to parameterize APSIM and simulate pigeon pea-sorghum intercropping at high and potential sites in central Tanzania.

Results of sorghum and pigeon pea simulated productivity under sole and intercropping

Sorghum. The mean sorghum grain yields, predicted by seasonal analysis (2011-2019), was significantly greater in sole cropping than intercropping. Sorghum grain yields declined by 33% in intercrops with pigeon pea compared with sole cropping. However, the depressed sorghum yields were compensated by pigeon pea yields (Figure 32). The difference in sorghum grain yield under sole cropping and intercropping was generally small in low rainfall seasons but were much higher in high rainfall seasons This suggests that under limited rainfall, both crops are heavily constrained, and pigeon pea, being a slow growing crop, does not severely affect sorghum being

[11] Verburg K (2016) Field Protocol to APSoil characterisations. Version 4. CSIRO, Australia.

already stressed. However, under conducive environments, the pigeon pea thrives and may suppress sorghum as it competes for water resources, suppressing sorghum grain yield. In these water-stressed environments, intercropping cereal and long-duration legumes has been shown to be a risky enterprise, as the coefficient of variation for sorghum grain yields was 73% compared with 46% under sole cropping. The reduction in sorghum yield in intercrops can be explained by the amount of the extractable water that was recorded at crop harvest. The amount of extractable water was almost depleted at harvest under intercropping systems suggesting that the crop might have suffered water stress before it reached its physiological maturity.

The computed LER for two sub-agroecological environments, with crops of varying phenology (long and medium duration), show that intercropping is only beneficial in the high potential sub-agroecology (LER=1.45 under medium duration pigeon pea and LER = 1.14 for Long duration pigeon pea). The LER for the same cropping systems had total LER of less than unity, implying that in such environments, intercropping is not beneficial over sole cropping.

Pigeon pea. Pigeon pea grain yield under intercrop with sorghum was suppressed with yield reduction of up to 74% compared with grain yield under sole cropping (Figure 33). The reduction in pigeon pea grain yield was markedly better in the high potential sub-agroecology compared to the low potential sub-agroecology. Under sole cropping, the productivity was 1645 Kg/ha and 1500 kg/ha at high and low potential sub-agroecologies, respectively, compared with productivity of 387 and 888 kg/ha under intercrop with sorghum.

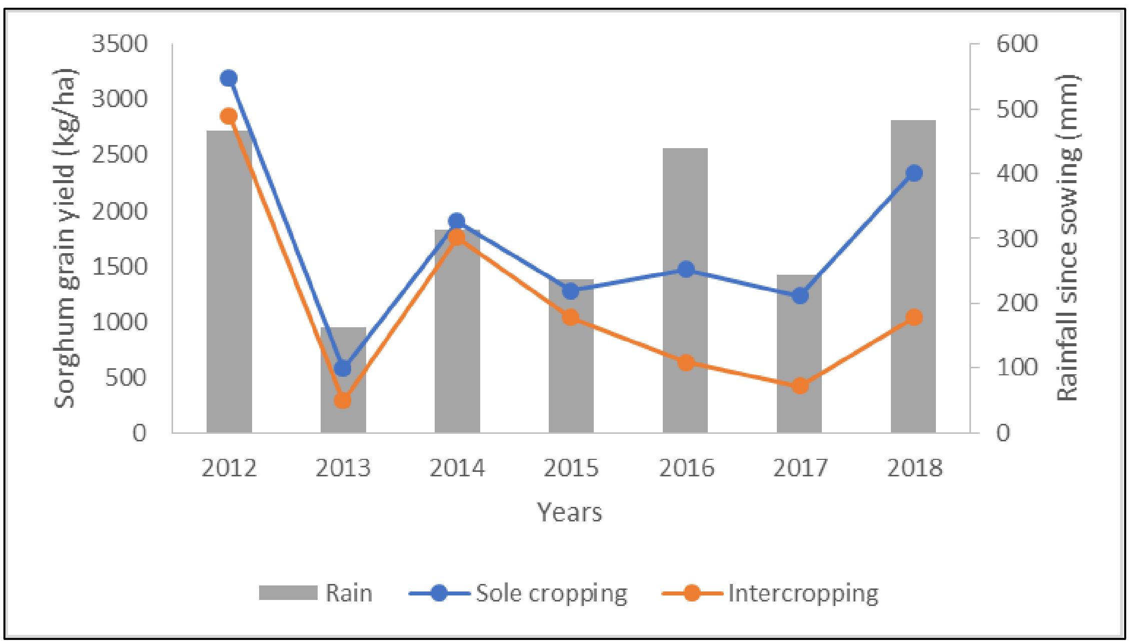


Figure 32. Comparison of predicted sorghum grain yields for sole cropping and intercropping system with pigeon pea during 2011-2019

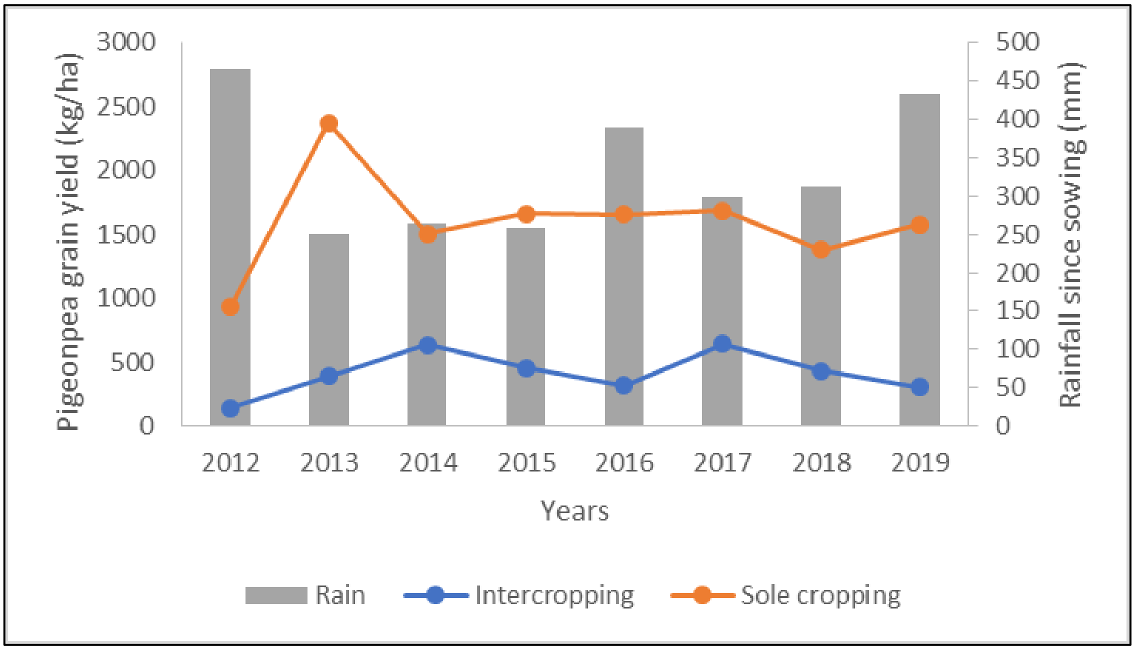


Figure 33. Comparison of predicted pigeon pea grain yields for sole cropping and intercropping system with sorghum during 2012-2019.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
Long-term implications of intercropping systems on climate, market risks, and resource use efficiency of smallholder farms established	Protocols for data collection and parameterization have been developed. Data on dates of critical operations (i.e., land preparation, planting, weeding, disease and pest incidence, plant establishment, and populations) have been collected.	Simulation studies have been conducted but not completed because some parameters in APSIM are not suitable for the sorghum material used. However, we have been able to simulate trends.	We have contacted the developers of APSIM (Agricultural Production Systems Research Unit (APSRU) in Australia) for assistance.
Data uploaded to DataVerse	To be completed by August	All materials have now been harvested; data is mostly processed; analysis either done and/or in progress and readied for uploading	Once meta files are completed, we will be able to upload data to DataVerse.
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August	Data sets to be submitted are the same as the ones described above and already summited to IFPRI for uploading	All explanations have been provided separately in FtF reporting document. Generally positive and mostly over-achieved.

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

Approaches to strategically use scarce N fertilizer resources must be at the fore, especially for risky rain-fed environments. This study (in its third year) is driven by economic considerations for N use – application of more N when rainfall conditions are favourable for high productivity or withdrawing N side-dressing application when rainfall is sub-optimal. We have treatments with a range of 'fixed' N application strategies, in which the intended N application rate is followed through irrespective of rainfall season quality. We contrast this with a more pragmatic N application strategy that is linked to rainfall season with consequent variable application.

Strategic application of low rates of side-dressing N fertilizer achieved equal or more maize yields when compared to several fixed N application options (Figures 34 and 35). This form of response farming results in high N use efficiency, and farmers have an opportunity to withhold N fertilizer application in case of drought. Farmers stay on the farms; thus, can quickly respond to rainfall events. Where several small N fertilizer splits become necessary, this technology is associated with increased labor demands. Also, other sources of N such as urea, that have a mineralization lag time, are not suitable for this technology. Only inorganic sources of N such as calcium ammonium nitrate or ammonium nitrate will be suitable for this technology.

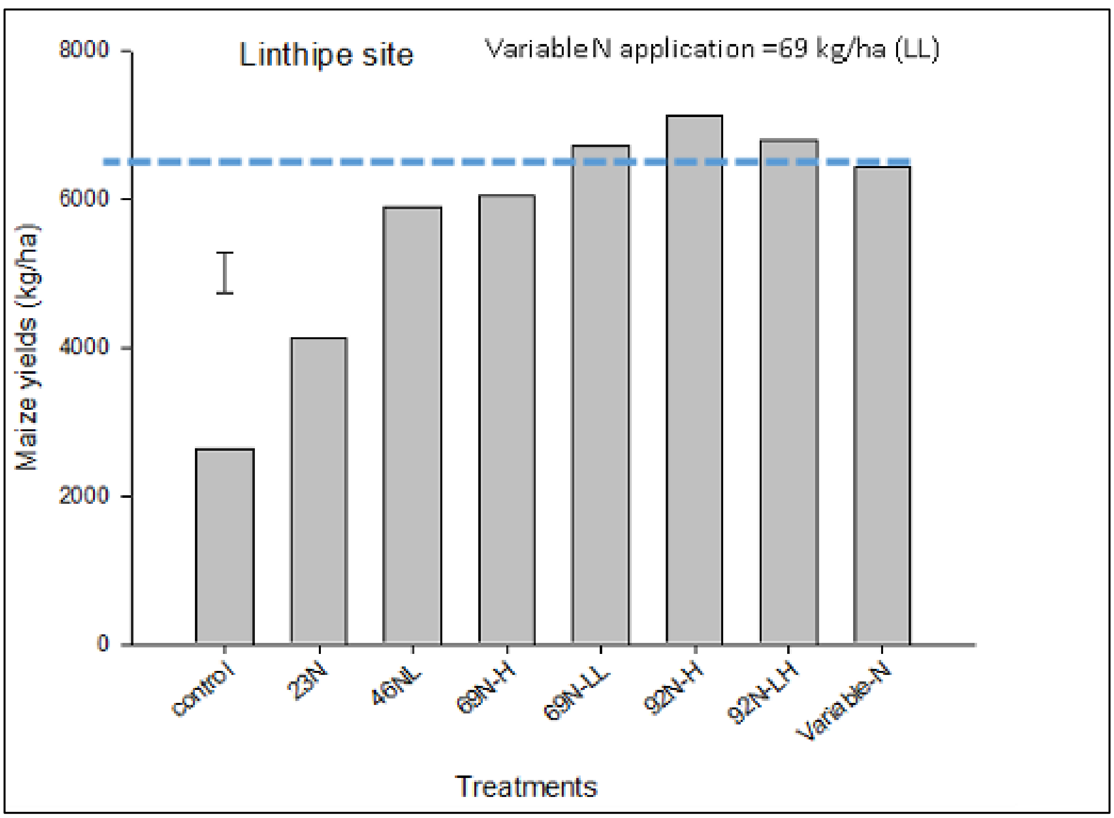


Figure 34. Maize productivity under several fixed N management strategies and the variable precision N application strategy for Linthipe site during the 2019/2020 cropping season.

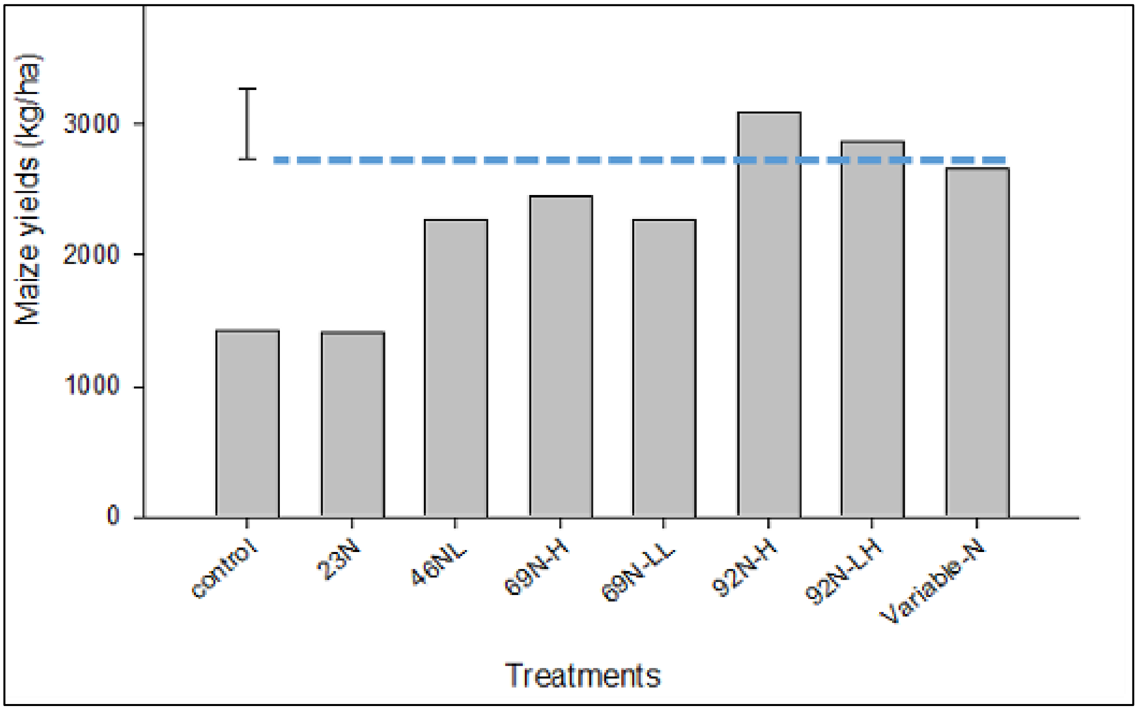


Figure 35. Maize productivity under several fixed N management strategies and the variable precision N application strategy for Msanama site during the 2019/2020cropping season. Variable N applied = 40 LL (non-fixed timing).

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
Field experiments established	Four field experiments were established in Linthipe, Ntubwi, Nsanama, and Nyambi extension planning	All trials were harvested during March and April 2020; all data processed	
Field days held with partners; DAEC disseminates promising results	Three field days with themes that covered different sub-activities were held; reports are being prepared	No further field days were held	
Soil water and nutrients use interactions assessed	Data collection is in progress	Data processed and partially presented here (Figures 28 and 29)	
Data uploaded to DataVerse	To be completed by August 2020	Data submitted for upload	
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August 2020	FtF data submitted to M&E officer	

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

Five nutrient, water, and residue management trials were established in the same EPAs as in 5.1.3.1. The trial has 12 treatments designed to address the questions:

1. Does incorporating soil water enhancing technologies increase/reduce the immobilization potential of maize residues?
2. What is the effect of varying the quantity of the crop residues incorporated (both maize and legumes) on mineral N dynamics, soil water content and maize productivity?
3. For farmers with limited fertilizer use (50% NP), how detrimental is use of maize residues (X0, X1, X2), with or without water conservation measures?
4. What is the fertilizer substitution value of different quantity residues generated from a groundnut/pigeon pea doubled-up system?

The following are the main findings from this study:

- With no fertilizer applied, incorporation of maize residues depressed maize yields, especially in the high rainfall Linthipe site (Figure 36);
- Tied ridges resulted in yield gains in some sites (e.g. Linthipe) and yield losses in Kandeu (data not shown), a site that has usual water logging problems due to a microclimate induced by a mountain range nearby; and
- The doubled-up legume technology had a particularly positive effect in Ntubwi site (Figure 37). Farmers who have poor access to N fertilizer resources should benefit from this technology.

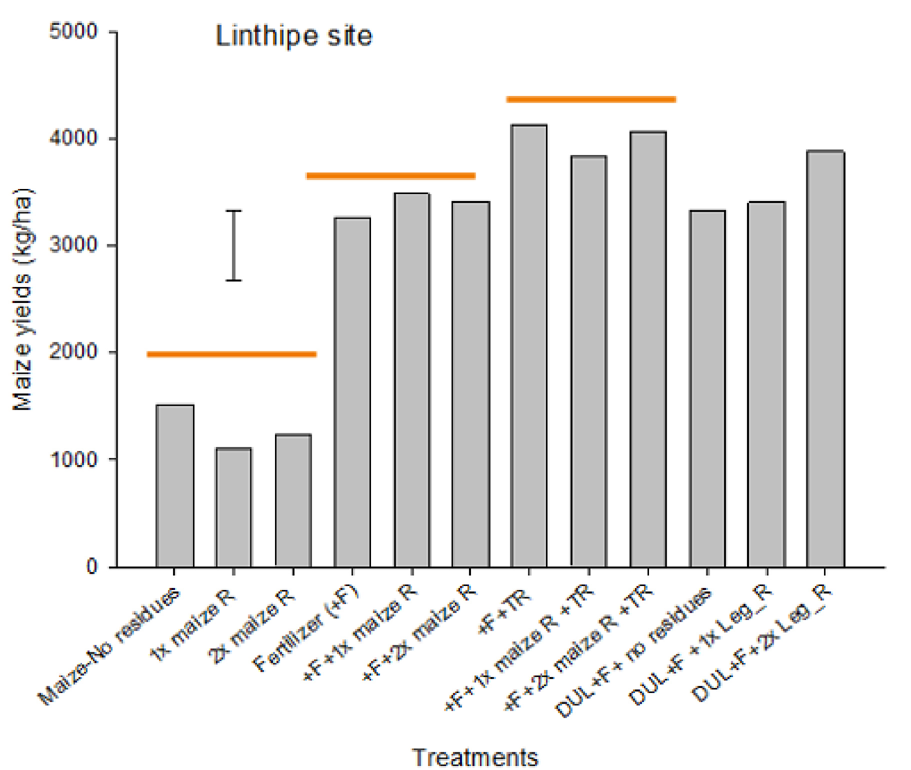


Figure 36. Effect of residue quality (maize or DUL residues), quantity (0,1x or 2x), and water management (ridges or tied ridges) on maize productivity at a site in Linthipe.

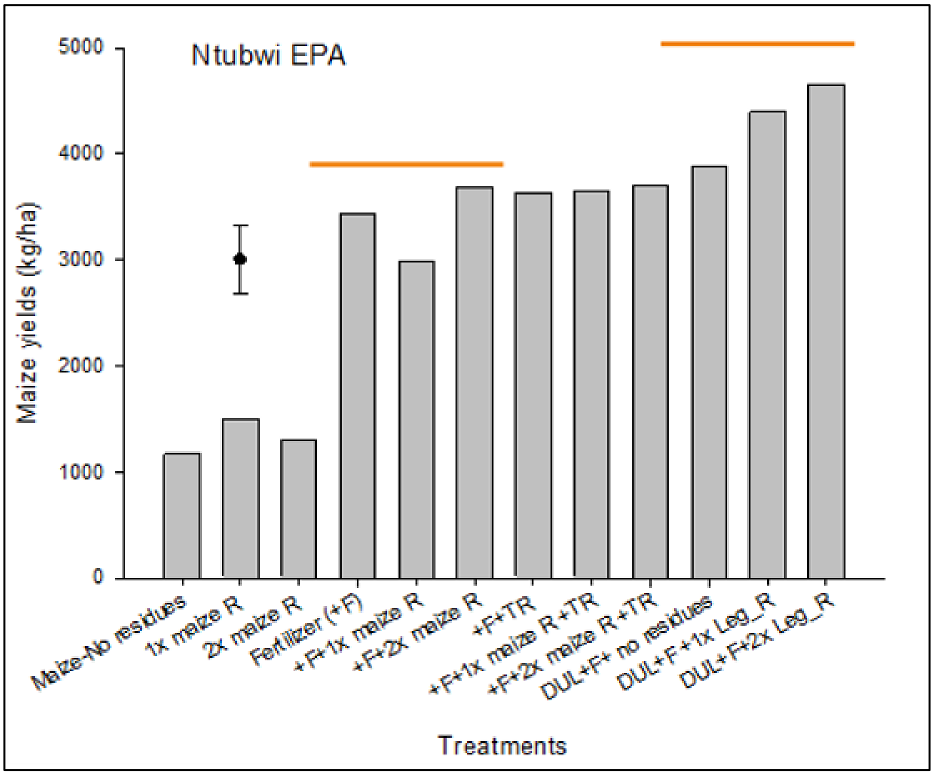


Figure 37. Effect of residue quality (maize or DUL residues), quantity (0,1x or 2x) and water management (ridges or tied ridges) on maize productivity at a site in Ntubwi.

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

Field experiments installed in 2019 to assess the integrative effect of *in-situ* rainwater harvesting and fertilizer micro-dosing on crop yield, water and nutrient use efficiency, were replicated in 2020 to collect the second-year data. One mother plot and two baby plots were established in Molet Village, one more mother plot and five baby plots in Mlali Village, and two baby plots in Sagara Village. Combined season x environment data analyses are being conducted for a publication. For this report, we observed that rainfall from the 2019/20 cropping year was much more than that of the 2018/19 cropping year.

***Effect of tied ridges and fertilizer micro doses on maize sole crop performance*.** Both maize grain and biomass yield increased with increasing fertilizer dose from 0 to 20 kg N/ha at all research sites in Mlali and Molet villages. However, the takeaway observation is that under high rainfall seasons and relatively steady soil water availability, tied ridges may result in productivity declines if the ridges are not drained to reduce excessive water in the root zone (Figure 38). The ponding effect in the tied ridges was also observed in the maize/groundnut intercrop system, while data for the maize/pigeon pea intercrop is not yet available because of late harvest of pigeon pea.

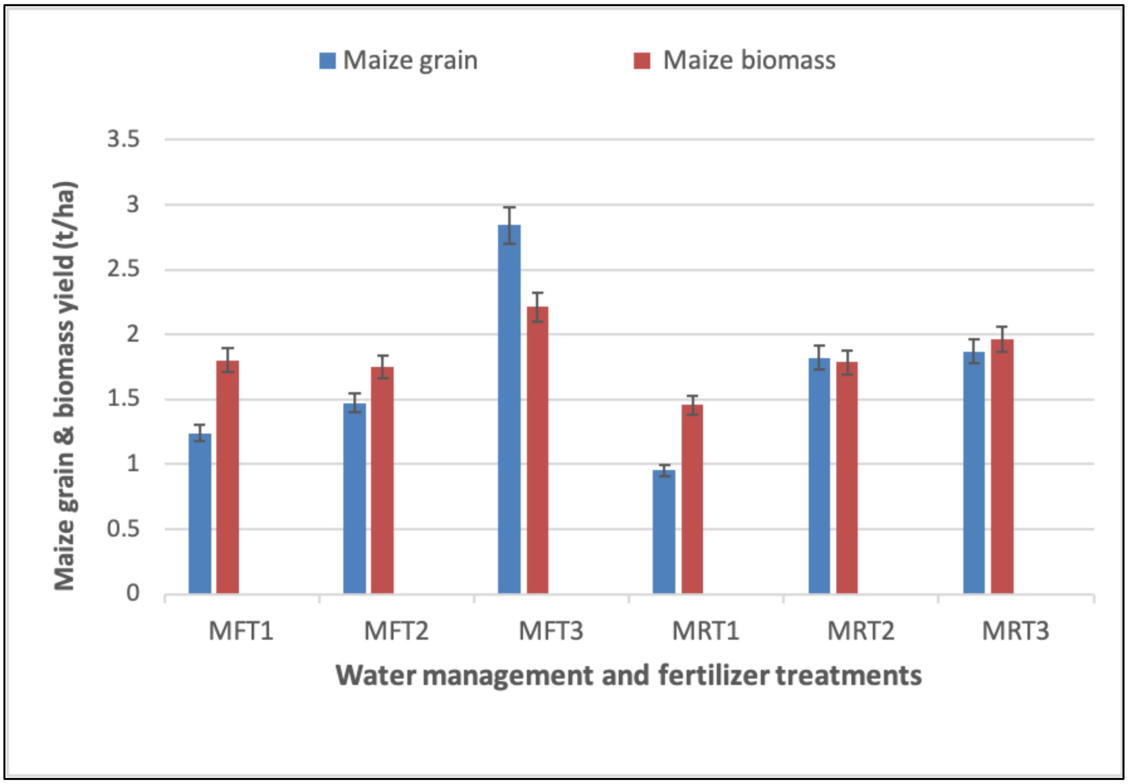


Figure 38. Effect of water management and fertilizer doses on maize sole crop yield - Mlali site. *MF= Maize sole crop on flat bed; MR = maize sole crop on tied ridges; T1 = 0 Kg of N and P/ha (control); T2 = 10 Kg N and P /ha; and T3 = 20 Kg N and P/ha*

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
Effect of integrating *in-situ* rainwater in harvesting and fertilizer micro-dosing on the productivity, water, and nutrient- use efficiency of maize-pigeon pea and maize-groundnut evaluated	Two mother trials were established instead of three because of budget limitations under the no-cost extension. Sagara site is being managed as a baby trial. Data collection is in progress.	Field (grain and biomass yield) data collection completed for maize and groundnuts Pigeon pea grain yield data collection extended beyond September	Delayed ripening of pigeon pea was a result of extended rains
Data uploaded to DataVerse	To be completed by August 2020	Not uploaded	Laboratory analysis results delayed computation of nutrient uptake and use efficiency
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August 2020	Submitted	

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

ILRI – Report not available despite reminders.

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

ILRI – Report not available despite reminders.

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)

For the testing of the FarmMATCH algorithm, we have continued with the conversion and improvement of the ARBES data files for Tanzania and Malawi. These data have been entered into a relational database (RDB). Variables were selected from this RDB and combined with GIS-based spatially explicit socio-economic and biophysical data. The combined dataset is being used to test the matching of selected technologies. For testing purposes, we derived the technologies from the ARBES dataset, but we also created artificial "technologies" to allow for a more systematic and effective testing of machine learning algorithms. And with this approach, we can see the effects of the different data sources and attributes on the matching result. The testing and further development of the matching algorithms is ongoing. The combined RDB database has been shared with other project researchers and can be used to parameterize a large number of farms in a whole-farm model for further analysis.

Exploration using the FarmDESIGN model for alternative farm plans revealed that there was room for improvement for both farms in all the three objectives (Figure 39). Substantial synergistic improvements could be obtained before a trade-off frontier would be encountered, particularly for the higher resource endowed (HRE) farm. In contrast, the lower resource endowed (LRE) farm would have considerably less opportunity to improve performance before approaching a trade-off frontier. The trade-off frontiers were apparent for socio-economic indicators of both farms as eventually, more operating profit was linked to less leisure time (Figure 39c). Likewise, for the LRE farm, a trade-off was noticeable between household leisure time and soil organic matter (SOM) balance (Figure 39b). Nonetheless, there were also synergies between SOM and profit (Figure 1a) for the LRE farm. Moreover, a generally synergetic relation was evident between SOM and leisure time objectives for the HRE farm (Figure 39b).

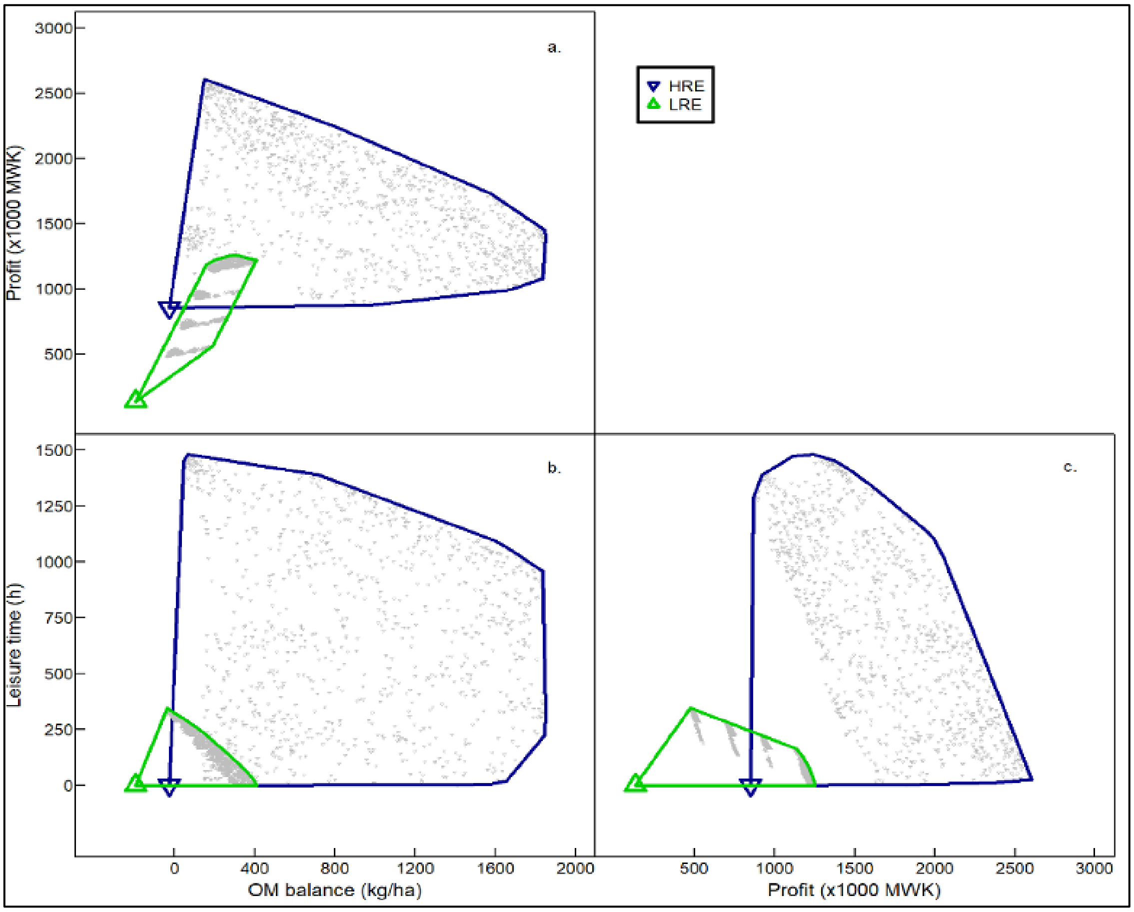


Figure 39. Relationship between farm performance indicators for the HRE and LRE farms, showing trade-offs and synergies. The smaller triangles indicate the original farm configurations.

Using Q-methodology, three farm types were distinguished based on the preferences and perspectives of farmers regarding sustainable intensification. The distinguishing statements are listed in Table 28.

Table 28. Distinguishing statements for each farmer-type (Q group) and the sorting criteria derived for each group (from the best hundred solutions for each group from the FarmDESIGN exploration results) to come up with the preferred solutions per perspective

Q Group	Distinguishing statements	Sorting criteria
Food focused	I would plant one seed of maize per planting station even though it is labor-intensive to improve my yield. (4) I am willing to work more hours on my farm to attain food-self-sufficient rather than work off-farm for immediate but short-lived gains. (0) I would burn crop residues to save on time and labor	Sort for area current crops (highest to lowest) Sort for leisure time (lowest to highest) Sort for SOM (highest to lowest)
Profit Oriented	I am willing to grow legumes in addition to the staple crop maize to improve food self-sufficiency. (3) I am willing to add new crops to increase profitability despite having to work more hours. (1)	Sort for OP (highest to lowest) Sort for new legume area (highest to lowest) Sort for SOM (highest to lowest)
Labor constrained	I am willing to increase number of chicken as they do not require much labor and do not compete for crop residues with the field (0) I would plant one seed of maize per planting station even though it is labor intensive to improve my yield. (-3)	Sort for livestock number (highest to lowest) Sort for leisure time (highest to lowest) Sort for new crop areas (highest to lowest)

The numbers in parenthesis are the Q grid positions for each statement.

Figure 40 displays the preferred 100 solutions for each solution combination, based on the sorting criteria presented in Table 28. There was an overlap between the ‘Food-Focused’ and ‘Profit-Oriented’ groups in desirable sets of solutions (Figure 40). These two groups, however, differ in crop preferences. The Profit-Oriented group is willing to add legumes to the cropping plan to enhance their profits. On the other hand, the Food-Focused group is willing to adopt solutions that do not require much change to the area of existing crops. The Labor-Conscious group was quite different from the other two groups. They considered labor when making choices. Farmers in this group preferred solutions that would leave them with more leisure time and would prefer to add livestock to their farms.

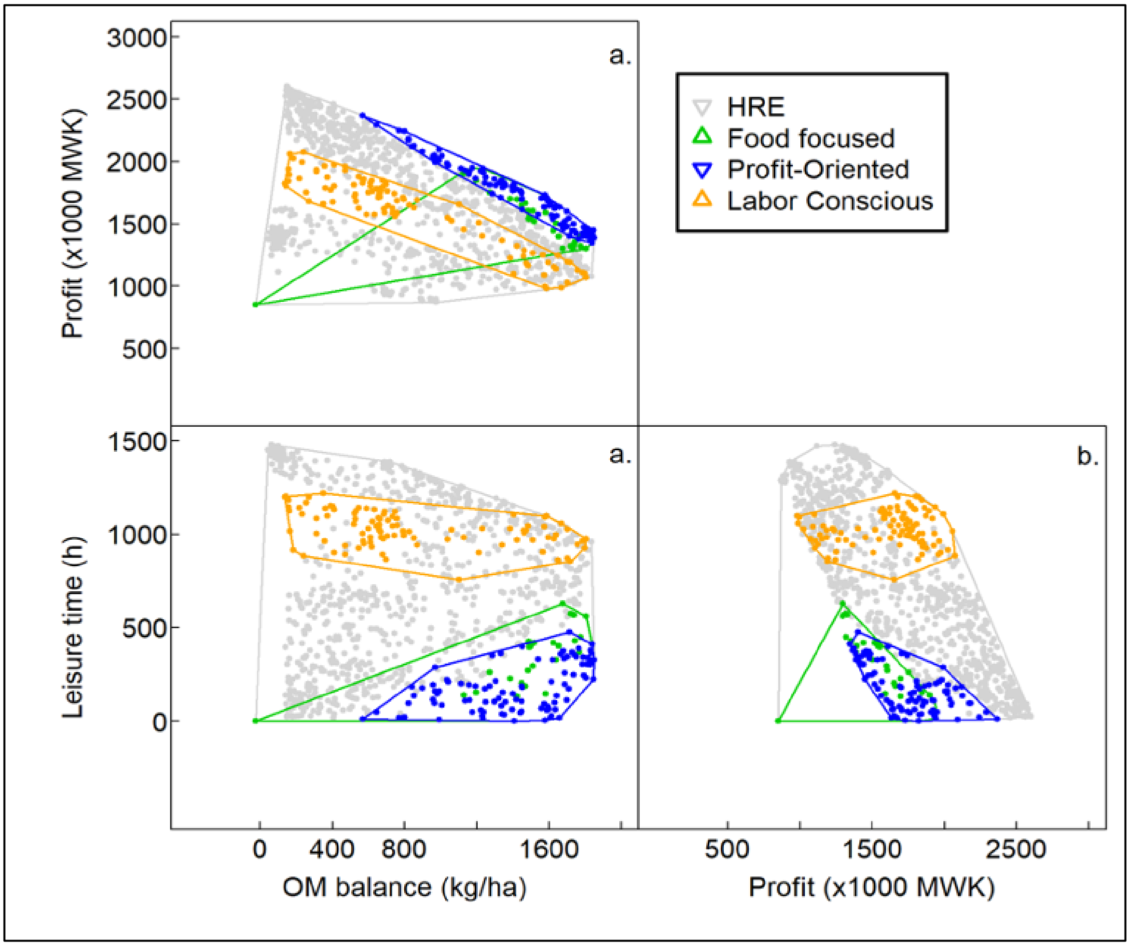


Figure 40. Solution space for the HRE farm with the 100 preferred options for improvement for the Food-Focused, Profit-Oriented, and Labor-Conscious farmers given their stated preferences for farm development (Table 28).

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
Journal article	The draft paper will be completed by 1 Oct 2020	Under development	New deadline - 31 March 2021
MSc student thesis	Change of delivery to a technical report that will be written by a software engineer and a senior researcher	Under development	Software engineer did not finish due to COVID-19-related disruptions before departure.
Data and algorithms in DataVerse	The relational database has been constructed; prototype app to test targeting has been developed	Have been submitted for entry into DataVerse	
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August	Reported	

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

Socio-economic assessments of the profitability of CA systems are ongoing but some key data are already provided (Table 29). The data shows strong economic benefits of growing crops under CA due to reductions in farm labor for planting and for weed control. Other key economic indicators show higher rates of returns, increased returns to labor, and a shorter payback time.

Other key indicators were derived from previous and ongoing surveys. The data from 2012 and 2019 show that there has been an improvement in crop diversification measured by the Crop Diversity index in all intervention areas (Figure 41). This has positive side-effects on household nutrition and diversity of the diet. A relatively large number of households are in the borderline to acceptable range of food consumption. Only Salima still has a great number of people under the poor food consumption category. Nevertheless, in the last eight years, there have been positive changes in getting people out of food insecurity, as measured by the Household Food Insecurity Access Score (Figure 42), with great progress evident in Lundazi and Chipata.

Table 29. Net-benefits of CSA technologies promoted in Southern Malawi and Eastern Zambia

Region	**CSA technology Net-benefits US$ ha^{-1}**			
	CP MZ + Gnuts/ PP rotation	**CA MZ + Gnuts/ PP rotation**	**CA MZ/PP int. & Gnuts/PP rotation**	
Southern Malawi	1145	1785	1673	
	CP Sole MZ	CA Sole MZ	CA MZ + Legume rotation	CA MZ + Legume int.
Eastern Zambia Manual System	422	626	618	281
Eastern Zambia Animal traction system	563	582	1099	

Note: CP = conventional tillage practice; CA = conservation agriculture; MZ = maize; PP = pigeon pea; Gnuts= groundnuts; int = intercropping

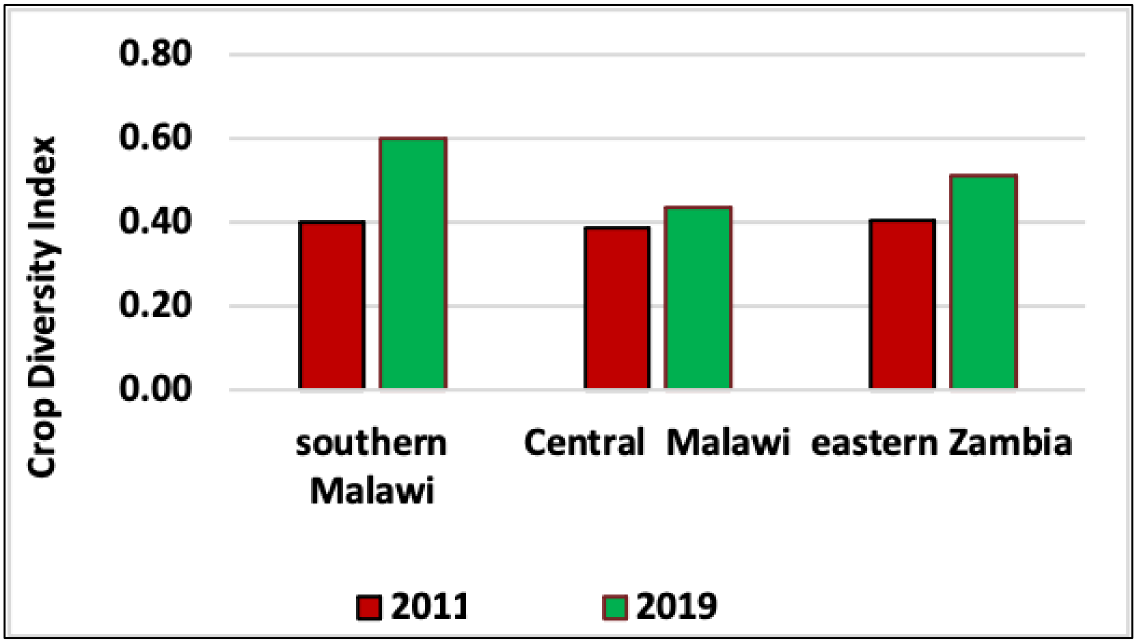


Figure 41. Crop Diversity Index measured at two time periods during the trial period (2011 and 2019)

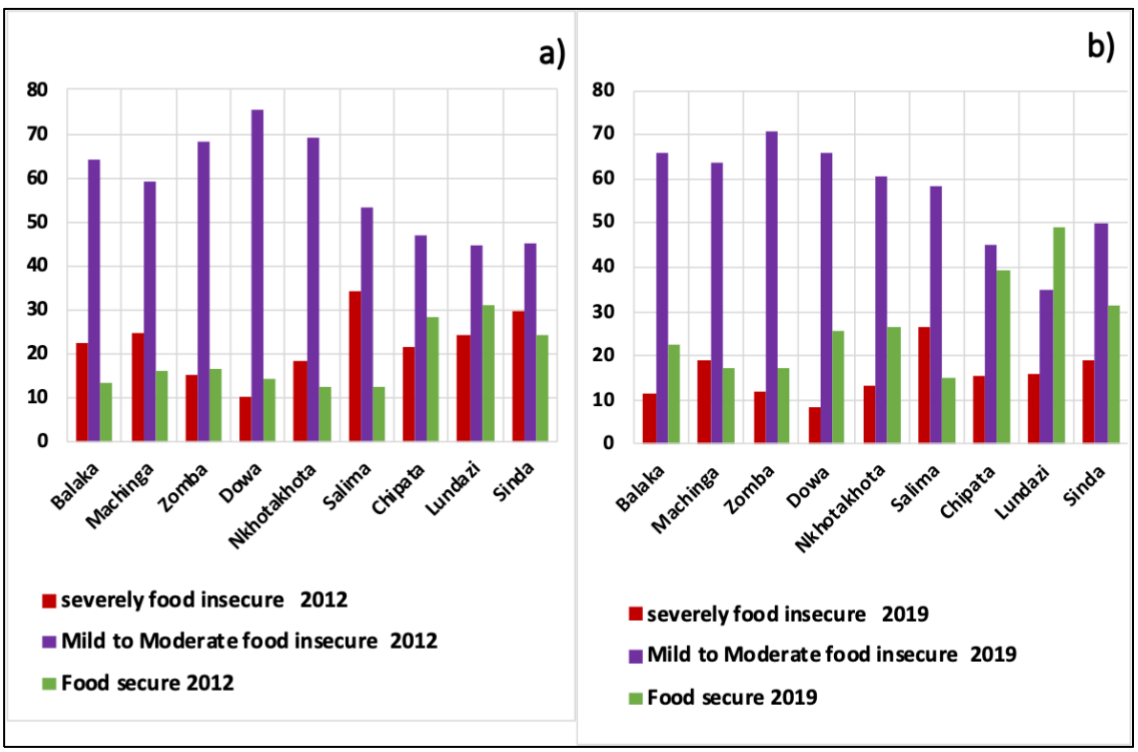


Figure 42. Status of Food Security measured by the Food Insecurity Access Score (HFIAS) at two time periods during Africa RISING research, 2012 (a) and 2019 (b).

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
PRA survey conducted	Protocols were developed (https://bit.ly/2Rp7T3B) but activity is currently delayed. It is expected to resume between June-August 2020.	Two PRAs were conducted and a third could not be completed due to COVID-19.	Delayed
Survey data analyzed	Activity is currently delayed. It is expected to resume between June-August 2020.	Data are still incomplete, and activity not finalized due to COVID-19.	Delayed
Field data analyzed and presented in meetings	Activity is currently delayed. It is expected to resume between June-August 2020.	Data are still incomplete, and activity not finalized due to COVID-19.	Delayed
Publications		A publication idea was developed and will be pursued looking at the economic benefits of some of the systems.	Delayed
Upload data to DataVerse	Activity is currently delayed until data is collected.	Socio-economic data not uploaded yet.	Delayed
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August 2020.	Completed	No deviation

Sub-activity 5.1.7.2: Innovative farmer survey applying SI principles in CA long-term trials in Malawi and Zambia

This activity could not be completed due to travel and meeting restrictions imposed by the Governments of Zimbabwe, Zambia, and Malawi due to COVID-19. We hope to capture this important data in 2020/2021 through CIMMYT's communication specialist and counterparts at IITA.

Sub-activity 5.1.7.3: Assess the effect of tied ridging, RTR, and rip tillage on maize productivity, net crop returns, household income, and food security

The main objective of this study was to examine the effect of TR/RTR, rip tillage, and fanya-juu' terracing on maize productivity, net returns, household income, and food security among the farmers using the technology. To this effect, a survey covering two districts of Kiteto and Kongwa, and involving 578 participants, was conducted to assess the level of adoption of these technologies and their impact on productivity, income, and food security. The survey was conducted later than planned because of COVID-19. Preliminary analysis of the results, targeting a publication, are described below.

Sources of SWC technology information. About 50% of the farmers reported that they obtained information on soil and water conservation technologies from friends, relatives or neighbors (Table 30). Another important source of information was the Africa RISING project (33%) and government extension agents (8.5%). This is plausible because the AR project has been conducting demonstration trials, and to some extent, promoting these technologies in the survey areas. Government extension agents also play an important role in the spread of improved agricultural technologies partly because they regularly interact with farmers.

Table 30. Sources of SWC information

Source of technology information	% farmers
Government extension	8.46
Farmer Coop/Union	1.71
Farmer group	3.15
NGO/CBO	3.87
Africa RISING	32.76
Relative/ Neighbor	49.59
Radio/ newspaper/ TV	0.27
Others	0.18
Total	**100**

Reasons for low adoption of SWC technologies. Several sampled households indicated that the high skill requirement or knowledge and the amount of labor required to implement SWC technologies were the main reasons (27%) for not adopting these technologies (Table 31). SWC technologies are generally labor-intensive and this has been cited as the major impediment for adoption by some previous studies (e.g., Fontes, 2020[12]; Kato et al., 2011[13]). About 21%

[12] Fontes, F.P., 2020. Soil and Water Conservation technology adoption and labor allocation: Evidence from Ethiopia. World Development. 127, 104754.

[13] Kato, E., Ringler, C., Yesuf, M., Bryan, E., 2009. Are soil and water conservation technologies a buffer against production risk in the face of climate change? Insights from the Nile basin in Ethiopia. Agricultural Economics. 42, 593–604

indicated that they were content with the farming practice they are currently using while 11% mentioned that SWC technologies were expensive.

Table 31. Reasons for not adopting SWC technologies

Reason	% farmers
Technology not available	0.77
Lack of cash/credit	6.91
Requires high skills	27.45
Satisfied with current practice	20.73
Expensive	11.13
Labor Intensive	27.45
Not enough land	3.45
Land is rented	1.34
Total	**100**

Adoption of soil and water conservation technologies. In this study, farmers were considered to have adopted SWC technologies if they allotted land to these technologies. Figure 35 shows the proportion of land under fanya juu (Swahili for 'throw uphill') terraces, ATR, RTR, and rip tillage, in other words, a proxy for the intensity of adoption of the S&WC conservation technologies. On average, about 13% of farmers adopted fanya juu terraces, 11% tied ridging, and 51% rip tillage. Only 7% adopted RTR on the average possibly because this technology is fairly new as compared to the others (Figure 43).

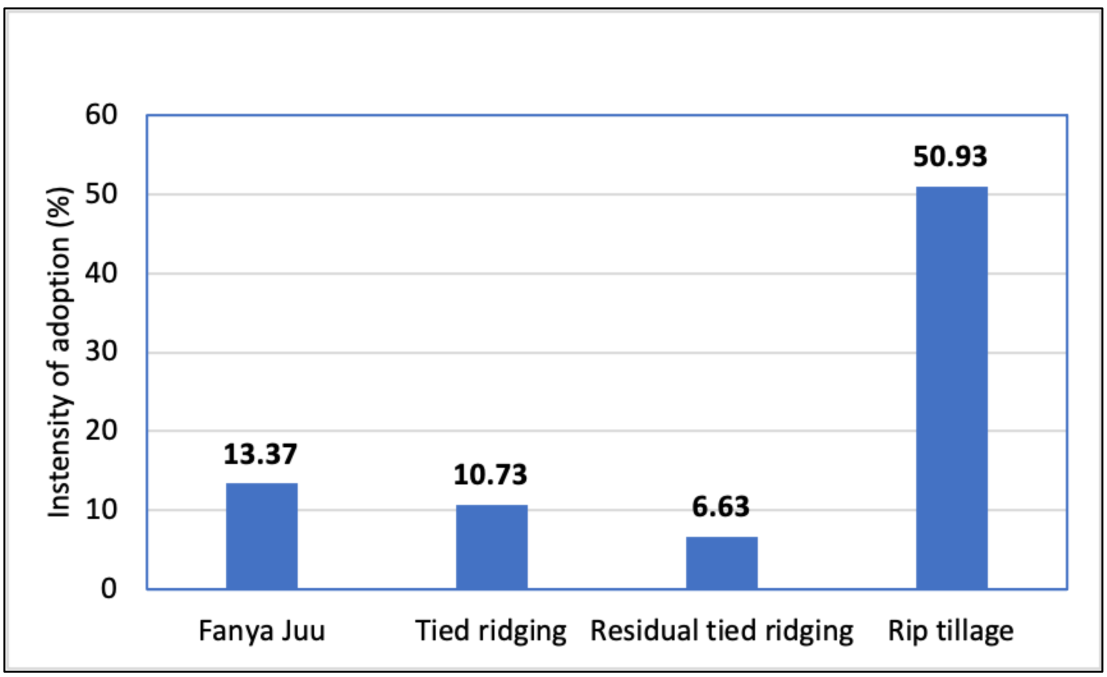


Figure 43. Intensity of adoption of soil and water conservation technologies.

Diffusion of SWC technologies. Adoption and diffusion of agricultural technologies are very complex, time-dependent, and can be influenced by the characteristics of the technology and socio-economic factors. In the technology adoption–diffusion process, farmers pass through different phases such as awareness, persuasion, decision, adoption, and the post-adoption evaluation. Information is sought at all these stages to reduce risk and uncertainty about the usefulness of the technology. Relatively very few farmers adopted SWC between 1980 and 1989 (Table 32), partly attributed to inadequate information of the benefits of these technologies available during this period. There was, however, an increase in the number of farmers adopting these technologies between 2000 and 2009 (12%) and the highest increase was observed between 2010 and 2020 (80%). It was during the time when most of the farmers became aware of the SWC technologies. It was during the 2010-2020 period when Africa RISING was active in testing and demonstrating the SWC technologies in the study districts.

Table 32. Year of first SWC implementation on farm (% of farmers)

Years	% of farmers
1980-1989	1.36
1990-1999	4.41
2000-2009	12.22
2010-2020	80.31

Stochastic dominance analysis for the maize yield distributions. In Kiteto and Kongwa districts, maize is the most important staple food; hence, SWC technologies are mostly applied in maize fields. The results in Table 30 suggest that the differences between adopters and non-adopters of the SWC technologies are reflected in increased maize yields. The results from the stochastic dominance analysis (Figure 44) confirmed this. The cumulative distribution functions (CDFs) for maize yield for the adopters of SWC technologies dominate those of the non-adopters at all yield levels, except for the rip tillage technology. This implies that there is a significantly higher probability that if randomly chosen, an adopter of fanya juu terraces, tied, and RTR will have higher maize yields than a non-adopter.

Table 33. Maize yields by the adoption of soil and water conservation technologies

Soil and water conservation technologies	Maize yield (kg/ha)		Difference
	Adopters	Non-adopters	
Fanya Juu terraces	1044.38	748.87	295.51***
Tied ridging	962.47	772.42	190.06 **
Residual tied ridging	1032.04	774.83	257.20**
Rip tillage	831.13	741.30	89.82

Note: * p<0.10, ** p<0.05, *** p<0.001

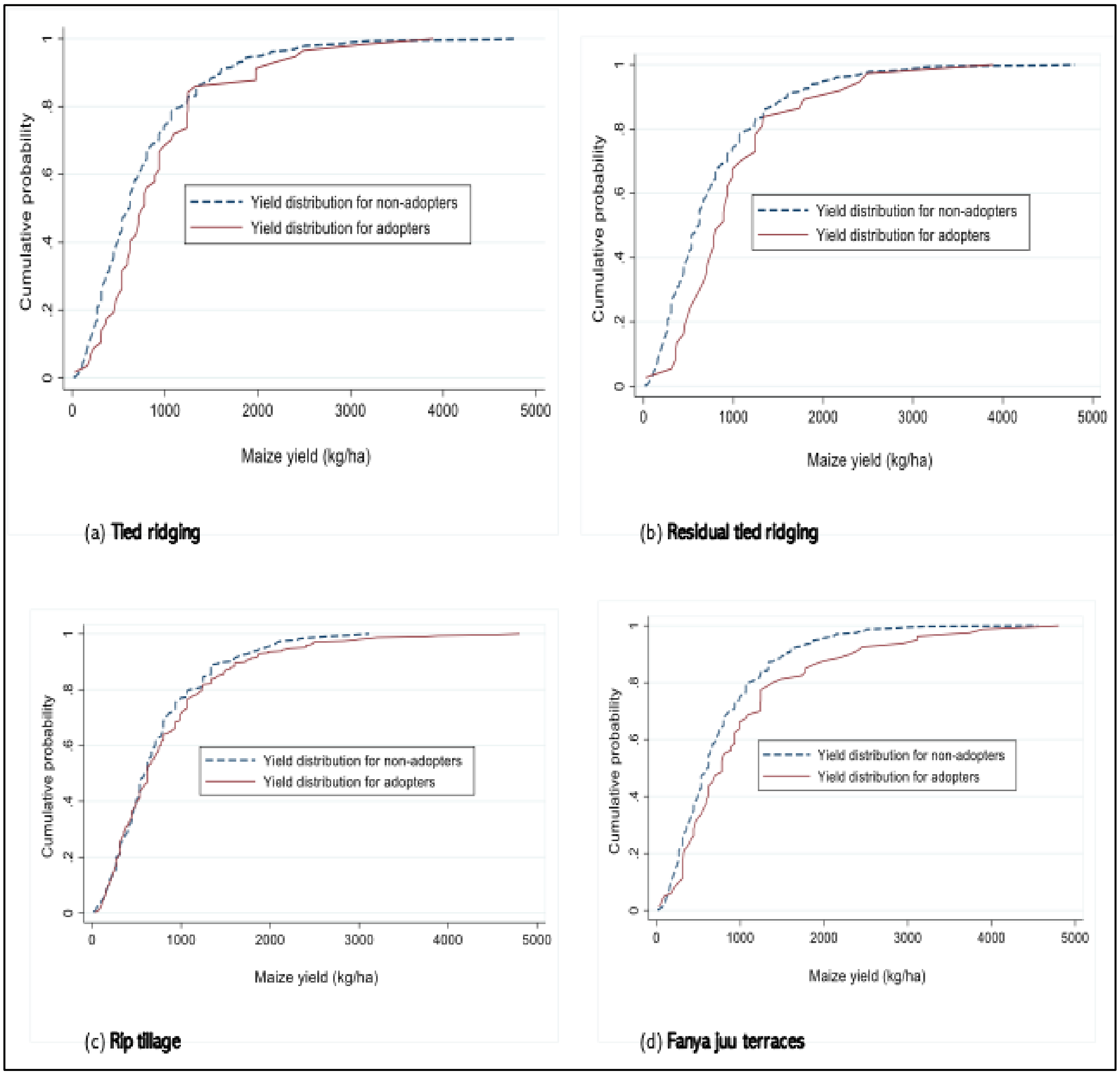


Figure 44. Cumulative distribution functions of maize yield for adopters and non-adopters of SWC technologies.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviations & explanation
Socio-economic and community factors affecting the use and non-use of tied ridging, residual tied ridging, rip tillage, and fanya-juu terracing identified	• Household questionnaire design completed • Questionnaire currently being programmed into survey • Sampling design and enumerators identified	• Survey conducted involving 578 households and 1025 plots • Preliminary adoption results analyzed	By this time, final results from the survey should have been analyzed. However, the COVID-19 outbreak delayed the field implementation of the survey.
The effect of tied ridging, residual tied ridging, rip tillage, and fanya-juu terracing on maize yields, net returns, household income, asset ownership and food security analyzed	• Household questionnaire design completed • Questionnaire currently being programmed into survey • Sampling design and enumerators identified	• Survey conducted involving 578 households and 1025 plots • Preliminary adoption results analyzed • Preliminary unconditional impacts of SWC technologies on yields analyzed	By this time, final results from the survey should have been analyzed. However, the COVID-19 outbreak delayed the field implementation of the survey.
Data uploaded to DataVerse	To be completed by August	Data will be uploaded to DataVerse by August 2021 after data cleaning is completed.	The data should have been uploaded by August 2020. However, COVID-19 outbreak delayed the survey and subsequent data organization.
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August	Data will be submitted to M& E by August 2021.	This will be submitted by August 2021 after data analysis.

Sub-activity 5.1.7.4: Determine the effect of the joint adoption of improved maize varieties and maize-legume rotation on maize productivity and crop incomes in Malawi

In Malawi, the AR project has been testing and promoting SI practices in the quest to improve soil fertility, maize, and legume productivity among others. The main objective of the study is to examine the effect of the adoption of a combination of improved maize varieties and maize-legume rotation on maize productivity, maize, and crop incomes in Malawi using panel data. The data for the analysis will come from the plot and household panel data surveys conducted by Africa RISING from 2015-2018 in Malawi in Dedza, Mangochi, and Ntcheu districts involving over 300 households and 1000 plots[14].

Considerable progress had been made with regards to data cleaning, data organization, and variable generation. The data consists of four rounds of surveys and so far, data from two surveys (2015 and 2016) have been cleaned and some variables have been generated. Data analysis based on the two survey data sets has commenced. It is envisaged that other data from follow-up surveys (2017-2018) will be cleaned by the end of December 2020. The table below shows the targeted deliverables for 2019/2020 and status on achievements.

[14] Wang, H., Snapp, S.S., Fisher, M. and Viens, F., 2019. A Bayesian analysis of longitudinal farm surveys in Central Malawi reveals yield determinants and site-specific management strategies. PloS one, 14(8), p.e0219296.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviations & explanation
The yield and income effects of the joint adoption improved maize and maize-legume rotations identified	Data organization and cleaning underway	Data from two surveys (2015 and 2016) have been cleaned and some variables have been generated. Preliminary data analysis has commenced.	Delays in obtaining the remaining data sets affected the variable generation process and analysis. The data will be shared after the analysis is completed. This applies for all other deliverables.
Validated land productivity and plot size inverse hypothesis	Data organization and cleaning underway	Data from two surveys (2015 and 2016) have been cleaned and some variables have been generated.	
Data uploaded to DataVerse	To be completed by August 2020	Data from two surveys (2015 and 2016) have been cleaned and some variables have been generated.	
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August 2020	Data from two surveys (2015 and 2016) have been cleaned and some variables have been generated.	

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

During the reporting period, we focused on the completion of partnership agreements for lead agencies and last mile partners. Two MOUs with DASPA and KFS will lead collation and aggregation of improved seed and/or grain while the three Community Seed Bank groups [Laikala (Umoja ni Nguvu); Mlali (Vindulwe); and Moleti (Kwimage)] are last mile delivery agencies. The agri-innovations developed by the team will be produced, scaled-up, and made available to farming communities of the semi-arid sub-agroecologies of central Tanzania. These three community seed banks will provide scaffold for further seed value chain studies on either dryland cereals and legumes, including taking a deeper dive on linkages with gender and nutrition.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation& explanation
Meeting held to agree on the MOU terms involving DASPA, TARI/ICRISAT, and respective DAICO's of Kongwa and Kiteto districts	Meetings were held on 29 December: Extension personnel and farmers training on principles of trial establishment and crop management/agronomy - Dodoma, Tanzania; and on 13 January: Kongwa Kiteto partners meeting with Dodoma Agricultural Seed Producers Association (DASPA)- Dodoma. MoUs have been drafted but not formalized.	No further meetings were held.	None
Farmer groups mobilized and engaged for the activity with a target to reach at least 4000 farmers	Meeting with private sector actors was held on 26 February: Meeting between Community Seed Bank Lead Farmers, Dodoma Agricultural Seed Producers Association (DASPA) and Kibaigwa Flour Supplies Company (KFC) - Dodoma, Tanzania	No farmer mobilization was done because: (1) it was off-season; and (2) institution implemented travel restrictions due to COVID-19.	None
Stakeholders trained on community seed banks especially for pigeon pea production	Only lead farmers were engaged, but the membership was not trained due to the COVID-19 lockdown	No stakeholder training was conducted due to COVID-19-realated restrictions.	None
Monitoring, training, and partnership support	Limited monitoring and support – This is ongoing only via telephone with village extension personnel and lead farmers	This was conducted by our field staff to monitor crop development and handle harvesting of grains. We also engaged host farmers to collect field data but this to was limited.	We were not able to reassemble data from most of the host farms (baby trials).
Data uploaded to Dataverse	To be completed by August	All materials have now been harvested; data is mostly processed; analysis either done and/or in progress and	Once meta files are completed we will be able to upload data to DataVerse.

		readied for uploading. Final description of the meta files is ongoing but encountered delays due to late receipt of some data sets	
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August	This was submitted separately and is uploaded by IFPRI.	All explanations have been provided separately in FTF reporting document.

Sub-activity 5.2.1.2: Summary from other partner engagements

- WorldVeg has linkages with Mboga and Matunda (MnM) project and TAHA in Zanzibar and Arusha. These projects have benefited from nutrition materials and scaling technologies validated during Africa RISING Phase 1 in Zanzibar.
- A to Z Textile Mills – manufacturers of hermetic storage bags, drying tarpaulins, and Aflasafe® (pre-harvest aflatoxin control product) (http://azpfl.com/index.php/en/) was our private sector partner that provided postharvest management inputs – hermetic bags.
- IITA's Aflasafe® project provided training materials on aflatoxin management.
- SERVIR-Africa project, hosted by RCMRD in Nairobi, Kenya, provided a land cover map that was used in assessing changes in land cover changes for sub-activity 1.3.1.3.
- CIAT is working in partnership with Babati District Council and with both Meru-Agro and Minjingu Fertilizer Company. We have maintained the relationship with TARI-Arusha who are involved in data collection and farmer training activities. A strong partnership has been created with East Africa Region Impact Centre (ECHO Community)- Arusha where both institutions are co-working in assessing the performance of lablab cover crop and its acceptability by farmers in Babati.
- CIMMYT has maintained a partnership with most organizations previously involved with the work (ZARI, GRT, TLC, Governmental extension services in Malawi and Zambia) and has established a new alliance with the Sustainable Intensification for Smallholder Farmers in Zambia (SIFAZ) project. In Eastern Zambia, this has led to the re-initiation of six additional target communities with SIFAZ funds, which follow similar research ideas and follow the success and experiences gained previously. In addition, CIMMYT has started interacting with FANRPAN, a policy network that might help in future projects targeting regulatory authorities.
- Building capacity for resilience food security project (CBfSRP) in Tanzania. Collaborations for supporting graduate students (Leah Renwick, Johannes Hafner and Martha Swamila) were made.
- The DAAD in country PhD program is managed through ICRAF and supports Martha Swamila since 2017. Martha also received partial financial support from the CBfSRP and the DAAD program.
- The discussion to develop MoU between ICRAF and Sustainable Agriculture Tanzania (SAT) for out-scaling agroforestry technologies was finalized at the end of August after being curtailed by COVID-19-related travel and meeting challenges. The process to develop the MOU will continue after administrative clearance by higher authorities at ICRAF.

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

Placement of hybrids follows product licensing process and seed companies or national maize breeding programs place the allocated hybrid in national performance trials (NPT). This process has not taken place. Following engagement with seed companies, we anticipate that seed companies will take up the new maize hybrids and plan to place them in NPT during 2021.

Sub-activity 5.2.2.2: Support the Ministry of Agriculture and NGO Extension in scaling CA-systems in Eastern Zambia and Malawi

The largest number of participants in different events was recorded by Southern Malawi. Other regions scaled down meetings dramatically during the COVID-19 lockdown. Summary numbers of events have been previously reported and final numbers directly communicated with the M&E personnel.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
Evaluation meetings of technology interventions held	Early and mid-season evaluations were conducted (https://bit.ly/2Rp7T3B)	Completed All evaluation meetings conducted	No deviation
Study tours with key players conducted	Study tour plans to all sites were finalized. Implementation may depend on COVID-19 situation.	One tour completed	Additional tours could not be done due to COVID-19 travel restrictions.
Field days conducted	Field days have only been conducted in some sites; others have been suspended due to COVID-19-related restrictions.	Field days conducted in Malawi; Zambia decided to not hold field days	Slight deviation
CA systems scaled to at least 10 000 farmers in Malawi and Zambia	Different activities aimed at encouraging scaling were conducted; about 50% of the target achieved	In total, 6412 farmers participated in different events.	64% of target, final number was affected by COVID-19
Data uploaded to DataVerse	To be completed by August	Completed	No deviation
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August	Completed	No deviation

Sub-activity 5.2.2.3: Partnership with Islands of Peace (IoP) for increasing the adoption of postharvest products

During the partnership period between Africa RISING and Iles de Paix, Kilimo Enelevu (KE) (2019/2020), a strategic plan was developed 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. However, the backstopping support by IITA has ended. Thus, the IoP will complete the scaling activity on their own, having gained confidence in their scaling capacity.

The commitment areas are summarized in Table 34, together with the achievements made. The activities that received attention during the present reporting period are marked in blue. For the purpose of this report, these have been grouped and described in sections B1–B3 as follows:

1. **Section B1: Africa RISING Support Areas 1 & 6:** Estimating nutritional gains of improved postharvest handling and storage practices of maize and common beans; a compositional interpretation.
2. **Section B2: KE Action 6/Africa RISING Support Area 5:** Formulation and delivery of actionable postharvest tips that support decision making of farmers for scaling via mobile phone messaging**.**
3. **Section B3: KE Actions 3, 4, & 5:** Installation of demonstrations in new villages and initiatives to link farmers to technologies.

Table 34. Commitment areas by partners and progress

Activity	Status
KE Actions as laid out in KE scaling strategy	
Action 1: KE-led identification, training, and deployment of champion farmers as agents of scaling	Accomplished in previous reporting period (September 2019 to February 2020)
Action 2: KE-led facilitation of the formation of postharvest management subcommittees to steer scaling in the villages	Accomplished in previous reporting period (September 2019 to February 2020)
Action 3: KE-led installation of demonstrations in new villages for farmers to learn the technologies	Continued in the present reporting period
Action 4: KE-led initiatives to link farmers to technology manufacturers/suppliers	Continued in the present reporting period
Action 5: KE-led initiatives to enhance business skills of farmers in action villages	Continued in the present reporting period
Action 6: KE-led and AR-supported *e*-extension initiative to enhance scaling	Continued in the present reporting period
Africa RISING support areas	
Area 1: Refining technologies and offering technical support in training of champion farmers.	Continued in the present period
Area 2: Preparation and reproduction of training materials.	Accomplished in previous reporting period (September 2019 to February 2020)
Area 3: Preparation of protocols for installation of demos and guidelines for monitoring and collection of scaling data in new action villages	Accomplished in previous reporting period (September 2019 to February 2020)
Area 4: Attendance to follow-up actions and formulation of questions for Iles de Paix's M&E annual survey	Suspended due to COVID-19
Area 5: Formulate and deliver actionable postharvest tips that support decision-making of farmers for scaling via mobile phone messaging	Accomplished in the present reporting period
Area 6: Identification of postharvest challenges within local farmer contexts and recommendation of best practices to address them.	Continued in the present reporting period

Sub-activity 5.2.2.4: Partnership with Islands of Peace for increasing the adoption of good agricultural practices (GAP) in vegetable production and improved nutrition

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
Provide technical backstopping to IDP to efficiently scale the technologies in nine villages	A feedback meeting was held and meeting outputs were used to design training modules for the current season. Meeting reports and training modules are being prepared for upload on the AR website. Training has been suspended due to COVID-19.	A total of 34 lead farmer trainers, 10 extension officers, 5 IDP staff, 2 intern students, and 1 district representative were trained on sustainable vegetable production. http://africa-rising-wiki.net/File:Wvegmonitoringbackstopping.docx	
Data uploaded to DataVerse	To be completed by August	Not done	
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August	FtF data was submitted	

<u>Sub-activity 5.2.2.5:</u> Partnership with LEAD Foundation to take to scale soil and water management technologies in erosion-prone areas of Central Tanzania

In July and August 2020, a study was conducted in seven villages in Kongwa district currently involved on scaling of fanya juu/chini terrace under Africa RISING/LEAD Foundation partnership. Through FGDs, the researchers gathered information on challenges encountered by lead farmers during installation of the Fanya juu/chini terraces. These farmers had received training on control of soil erosion using Fanya juu/chini terraces and are responsible for the technology rollout. The challenges identified are given below.

- The technology is labor intensive and family labor was insufficient. There is a need to develop a workplan under the existing partnership to introduce voluntary group formation for installing the terraces.
- The technology requires expertise. The trained farmers did not perform well in Year 1 of the technology rollout despite provision of working gears. Continued supervision by researchers for some considerable time was considered necessary.
- Resources are required to secure equipment for the construction of the terraces (i.e., spades, mattocks, and tape measures).

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
At least 20 demonstration sites installed with Fanya juu terraces	A total of 50 demonstrations were installed.	NA	None
At least 200 hectares Fanya juu terraces coverage	A total of 328 ha were covered with Fanya juu/chini terraces.	NA	None
At least 500 farmers across four districts trained on use of Fanya juu terrace technology through LEAD/Africa RISING partnership	-	A total of 1300 farmers across participating districts in Dodoma region received training.	The lead foundation conducted training twice following demand from participating villages.
Key challenges and success on installing of Fanya juu terrace technology in erosion-prone areas of Central Tanzania identified and quantified	In progress	Field visit in participating villages revealed that farmers engaged only members of household in construction of terrace; thus was reported to be labor intensive.	None
At least 300 farmers exposed to Fanya juu/chini terrace technology during agricultural shows	-	A total of 4460 persons were exposed to soil water management interventions at Nane Nane: 734 individuals (410 females and 324 males); 8 groups 450 (92 females and 358 males); secondary schools (450 females and 620 males); higher learning institutions (806 females and 60 males)	
At least 50 LEAD Foundation staff, lead farmers, and extension personnel capacitated on installation of Fanya juu terrace techniques	-	During training of lead farmers, LEAD Foundation and 11 extension officers were trained on installation of Fanya juu/chini terrace	None
Upload data to DataVerse	To be completed by August	NA	None
FtF indicators data submitted to M&E/IFPRI for upload	To be completed by August	Done	None

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

Below is the progress made during this reporting period.

1. From May to July 2020, a team of young social scientists from UDOM, together with consultant Nicolas Patt, prepared a draft article on the results of the gender evaluation of SWC technologies conducted in August 2019. Following a mixed methods approach, descriptive statistics are evaluated against the findings from participatory exercises and qualitative data from FGDs. The draft article will need improving and follow-up data analysis before submission to a journal.
2. A follow-up question on the drudgery involved in establishing tied ridges was integrated into the survey the Africa RISING economist conducted on soil and water conservation practices in July 2020. Results will become available in the course of data analysis.
3. Research on rip tillage in Kiteto district was delayed. UDOM remained closed between mid-March and the end of June 2020 due to the COVID-19 pandemic. As a result, students could not present their proposals. Hence, the period was used to prepare tools for field research. After proposal defense in July, students went to the field in mid-September for data collection. Currently, FGDs and key informant interviews are being transcribed, participatory exercises collated, and survey data entered and analyzed.

Targeted deliverables for 2019/2020 and status on achievements

Deliverables	Status (March 2020)	Status (September 2020)	Deviation & explanation
Recommendations (fanya juu and tied ridges) in biannual reports	To be developed by team of social scientists	Data analysis for the development of recommendations was completed by a team of young social scientists	Data analysis needs to be further homed in order to arrive at valid recommendations
Recommendations (rip tillage) in Master of Arts (MA) theses by Oct 2020	UDOM - MA research implementation delayed due to COVID-19	Field research complete, data analysis and write up in process	Development of recommendations was delayed due to late research, analysis, and write-up

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

In the last report, preliminary findings were presented. We did not make progress during this reporting period because the student conducting the study fell sick and the work has since been delayed. However, we have discussed with supervisor Wanjiku to complete the data analysis and manuscript write-up as we wait for guidance from the university.

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: SA-specific monitoring and evaluation activities led by IFPRI

- The M&E officer collaborated with AR researchers to gather data on FtF indicators for FY 2020 (October 2019-September 2020). Data are being verified for completeness and consistency, including discrepancy narratives that adequately justify the reasons for +/- over/under achievement. Likewise, researchers have successfully updated the Implementing Mechanisms Performance Narrative Forms. The achievements will be uploaded onto the new USAID's Development Information System (DIS) platform starting 19 October 2020.
- With support from the ESA M&E officer, IFPRI has continued to manage program-generated data, including facilitation of data upload onto the program data repository platform - DataVerse[15]- and monitoring users' data requests. During this reporting period, researchers have submitted 35 datasets that are currently under review for eventual presence of Personally Identifiable Information (PII) and other quality checks before final upload onto the platform.
- IFPRI also continued its collaboration with WUR and IITA to build the FarmMATCH model, a framework for typology-based targeting and scaling of agricultural innovations. The goal of this collaborative research is to generate evidence to guide and facilitate the dissemination of best-fit integrated crop-livestock technologies to small-scale farmers in a landscape context. The team has developed various machine learning (ML) algorithms to match technologies to farms based on GIS (biophysical, social, and economic) and farm-level data collected as part of the Africa RISING Baseline Evaluation Surveys (ARBES). The team has created a dataset for ML using GIS and ARBES data for Tanzania and expects to replicate the work for Malawi and produce a report by the end of 2020.
- The M&E officer, together with IFPRI, provided input to an Africa RISING -NAFAKA household survey aimed at gathering survey data to assess the impact of adoption of validated AR technologies scaled up as part of the Africa RISING-NAFAKA collaboration. The survey has been implemented in the District Councils of Kilolo, Iringa, Wanging'ombe, Mbozi, Momba, Kilombero, and Kilosa covering 650 farmers. Data analysis is underway for internal NAFAKA reporting purposes.
- The M&E officer, together with IFPRI, also collaborated with Africa RISING researchers in Kongwa district (Tanzania) to conduct a survey on soil and water management conservation practices. It will focus on participant's knowledge about Africa RISING technologies (*fanya juu/chini* terraces, annual tied ridges, residual tied ridges, rip tillage, minimum tillage, crop

[15] Accessible here: https://DataVerse.harvard.edu/DataVerse/AfricaRISING.

rotation, and intercropping. Data analysis is currently underway for a report and a manuscript for journal submission.

- The M&E officer worked with Africa RISING researchers and development partners to compile a database of Africa RISING beneficiaries and monitor achievements relative to targets previously set. Main tasks performed during this reporting period include:
    - Discussions with development partners to harmonize scaling beneficiary data. Visits were conducted to the *Lead Foundation* in Dodoma (Tanzania), Island of Piece (Arusha, Tanzania) and Africa RISING - NAFAKA (Mbeya, Tanzania). For the same objectives virtual meetings took place with researchers in Malawi and Zambia. Information has also been compiled on scaling approaches and technologies being scaled-up.
    - Update of the beneficiary and technology tracking tool (BTTT) using data on Africa RISING beneficiaries who are directly engaged in the validation of various Africa RISING innovations. This latest round of updates was completed for Malawi and Zambia, ongoing for Tanzania.

Direct and Scaling Beneficiaries

Following M&E officer interactions with Africa RISING researchers and development partners during the reporting period, numbers of direct and scaling beneficiaries for 2019-2020 were compiled. Figure 45 shows the total cumulative number of farmers directly interacting with AR researchers in the testing and validation of different AR technologies (direct beneficiaries) since project inception (7894), representing 96% achievement. There is over achievement in Tanzania (122%) and under achievement in Zambia (47%).

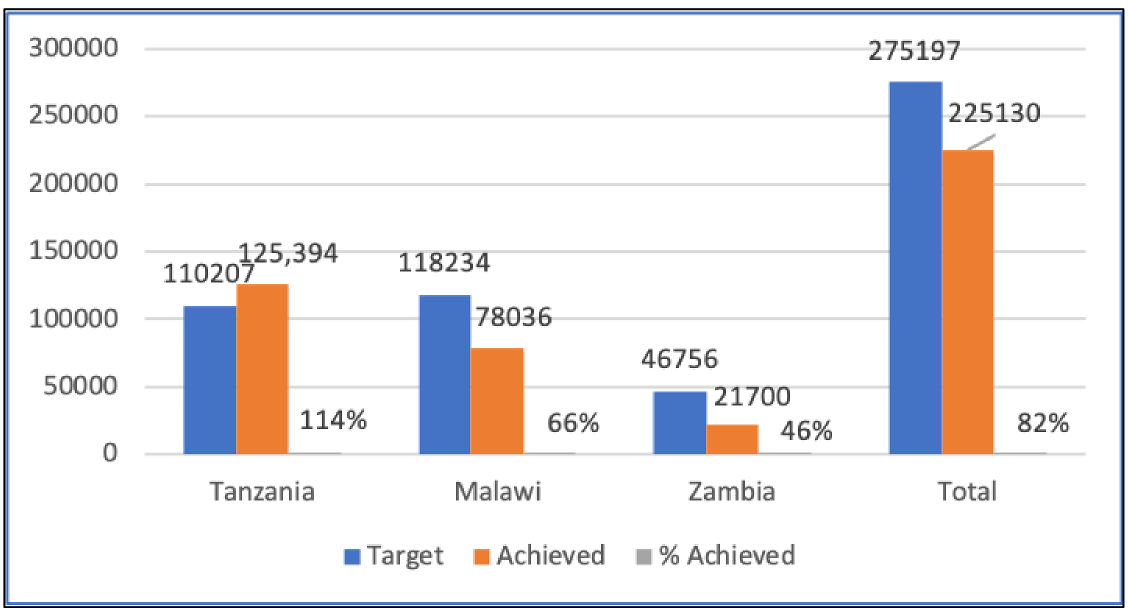


Figure 46. Number of scaling beneficiaries reached as of Sept 2020 (against 2016-2020 cumulative targets).

Capacity building

Table 19: 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						
Farmers' field day	CIAT	Gallapo	21 to 22 May 2020	Farmers	81	28
Farmer' field day	CIAT	Sabilo	23 to 24 May 2020	Farmers	128	38
Nane Nane (Farmers' week Fair). *Mbili-Mbili* and Doubled up-up legume stall visitors	CIAT	Arusha	1-08 August 2020	Farmers & other stakeholders	1896	42
Field days	CIMMYT	Various, Malawi	14 to 18 April 2020	Farmers	959	58
Socio-economic survey approaches	IITA	Arusha		Enumerators	13	40
Control of soil erosion using Fanya juu/chini terrace	TARI	Mtumba college	July to August 2020	Farmers and extension workers	1300	45
Improved nursery management specifically on seedbed preparation, vegetable seed sowing in nursery beds and trays	WorldVeg	Karatu	6 to 11 July 2020	Lead farmer trainers and government extension agents	70	47
Sustainable vegetable production	WorldVeg, IDP	Karatu	18 to 22 August 2020	ToT: Farmers' group representatives, IDP technical staff, and government extension agents	52	63
Data collection in demo plots	WorldVeg	Karatu	31 August to 5 September 2020	Farmers' group representatives and	32	56

				government extension agents		
Graduate training						
Plant Health (internship)	IITA	University of Nebraska	June-October 2020	PhD student, Nathan Fortner	1	0
Farming systems ecology	IITA, WUR	Wageningen University	March to November 2020	MSc student, Shinhye Lee	1	100
Agricultural Economics	OSU, IITA	Oregon State University	January 2019 to August 2020	PhD student, Srabashi Ray	1	100
Case studies: Application of SI technologies among farmers	CIMMYT, MSU	LUANAR University of Zimbabwe	November 2019 to August 2020	MSc students, Isaac Mavhiko and Tinashe Taringa	2	50
Gender analysis of rip tillage technology	IITA	University of Dodoma	2019 to 2021	MA students, Julius Anatory and Zamaradi Said	2	50
Drought resistance of maize – *Gliricidia* intercropping	ICRAF	UC Davis	October 2019 to September 2020	MSc student Leah Renwick	1	100
Enhancing Food and Energy Security via Agroforestry	ICRAF	Humboldt University	October 2019 - September 2020	PhD student, Johannes Hafner	1	0
Profitability of *Gliricidia*-based cropping system	ICRAF/IITA	Sokoine University of Agriculture	October 2019 - December 2020	PhD student, Martha Swamila	1	100

Policy planning and management (Thesis delayed/deferred)	ICRISAT	SUA	2019 to 2020	MSc student, Felista Saluti	1	100
Human nutrition (Theses submitted)	ICRISAT	SUA	2019 to 2020	MSc students, Monica Chande and Ruth Mremi		100
Crop Science (Thesis submitted)	ICRISAT	SUA	2019 to 2020	MSc student, Simon Wabwire	1	0
Buffer and adaptive capacity to harness resilience of different farm types	WUR	WUR	October 2019 to August 2020	MSc student, Fungai Chinesengwa	1	100
Piloting of targeting and scaling of agricultural innovations	WUR	WUR	October 2019 to August 2020	MSc student, Shinhye Lee	1	100
Agroecology	MSU	MSU	Completion April 2020	PhD, Chiwimbo Gwenambira	1	100
Agronomy	LUANAR	LUANAR	2018 to 2020	MSc student, Jester Kalumba	1	0
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
Agronomy	CIAT			PhD student, Michael Kinyua	1	100
Plant Health (internship)	IITA	University of Nebraska	June-October 2020	PhD student, Nathan Fortner	1	0

Challenges and actions taken

The ESA Project was implemented in the best way possible, but a major deterrent was the outbreak of the CORONA virus, which limited planning at project level, field visits, field days, socio-economic surveys, M&E after March 2020. Activities dependent on field crops cannot be conducted again, while independent field activities were postponed to 2020/2021. No-cost extensions are being processed for such activities.

For field experiments, lead farmers supported by extension staff were deployed to take measurements for yield and other attributes. Use of the mobile phone for guidance became the most useful tool.

The COVID-19 challenges also affected graduate student progress because they were failing to access advisors and computing facilities. For many, progress was delayed.

For most of the project areas, this season experienced very unusually heavy rainfall. Researchers are turning this into an opportunity that will enable better estimation of performance of crop technologies from multi-year trialling, enabling them produce more realistic recommendations. This is critical given that one good season such as the 2019-2020 is experienced once in four to six years.

Failing to report (timely) and submitting quality reports by partners has come back as an issue.

Lessons learned

The lockdowns and curfew imposed because of COVID-19 elevated the use of e-communications. Scientists were forced to learn how to utilize these for meetings and networking. The period also offered opportunities for the researchers to attend to their data and draft manuscripts for peer reviewed publications.

Communications and knowledge sharing

The main communication channels supported during the reporting period are listed below.

- 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/
- Repository: https://cgspace.cgiar.org/handle/10568/16501

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

- External Review Team visit to Africa RISING sites in Malawi and Tanzania – a photo report (3 April 2020)
- External review of the Africa RISING program concludes (22 April 2020)
- Africa RISING partners publish soil fertility management guidebook (14 June 2020)
- Africa RISING Annual Progress Report 2018 – 2019 now available (6 July 2020)
- Undeterred by COVID-19: How Africa RISING is adapting operations for continuity in research and delivery (20 August 2020)
- Need to help farmers address declining soil fertility inspires young researcher to develop microdosing machine (27 August 2020)
- AMINA—Why I can't stop producing bean quality declared seed (Pg. 28 AR-NAFAKA report to USAID Tanzania)
- SARO 5—the 'miracle' rice variety putting a smile on farmers' faces (Pg. 30 AR-NAFAKA report to USAID Tanzania)
- Beating the drought in Tanzania's semiarid Iringa Region (Pg. 32 AR-NAFAKA report to USAID Tanzania)

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

- 28-30 September: Africa RISING ESA Review and Planning virtual meeting - virtual
- 31 August - 5 September: Vegetable farmer's training on demo plot management - [Chemchem, Rhotia- Kainam, Bashay, Bugeri, Changarawe, Kambi ya Simba, Slahhamo and G'lambo Villages]Karatu District, Tanzania
- 18 - 22 August: Training of Trainers course (TOTs) on sustainable vegetable production - Karatu District, Tanzania
- 11-25 August: Africa RISING - NAFAKA project close-out meetings
- 30 July: Malawi and Zambia project partners review meeting - virtual
- 28 July: Tanzania project partners review meeting - virtual
- 6-11 July: Monitoring and backstopping for vegetable farmers - Karatu District, Tanzania
- 18 May: WorldVeg demo plots monitoring visit - Karatu District, Tanzania

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

- Anders, E.J., Zulu, L.C. and Jambo, E.R. 2020. Limits to grain-legume technology integration by smallholder farmers: The case of time-sensitive labor demands and food security primacy in Malawi. Agricultural Systems 184:102879.
- Christopher Mutungi, Musa Chamwilambo, Silvester Masanja, Caleb Massam, Peter Wayda, Judith Tungu, Audifas Gaspar, Mateete Bekunda, Adebayo Abass. 2020. Quality and storability of common beans in small-holders farm stores in Northern Tanzania: A multivariate analysis of agro-location, variety, and storage method effects. Journal of Stored Products Research 89. https://doi.org/10.1016/j.jspr.2020.101723
- Swamila, M., Philip, D., Akyoo, A. M., Sieber, S., Bekunda, M., and Kimaro, A. A.2020. Gliricidia Agroforestry Technology Adoption Potential in Selected Dryland Areas of Dodoma Region, Tanzania. Agriculture.
- Fischer, G., Darkwah, A., Kamoto, J., Kampanje-Phiri, J., Grabowski, P. and Djenontin, I.N.S. 2020. Sustainable agricultural intensification and gender-biased land tenure systems: An exploration and conceptualization of interactions. International Journal of Agricultural Sustainability
- Hermans, T.D.G., Whitfield, S., Dougill, A.J. and Thierfelder, C. 2020. Bridging the disciplinary gap in conservation agriculture research, in Malawi: A review. Agronomy for Sustainable Development 40:3.
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- Doubled-up legumes technology (https://hdl.handle.net/10568/108796)
- Enhancing partnership among Africa RISING, NAFAKA and TUBORESHE CHAKULA Programs for fast tracking delivery and scaling of agricultural technologies in Tanzania: Quarterly Report (01 October 2019–31 December 2019) (https://cgspace.cgiar.org/handle/10568/108410)
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- Maize production manual for smallholder farmers in Tanzania (https://cgspace.cgiar.org/handle/10568/109806)
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- Performance evaluation of the Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) program (https://hdl.handle.net/10568/108031)
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- Interactive voice response for dissemination of agronomy technologies in Malawi - the opportunities and pitfalls (https://www.slideshare.net/africa-rising/asacssa-chikowo-215907123)
- Automated irrigation as a game-changer in sub-Saharan Africa: Is it enough? (https://www.slideshare.net/africa-rising/asacssa-kizito)
- Transforming maize-legume value chains: A business case for climate-smart agriculture in Southern Africa (https://www.slideshare.net/africa-rising/crasswebiner-thierfelder)